Lecture Notes in Networks and Systems 696

Xin-She Yang
R. Simon Sherratt
Nilanjan Dey
Amit Joshi *Editors*

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Lecture Notes in Networks and Systems

Volume 696

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Xin-She Yang · R. Simon Sherratt · Nilanjan Dey · Amit Joshi
Editors

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Editors
Xin-She Yang
Department of Design Engineering
and Mathematics
Middlesex University London
London, UK

Nilanjan Dey
Department of Computer Science
and Engineering
Techno International Newtown
Chakpachuria, West Bengal, India

R. Simon Sherratt
Department of Biomedical Engineering
University of Reading
England, UK

Amit Joshi
Global Knowledge Research Foundation
Ahmedabad, India

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Preface

The Eighth International Congress on Information and Communication Technology will be held during 20–23 February 2023, in a hybrid mode, physical at London, UK, and digital platform: Zoom. ICICT 2023 was organised by Global Knowledge Research Foundation and managed by G. R. Scholastic LLP. The associated partners were Springer and InterYIT IFIP. The conference will provide a useful and wide platform both for display of the latest research and for exchange of research results and thoughts. The participants of the conference will be from almost every part of the world, with backgrounds of either academia or industry, allowing a real multinational multicultural exchange of experiences and ideas.

A great pool of more than 1300 papers were received for this conference from across 113 countries among which around 361 papers were accepted and will be presented physically at London and digital platform Zoom during the four days. Due to the overwhelming response, we had to drop many papers in the hierarchy of the quality. Total 46 technical sessions will be organised in parallel in four days along with a few keynotes and panel discussions in hybrid mode. The conference will be involved in deep discussion and issues which will be intended to solve at global levels. New technologies will be proposed, experiences will be shared, and future solutions for design infrastructure for ICT will also be discussed. The final papers will be published in four volumes of proceedings by Springer LNNS Series. Over the years, this congress has been organised and conceptualised with the collective efforts of a large number of individuals. I would like to thank each of the committee members

and the reviewers for their excellent work in reviewing the papers. Grateful acknowledgements are extended to the team of Global Knowledge Research Foundation for their valuable efforts and support.

I look forward to welcoming you to the 8th Edition of this ICICT Congress 2023.

Amit Joshi, Ph.D.
Organising Secretary, ICICT 2023
Director—Global Knowledge Research Foundation
Ahmedabad, India

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Editors and Contributors

About the Editors

Xin-She Yang obtained his D.Phil. in Applied Mathematics from the University of Oxford. He then worked at Cambridge University and National Physical Laboratory (UK) as a Senior Research Scientist. Now he is Reader at Middlesex University London, Fellow of the Institute of Mathematics and its Application (IMA) and a Book Series co-editor of the *Springer Tracts in Nature-Inspired Computing*. He was also the IEEE Computational Intelligence Society task force chair for Business Intelligence and Knowledge Management (2015–2020). He has published more than 25 books and more than 400 peer-reviewed research publications with over 78,600 citations, and he has been on the prestigious list of highly cited researchers (Web of Sciences) for seven consecutive years (2016–2022).

R. Simon Sherratt was born near Liverpool, England, in 1969. He is currently a Professor of Biosensors at the Department of Biomedical Engineering, University of Reading, UK. His main research area is signal processing and personal communications in consumer devices, focusing on wearable devices and health care. He received the first place IEEE Chester Sall Memorial Award in 2006, the second place in 2016 and the third place in 2017.

Nilanjan Dey is an Associate Professor at the Department of Computer Science and Engineering, Techno International New Town, India. He is Editor-in-Chief of the *International Journal of Ambient Computing and Intelligence*; a Series co-editor of *Springer Tracts in Nature-Inspired Computing* (STNIC), *Data-Intensive Research* (DIR), Springer Nature; and a Series co-editor of *Advances in Ubiquitous Sensing Applications for Healthcare*, Elsevier. He is a fellow of IETE and a Senior Member of IEEE.

Amit Joshi is currently the Director of Global Knowledge Research Foundation, also an Entrepreneur and Researcher who has completed his master's and research in the areas of cloud computing and cryptography in medical imaging. He has an experience of around 10 years in academic and industry in prestigious organisations. He is an active member of ACM, IEEE, CSI, AMIE, IACSIT-Singapore, IDES, ACEEE, NPA and many other professional societies. Currently, he is the International Chair of InterYIT at International Federation of Information Processing (IFIP, Austria). He has presented and published more than 50 papers in national and international journals/conferences of IEEE and ACM. He has also edited more than 40 books which are published by Springer, ACM and other reputed publishers. He has also organised more than 50 national and international conferences and programs in association with ACM, Springer, IEEE to name a few across different countries including India, UK, Europe, USA, Canada, Thailand, Egypt and many more.

Contributors

Aldi Abilawa Universitas Muhammadiyah Yogyakarta, Kasihan, Indonesia

Maria-Ines Acosta-Uriguen Universidad Del Azuay, Cuenca, Ecuador

Funmi Adebesin University of Pretoria, Pretoria, South Africa

Shohibul Adib Islamic Politics, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Sohana Afroz Department of Computer Science and Engineering, Daffodil International University, Dhaka, Bangladesh

Tajim Md. Niamat Ullah Akhund Department of Computer Science and Engineering, Daffodil International University, Dhaka, Bangladesh

Arnisha Akter United International University, United City, Dhaka, Bangladesh

Sumaiya Akter United International University, United City, Dhaka, Bangladesh

Abdulaziz Al-Abri Advanced Cybersecurity Academy, Muscat, Oman

Rami Al-Hajj College of Engineering and Technology, American University of the Middle East, Egaila, Kuwait

Intisar Al-Mandhari Advanced Cybersecurity Academy, Muscat, Oman

Gustavo De Los Ríos Alatorre Instituto Tecnológico y de Estudios Superiores de Monterrey, Monterrey, NL, Mexico

Arjay R. Alba Bulacan State University, City of Malolos, Philippines

Valentina Alberti European Commission, Joint Research Centre (DG JRC), Ispra, VA, Italy

Salah Eddin Algabsi Computer Engineering Department, Atilim University, Ankara, Turkey;
Graduate School of Natural and Applied Sciences, Atilim University, Ankara, Turkey

Ahmed AlKalbani Advanced Cybersecurity Academy, Muscat, Oman

Sascha Alpers FZI Forschungszentrum Informatik, Software Engineering, Karlsruhe, Germany

Ahmed Alrehaili Department of Informatics, University of Sussex, Falmer, Brighton, UK;
Faculty of Computer and Information Systems, Islamic University of Madinah, Medina, KSA, Saudi Arabia

Angelos Amditis Institute of Communication and Computer Systems, Athens, Greece

Din Marvin Anave School of Information Technology, Mapúa University, Manila, Philippines

Pablo Arévalo Universidad Del Azuay, Cuenca, Ecuador

Masayoshi Aritsugi Kumamoto University, Kumamoto, Japan

Tazkia Tasnim Bahar Audry United International University, United City, Dhaka, Bangladesh

Hazim Awbi University of Reading, Reading, UK

Paulina Ayala FISEI, Universidad Tecnica de Ambato, UTA, Ambato, Ecuador

Stephen Azeez Department of Computing, Atlantic Technological University, Letterkenny, Donegal, Ireland

Muhammad Azhar Islamic Politics, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Saaidal R. Azzuhri Department of Computer System and Technology, Faculty of Computer Science and Information Technology, University of Malaya, Kuala Lumpur, Malaysia

Nasia Balakera Institute of Communication and Computer Systems, Athens, Greece

Marianne Alfredine Omonlola Balogoun Africa Center of Excellence in Mathematics and Computer Sciences, Dangbo, Benin

Kenya Bannaka Kobe Tokiwa University, Kobe, Japan

Sabrina Barbosa Rio de Janeiro State University, Rio de Janeiro, RJ, Brazil

Alejandro Israel Barranco-Gutiérrez Tecnológico Nacional de México (TecNM), Celaya, México

Sussy Bayona-Oré Universidad Autónoma del Perú, Lima, Perú

Christoph Becker FZI Forschungszentrum Informatik, Software Engineering, Karlsruhe, Germany

Natalia Beloff Department of Informatics, University of Sussex, Falmer, Brighton, UK

Alexandra Bermeo Universidad Del Azuay, Cuenca, Ecuador

Eric Blancaflor School of Information Technology, Mapúa University, Manila, Philippines

Hung Bui Faculty of Computer Science and Engineering, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam;
Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam

Michael Cabanillas-Carbonell Universidad Privada del Norte, Lima, Perú

Gustavo Caiza Universidad Politecnica Salesiana, UPS, Quito, Ecuador

Francisco J. Cantu-Ortiz Instituto Tecnológico y de Estudios Superiores de Monterrey, Monterrey, NL, Mexico

Priscila Capriles Federal University of Juiz de Fora, Juiz de Fora, MG, Brazil

Alberto Cardoso Department of Informatics Engineering, Centre for Informatics and Systems of the University of Coimbra (CISUC), University of Coimbra, Coimbra, Portugal

Cristian Castillo-Olea CETYS Universidad, Mexicali, Mexico

Hector G. Ceballos Cancino Instituto Tecnológico y de Estudios Superiores de Monterrey, Monterrey, NL, Mexico

Priscila Cedillo Universidad de Cuenca, Cuenca, Ecuador

C. A. Cerón-Álvarez Faculty of Electrical and Electronic Engineering, Universidad Veracruzana, Veracruz, Mexico

Olena Chaikovska Kyiv National University of Culture and Arts, Kyiv, Ukraine

Hakima Chaouchi SAMOVAR, Télécom SudParis, Institut Polytechnique de Paris, Evry, France

Paul A. Chasi-Pesantez Universidad Politécnica Salesiana, Cuenca, Ecuador

Luis Enrique Chinea-Mujica Tecnológico Nacional de México (TecNM), Celaya, México

Konstantin Chterev Black Sea Research Fund, Varna, Bulgaria

Cinzia Cocco European Commission, Joint Research Centre (DG JRC), Ispra, VA, Italy

Geoffrey Collins Northern Ireland Water, Belfast, Northern Ireland, UK

Eusébio Conceição FCT—Universidade do Algarve, Faro, Portugal

Maria Inês Conceição Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal

Sergio Consoli European Commission, Joint Research Centre (DG JRC), Ispra, VA, Italy

Firmino Oliveira da Silva Research Center, ISLA—Instituto Politécnico de Gestão e Tecnologia, Gaia, Portugal

Christian Daase Otto-Von-Guericke University Magdeburg, Magdeburg, Germany

Pavle Dakić Faculty of Informatics and Information Technologies, Institute of Informatics, Information Systems and Software Engineering, Slovak University of Technology in Bratislava, Bratislava, Slovakia;
Faculty of Informatics and Computing, Singidunum University, Belgrade, Serbia

Renata Danielienė Vilnius University Kaunas Faculty, Kaunas, Lithuania

Paulius Danielius Vilnius University Kaunas Faculty, Kaunas, Lithuania

Dimo Daskalov Dentaprime Dental Clinic, Varna, Bulgaria

Joana de Matos Monteiro Research Center, ISLA—Instituto Politécnico de Gestão e Tecnologia, Gaia, Portugal

N. J. Montes de Oca-Mora Micro and Nanotechnology Research Center, Universidad Veracruzana, Veracruz, Mexico

José Guadalupe Deanda-Rincón Regional Center for Optimization and Development of Equipment (CRODE), Celaya, México

Hans Christian Deniega School of Information Technology, Mapúa University, Manila, Philippines

Sumanth Desai KLS Institute of Management Education and Research, Belagavi, Karnataka, India

Arlina Dewi Master of Hospital Administration, Faculty of Post Graduate Program, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Moussa Diallo Department of Computer Science, Polytechnic Institute (ESP), Cheikh Anta Diop University, Dakar, Senegal

Javier Diaz-Carmona Tecnológico Nacional de México (TecNM), Celaya, México

Rozalina Dimova Department of Communication Engineering and Technologies, Faculty of Computer Sciences and Automation, Technical University of Varna, Varna, Bulgaria

Thierno Ibrahima Diop Baamtu, Dakar, Senegal

Fatoumata A. Y. Diouf Department of Computer Science, Polytechnic Institute (ESP), Cheikh Anta Diop University, Dakar, Senegal

Pantelis Dogoulis Department of Computer Science, University of Luxembourg, Luxembourg, Luxembourg

Yuming Dong Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, Shenzhen, China;
The Chinese University of Hong Kong, Hong Kong, China

Michel Dossou Research Unit in Photonics and Digital Broadcasting (URPHORAN), Abomey-Calavi, Benin

Tihomir Dovramadjiev Department of Industrial Design, Faculty of Shipbuilding, Technical University of Varna, Varna, Bulgaria

Sara Durski University of Education Weingarten, Weingarten, Germany

Manuel Dworzak Computer Networks Group, University of Bamberg, Bamberg, Germany

Cansu Cigdem EKIN Computer Engineering Department, Atilim University, Ankara, Turkey

Andrés Epifanía-Huerta Universidad Nacional de San Martin, Tarapoto, Perú

Alejandro Espinosa-Calderón Regional Center for Optimization and Development of Equipment (CRODE), Celaya, México

Alberto Velasquez Fernandez Universidad Privada del Norte, Lima, Perú

Junya Fukumoto Tohoku University, Sendai, Japan

Marcelo V. Garcia FISEI, Universidad Tecnica de Ambato, UTA, Ambato, Ecuador;
DISA, University of the Basque Country, EHU/UPV, Bilbao, Spain

Georgi Georgiev South-West University "Neofit Rilski", Blagoevgrad, Bulgaria

Puja Ghosh United International University, United City, Dhaka, Bangladesh

Leonardo Goliatt Federal University of Juiz de Fora, Juiz de Fora, MG, Brazil

João Gomes CINTAL, Faro, Portugal

Marcel Großmann Computer Networks Group, University of Bamberg, Bamberg, Germany

Luis F. Guerrero-Vásquez Universidad Politécnica Salesiana, Cuenca, Ecuador

Bamba Gueye Department of Mathematics and Computer Science, Faculty of Science and Technology (FST), Cheikh Anta Diop University, Dakar, Senegal

Sergio Eduardo Vega Guzmán Instituto Tecnológico y de Estudios Superiores de Monterrey, Monterrey, NL, Mexico

Sanjay V. Hanji KLE Technological University, Belagavi, Karnataka, India

Savita S. Hanji KLE Technological University, Belagavi, Karnataka, India

Fumiko Harada Research Organization of Science and Technology, Ritsumeikan University, Kyoto, Shiga, Japan

Timothy James Hardman School of Engineering, University of KwaZulu-Natal, Durban, South Africa

Md. Umaid Hasan Department of Computer Science and Engineering, Daffodil International University, Dhaka, Bangladesh

Kazumi Hatayama Division of Electronics and Informatics, Gunma University, Kiryu, Gunma, Japan

Marie Hattingh University of Pretoria, Pretoria, South Africa

Bernd Hedenetz Mercedes-Benz AG; MB.OS Base SW Development, Sindelfingen, Germany

Shagufta Henna Department of Computing, Atlantic Technological University, Letterkenny, Donegal, Ireland

Mega Hidayati Islamic Politics, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Anne-Carole Honfoga Research Unit in Photonics and Digital Broadcasting (URPHORAN), Abomey-Calavi, Benin

Vinasétan Ratheil Houndji Institut de Formation et de Recherche en Informatique (IFRI), Abomey-Calavi, Benin

Ingrid Hrga Faculty of Informatics, Juraj Dobrila University of Pula, Pula, Croatia; Faculty of Informatics and Digital Technologies, University of Rijeka, Rijeka, Croatia

Nguyen Quang Hung High Performance Computing Laboratory, Faculty of Computer Science and Engineering, Advanced Institute of Interdisciplinary Science and Technology, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam;
Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam

Titih Huriah Community Nursing Department, Master of Nursing, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Juan Hurtado Instituto Superior Tecnológico Particular Sudamericano, Cuenca, Ecuador

Remigio Hurtado Universidad Politécnica Salesiana, Cuenca, Ecuador

Seungwook Hwang Korea Maritime and Ocean University, Busan, South Korea

Mohamed M. Ibrahim Department of Computer System and Technology, Faculty of Computer Science and Information Technology, University of Malaya, Kuala Lumpur, Malaysia

Tamotsu Ichikawa ROHM Semiconductor, Yokohama, Japan

Kunitoshi Igarashi Kumamoto University, Kumamoto, Japan

Daisuke Iimori Division of Electronics and Informatics, Gunma University, Kiryu, Gunma, Japan

Atsuki Imada Tokushima University, Tokushima, Japan

Koumei Imai Tokai University, Kanagawa, Japan

Rafia Inam Ericsson Research, Stockholm, Sweden;
KTH Royal Institute of Technology, Stockholm, Sweden

Sanjeev Ingalagi KLS Gogte Institute of Technology, Belagavi, Karnataka, India

Orlando Iparraguirre-Villanueva Universidad Autónoma del Perú, Lima, Perú

Takashi Ishida ROHM Semiconductor, Yokohama, Japan

Naohiro Ishii Advanced Institute of Industrial Technology, Tokyo, Japan

Md. Motaharul Islam United International University, United City, Dhaka, Bangladesh

Malinka Ivanova Technical University of Sofia, Sofia, Bulgaria

Marina Ivasic-Kos Faculty of Informatics and Digital Technologies, University of Rijeka, Rijeka, Croatia;
Center for Artificial Intelligence, University of Rijeka, Rijeka, Croatia

Kazunori Iwata Aichi University, Nagoya, Japan

Ons Jelassi LTCI, Télécom Paris, Institut Polytechnique de Paris, Palaiseau, France

Rashida Jesmin Department of Zoology, Government Hajee Korop Ali Memorial College, Sirajganj, Bangladesh

Karl H. Johansson KTH Royal Institute of Technology, Stockholm, Sweden

Hasse Jubba Islamic Politics, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Shogo Katayama Division of Electronics and Informatics, Gunma University, Kiryu, Gunma, Japan

Takafumi Katayama Tokushima University, Tokushima, Japan

Kentaroh Katoh Division of Electronics and Informatics, Gunma University, Kiryu, Gunma, Japan

Khadidiatou Wane Keita Polytechnic Institute (ESP), Dakar, Senegal

Tarikuzzaman Khan Department of Computer Science and Engineering, Daffodil International University, Dhaka, Bangladesh

Svitlana Khrushch Kyiv National University of Culture and Arts, Kyiv, Ukraine

Aoi Kishida Kobe City Nishi-Kobe Medical Center, Kobe, Japan

Haruo Kobayashi Division of Electronics and Informatics, Gunma University, Kiryu, Gunma, Japan

Tomoharu Kobayashi Graduate School of Information Science and Engineering, Ritsumeikan University, Kyoto, Shiga, Japan

Fotios K. Konstantinidis Institute of Communication and Computer Systems, Athens, Greece

Kateryna Kotsiubivska Kyiv National University of Culture and Arts, Kyiv, Ukraine

Ryosuke Kozaki Hyogo University of Teacher Education, Hyogo, Japan

Yasuhiro Kozaki Osaka Kyoiku University, Osaka, Japan

Carsten Kühnel University of Applied Sciences, Erfurt, Germany

Gowri Kurthkoti Sridhara Rao Purdue University, Fort Wayne, IN, USA

Anna Kuwana Division of Electronics and Informatics, Gunma University, Kiryu, Gunma, Japan

Richard Kyung CRG-NJ, Cresskill, NJ, USA

Evangelia Latsa Institute of Communication and Computer Systems, Athens, Greece

Duy Thanh Le Computer Networks Group, University of Bamberg, Bamberg, Germany

Triet Le Faculty of Computer Science and Engineering, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam;
Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam

Hyunseo Lee Seoul International School, Seoul, Korea

Kwangil Lee Korea Maritime and Ocean University, Busan, South Korea

Yan Liang School of Resources and Environment, University of Electronic Science and Technology of China, Chengdu, China

Juan-Fernando Lima Universidad Del Azuay, Cuenca, Ecuador

Noel B. Linsangan Mapua University, Manila, Philippines

Yanfei Liu Purdue University, Fort Wayne, IN, USA

Zhenyu Lu Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, Shenzhen, China;
School of Resources and Environment, University of Electronic Science and Technology of China, Chengdu, China;
The Chinese University of Hong Kong, Hong Kong, China

F. López-Huerta Faculty of Electrical and Electronic Engineering, Universidad Veracruzana, Veracruz, Mexico;
Faculty of Construction and Habitat Engineering, Universidad Veracruzana, Veracruz, Mexico

Maria Manuela Lúcio FCT—Universidade do Algarve, Faro, Portugal

Archie Brendan Mangubat School of Information Technology, Mapúa University, Manila, Philippines

George Maramba University of Pretoria, Pretoria, South Africa

Adele H. Marshall School of Mathematics and Physics, Queen's University Belfast, Belfast, UK;
Joint Research Centre in AI for Health and Wellness, Ontario Tech University, Oshawa, Canada

Ute Massler University of Education Weingarten, Weingarten, Germany

D. Mata-Hernandez Electronic Engineering Department, Universitat Politècnica de Catalunya, Barcelona, Spain

Luboš Matějka DCSE, University of West Bohemia, Plzeň, Czech Republic

Sayaka Matsumoto Tokyo Institute of Technology, Tokyo, Japan

Tokuro Matsuo Advanced Institute of Industrial Technology, Tokyo, Japan

Tendani Mawela University of Pretoria, Pretoria, South Africa

Derguene Mbaye Université Cheikh Anta Diop, Dakar, Senegal

Serigne Mbaye Cheikh Anta Diop University (UCAD), Dakar, Senegal

Matthew McCrory School of Mathematics and Physics, Queen's University Belfast, Belfast, UK

Ameyalli Mendias-Alarcon School of Medicine and Psychology, Autonomous University of Baja California, Tijuana, Mexico

Israel Mendonça Kumamoto University, Kumamoto, Japan

Mario Alberto Mendoza-Bárcenas Instituto Politécnico Nacional (IPN), México City, México

Kenichiro Mitsunari Kobe Tokiwa University, Kobe, Japan

Marcia Mkansi University of South Africa, Muckleneuk, Pretoria, Republic of South Africa

Valentina Montalto European Commission, Joint Research Centre (DG JRC), Ispra, VA, Italy

Beata Mrugalska Faculty of Engineering Management, Poznan University of Technology, Poznan, Poland

Naoto Mukai Sugiyama Jyogakuen University, Nagoya, Japan

Wolfgang Müller University of Education Weingarten, Weingarten, Germany

Arantxa Muñoz Universidad Politécnica Salesiana, Cuenca, Ecuador

Katsuhiko Murakami University of Tokyo, Tokyo, Japan

Taras Mykytyn Rivne State Humanity University, Rivne, Ukraine

Hisami Nakata Kobe Tokiwa University, Kobe, Japan

Yasuo Nakata Kobe Tokiwa University, Kobe, Japan

Takayuki Nakatani Division of Electronics and Informatics, Gunma University, Kiryu, Gunma, Japan

Lizbeth M. Naranjo-Mora Universidad Politécnica Salesiana, Cuenca, Ecuador

Nagaraj Navalgund KLE Technological University, Hubli, Karnataka, India

Ivan Nedyalkov South-West University "Neofit Rilski", Blagoevgrad, Bulgaria

Naman S. Negi LTCI, Télécom Paris, Institut Polytechnique de Paris, Palaiseau, France

Duong Nguyen Faculty of Computer Science and Engineering, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam;
Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam

Phu Nguyen Faculty of Computer Science and Engineering, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam;
Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam

Xiao Ni University of Applied Sciences, Erfurt, Germany

Nikola Nikolov Technical University, Varna, Bulgaria

Ikuhiro Noda Kobe Tokiwa University, Kobe, Japan

Aleksandar Novakovic School of Mathematics and Physics, Queen's University Belfast, Belfast, UK;
Joint Research Centre in AI for Health and Wellness, Ontario Tech University, Oshawa, Canada

Aaron Luntala Nsakanda University of South Africa, Muckleneuk, Pretoria, Republic of South Africa

Nurjannah Community Nursing Department, Stikes Mitra Adiguna Palembang, Palembang, Indonesia

Nursetiawan Civil Engineering, Faculty of Engineering, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Andreas Oberweis FZI Forschungszentrum Informatik, Software Engineering, Karlsruhe, Germany

Norman Fong Ochoa Universidad Nacional Mayor de San Marcos, Lima, Perú

Alex C. Ochoa-Siavichay Universidad Politécnica Salesiana, Cuenca, Ecuador

Kazuya Odagiri Sugiyama Jyogakuen University, Nagoya, Japan

Gaku Ogihara Division of Electronics and Informatics, Gunma University, Kiryu, Gunma, Japan

Toshiyuki Okamoto ROHM Semiconductor, Yokohama, Japan

Atsushi Okuyama Tokai University, Kanagawa, Japan

Cristina Oliveira Universidade de São Paulo (USP), São Paulo, Brazil; Center for Artificial Inteligence (C4AI-USP), São Paulo, Brazil

Masato Omori Kobe Tokiwa University, Kobe, Japan

Jorge O. Ordoñez-Ordoñez Universidad Politécnica Salesiana, Cuenca, Ecuador

Marcos Orellana Universidad Del Azuay, Cuenca, Ecuador

Soraia Oueida College of Engineering and Technology, American University of the Middle East, Egaila, Kuwait

Acheampong Owusu University of Ghana Business School, University of Ghana, Legon, Accra, Ghana

Beatriz Alejandra Bosques Palomo Instituto Tecnológico y de Estudios Superiores de Monterrey, Monterrey, NL, Mexico

Francesco Panella European Commission, Joint Research Centre (DG JRC), Ispra, VA, Italy

Dimitrios-Panagiotis Papageorgiou Aristotle University of Thessaloniki, Thessaloniki, Greece

Vasileios E. Papageorgiou Aristotle University of Thessaloniki, Thessaloniki, Greece

Marco Papp Universidade de São Paulo (USP), São Paulo, Brazil

Diana Pavlova Dentaprime Dental Clinic, Varna, Bulgaria

Ireland John San Pedro School of Information Technology, Mapúa University, Manila, Philippines

Walpola Layantha Perera University of Applied Sciences, Erfurt, Germany

Ladislav Pešička DCSE, University of West Bohemia, Plzeň, Czech Republic

Thien Pham Faculty of Computer Science and Engineering, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam;
Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam

Nutteerat Pheeraphan Srinakharinwirot University, Bangkok, Thailand

Cristian Picón Universidad Politécnica Salesiana, Cuenca, Ecuador

Carbajal Montalban Walter Piero Universidad Privada del Norte, Lima, Perú

Yoyok Bekti Prasetyo Community Nursing Department, School of Nursing, Universitas Muhammadiyah Malang, Malang, Indonesia

Firman Pribadi Universitas Muhammadiyah Yogyakarta, Kasihan, Indonesia

Wilson Pujay-Iglesias Universidad Autónoma del Perú, Lima, Perú

Zuly Qodir Islamic Politics, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Nguyen Thanh Quan High Performance Computing Laboratory, Faculty of Computer Science and Engineering, Advanced Institute of Interdisciplinary Science and Technology, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam;
Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam

Tho Quan Faculty of Computer Science and Engineering, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam;
Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam

Carla Soley Ramírez Universidad Privada del Norte, Lima, Perú

Maribel Karina Flores Ramirez Universidad Privada del Norte, Lima, Perú

S. E. Ramírez-Domínguez Micro and Nanotechnology Research Center, Universidad Veracruzana, Veracruz, Mexico

Jean Paul Roux University of South Africa, Muckleneuk, Pretoria, Republic of South Africa

Franco Ruggeri Ericsson Research, Stockholm, Sweden;
KTH Royal Institute of Technology, Stockholm, Sweden

Marcos Salinas-Escobar FISEI, Universidad Tecnica de Ambato, UTA, Ambato, Ecuador

Agus Samsudin Universitas Muhammadiyah Yogyakarta, Kasihan, Indonesia

M. Mesbahuddin Sarker Institute of Information Technology, Jahangirnagar University, Dhaka, Bangladesh

Keno Sato ROHM Semiconductor, Yokohama, Japan

Eric Sax Institute for Information Processing Technologies (ITIV), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Philipp Schumacher Mercedes-Benz AG; MB.OS Base SW Development, Sindelfingen, Germany

Madoune R. Seye Department of Computer Science, Polytechnic Institute (ESP), Cheikh Anta Diop University, Dakar, Senegal

Mykola Shershun Institute of Environmental Management and Agroecology of the Ukraine's National Academy of Agrarian Sciences, Kyiv, Ukraine

Wen Chung Shih Asia University, Taichung City, Taiwan

Hiromitsu Shimakawa Graduate School of Information Science and Engineering, Ritsumeikan University, Kyoto, Shiga, Japan

Takashi Shimamoto Tokushima University, Tokushima, Japan

Ihor Sliusar Poltava State Agrarian University, Poltava, Ukraine

Vadym Slyusar Central Research Institute of Armaments and Military Equipment of Armed Forces of Ukraine, Kyiv, Ukraine

Hanlie Smuts University of Pretoria, Pretoria, South Africa

Tian Song Tokushima University, Tokushima, Japan

Daniel Staegemann Otto-Von-Guericke University Magdeburg, Magdeburg, Germany

Igor Stupavský Faculty of Informatics and Information Technologies, Institute of Informatics, Information Systems and Software Engineering, Slovak University of Technology in Bratislava, Bratislava, Slovakia

Sri Sundari School of Medicine, Faculty of Medicine and Health Sciences, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Supriyatiningsih Obstetrics and Gynecology, Faculty of Medicine and Health Sciences, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Arni Surwanti Universitas Muhammadiyah Yogyakarta, Kasihan, Indonesia

Misaki Takagi Division of Electronics and Informatics, Gunma University, Kiryu, Gunma, Japan

Kunihiko Takamatsu Tokyo Institute of Technology, Tokyo, Japan

Marius Take FZI Forschungszentrum Informatik, Software Engineering, Karlsruhe, Germany

Benedito Chi Man Tam Department of Informatics Engineering, Centre for Informatics and Systems of the University of Coimbra (CISUC), University of Coimbra, Coimbra, Portugal;
Faculty of Applied Sciences, Macao Polytechnic University, Macao SAR, China

Su-Kit Tang Faculty of Applied Sciences, Macao Polytechnic University, Macao SAR, China;
Engineering Research Centre of Applied Technology on Machine Translation and Artificial Intelligence of Ministry of Education, Macao Polytechnic University, Macao SAR, China

Jules-Raymond Tapamo School of Engineering, University of KwaZulu-Natal, Durban, South Africa

Gisele Goulart Tavares Federal University of Juiz de Fora, Juiz de Fora, MG, Brazil

Ahmad Terra Ericsson Research, Stockholm, Sweden;
KTH Royal Institute of Technology, Stockholm, Sweden

Nam Thoai High Performance Computing Laboratory, Faculty of Computer Science and Engineering, Advanced Institute of Interdisciplinary Science and Technology, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam;
Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam

Maryna Tolmach Kyiv National University of Culture and Arts, Kyiv, Ukraine

Yuliia Trach Kyiv National University of Culture and Arts, Kyiv, Ukraine

Georgios Tsimiklis Institute of Communication and Computer Systems, Athens, Greece

Klaus Turowski Otto-Von-Guericke University Magdeburg, Magdeburg, Germany

Taylor Rodriguez Vance Capitol Technology University, Laurel, MD, USA

S. E. Vázquez-Valdes Faculty of Construction and Habitat Engineering, Universidad Veracruzana, Veracruz, Mexico

Flor Helena Valencia Velarde Instituto Tecnológico y de Estudios Superiores de Monterrey, Monterrey, NL, Mexico

Carlos Vera-Hernandez School of Medicine and Psychology, Autonomous University of Baja California, Tijuana, Mexico

Andreas Vetter Mercedes-Benz AG; MB.OS Base SW Development, Sindelfingen, Germany

Christian Vollrath University of Applied Sciences, Erfurt, Germany

Viktoriia Volynets Kyiv National University of Culture and Arts, Kyiv, Ukraine

Hai Vu Faculty of Computer Science and Engineering, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam;
Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam

Pattaranun Waitayasin Srinakharinwirot University, Bangkok, Thailand

Naoya Wakabayashi Ritsumeikan University, Kyoto, Japan

Shanti Wardaningsih Master of Nursing, Postgraduate Program, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Martin White Department of Informatics, University of Sussex, Falmer, Brighton, UK

R. M. Woo-García Faculty of Electrical and Electronic Engineering, Universidad Veracruzana, Veracruz, Mexico;
Faculty of Construction and Habitat Engineering, Universidad Veracruzana, Veracruz, Mexico

Feng Wu School of Electrical and Information Engineering, Changzhou Institute of Technology Changzhou, Changzhou, China

Ruxi Xiang School of Electrical and Information Engineering, Changzhou Institute of Technology Changzhou, Changzhou, China

Qinquan Xu School of Electrical and Information Engineering, Changzhou Institute of Technology Changzhou, Changzhou, China

Alina Yakymchuk University of Information Technology and Management in Rzeszow, Rzeszow, Poland;
Lesya Ukrainka Volyn National University, Lutsk, Ukraine

Tianyu Yang Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, Shenzhen, China;
The Chinese University of Hong Kong, Hong Kong, China

Vasyl Yurchyshyn Department of Computer Systems Software, Igor Sikorsky Kyiv Polytechnic Institute National Technical University of Ukraine, Kyiv, Ukraine

Yaroslav Yurchyshyn Department of Computer Systems Software, Igor Sikorsky Kyiv Polytechnic Institute National Technical University of Ukraine, Kyiv, Ukraine

Maha Zayoud College of Engineering and Technology, American University of the Middle East, Egaila, Kuwait

Longan Zhang School of Electrical and Information Engineering, Changzhou Institute of Technology Changzhou, Changzhou, China

Yujie Zhao Division of Electronics and Informatics, Gunma University, Kiryu, Gunma, Japan

Xifang Zhu School of Electrical and Information Engineering, Changzhou Institute of Technology Changzhou, Changzhou, China

Ontology Engineering to Model the European Cultural Heritage: The Case of *Cultural Gems*

Valentina Alberti, Cinzia Cocco, Sergio Consoli, Valentina Montalto, and Francesco Panella

Abstract *Cultural gems* is a web application conceived by the European Commission's Joint Research Centre (DG JRC), which aims at engaging people and organizations across Europe to create a unique repository of cultural and creative places. The main goal is to provide a vision of European culture in order to strengthen a sense of identity within a single European cultural realm. *Cultural gems* maps more than 130,000 physical places in over 300 European cities and towns, and since 2020 it also lists online cultural initiatives. The new release aims, among other, to increase the interoperability of the application. At this purpose, we provide an overview on the current development of an ontology for *Cultural gems* used to map cultural heritage in European cities by using Linked Open Data (LOD) standards and making the data *FAIR*, that is *F*indable, *A*ccessible, *I*nteroperable and *R*eusable. We provide an overview of the methodology, presenting the structure of the ontology, and the services and tools we are currently building on top.

Keywords ICT and society · Technology for governance · Social applications of the semantic web · Urban informatics · Cultural heritage

V. Alberti · C. Cocco · S. Consoli (✉) · V. Montalto · F. Panella
European Commission, Joint Research Centre (DG JRC), Ispra, VA, Italy
e-mail: sergio.consoli@ec.europa.eu

V. Alberti
e-mail: valentina.alberti@ec.europa.eu

C. Cocco
e-mail: Cinzia.COCCO@ext.ec.europa.eu

V. Montalto
e-mail: valentina.montalto@ec.europa.eu

F. Panella
e-mail: francesco.panella@ec.europa.eu

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1 Introduction and Background

Culture can be considered one of the ways to preserve and relaunch cities' attractiveness in the face of sanitary crisis [1, 2]. People dwelling in cities can join forces, supporting the process, sharing information on culture and creativity and highlighting what is unique in each city. *Cultural gems* (CG)[1] is a crowdsourced web application created by the Joint Research Centre (DG JRC)[2] of the European Commission. The platform, which is free and open source, has the objective of mapping relevant artistic and cultural locations in cities of the Euro area. The main goal is to document the range of culture and creativity found in European cities and towns by producing crowdsourced maps and a shared database of these locations. The source of information on the set of cultural locations comes from both OpenStreetMap[3] and the data shared by municipalities, research organizations and other private and public institutions in Europe. In this way, users are presented with enriched maps of EU cities, which are easily sharable and visualizable in user-friendly ways. The application offers a digital tool and resources to help local authorities and individuals who work or are just interested, in the artistic and cultural domains, in order to promote these sectors within their cities [14].

The platform was first inaugurated in December 2018 in the context of the European Year of Cultural Heritage.[4] *Cultural gems* has been featured in several policy documents, such as *The European framework for action on cultural heritage*, coming from the 2018 European Year of Cultural Heritage[5]; *Tourism and transport in 2020 and beyond*,[6] as a tool to support proximity tourism (COM/2020/550); *EU guidelines for the safe resumption of activities in the cultural and creative sectors—COVID-19*, as one of the actions to support the sustainable recovery of the cultural sectors (2021/C262/01).[7] Since its launch, CG is continuously evolving to meet users' needs. Currently, the application contains information on more than 130,000 cultural venues in over 300 European cities. *Cultural gems* has been also used as a communication and outreach tool, highlighting cultural initiatives both at European and local levels. Since 2020 a dedicated section lists more than 400 cultural initiatives accessible online.[8] In 2021, *Cultural gems* was enriched by contributions and collaborations with local authorities, universities, schools and users from all over Europe. In some cities, contributions were particularly detailed and well-finished, such as in Izola (Slovenia), Karlsruhe (Germany), Plovdiv (Bulgaria), Lisbon and

[1] *Cultural gems* application: https://culturalgems.jrc.ec.europa.eu/.

[2] https://joint-research-centre.ec.europa.eu/index_en.

[3] https://www.openstreetmap.org/.

[4] https://culture.ec.europa.eu/cultural-heritage/eu-policy-for-cultural-heritage/european-year-of-cultural-heritage-2018.

[5] https://culture.ec.europa.eu/sites/default/files/2021-07/European-framework-for-action-on-cultural-heritage.pdf.

[6] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0550.

[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021XC0705(01).

[8] https://culturalgems.jrc.ec.europa.eu/eu-culture-from-home.

Coimbra (both in Portugal). Further, in the occasion of the Portuguese Presidency of the Council of the European Union, ad-hoc activities were led with Portuguese cities that have been particularly active as contributors. A dedicated page presents the main contributions to the Portuguese cities.[9] The section "EU Culture from Home" kept growing, supporting users during the confinement period due to the COVID-19 pandemic, while more and more city stories were used to map intangible heritage in European cities.[10] In 2022, the platform is changing data infrastructure to improve data interoperability and information accessibility. At the purpose, we want to exploit the enormous potential of artificial intelligence for cultural heritage [7–9, 14], and in particular those derived by the adoption of semantic technologies and Linked Open Data (LOD) [11, 12], to facilitate the interconnection with disparate datasets and ontologies in the cultural heritage field [15, 17], such as Europeana[11] [6] and the Knowledge Graph of the Italian Cultural Heritage (ArCo)[12] [4, 5], using metadata standards and increasing semantic interoperability of the application.

2 *Cultural Gems* Ontology

An ontology for *Cultural gems* has been designed from the main CG classes used in the application, whose current classification is loosely based on the "concentric circles model of cultural industries" by Throsby [18]. The ontology aims at modelling this cultural heritage data. The categories are mainly organized to match also the OpenStreetMap categorization[13] relevant to our mapping purposes for both interoperability and clarity purposes.

The goal consists of building an ontology that is compatible and aligned whenever possible, with existing ontologies in the related domain, that are used as a de facto standard for representing cultural heritage data. These include, for example, the already mentioned Europeana and ArCo ontologies, and services like the Hellenic Aggregator of Digital Cultural Content,[14] among others, for linking and aggregating the generated application data with the various cultural heritage LOD available online.

We heavily rely on ontology design patterns (ODPs) principles [10] to build our ontology, that is, whenever possible we reuse existing ODPs from online ontology repositories. Reused patterns are annotated with the OPLa ontology [3, 16] in order to facilitate ontology class mapping and identification. For example, we directly reuse classes and properties from the available OntoPia Public Administration vocabulary[15]

[9] https://culturalgems.jrc.ec.europa.eu/portuguese-semester.

[10] As an example of a city story describing a tradition of the city, see Fado in Lisbon.

[11] https://www.europeana.eu/en.

[12] http://dati.beniculturali.it/arco/.

[13] https://wiki.openstreetmap.org/wiki/Map_features.

[14] https://www.searchculture.gr/aggregator/portal/.

[15] https://github.com/italia/daf-ontologie-vocabolari-controllati/tree/master/.

and from an ontology describing cultural events and sites (Cultural-ON ontology)[16] [13]. We indirectly reuse patterns from existing ontologies, e.g. CIDOC-CRM,[17] and include explicit alignments to them. Furthermore, our ontology definition reuses various classes and properties of the ArCo network of ontologies, connected by *owl:imports* axioms. The main classes of our *Cultural gems* ontology are mapped to RDF/OWL as subclasses of the top-level hierarchy of ArCo, in particular: *:CulturalProperty*, which has two subclasses *:TangibleCulturalProperty* and *:IntangibleCulturalProperty*. The first is further specialized in *:MovableCulturalProperty* and *:ImmovableCulturalProperty*. Other specific types of cultural properties we reuse are: *:ArchaeologicalProperty*, *:HistoricOrArtisticProperty* and *:MusicHeritage*. The cultural events module, which extends the Cultural-ON ontology, has been also used to map cultural events and exhibitions involving a cultural property.

The main classes of *Cultural gems* are then mapped to those class definitions, as illustrated in Fig. 1. The top CG hierarchy consists of the following classes:

- *:EUCultureFromHome*—Class representing cultural initiatives in European cities accessible online. For example, travel restrictions and social distancing might be limiting the possibility to visit venues and to taste cultural fragrances of European cities and towns in person. Museums, theatres, local cultural organizations, libraries and many more work to keep culture alive online in difficult times. This category maps a selection of initiatives and organized events accessible online.
- *:Cinemas and theatres*—Class representing cultural venues such as cinemas, theaters or opera houses.
- *:Art galleries and museums*—Class representing cultural venues such as art galleries and museums.
- *:Artworks*—Class representing public-space artworks created and displayed outside of the typical art gallery setting.
- *:Creative spaces*—Category that depicts physical objects and components at various scales that are intended to encourage or support creative business workflows and creativity.
- *:Historic sites*—Set of official locations where historical artefacts from the realms of, among others, politics, war, culture or society, have been preserved because of their cultural heritage value. Historic sites are frequently covered by legal protection, and many of them have received formal national historic site designation. Any building, location, landscape or structure that is locally, regionally or nationally significant, qualifies to be classified as a historic site. This often implies that the location must be at least 50 years old.
- *:Religious heritage*—Any type of property with religious or spiritual connotations, such as among others, churches, sanctuaries and cemeteries falls under the category of religious heritage venues.
- *:Memorials and monuments*—Class that represents various forms of historical monuments and attractions.

[16] https://dati.beniculturali.it/cultural-ON/ENG.html.

[17] http://www.cidoc-crm.org/.

Fig. 1 Hierarchy of the main classes of the *Cultural gems* ontology

- *:Events and festivals*—Class representing various forms of events and festivals.
- *:Music venues*—Class that represents any venue used for a concert or musical performance, including recording and rehearsal studios.
- *:Community spaces*—Class representing various kinds of community spaces.

Note also that the location module of ArCo has been leveraged to represent spatial and geometry data. A cultural gem in the application may be assigned with multiple locations, which are represented by means of the ontology class *a-loc:LocationType*. Furthermore, it can be the case that a cultural location of a gem is valid only within a specific time interval. This is represented by using the *a-loc:TimeIndexedTypeLocation* ontology class, that is an extension of the TimeIndexedSituation ontology pattern.[18] The reference namespace for the ontology definition is: https://culturalgems.jrc.ec.europa.eu/ontology/cultural-gems/, accounting so far to an overall of 67 classes.

Cultural gems data in the application are then mapped as individuals of the CG ontology by means of an ETL (Extract-Transform-Load) Python job performed daily (at night). The resulting data ontology, available in both Turtle and RDF/XML for-

[18] http://www.ontologydesignpatterns.org/cp/owl/timeindexedsituation.owl.

mats, currently accounts for around 2.9M triples. The reference namespace for the data is: https://culturalgems.jrc.ec.europa.eu/resource/.

Currently, data resources have been linked to DBpedia[19] and GeoNames[20] using **owl:sameAs** axioms. Further alignments to other popular cultural heritage ontologies, such as Europeana and ArCo data, will be provided soon. This entity linking task, object of currently ongoing work, is performed by using the LIMES tool,[21] a widely-employed entity linking and discovery tool for linked data.

Commonly-used style guidelines for labelling and representing ontology definitions and resources have been employed in our ontology engineering exercise. In particular, ontology data names have been represented in lowercase, substituting eventual space characters with dashes. Ontology definition class names, instead, have been represented using uppercase. Source ontology definition and data files are available in RDF/XML and Turtle formats within the Joint Research Centre Data Catalogue[22] at the following permanent location: https://data.jrc.ec.europa.eu/dataset/9ee32efe-af81-48e4-8ad6-a0db06802e03. These ontologies will be officially released soon also within the European Data portal,[23] the official data repository for European data.

3 Interaction and Visualization of the Data

Currently, we are implementing various intuitive and user-friendly access services to the designed ontologies, including content negotiation, visualization and navigation of data, improved exploitation of the available information and knowledge discovery. We enable the interested community to consume the produced data and ontology under Creative Commons Attribution 3.0 Unported (CC BY 3.0) license.[24] Ontology resources are stored in the RDF named-graph: https://culturalgems.jrc.ec.europa.eu/resource/, while the ontology definition in: https://culturalgems.jrc.ec.europa.eu/ontology/cultural-gems/.

Technically, the access to the data and ontology is possible by means of SPARQL queries on CELLAR,[25] the Publications Office's common repository of metadata and content, and using its REST APIs SPARQL endpoint services.[26] SPARQL is referred by W3C as the standard language for referencing RDF data and interacting with it. The SPARQL query language interface has a text box where queries can be entered.

[19] https://www.dbpedia.org/.

[20] http://www.geonames.org/.

[21] https://aksw.org/Projects/LIMES.html.

[22] Joint Research Centre Data Catalogue: https://data.jrc.ec.europa.eu/.

[23] European Data portal: https://data.europa.eu/en.

[24] https://creativecommons.org/licenses/by/3.0/.

[25] https://op.europa.eu/en/web/webtools/linked-data-and-sparql.

[26] https://data.europa.eu/data/datasets/sparql-cellar-of-the-publications-office.

The REST web service to access the dedicated CELLAR SPARQL endpoint[27] requires the user to specify as input a given SPARQL query, while giving the result of the query as output in one of the formats that follows: *text/html*, *text/rdf+n3*, *application/xml*, *application/json* or *application/rdf+xml*. Suppose, as an example, that you want to get all the RDF data from the CELLAR Sparql endpoint about the Museu do Fado gem, whose resource in the data ontology corresponds to https://culturalgems.jrc.ec.europa.eu/resource/cultural-gems/27213.

This would be translated in the Sparql query:

DESCRIBE <https://culturalgems.jrc.ec.europa.eu/resource/cultural-gems/27213> that, if executed in CELLAR, would produce the result available here.

We also adopt the *Live OWL Documentation Environment (LODE)* to browse the ontology in an human-readable way. LODE indeed enables the visualization in intuitive HTML pages of the ontology general axioms, namespace declarations, named individuals, classes and, finally, data, annotation and object properties.[28] The entire ontology is also accessible as a force-directed graph visualization through *WebVOWL*.[29] The interaction with these tools enable customization of the visualizations so that the user is presented with a user-friendly description of the ontology elements and is able to exploit better the underlying information.

We are also integrating two further visualization tools: LodView and LodLive. LodView[30] is a web application developed in the Java language which provides dereferentiation of URIs following W3C standards. It basically supports users by providing representations of our RDF resources through custom intuitive HTML pages. The tool implements content negotiation of our ontology data and allows to download the selected RDF resource in various formats, such as *xml*, *ntriples*, *turtle* and *ld+json*.

For example, the LodView representation of the Museu do Fado gem, in Portugal, is available at http://ec2-54-154-163-28.eu-west-1.compute.amazonaws.com:441/lodview/resource/cultural-gems/27213.html (see also Fig. 2). Here you can exploit and navigate the data entity, seeing for example that this gem belongs both to the Museum and EU Culture from Home categories and downloading the raw data in one of the available formats, e.g. json or csv, among others.

The second tool, LodLive,[31] allows to depict the RDF data via an effective graph representation, enabling the navigation of the ontology resources. The user is able, for instance, to expand the relationships of a given ontology resource in an automated way and explore the structure of the RDF data. It is also possible to associate images

[27] https://publications.europa.eu/webapi/rdf/sparql.

[28] http://ec2-54-154-163-28.eu-west-1.compute.amazonaws.com:8090/lode/extract?url=https://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/CC-COIN/cultural-gems/ontology-definition/cultural-gems.owl.

[29] https://service.tib.eu/webvowl/#iri=https://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/CC-COIN/cultural-gems/ontology-definition/cultural-gems-skeleton.owl.

[30] http://lodview.it/.

[31] http://lodlive.it/.

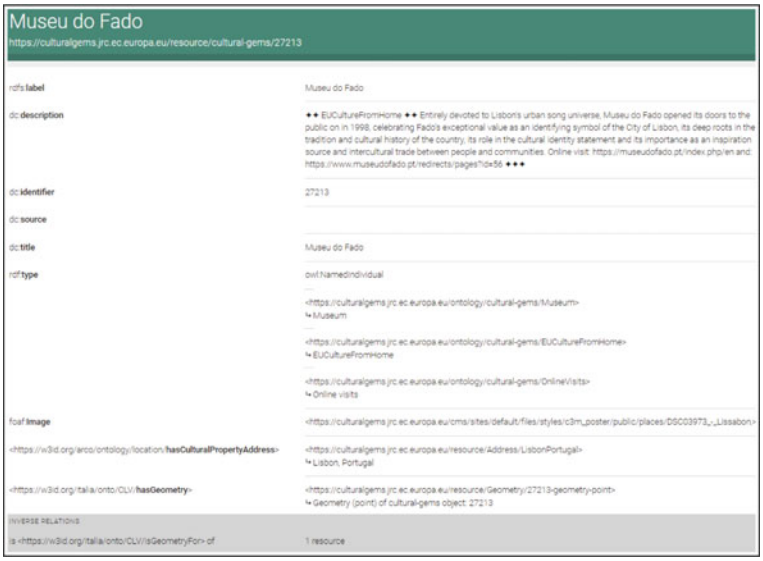

Fig. 2 LodView visualization of the Museu do Fado gem

and geo-coordinates to the data instances and evaluate **owl:sameAs** and inverse relations. Figure 3 shows, for instance, the relations of the Museu do Fado gem to the other data entities using the LodLive tool.

We plan to integrate further semantic services along with content negotiation of the data into the production environment of the application soon.

4 Conclusion

We have described our work related to the development of an ontology for the *Cultural gems* web application, which supports on mapping relevant artistic and cultural locations in cities of the Euro area. We expect to achieve various added values to the current application. Given that the adoption of ontologies allows a smooth linking of heterogeneous data sources, the platform will certainly benefit on an increased flexibility on data integration, enabling semantic interoperability. Data quality will also improve since the (re)adoption of existing ontologies forces to implement mechanisms and procedures to clean the underlying information and correct progressively errors within the data layer of the application. New services to end-users will also be offered to both the private and public sectors, as a result of the larger availability of information to easily consume from the platform. Costs are also reduced, given that the reuse of existing ontologies in the platform brings to lower the costs related to software development and maintenance services. Our final goal consists in further promoting interconnections among practitioners and researchers involved in the cul-

Fig. 3 View of the relationships of the Museu do Fado gem to the other data entities using LodLive

tural heritage field into a common dialogue, contributing to the EU-wide project of culture and creativity promotion.

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Coexistence of Wi-Fi 6E with LTE-U/ LAA in the 5 GHz Frequency Band

Mohamed M. Ibrahim and Saaidal R. Azzuhri

Abstract This work is how to achieve high user throughput with high performance in congested areas by amending the existing coexistence methods and enhancing the performance metrics by updating some input metrics such as duty cycle period, energy detection threshold, data transfer period, etc. The simple topology will verify the basic concept of LTE-U/LAA coexistence with Wi-Fi. Then the indoor-crowded coexistence scenarios of LTE-LAA/U and Wi-Fi 6E in the 5 GHz will be the main idea of this study using the enhanced CAT-4 LBT algorithm design. The proposed model evaluated the coexistence performance based on CDF of throughput and latency. The transport layer of wireless communication will play a worthy role. When using the TCP protocol, the Wi-Fi throughput and latency will be more effective than the LAA operator. When using the UDP protocol, the LTE-LAA network has better throughput and latency than the Wi-Fi network. The throughput and latency for LTE-U and Wi-Fi operators are roughly identical using the FTP protocol. Overall, the throughput improved by 20%, and an approximately 2 ms delay time of the handover compared to the previous research results.

Keywords Wi-Fi networks · LTE cellular systems · Coexistence methods · Fair resource sharing · Unlicensed spectrum

1 Introduction

A physical layer in WLAN work as a peer-to-peer bit rate to reach more than 1 Gbps throughput. Wi-Fi employs Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) as a channel access method. The Clear Channel Assessment (CCA)

M. M. Ibrahim (✉) · S. R. Azzuhri
Department of Computer System and Technology, Faculty of Computer Science and Information Technology, University of Malaya, 50603 Kuala Lumpur, Malaysia
e-mail: 17220121@siswa.um.edu.my

S. R. Azzuhri
e-mail: saaidal@um.edu.my

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method is a contention-based protocol that can direct a Wi-Fi node to listen to the shared medium to determine its status [1].

When transmission opportunity (TXOP) is up, it should contend for the wireless medium. The countdown stops when another station starts sending. When a station contains frames to send, the station will wait for some time, equal to Arbitration Inter-Frame Spacing (AIFS), which prioritizes one access category over the other. It will wait until its network allocation vector reaches zero, and then it will wait for the contention window (CW) to complete.

On the other hand, long-term evolution (LTE) is an entirely different technology from its predecessor. It is controlled by a single network operator scheduling all the transmissions and does not have the distributed coexistence function that Wi-Fi inherently has. When allocating these two technologies, overlapping each other, Wi-Fi will hear LTE talking and essentially shut down [2]. However, LTE-License-Assisted Access (LTE-LAA) is on track to adopt Wi-Fi-like coexistence features. The FCC has looked to the industry to develop collaborative solutions within a flexible regulatory framework. The unlicensed spectrum can split into numerous carriers with a bandwidth of 20 MHz each [3].

LTE-U uses a carrier sense adaptive transmission (CSAT) approach that relies on the adaptive duty cycle that senses channel utilization to set the duty cycle parameters. If the LTE-U UEs' traffic demands can be fulfilled using only the primary carrier, the secondary carrier can be turned off to relieve the strain. If two Wi-Fi nodes are next to each other and replace one with LTE-U, the gain will increase from both LTE-U and Wi-Fi spectrum efficiency and improve the Wi-Fi performance. CSAT schedules transmissions depending on the intended duty cycle [4].

Furthermore, LTE-LAA uses LBT-based techniques to detect channel availability. Transmissions between Wi-Fi and LTE could happen in a matter of seconds. ED can detect signals as low as -62 dBm in Wi-Fi and LTE transmitters [5]. Preamble detection can only be used by Wi-Fi devices to identify signals from other Wi-Fi transmitters greater than -82 dBm. The Wi-Fi stations would be notified to begin a transmission via LAA devices.

Our contribution to this work is to improve the handover mechanism of Wi-Fi and cellular communications by improving the data rate and reducing time latency in real-time applications. The various bandwidth split options are defined when resources are allocated to many users equally. Also, this paper focuses on reducing media access control overhead and improving transmission flexibility and the physical layer during the session transfer between Wi-Fi and LTE networks. The radio frame structure and a physical layer in cellular technologies have a primary role in coexistence with other Wi-Fi systems [6].

The scope of this study is summarized as follows:

1. This study focuses on updating the existing coexistence mechanism between IEEE 802.11ax and cellular technology, such as LTE. Therefore, other wireless technologies such as Bluetooth and Zigbee are out of scope.

2. This study focuses on enhancing the throughput and reducing the coexistence time delay of Wi-Fi and LTE cellular communications via a simulation program. Thus, it does not test real-time condition experiments.

The rest of the papers are structured as follows; Sect. 2 discusses the most related work to this study. Section 3 outlines the methods used. The first scenario is a simple design then the second scenario is an indoor dense scenario experiment. Section 4 analyzes the results using the ns-3 open-source network simulator to comprehend how LTE and Wi-Fi share channel access. Section 5 evaluates the results and explains the difference between each finding. Finally, Sect. 6 concludes the paper.

2 Related Work

The research community is becoming more interested in the coexistence of Wi-Fi and cellular networks in the unlicensed shared spectrum. A discrepancy in TXOP transmission time and energy detection (ED) reduces the coexistence throughput shown in Sathya et al. [7]. However, their method cannot modify parameters like TXOP duration or preamble detection during the coexistence method. Also, Mekonnen et al. [8] compared Wi-Fi performance and delay to other systems using three Markov chain models. A channel is examined for DIFS time to see if it is idle. However, this LBT approach has a longer delay time and lower channel utilization.

UL transmissions use single-carrier frequency division multiple access (SC-FDMA) explained in Naik et al. [5]. License-anchored systems (LTE-U, LTE-LAA) that the anchor is the principal carrier and operates on a licensed spectrum. But it does not include any experiments to examine their theories. Also, a new contention window (CW) approach was used for LAA to enable the coexistence of LTE and Wi-Fi, according to Alhulayil and López-Benítez [9]. The proposed system is used when there are more traffic demands. Static muting, LBT, and RTS/CTS are just a few coexisting strategies available. But it incurs a significant delay in transmission.

Before transmission, the LBT technique LAA device can calculate the medium and confirm the measured energy, as proposed in Falconetti et al. [10]. The LAA LBT procedure's energy detection (ED) threshold and freeze period (FP) can impact LAA's channel access opportunities. But this method decreases the average user data rate when the served traffic increases because of interference and delays. Also, Jian et al. [11] suggested a Duet as a solution for LTE-U and Wi-Fi coexistence in unlicensed bands. Wi-Fi employs a dispersed MAC system, whereas LTE-U uses a centralized MAC protocol. But this mechanism costs additional energy and inaccurate duty cycle periods.

Wi-Fi and LTE-A are not interfered with using the almost blank subframe (ABS) method, as explained in Yuan et al. and Zhang et al. [12, 13]. The spectrum sensing method can only evaluate the quality of the user channel using a BS statistical estimate because it cannot determine which cells are communicating. Moreover, UEs can convert from Wi-Fi to cellular via the core network's gateway, as shown in Zhang

et al. [13]. The Wi-Fi APs may recognize the channel and communicate via LTE broadcasts during the random ABS. However, this solution has the disadvantage of requiring synchronization of Wi-Fi and LTE.

Also, Al-dulaimi et al. [14] used a secondary carrier via various RAN technologies. The network topology contains management resource that is shared network operations and spectral resources that cost high power resources. Moreover, Wi-Fi broadcasts are slotted with a random duration between idle and busy phases, as proposed in Abdelfattah and Malouch [15]. Modifying the duty cycle percentage from 50 to 41% to lower the overhead for LTE-U to use the Wi-Fi channel is an excellent option for coexistence. However, sometimes, the Markov chain model is incompatible with the MAC protocol of Wi-Fi.

Time division multiple access (TDMA) and frequency division multiple access (FDMA) scheduling mechanisms are used in cellular systems, according to Sathya et al. [6]. Wi-Fi used in the same preamble might result in better spectral usage for coexistence. However, this method has a dilemma arising in a fair backoff NR-U and Wi-Fi coexistence in the 6 GHz band. On the other hand, some devices used the CTS-to-self variation to secure transmissions in mixed-mode situations, as proposed Candal-Ventureira [16]. Because it can achieve larger throughputs, CTS-to-self is better than RTS/CTS. However, it is unable to address the hidden nodes issue. AP identifies considerable activity from surrounding BSSs.

MAC time-sharing methods and channel selection methods (spectrum sharing in frequency) were the two categories of spectrum sharing methods, as explained in Voicu et al. [17]. However, in other circumstances, time-sharing MAC approaches are irrelevant. Also, Kozlov [18] implemented the simulation using two communication channels (CCs) operating on non-overlapping frequency channels to transmit data simultaneously. However, it does not feature the traditional Wi-Fi inter-system interference simulation.

Certain RBs have been set aside to control traffic in specialized channels with user traffic, according to Maglogiannis et al. [1]. However, it employed complicated techniques and CCE overflow timeslots to handle requests from several networks. Moreover, Reddy and Roy [4] suggested a new approach based on sense before transmit (SBT) that assigns secondary carriers in the uplink and downlink directions in the unlicensed spectrum to carry traffic using reciprocity theory based on channel state information (CSI). But when the channel estimate error increases, the LTE-U user's performance suffers.

On the other hand, Li et al. [2] introduced that LTE-U used the almost-blank subframes (ABS) capability to blank a section of LTE transmission to increase Wi-Fi throughput. However, it did not concentrate on the coexistence of unlicensed multi-band frequencies in a dense environment. Also, Naik et al. [19] researched the difficulties of communicating low-band and high-band signals and established a detection threshold in wireless technology. However, the coexistence with LBE/LBT devices still requires channel access parameters optimization used by the LBT-based MAC protocols in NR-U and Wi-Fi.

Furthermore, Garcia-Saavedra et al. [20] created two LAA transmission rules, Orthogonal Random LBT Unlicensed Access (ORLA) and Optimal Orthogonal LAA

Access (OLAA), to increase LAA throughput in asynchronous and synchronous applications. However, the suggested transmission policies increase LBT throughput by 200% without increasing the Wi-Fi throughput. Moreover, Mukherjee et al. [3] proposed a carrier that detects radio signal interference using dynamic frequency selection (DFS). However, their technique reveals that when utilizing the licensed PCell, UE uses more power and lower frequencies.

In addition, for coexistence between LTE-U and Wi-Fi, Charalampou et al. [21] analyzed power consumption for all nodes in the testbed scenario in the srsLTE software. Also, Giuliano et al. [22] put their planned coexistence scenario to the test on a testbed. srsLTE software was used to implement LTE eNB on the USRP b-210 platform. But the proposed scenarios' throughput has limitations on each category in real-life conditions.

3 Simulation Setup

This section explained the simulation setup of our work. We are using the NS3.26 program installed in Ubuntu VM with installed libraries such as Gnuplot, libxml2, python-kiwi, python3. We investigate the two scenarios; one design is verification of our design via a simple setup, and the second design is via the indoor scenario. The cellular parameters are channel access manager, packet data flow, transmission duty cycle, and sensing threshold. The Wi-Fi parameters are CW update rule, TXOP, cyclic prefix duration, different detection thresholds, etc.

3.1 Data Collection

The data is gathered from the MAC and physical layers of Wi-Fi 6E, the physical and logical layer of LTE-U/LAA frame designs from the academic surveys and professional papers. The simulation model will handle the radio waves of different wireless communication systems and compare the signals interference when working in the shared wireless spectrum. The radio waves can combine, causing an increase in wave amplitude to reach a seamless integration method.

3.2 Simulation Design Procedures

The first design: Implement a simple model between Wi-Fi 6E and LTE-U/LAA in the 5 GHz band. It contains two operators. This is to verify our working solution is indeed a working one. Operator A contains either LTE-U or LTE-LAA network architecture, including one eNB and one UE. Operator B has a Wi-Fi 6E infrastructure network containing one AP and one STA, close to operator A's area.

Figure 1 shows the two cells whose radio coverage overlaps. Two operators in the same region with transmissions may impact mechanisms such as clear channel assessment, adaptive modulation, and coding. Either LTE-U or LTE-LAA operates on 5.180 GHz, and Wi-Fi 802.11ax works on channel 36 (5.180 GHz). The application data rate is 20 Mbps, which saturates the Wi-Fi link but can be handled by the LTE link.

The second design: Implement a dense deployment scenario between Wi-Fi 6E network and LTE-LAA/U cellular networks in the 5 GHz band. It contains two operators. Operator A contains either LAA or LTE-U network architecture, including eNBs and UEs located at different distances. Operator B has a Wi-Fi 6E infrastructure network containing APs and STAs in the same coverage zone, as shown in Fig. 2.

Figure 2 depicts two different wireless network operators in the program, each with four cells and five UEs. Each operator has four BS and twenty UEs. The BS's positions are established (offset from one another by default of 5 m). The bounding box of a simulation is 120 × 50 m. The small cells of each operator are centered along the shorter dimension of the building. There is a random distance between the two operators' closest nodes. UEs (STAs) travel at a 3 km/h speed within the bounding box. Each operator uses a 75 Mbps constant bit rate UDP flow as a simulation data rate. UDP transmissions are employed from the backhaul to the BSs. On the other hand, the TCP segment contains 1440 bytes, and the initial CW of TCP consists of 10 segments. Also, FTP is used to control and manage traffic.

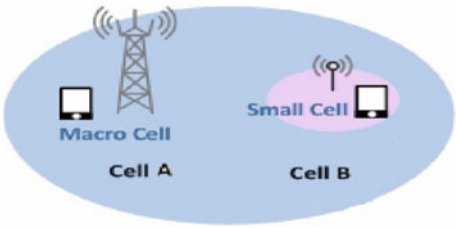

Fig. 1 Simple Wi-Fi 6E coexistence design with LTE-U/LAA

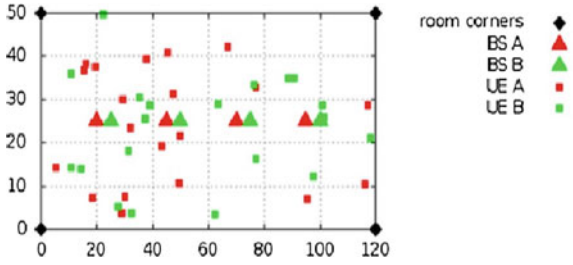

Fig. 2 Wi-Fi 6E coexistence with LTE-LAA/U (indoor scenario)

4 Simulation Results

4.1 Wi-Fi 6E Coexistence with LTE-U

Our first simulation setups are shown in Table 1. The parameters used in this simple scenario are d1 and d2 distances, channel access manager, packet data flow, number of BS and users, the duty cycle attributes, minimum threshold multi-user value (Threshold Mu Low), and the maximum threshold value (Threshold Mu High).

Figure 3 depicts that when enabling CSAT, d2 equals 50 m, Threshold Mu Low equals 0.3, and Threshold Mu High equals 0.5. Moreover, CDF measures the average throughput and latency as performance analysis metrics. The throughput and latency of the LTE-U network are better than the Wi-Fi network. The LTE-U will utilize more radio spectrum resources than the Wi-Fi network.

Figure 4 displays that when enabling CSAT, d2 to equal 100 m, Threshold Mu Low equals 0.3, and Threshold Mu High equals 0.5. The throughput and latency of the LTE-U operator are approximately equal to the Wi-Fi operator.

Table 1 Simulation parameters of simple scenario (LTE-U with Wi-Fi 6E)

Parameters	Settings	Details
Center frequency	5.180 GHz	Frequency band
LTE-U band	252	–
LTE-U/Wi-Fi bandwidth	20 MHz	–
Wi-Fi channel	36	–
Cell config A	LTE-U	Cell A vendor (Operator A)
Cell config B	Wi-Fi 6E	Cell B vendor (Operator B)
Number of eNB/AP (carrier)	2	One/Operator
Number of UE/STA	2	One/BS
Intra-cell distance	10 m	Distance between UE and BS
Inter-cell distance	50, 100 m	Distance between two base stations
Channel access manager	CSAT	Channel access category
CSAT duty cycle	0.5	Portion of ON time in CSAT cycle
CSAT cycle duration	160	Duration of CSAT cycle in several subframes
MU1	0.1, 0.2, 0.3	Threshold MU Low (CSAT adaptation)
MU2	0.3, 0.4, 0.5	Threshold MU High (CSAT adaptation)
ftp Lambda	3.5	Packet arrival rate
Transport protocol	UDP	Transport type

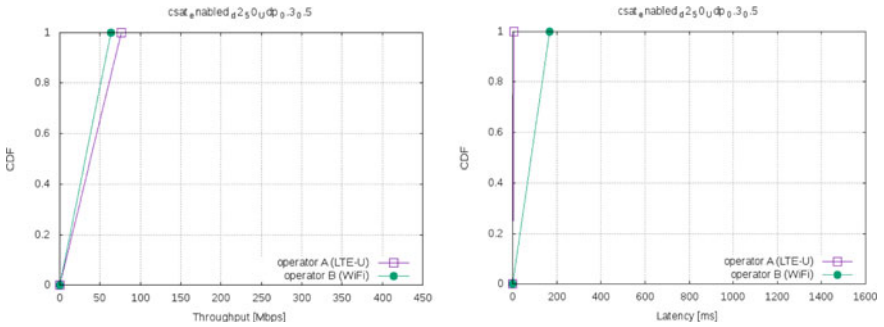

Fig. 3 First performance simulation outcome (Wi-Fi 6E/LTE-U)

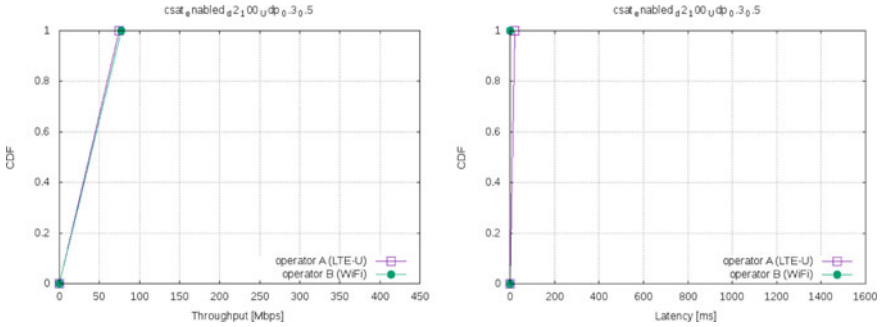

Fig. 4 Second performance simulation outcome (Wi-Fi 6E/LTE-U)

4.2 Wi-Fi 6E Coexistence with LTE-LAA

Table 2 shows the simulation settings for the parameters in the second scenario, such as d1 and d2 distances, channel access manager, packet data flow, energy detection threshold, contention window, and LBT TXOP. The LBT is different than in LTE-U attributes such as TXOP, user reservation signal, and CW update rule.

LAA prevents Wi-Fi from using the channel when d2 equals 50 m. The default result of the code shows operator A (LTE-LAA) has a throughput of 65.3 Mbps and the lowest latency of 34.1 ms. However, operator B (Wi-Fi 6E) has no throughput without latency. The LTE-LAA will take all the radio resources of the channel to send its data to the users. However, when d2 equals 65 m, the result shows operator A (LTE-LAA) has a throughput of 65.3 Mbps and a latency of 34.1 ms. However, operator B (Wi-Fi 6E) has acquired a throughput of 76.8 Mbps and lower latency of around 0.8 ms.

Table 2 Simulation parameters of simple scenario (LAA with Wi-Fi 6E)

Parameters	Settings	Details
Center frequency	5.180 GHz	Frequency band
LTE-LAA band	252	–
LTE-LAA/Wi-Fi bandwidth	20 MHz	–
Wi-Fi channel	36	–
Cell config A	LTE-LAA	Cell A vendor (Operator A)
Cell config B	Wi-Fi 6E	Cell B vendor (Operator B)
Number of eNB/AP (carrier)	2	One/Operator
Number of UE/STA	2	One/BS
Intra-cell distance	10 m	Distance between UE and BS
Inter-cell distance	50, 65 m	Distance between two base stations
Channel access manager	LBT	Channel access category
LAA Ed Threshold	− 72 dBm	CCA-ED threshold for channel access manager
ftp Lambda	1.5	Packet arrival rate
LBT TXOP	8 ms	TXOP for LBT devices
CW Update Rule	80%	Rule to update contention window of LAA
Transport protocol	UDP	Transport type

4.3 Wi-Fi 6E Coexistence with LTE-LAA Using UDP/TCP Protocol

The evaluation of performance metrics of these output flows:

1. Cumulative distribution function (CDF) of throughput: Throughput is the amount of data received on a flow divided by the time between the first and last packet.
2. CDF latency: Time from packet arrival in the MAC buffer of devices (eNB, AP, UE, STA) to packet transmission success.

Table 3 displays some parameters used in the indoor coexistence example, such as channel access manager, packet arrival rate, energy detection threshold, LBT TXOP, BS spacing distance, MU1, MU2, data transfer duration, and transport protocol.

Figure 5 shows the left-hand side diagram that the LAA operator has a slightly higher throughput than the Wi-Fi operator. The right-hand side diagram shows both operators have latency values that are approximately equivalent to each other. Using UDP-based file transfer applications, customers experience the best throughput in the LAA network compared to a Wi-Fi network in the unlicensed carrier.

Figure 6 represents the left-hand side diagram showing the Wi-Fi operator has a significantly higher throughput than the LAA operator. The right-hand side diagram shows the Wi-Fi operator has lower latency than the LAA network. Using Wi-Fi and TCP-based file transfer applications, Wi-Fi users will get higher throughput than in the LAA network.

Table 3 Simulation parameters of indoor scenario (LTE-LAA/U with Wi-Fi 6E)

Parameters	Settings	Details
Cell config A	LTE-LAA/U	Cell A vendor (Operator A)
Cell config B	Wi-Fi 6E	Cell B vendor (Operator B)
Number of carriers	4	Four carriers/operator
Number of UEs	5	Five user equipment or base stations/carrier
Intra-cell distance	10 m	Intra-cell separation
Inter-cell distance	10 m	Inter-cell separation
Bs spacing	5 m	Spacing between the two BSs of different operators
Channel access manager	LBT or CSAT	Channel access category
LAA ED threshold	− 62, − 72, − 82 dBm	CCA-ED threshold for channel access manager
ftp lambda	0.5, 1.5, 2.5	Packet arrival rate
LBT TXOP	8 ms	TXOP for LBT devices
CW update rule	80%	Rule to update contention window of LAA
CSAT cycle duration	160	Duration of CSAT cycle in number of subframes
MU1	0.1, 0.2, 0.3	Threshold MU Low (CSAT adaptation)
MU2	0.3, 0.4, 0.5	Threshold MU High (CSAT adaptation)
Transport protocol	UDP/TCP/FTP	Transport type
Data transfer duration	48, 80, 240 ms	Data transfer duration for the packet in LAA

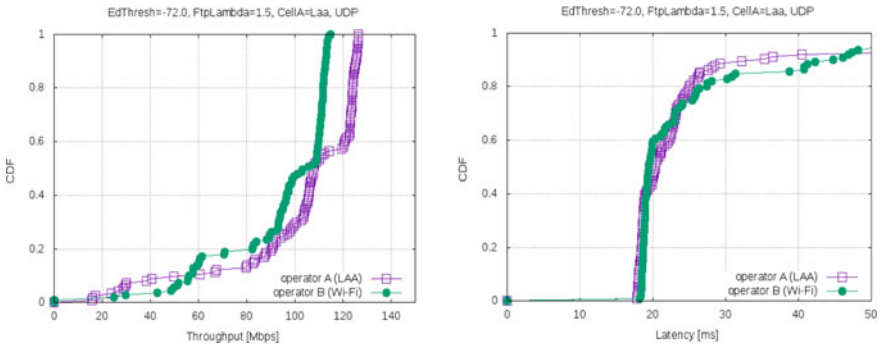

Fig. 5 Indoor coexistence performance (Wi-Fi 6E/LAA) with UDP

4.4 Wi-Fi 6E Coexistence with LTE-U Using FTP Protocol

Figure 7 illustrates the left-hand side diagram that the LTE-U operator has a higher throughput than the Wi-Fi operator in some values. The right-hand side diagram shows the Wi-Fi operator has approximately the same latency as the LTE-U network.

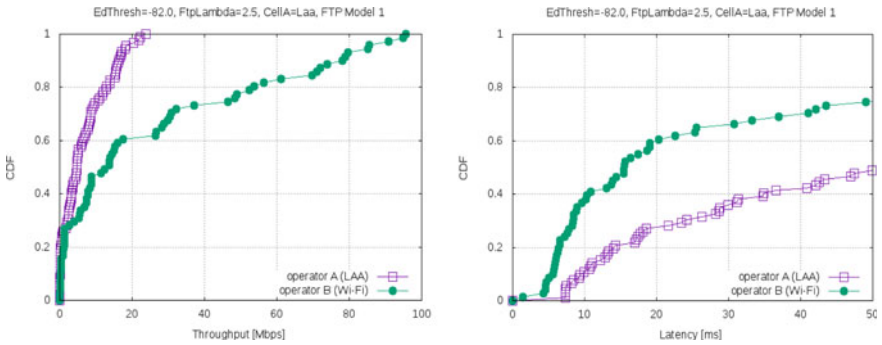

Fig. 6 Indoor coexistence performance (Wi-Fi 6E/LAA) with TCP

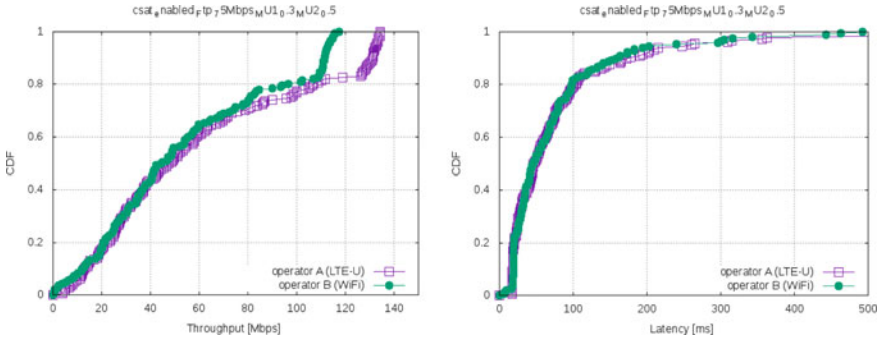

Fig. 7 Indoor coexistence performance (Wi-Fi 6E/LTE-U) with FTP

The coexistence outcome will get a higher performance rate for both networks when using LTE-U with FTP protocol in the indoor coexistence with the Wi-Fi networks.

5 Discussion

5.1 Wi-Fi 6E Simple Coexistence Scenario with LTE-U/LAA

When the distance between two stations is high in the first scenario, the Wi-Fi operator will acquire chances to use the same radio resources as LTE-U. But, in the second scenario, Wi-Fi will get more radio resources than LAA, which is better than the previous Wi-Fi 6E coexistence with the LTE-U scenario because it avoids interference inside the carrier sense range. However, in some cases, the performance of LTE-U coexistence with Wi-Fi degrades because flows affected by LTE-U OFF periods have significant delays, and the number of possible collisions has grown because of the duty cycle modification. On the other side, Wi-Fi networks get a low

throughput and lower medium resources in some cases in LAA coexistence due to the influence of reservation and control transmission signals, and the hidden terminals incur collisions.

5.2 Wi-Fi 6E Indoor Coexistence Scenario with LTE-LAA/ LAA

The proposed technique compares the mean and cumulative distribution function (CDF) of delay and throughput under different signal/energy detection thresholds utilized to conclude fairness. The built-in flow monitor tool tracks per-flow statistics at the IP layer to determine throughput and latency. CDF is calculated because the nodes' locations are randomly allocated. The CDFs are then created by post-processing these results. CDF of throughput and latency is calculated for every node as an average value in the indoor-crowded scenario.

In UDP, the throughput and latency of the LTE-LAA network are better than the Wi-Fi network because there is no guarantee of connection delivery between the sender and the receiver. When the energy detection threshold value increases, the LTE-LAA throughput has a higher value, and the Wi-Fi network gets a lower latency time. However, in TCP, the Wi-Fi throughput and latency will be more efficient than the LAA operator because there are more details for LTE-LAA than the Wi-Fi network structures. The LAA curve is skewed significantly to the right, indicating low throughput compared to the Wi-Fi network because of the LTE's high latency.

The throughput and latency of both operators change when increasing values of Ed Threshold and FTP Lambda. When the energy detection threshold value increases, the LTE-LAA throughput has a higher rate, and the Wi-Fi network gets a lower latency time when using UDP. However, in TCP, the LAA curve is skewed significantly to the right, indicating low throughput compared to a Wi-Fi network because of the LTE system's high latency, particularly the round-trip time, which fluctuates between 10 and 30 ms because of the delay in scheduling and sending the TCP ACK upstream. The LAA average latency ranges from 4 to 48 ms and a median of 11 ms. But Wi-Fi latency is between 2 and 5 ms.

By increasing the parameter values (energy detection threshold and packet arrival rate) in UDP data flow, Wi-Fi throughput increases from (110 to 118 Mbps). However, LAA throughput remains at (130 Mbps) in all cases, and latency fluctuates in values similar in both wireless systems with a little higher value for LAA than in the Wi-Fi network. On the other hand, when increasing the parameter values (energy detection threshold and packet arrival rate) in TCP data flow, Wi-Fi throughput remains at (100 Mbps). However, LAA throughput remains low in the range (20–25 Mbps), and latency remains fluctuations the same value approximately in some cases in each system, with a little higher value for Wi-Fi than LAA network.

However, in FTP, the throughput and latency for LTE-U and Wi-Fi operators are nearly similar, indicating low transmission time delay with a high data rate for low

latency and high-bandwidth applications. The throughput and latency for LTE-U and Wi-Fi operators are nearly similar, indicating a high coexistence performance indicator and a fair manner of sharing radio resources. When increasing Threshold Mu values in FTP, the outcome of LTE-U coexistence with Wi-Fi displays fair radio resource sharing at a throughput of 110 Mbps.

The Wi-Fi/LTE latency needs to transfer buffer status reports upstream, receive downlink control information (DCI) message on the downlink channel, and then schedule the ACK for transmission on the next subframe. Also, throughput decreases due to the higher channel occupancy time (COT). There will be less congestion in the LAA network when TCP (13%) and UDP (5%) are utilized. FTP is used to flow the packets between nodes in the LTE-U network to reduce signal interference and prevent signal jamming.

Moreover, each flow consists of 354 packets with 1448 bytes of 1476 bytes payload. It contains 1000 TXOPs at the Wi-Fi layer, each with best-effort traffic and a PPDU consisting of aggregated-MPDUs of up to 4 ms a piece. Because most flows are less congested than other flows, the transfer occurs without channel congestion, and the 0.5 MB file is transferred as quickly as possible. The coexistence curves may converge in some places while diverging in other sections of the simulation outcomes.

The main important LBT scheme features, such as contention windows and defer periods, should be customizable to allow for fair coexistence with other unlicensed spectrum technologies. The results reveal that by modifying parameters like the energy detection threshold, flow packet rate, threshold MU, and data transfer duration time, the proposed techniques can acquire a shared radio spectrum between the Wi-Fi 6E network and the LTE cellular system. The IEEE 802.11ax model was employed for the small cells in the indoor environment. The channel access structure, at least for downlink data transmissions, consists of a category 4 LBT system with random backoff and variable contention windows based on experimental results. Moreover, while LTE SINR distribution is unaffected by decoding, Wi-Fi user SINR distribution depends on preamble decoding.

6 Conclusion

The two simple scenarios have proved that LTE-LAA surpasses LTE-U in the coexistence with the Wi-Fi 6E networks based on data rate and delay with higher wireless connectivity reliability when sharing the bandwidth. However, according to indoor coexistence scenarios, the cumulative distribution function (CDF) of throughput and latency was compared using UDP/TCP/FTP protocols. Co-channel allocation decision-making defines parameters to decide whether to choose another AP or other LTE BSs to get higher spectrum utilization efficiency. The analytical and simulation comparisons yielded accepted results by achieving a higher data rate and lower latency with low power consumption. When the performance of the Wi-Fi network is more elevated than LTE, we can utilize some user applications, such as web browsing,

email, over the Wi-Fi networks. However, when the LTE performance is higher, we can use applications such as VOIP, video streaming, over the LTE network. The future work will tend to coexist with the next generation of cellular communication and the new wireless technology, for instance, NR-U, ORAN, and Wi-Fi 7, in IoT and cloud applications as wireless infrastructure. Moreover, future fairness research will focus on generalizing a new model framework by including second-order stochastic dominance notions to allow fairness to be determined even when non-monotonic curves intersect to avoid any loss in the packet transfer.

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The Effects of Digital Banking Platforms on the Profitability of a Bank: The Case of a Private Bank in Ghana

Acheampong Owusu

Abstract Businesses are adapting digital technologies to reach bigger markets, reduce operational costs, improve financial performance or profitability, and gain competitive advantage. The banking sector in Ghana is a very competitive one with most banks adapting one or more forms of digital banking products to facilitate their current operations, gain competitive advantage, and achieve future business goals. While many studies have accessed the impact of digital banking solutions on the profitability of financial institutions mostly in developed economies, the same cannot be said about developing economies. There is, therefore, the need to add to the body of knowledge on how digital banking solutions impact the profitability of banks in developing countries. This paper was underpinned by the updated DeLone and McLean IS success model and used a qualitative approach with purposive sampling of 28 staff and customers to assess a private bank's digital banking platforms through thematic data analysis. The findings show that system usage and user satisfaction which results in net benefits are positively influenced by information quality, system quality, and service quality. It is therefore concluded that the deployment and use of digital banking solutions improve the profitability of banks. Other implications are also discussed.

Keywords Digital banking platforms · DeLone and McLean IS success model · Profitability · Banks · Ghana

1 Introduction

Developments in internet services such as E-commerce and the digitization of processes have necessitated the need for financial institutions to extend their services across multiple digital channels to ensure business success. However, many adopters of such innovations have not associated the experience their customers derive from

A. Owusu (✉)
Business School, University of Ghana, Legon, Accra, Ghana
e-mail: aowusu@ug.edu.gh

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such platforms with their business performance [1]. Globally, the banking industry has seen a tremendous change over the years evidenced by diverse means of service delivery [2]. While information technologies have revolutionized the way of life, studies have shown that increasing consumer patterns, such as enhanced customer pro-activity and growing desires for comfort, have contributed to a rapid transformation of the banking and financial services sector [3].

Through the use of such electronic platforms, digital banking has become the new means by which banks render services such as deposit taking, funds transfer, cash and electronic money withdrawal, bank account management, payment of bills, and other financial services. It is therefore imperative for owners and managers of retail banks to deploy integrated systems or applications with the ability to run the entire business process on a computer to survive, gain a competitive advantage as well as fulfill the global requirements of the business process [4]. Many banks have invested in digital platforms worldwide to increase their profitability and their competitive stance in their related markets [5–7].

This adoption, in the context of Ghana, is not only for the delivery of efficient banking services to their customers but also serves as a way of marketing or reaching out to Ghanaian society and the world in general [8]. To this end, the Bank of Ghana (BOG) through the Ghana Interbank Payment and Settlement System (GhIPSS) is now developing websites and other payment platforms for transactions and the dissemination of information whiles making their activities known to the Ghanaian society at large [8].

Understanding the effects of digital banking platforms on the banking sector profitability requires an appreciation of the strengths, weaknesses, opportunities, and threats of these platforms and how they can improve efficiency and the customer experience in the retail banking sector. Hitherto, the entire exercise of retail banking used to be carried out manually which was fraught with major challenges. However, in recent times, almost all the banks in Ghana have seen the introduction of some kind of digital banking platform in their operations to capture clients easily through their various banking processes like account opening, cash withdrawal, account balance check, etc. which are easily delivered seamlessly through these digital platforms [8].

There have been several studies accessing the impact of digital banking solutions on the profitability of banks [8]. However, the majority of the studies have a context of developed countries with a few of them having developing countries [8] as their context. While some researchers are of the view that digital banking platforms have a positive impact on the profitability of banks, other researchers do not see a strong correlation between the two [9]. These inconclusive results call for further studies. This study thus assesses the effect of digital banking platforms on the profitability of banks. The factors that contribute to the profitability of banks from the use of digital banking platforms are examined.

The study, therefore, seeks to answer the research questions below:

1. How does digital banking platform implementation create operational benefits?
2. How does digital banking platform implementation affect profitability in the banking sector?

The deployment of digital banking platforms is a constantly evolving one with continuous improvement in technology. The findings of this research will help relevant stakeholders in the banking sector in deciding the best approach to adapt to improve customer experience as far as digital banking solutions are concerned. This will also help identify the areas that will require further research as far as digital banking platforms and their effectiveness are concerned. The findings of the study would also be useful for policymakers and managers of banks and other financial institutions since it will give them an insight as to how deploying digital platforms applications can affect the profitability of banks.

The rest of the paper is organized as follows. Section 2 introduces readers to the theoretical framework and the conceptual model with propositions development. Section 3 discusses the methodology with the data collection method and sample size used. Section 4 outlines the data analysis, findings, and discussions. Section 5 concludes with implications for research, policy, practice, and limitations.

2 Literature Review

2.1 Theoretical Foundation: IS Success Model

The study employs the information system success model as its research framework. The updated DeLone and McLean IS Success Model [10] is the theory that will shape the direction of the research. The updated model consists of six main constructs that lead to information systems success.

The updated DeLone and McLean IS Success model theorizes that a given system's information quality, service quality, and system quality will significantly in a positive manner influence "user's intention to use the system" or the actual use of the same which can then "lead to user satisfaction" [11]. In other words, to know whether the information system one has invested in is going to bring success, the information quality, system quality, and service quality of the said system should be good enough to have a positive effect on the "user's intention to use the system or actual system use" which will also lead to "user satisfaction".

The D&M has been widely used to gauge the success of various technological innovations [9–11].

2.2 Conceptual Model

Figure 1 illustrates the conceptual framework created for this study established on the "DeLone and McLean [10] IS Success Model" and extant literature.

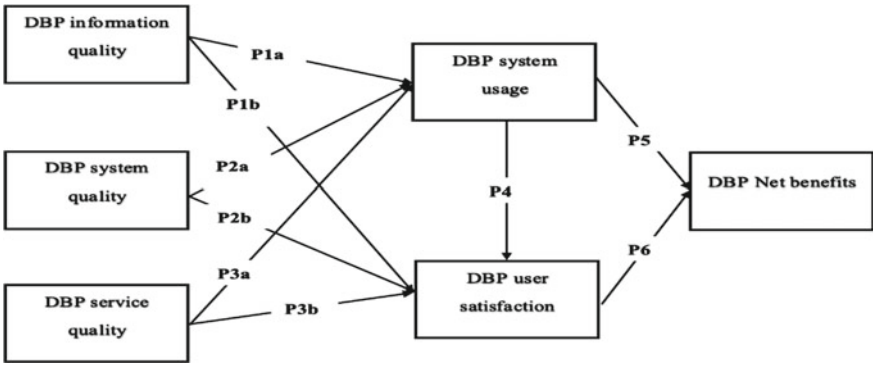

Fig. 1 Conceptual model

2.2.1 Digital Banking Platform Information Quality

Information quality (INFOQUAL) is described as the extent to which information generated from the system is perceived by the user of the system as being accurate, complete, well-formatted, and timely [10, 11]. Information quality is measured by determining how current, consistent, accurate, and complete the information is Abdurrahaman et al. [12]. This indicates that the information from digital banking platforms should be complete, relevant readable, and easy to understand DeLone and McLean [10]. Thus, a customer should be able to use the digital banking platform to perform a transaction in which [5] the output from the platform is of high quality to achieve desired request or result. Customers also expect to receive relevant information from digital banking platforms Owusu [11]. This comprehensive information is anticipated to lead to digital banking platform approval as well as user satisfaction from a bank's customers. A positive substantial correlation has been found between information quality and user satisfaction [9].

For this research, information quality is examined and has been rewritten as "DBP information quality". This researcher, therefore, proposes that:

P1a: DBP Information Quality will positively impact DBP System Use.

P1b: DBP Information Quality will positively impact User Satisfaction.

2.2.2 Digital Banking Platform System Quality

System quality (SYSQU) is the extent to which the user sees the systems under discussion as easy to use, available, reliable, amicable, responsive, and flexible [10, 11]. It is a measure of how consistent the user interface of digital banking applications is, and the quality and level of documentation provided Abdurrahaman et al. [12]. It is therefore expected that the ease of use of the digital banking system where the system can be used by customers who may not necessarily be tech savvy, works as required and when required will lead to user satisfaction. The digital banking platform

which is easy to use and responsive to a bank's client's needs will lead to system acceptance and user satisfaction. As the bank's customers and staff continue to use digital banking platforms for their banking transactions and gain satisfaction from the same, their opinions must be factored into this research. It has been established in previous studies that system quality is positively and significantly related to system use as well as user satisfaction [9]. Other studies found no significant correlation between system quality and user satisfaction [11]. For this research, system quality is examined and has been rewritten as "DBP system quality". This researcher, therefore, proposes that:

P2a: DBP System Quality will positively impact DBP System Use.

P2b: DBP System Quality will positively impact User Satisfaction.

2.2.3 Digital Banking Platform Service Quality

Service quality (SERVQUAL) is the degree to which the user sees all the support needs such as responsiveness, reliability, empathy, and assurance offered to the system by the service provider [10, 11]. This is the construct that reflects the technical competence and empathy the customers get when they run into any difficulty while transferring money, opening an account, paying bills, etc. [11]. The quality of service provided by the developers of the system is determined by the users of the system. This means that the support a bank's staff and its customers receive from the developers, the vendors, or its own IT staff and other personnel on the operations of the digital banking platform will go a long way to enhance the usage and user satisfaction of the platform for the service delivery and transaction delivery of both the bank and its customers. The response the user receives is what is being assessed [11]. Some studies, however, indicate that there is no positive significant relationship between service quality and system use even though those studies identified a positively significant correlation between service quality and user satisfaction [11]. Contrary to previous studies, Tam and Oliveira [9] disclosed that the link between service quality and system use is insignificant even though there is a positive significant correlation between service quality and user satisfaction.

For this study, service quality is what is examined and rewritten as "DBP service quality". This researcher, therefore, proposes that:

P3a: DBP Service Quality will positively impact DBP System Use.

P3b: DBP Service Quality will positively impact User Satisfaction.

2.2.4 Digital Banking Platform System Use (Usage)

System use (SYSUS) is a measure of how a user believes their output will be enhanced by the use of the system under review [10, 11, 13]. In this study, system use includes everything that a bank's staff and their customers do on the system, i.e., from login to navigation, to information retrieval and execution of a transaction. Thus, when a bank's staff and customers continue to use the digital banking platform, it may

enhance their performance [6, 7]. Once the users know that using the system enables them to finish their tasks accurately and on time, it is anticipated that their satisfaction level will also rise. Previous studies have established that user satisfaction and system use as well as net benefits and system use respectively are positively and significantly related Tam and Oliveira [9].

For this study, the system use is measured and reworded as DBP system use/ usage. This researcher, therefore, proposes that:

P4: DBP System Use has a positive significant correlation with User Satisfaction with DBP technologies.

P5: DBP System Use has a positive significant correlation with Net Benefits.

2.2.5 Digital Banking Platform User Satisfaction

User satisfaction (USESAT) is defined as the extent to which the user believes that the digital banking platform meets his or her requirement [10, 11]. User satisfaction serves as one of the moderators of the correlation between information quality, system quality, service quality, and net benefit [13]. A Bank's digital banking platform users will display a good attitude toward the various banking channels if it can give them the result of the service or the transaction they are expecting. Consequently, once a bank's staff and customers are satisfied with the system, it will lead to high benefits. A lot of previous research has established that user satisfaction and net benefits are significantly and positively related [9, 11].

This study, therefore, proposes that:

P6: A higher level of User Satisfaction has a significant positive correlation with Net Benefits.

2.2.6 DBP Net Benefits

Net benefits (NETBEN) is the extent to which the digital banking platform is contributing to the success of individuals, groups, industries, and organizations [10, 11]. Net benefits is the most important success measure because it reflects the balance of the true impacts of the digital banking platform on customers, staff or employees, organizations, and others in the operational chain of a bank [11]. Net benefits answer questions like, has the digital banking platform application system purchase saved the bank time and money? Have the benefits such as organizational strategy implementation, supply-chain efficiencies, and customer responsiveness, yielded positive profitability for the bank? [11].

3 Research Methodology

This study adopted a qualitative approach and used an interview guide for data collection. The researcher collected data for the study from multiple sources. These sources consisted of interviews, informal discussions, documents, and artifact analysis. The respondents were mainly key top managers from the bank under investigation referred to as BankA and officials of the IT department who were knowledgeable about the various digital banking platforms. Respondents came from three main units of BankA. These units are IT and Operation Supports; E-Business, E-Banking, and Internet Banking; Corporate/Retail. Again, data was collected from some customers of BankA.

Purposive sampling was adopted for the study as it enables researchers to distinguish and select key informants who have the relevant information required to achieve the research objectives.

Because the deployment of various digital platforms happened at the head office of the bank in Accra, all the interviews were conducted there. A sample size of twenty-eight (28) was selected for the study. The interview participation is presented in Table 1.

3.1 Data Collection Method

The study used interviews as its main method of data collection. On average, each interview lasted between 30 min and 1 h. All interviews were recorded with an audio recorder with some notes taken alongside the recording in other to ask probing questions.

Table 1 Participants selected for the study

Units	Participants	Total
Information technology	Manager (1), Employees (3)	4
Operation support	Manager (2), Employees (3)	5
E-business	Manager (1), Employees (2)	3
E-banking	Manager (1), Employees (2)	3
Internet banking	Manager (2), Employees (3)	5
Corporate banking	Manager (2), Employees (2)	4
Retail banking	Manager (1), Employees (3)	4
Total		28

4 Findings and Discussions

All interviews recorded were transcribed and sorted out in themes. The researcher guided the study with a data management plan. Transcribed data were put into themes reflecting the objectives of the study and the constructs from the conceptual framework. The similarities and variations in responses were observed, and the necessary inferences were drawn from key respondents' answers. The researcher used direct quotations voiced out by respondents to emphasize some of the points being made in the course of data analysis.

4.1 Information Quality

The information quality is assessed as being accurate, timely, reliable, complete, and well-formatted. From the data obtained from the interviews on information quality, participants responded that the information on the digital banking platform was of good quality. One respondent had this to say:

> *Information quality is excellent, real-time, and maintains privacy because of this I always use the BankA Mobile App for my transactions.*

Another interviewee stated that

> *Information on the platform is simple to understand and use, timely, and targeted to the appropriate audience.*

Thus, from the theory, when information quality is good, it will lead to the intention to use and actual use of the system.

Consequently, the integration of digital banking platforms has fast-tracked operational processes and reduced waiting time for a transaction which supports propositions P1a and P1b. These findings corroborate that of Selvaraj and Ragesh [14].

4.2 System Quality

The system quality metrics measure key qualities of a system which are usefulness, usability, responsiveness, reliability, and flexibility. From the interview, the majority of the participant agreed that the digital banking platform was accessible, responsive, and reliable during working hours and only had a few downtimes. They also confirmed that these downtimes are normally planned and announced before they occur. A respondent stated that

> *the platforms are accessible with a high level of security, protection, robustness, and reliability.*

Another pair of respondents respectively stated that the digital banking platforms of BankA are

very flexible to use as well as easy and user friendly, easy to understand and transact business.

The interviewees confirmed that they used the digital banking platforms as a result of these good qualities of the system. Also, the interviewees confirmed that the ease of use of the system together with its responsiveness and its reliability is the primary reason for which they use the system and derive user satisfaction. Again, they confirmed that the secure reliable nature of these platforms ensures customers are confident when performing transactions knowing they can have access to their funds at any time in a secure manner. These findings corroborate that of Ozili [15] and confirm propositions P2a and P2b.

4.3 Service Quality

Service quality is the quality of support that users get from developers or the IT department to use the digital banking platform. In other words, it describes the extent to which the system gets technical support and sufficient resources from top management and IT/IS staff to ensure its day-to-day running of such. These qualities include reliability, responsiveness, assurance, and empathy. With service quality, most respondents said the service quality was good. One major customer who runs a school and uses the BankA App, one of the digital platforms, to collect school fees had this to say:

Very good service support. We always get 24/7 support from the BankA IT staff. They give us active participation when we call them on the phone or even WhatsApp chats.

An employee also responded as stated below:

Exceptional especially with technical support from the Technology staff.

Thus, when the service quality of the system is good it enhances good usage of the digital banking platform. These findings support that of Tam and Oliveira [9] and confirm propositions P3a and P3b.

4.4 System Use (Usage)

System use or usage describes the frequency of use of the system. The nature of the use of the digital banking platform consists of bill payments, money transfers, account statement requests, cheque orders, deposits, withdrawal alerts, etc. From the responses obtained from the interviews, system use had a highly positive response. Those that used the digital banking platform said they were very satisfied with the use of the system because it gives them convenience. Most of the respondents responded

that they use digital banking platforms daily to perform transactions on their accounts from any place and at any time. Staff also indicated that they use internal applications and business process tools such as Processmaker because it facilitates their operational activities. This implies that usage has enormous consequences on satisfaction. Some of the members of management also hinted that the bank had successfully reduced the rate at which they set up new branches because there is a deliberate effort to drive transaction traffic to the digital platforms. This also helped the bank to reduce its operational cost and gain a competitive advantage. He also hinted that the quality of work from staff has improved as a result of the deployment and use of such platforms.

A few of the responses are outlined below:

The platforms provide convenience. I do not need to go through a lot of traffic to reach the banking hall to perform a transaction.

Simplicity, Convenience and Reliability.

Since most of the participants responded in the affirmative that they use the digital banking platform, it is clear that the performance of the bank is significantly affected by the digital banking platforms with accompanying fees and commissions which are components of profitability to the bank [16] and thus confirm proposition P4.

4.5 User Satisfaction

All the participants interviewed are satisfied with the overall performance of the digital banking platform. From the data collected, some respondents explained that the full potential of the Digital banking platform has not been fully exploited and they wish all their operations were fully digitized. However, the respondents are gratified with the performance of the existing digital banking platforms.

Generally, the responses from the interviews showed that users like to share knowledge of their experience on the digital banking platform with their colleagues. The users' attitudes are important measures of the digital banking platform's ability to provide user satisfaction. Sample responses are as outlined below:

*There is a high level of satisfaction from the usage of the platforms especially *737#.*

Most users are satisfied with the service.

From the responses to the interviews, the information quality directly affects the quality of service which also has a direct positive influence on employees' attitudes toward the system and on user satisfaction. The full potential of the digital banking platform installed can only be exploited if the users are satisfied with the system.

4.6 Net Benefits

Drawing from the themes of the interview, the majority of the respondents believed that their satisfaction or attachment to the digital banking platform is a result of the good features of the information quality and service quality of the platforms. This implies that when all these constructs are positive, it will affect user satisfaction which will also generate the net benefits of the Digital banking platform which will also affect the bank's profitability. Usage of the digital banking platforms has a positive influence on the continual user satisfaction of the system leading to the realization of net benefits to the bank thereby affecting the profitability of the bank. For any institution to maximize profitability, the operational cost must be reduced to its minimum [17]. The findings show that another reason for adopting digital banking platforms is the ubiquity of smartphones which catapulted the rate of change within the banking industry at a breath-taking pace [18]. Also, the proliferation of smartphones and the internet penetration surge within Ghana in recent years is a major contributor to the high level of competition within the banking industry in Ghana. These findings confirm propositions P5 and P6.

5 Conclusion, Recommendations, and Limitations

5.1 Conclusion

The main objective of this study was to access the effects of digital banking platforms on the profitability of banks. This was done by applying the six constructs of the DeLone and McLean IS success model to design a conceptual framework that was used to measure the digital banking platform on probability. Judging from the views of the respondents, the finding of this study indicate that the digital banking platform brings efficiency, effectiveness, information sharing, increase market share, convenience, and reduced operating costs to the bank. The factors together with proper business and information systems alignment provide banks with a competitive advantage.

5.2 Implications for Research

The findings of the research have added to the literature in terms of digital platforms through the lens of the DeLone and McLean IS success model which was used to explain the ability of digital banking platforms to improve customer experience, facilitate communication, reduce operational cost, improve turnaround time, provide a competitive advantage, and improve the profitability of banks.

5.3 Implications for Policy

Regulators of the financial industry and policymakers can use the finding of this research to draw up regulations and policies to guide the design, development, implementation, and deployment of digital banking solutions by banks and financial institutions.

5.4 Implications for Practice

For practitioners, this study provides a deeper insight into what customers and users look out for when accessing a bank's digital banking platforms. It provides a depth of knowledge on how banks can improve their profitability and gain a competitive advantage using digital banking solutions. This knowledge will serve as a basis for managers and decision-makers in banks to deploy digital banking solutions. This study will also help software architects in the design and implementation of software solutions that cater to the needs of bank customers and staff.

5.5 Limitations and Suggestions for Future Research

The study was not a generalized representation for evaluating the effect of digital banking platform profitability on banks in the entire country because it was handicapped in scope by using a single bank as a case study. Future studies may explore the profitability by using a survey approach with a big sample size from multiple banks to ensure a generalization of the Ghanaian context.

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Assessing Impact of Online Payment Systems Usage During COVID-19 Pandemic

Acheampong Owusu

Abstract The main objective of this study is to assess online payment systems usage in Ghana during the COVID-19 pandemic using graduate students at a public university as a case study. The study used a qualitative research method by way of interviews to collect data from 25 graduate students sampled purposively and used thematic analysis in analyzing the data. The results indicate that the COVID-19 pandemic influenced students to use online payment systems a lot due to movement restrictions and the risk of getting infected with the virus. Also, it was revealed that the system quality, security quality, and service quality of the online payment platforms influenced their usage. Again, the analysis revealed that the use of online payment platforms comes with a lot of challenges including poor network connectivity issues, an increasing rate of fraudsters, and agents having limited cash at the point of transaction. Implications are also discussed.

Keywords Online payment systems · COVID-19 pandemic · Digitalization · Ghana

1 Introduction

Digitalization is rapidly taking over the world, and this is making a lot of countries move from the physical cash system to digital systems where financial transactions are made [1, 2]. Most of the developed countries have already implemented online payment systems [3], whereas the developing countries are now beginning to realize its benefits and have started implementing them as well and many call this the cashless economy [1]. The paperless economy is a type of economy in which business transactions are conducted without the use of actual cash, with a greater emphasis placed on digital payment methods. Purchases of goods and services are made through the use of electronic money media, such as credit cards and debit cards, direct bank transfers

A. Owusu (✉)
University of Ghana Business School, University of Ghana, Legon, Accra, Ghana
e-mail: aowusu@ug.edu.gh

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from one account to another, visa cards, smart cards, mobile payment systems, and other technologies, among others [1, 4].

The COVID-19 (coronavirus disease of 2019) pandemic, also known as the coronavirus pandemic, is an ongoing pandemic (https://en.wikipedia.org/wiki/Pandemic) of coronavirus disease 2019 (https://en.wikipedia.org/wiki/Coronavirus_disease_2019) caused by severe acute respiratory syndrome coronavirus 2 (https://en.wikipedia.org/wiki/Severe_acute_respiratory_syndrome_coronavirus_2) (SARS-CoV-2) [5]. On March 11, 2020, COVID-19 was announced as a pandemic by the World Health Organization [6]. The pandemic has caused serious repercussions concerning the health and economic sectors globally. Due to this global pandemic, about three hundred cities in countries around the world had to go into immediate lockdown to curb the spread and reduce the deaths that had been brought about by the pandemic. This led to severe global socioeconomic disruption, the postponement or cancelation of sporting, religious, political, and cultural events, and widespread shortages of supplies exacerbated by panic buying [7]. Thus, the lockdown resulting from the pandemic led to the growing need for online payments which was not a problem in developed countries since this was not new [2]. However, in developing countries where most transactions are done with cash and face-to-face, there was a challenge in adapting. Nevertheless, due to the ongoing pandemic, it has become more of a necessity than a convenience for the general public to adopt and adapt the use of financial technology solutions to operate their businesses or their daily transactions [8].

In the previous decade, there have been considerable advancements in Ghana's payment system, particularly in terms of infrastructure for processing payments [9]. For example, advancements in national economic infrastructure, which include the availability of Global System for Mobile Communications (GSM) technology, expanded Internet penetration, and the steadily rising deployment of Automated Teller Machines (ATMs) over the past decade, have all had a positive impact on the country's payments landscape [10]. To its credit, Ghana, a developing country in West Africa, has taken the risky step of establishing an electronic payment system that allows transactions and agreements to be completed without the need for real cash. E-zwich card was introduced by the Bank of Ghana (BoG), the banking industry's regulator, through the Ghana Interbank, Payment and Settlement Systems (GhiPPS), which allows Ghanaians to feel more at ease using the card to transact business activities rather than physical cash, according to the BoG [1]. GhIPSS, which is ISO 27001 certified, was implemented and operates National Switch systems and the biometric chip card payment system, e-zwich, CCC (code control line) systems, and Automated Clearing House (GACH) systems [10]. On the other hand, despite the rising usage of online payment schemes in the country, cash remains the most extensively utilized retail payment tool in the country. According to the KPMG [10] report on payment developments in Africa, improving infrastructure and distribution channels is the key to adopting e-money and payments in Ghana. The report indicates that, although ATMs are quite common, especially in large cities, the adoption of Point-of-Sale (POS) systems has been poorly done making it rare to find a POS

terminal at a merchant. This study is therefore intended to assess how online payment platforms helped business transactions during the COVID-19 pandemic in Ghana.

Due to the COVID-19 protocol of social distancing, most businesses were forced to move to the cashless system without much education on it in terms of security and awareness. Thus, it is necessary to assess its effectiveness.

Consequently, the study was guided by the following questions:

1. Did the COVID-19 pandemic influence online payment platform usage?
2. Do online payment platforms' system quality, security quality, and service quality influence their usage?
3. What are the benefits and challenges of using an online payment platform during the COVID-19 pandemic?

The significance of this research can be assessed from three distinct perspectives: its contribution to the body of knowledge, its impact on policy, and its impact on practice. The study contributes to the body of knowledge, as the results can be a source of literature or secondary data for those in the academic field. In practice, the study is very beneficial to organizations and institutions as the findings of this study could assist them to improve their online payment products and services. In addition, this study is expected to raise awareness of online payment platforms and serve as a guide for developing countries with limited technology infrastructure to use similar systems in the future.

The rest of the study is organized as follows: the literature review section follows, then the methodology, analysis, findings, and discussions follow. The study then concludes with implications and suggestions for future studies.

2 Literature Review

2.1 Theoretical Framework

This section reviews the theoretical foundations of the study and will specifically review the updated information system success model.

2.1.1 Updated Information System Success Model

The modified IS success model underpins this research. The modified DeLone and McLean information systems success model [11] includes three key independent variables: information quality (IQ), system quality (SQ), and service quality (SVQ). Furthermore, the major dependent variables are intention to use or actual use, user satisfaction, and net benefits.

The modified DeLone and McLean information systems success model has garnered considerable interest from a range of technical innovation analyses [12].

Examples of papers that have adopted the updated DeLone and McLean IS success model include, "The impact of audio-visual technologies on university teaching and learning in a developing economy" [12], "Evaluating factors affecting user satisfaction in university Enterprise Content Management (ECM) systems" [13], and "Adoption of web-based learning management systems" [14].

2.2 *Conceptual Framework and Propositions*

The reason for the selection of this model is to ascertain the service and behavioral patterns of online payment systems, given the circumstance of a pandemic. The IS success model was used to investigate the online payment system quality, security quality, service quality, system usage, and the benefits the users got from using these platforms during the pandemic as shown in Fig. 1.

2.2.1 Online Payment System Quality (OPS Quality)

System quality is the degree to which a platform or a system meets the expectations of its users in terms of its reliability, responsiveness, and flexibility [11, 15]. According to Abdurrahaman et al. [13], renowned experts have discovered a direct link between the quality of a system and the likelihood of it being used. Vance et al. [16] established a strong positive association between System Quality and the rate of adaptation among people who use digital technologies. System quality is a key factor of online payment platforms, and some of these online payment platforms include credit cards, debit cards, mobile money platforms, expresspay, and the like. As such, this is to help us understand the standard created by online payment platforms in Ghana. The accessibility, efficiency, convenience of its use, and esthetic impact of online payment systems are all factors in system quality. Customer trust might well be harmed by flawed system quality. If online payment systems offer weak replies, customers may have to wait a long time for them to load and respond. This could make them apprehensive and ruin their delight. Users' trust in an information system is determined, and digital payment technologies are influenced by system quality in past findings [16]. The proposition for system quality includes:

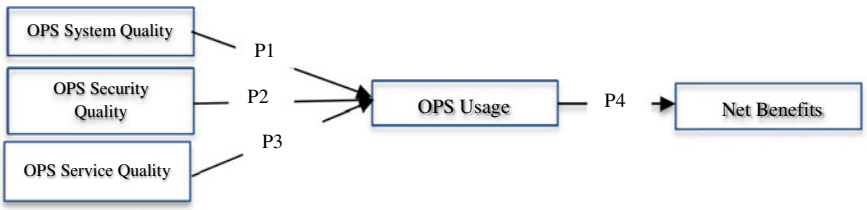

Fig. 1 Conceptualized model of the assessment of online payment systems

Proposition 1: Online Payment System Quality has a positive effect on OPS Usage.

2.2.2 Online Payment System Security (OPS Security)

Information security refers to the methods, procedures, and technology used to safeguard data from unauthorized access (confidentiality), alteration, or accidental change (integrity), and to ensure that information is easily available (availability) to authorized users on demand [17]. Gardachew [18] asserts that e-banking and e-payment apps pose a security risk since they rely so heavily on vital information and communications technology (ICT) systems, leaving financial institutions and businesses open to attack and putting clients at risk. Therefore, banks must understand and deal with security vulnerabilities if they are to leverage the potential of ICTs in providing e-banking services. This is to ascertain how well security countermeasures have been implemented. Users' views of security and trust in online services have been shown as major worries [4]. There was a discovery that trust and perceived security have a beneficial impact on online payment system usage [19]. The proposition for system security includes:

Proposition 2: Online Payment System Security has a positive effect on OPS Usage.

2.2.3 Online Payment System Service Quality (OPS ServQual)

Service quality is described as the degree of mismatch between users' perceived expectations for service and their judgments of the service delivered [20]. Customer service quality is measured by a variety of attributes including empathy, competence, confidence, follow-up services, responsiveness, and reliability [13]. This in turn helps to measure the support services that online payment businesses offer to the users of their various platforms. Considering human–internet connection is the primary means of delivery of services and interaction in the e-banking industry, service quality features are critical. Numerous studies have revealed a positive correlation between system use and satisfaction with service quality, as well as a negative correlation between system use and contentment with service quality [12, 15, 21]. The propositions for service quality include:

Proposition 3: Online Payment System Service Quality has a positive effect on OPS Usage.

2.2.4 Online Payment System Usage (OPS Usage)

This metric measures how much a stakeholder believes that a specific system has helped him or her personally or their group's overall success in the workplace [11]. This is to help ascertain or measure the frequency with which people use online payment platforms in Ghana. Essential factors, such as user experience with the

internet and its browsing features in online payment systems usage activities [22], are required to increase a company's website's reputation and awareness, as well as mental trust in mobile payments. Telecommunications infrastructure and distribution channel improvement are the keys to the adoption of e-money and payments in Ghana [10]. As per the study done by Owusu [12], several studies have discovered a correlation between system utilization and user happiness, as well as a link between net benefits and system use. The proposition for the system usage includes:

Proposition 4: Online Payment System Usage has a positive effect on Net Benefits.

2.2.5 Net Benefits

The net benefit is described as the amount to which the user benefits from the system, such as time and cost savings when using it for digital purposes such as electronic payments [15]. When individuals are using and enjoying the system, this will likely have a positive impact on their daily transactions or their businesses. Online payment systems are quickly becoming a smooth, quick, and simple way to make payments. However, many businesses in Ghana are yet to accept online payments due to a lack of knowledge [23]. Employee salary payments may be made electronically, which improves security while also cutting down on time and cost [24]. The net benefit that an information system may give is an important component of the system's overall value to its users or the underlying company. One of the objectives of this paper is to examine the net benefits that may be gained from using online payment systems during unusual events such as pandemics.

3 Methodology

This study is qualitative research, and its focus was on the assessment of online payment platforms during the COVID-19 pandemic in Ghana. The researcher focused on semi-structured interviews and designed the questions using the open-ended approach based on the underpinning theory.

3.1 Data Collection

Data collected for this study occurred in May 2021 from students in a public university in Ghana. The participants were twenty-five (25) students who were all at the MBA/MPhil level. The interviews were conducted via phone calls due to the restrictions brought about by the COVID-19 pandemic.

3.2 Data Analysis

The data was analyzed thematically through the identification of themes related to the mode of adaptation of these platforms by individuals in these groups as well as the major effects of the usage on service organizations.

4 Findings and Discussions

4.1 Did the COVID-19 Pandemic Influence Online Payment Platform Usage? (Research Question 1)

To identify if COVID-19 influences their usage of online payment platforms, participants were asked a series of questions. Participants were asked to indicate how the COVID-19 pandemic affected their use of online payment platforms and give reasons for their answers.

In answering the question, one participant said:

> *Yes, it did affect it positively. This is because I turned to hold less of physical cash but more of electronic cash [ST11].*

Another participant answered the question by indicating that:

> *COVID-19 made me appreciate the use of these platforms. I'm a physical cash person, but due to the pandemic and restrictions, I understood how important online payment platforms are. Saved me from going to the banks and crowded places [ST12].*

The responses above indicate that in the opinion of participants the outbreak of the COVID-19 pandemic increased their appreciation of online payment platforms as most participants started using or increased their usage of the online payment platform. This is a result of the COVID-19 pandemic which made it risky to even move out to make physical payments.

This finding is supported by the WHO [6] which reported that the outbreak of the COVID-19 pandemic increased online transactions globally and that of Merritt [25].

4.2 Online Payment Platforms' System Quality, Security Quality, and Service Quality Influence Their Usage (Research Question 2)

To identify the system quality, how secure online payment platforms are, and the service quality, participants were asked various questions. The first question asked was what they think of the well-being or state of the online payment platforms in Ghana in terms of their functionality.

In answering the question, this is what one participant had to say:

I do believe they are working, more room for improvement and awareness. Quite easy to send a family member or friend in the village money without the bank stress [ST6].

Another participant responded that:

Well, for me, I think there is more room for improvement in terms of the robustness of the systems although the systems work satisfactorily [ST9].

The above responses indicate that, to a large extent, participants believe that the existing online payment platforms in Ghana are performing well and have become very popular over time. However, some participants still believe that the system can be improved especially when it comes to the few challenges with online payment systems such as connectivity issues.

Secondly, respondents were also asked to indicate what they think about the system quality in terms of responsiveness, navigation, and efficiency. The responses provided by participants are quoted as follows:

In answering the question, one of the interviewees said:

For the Momo platform, it is quite okay for the average educated person. But most of the old aged and individuals with little education find it difficult for the navigation [ST16].

Another participant answered the question by indicating that:

Well, I would say that, when it comes to the quality of the online payment platforms in Ghana in terms of responsiveness, navigation, and efficiency, it is not bad. I think it is okay [ST17].

The above responses suggest that students believe that the existing online platform system quality in terms of responsiveness, navigation, and efficiency is very good as the online platforms respond favorably despite the occasional network challenges that occur during transactions.

Again, participants were asked to indicate with reasons as to whether the online payment platform they use is costly in terms of service quality.

One participant said:

I believe the MTN Momo is expensive, for taking 1% on every transaction is a high cost. The Vodafone cash is less expensive [ST6].

Another participant answered the question by indicating that:

MTN mobile money is costly, I usually prefer Vodafone which has now waived transactional costs of their platform [ST7].

The responses from the participants show that the service quality of the current online payment platforms in Ghana in terms of cost is relatively expensive considering the percentage of deductions per transaction.

To further answer the second research question of the study, participants were asked to indicate their opinion as to what the security of the system is like in terms of authentication, confidentiality, and integrity. In answering the question, participants provided different answers to the question as quoted below:

One participant answered the question by indicating that:

They are doing well with the security. They recently introduced the use of ID cards for withdrawal with the MTN MoMo platform [ST22].

Another participant answered by saying:

The system keeps the confidentiality and integrity of users. It is also very authentic [ST23].

The responses above give a clear indication that, in the opinion of the study's participants, the security of the system in terms of authentication, confidentiality, and integrity is relatively good as the system has put in place measures like the use of ID cards for authentication which guarantee the security of the user.

The findings demonstrated students believe that the existing online platforms in terms of the system quality (responsiveness, navigation, and efficiency) are very good as the online platforms respond favorably despite the occasional network challenges that occur during transactions. Thus Proposition 1 is supported. This finding is supported by Kwadzo et al. [26] whose study found that the quality of the current online payment systems in Ghana is good and easy to use and that of Vance et al. [16]. Moreover, the findings demonstrated that, in the opinion of the study's participants, the security of the system in terms of authentication, confidentiality, and integrity is relatively good as there are measures like the use of ID cards for authentication which guarantee the security of the user. Thus, proposition 2 is supported. This finding supports that of Gardachew [18] who finds that the security of online payment systems especially mobile money is relatively good and safe to use and that of von Solms and van Niekerk [17] and Stewart and Jürjens [19]. Again, the findings demonstrated that the service quality of the current online payment platforms in Ghana in terms of cost is relatively expensive considering the percentage of deductions per transaction. It has therefore been shown that the majority of students believe that the service quality in terms of cost is very expensive. Thus, Proposition 3 is not supported. Nevertheless, because of the ease of use and the convenience aspect of it, users are still being forced to use it. Also, some are switching to "Voda cash" which is more affordable. This finding buttressed that of Park et al. [27] that the charges per transaction on online payment platforms are relatively high.

4.3 The Benefits and Challenges of Using Online Payment Platforms During the COVID-19 Pandemic (Research Question 3)

To identify the benefits and challenges of using online payment platforms during the COVID-19 pandemic, participants were asked various questions.

Participants were, first of all, asked to indicate some of the benefits they enjoy when they use online payment platforms. In answering the question, one student said:

It is user-friendly. It is easier and faster. It can be accessed easily [ST11].

One of the participants answered by indicating that:

Easier, efficient, and you feel like your money is always with you, unlike banks where you know your money is far away. hahaha [ST12].

The responses above indicate that people benefit a lot from the use of online payment platforms. Most importantly, people feel the use of online payment platforms is easier, more convenient, faster, and highly efficient and they are easily accessible. Thus, proposition 4 is supported. This finding is sustained by Chan and Chong [22] and Loh et al. [28] whose study found that online payment platforms have benefitted consumers a lot since their implementation as a result of their convenience.

Participants were further asked to indicate if there are any challenges with online payment platforms and state the challenges. In answering the question, one participant responded by saying:

Yes, there are a lot of challenges. The fraud on the MoMo platform is a lot, this puts a question on security, there is a problem of network issue sometimes and there is also a problem of agents having limited e-cash to dispense sometimes [ST15].

Another participant added:

There are some challenges when it comes to the use of online payment platforms. We face challenges like network fluctuation which affects safer and faster transactions as well as fraudsters trying to impersonate people that I do business with [ST18].

One of the responses from the participants indicated that:

Yes, the increase rate of fraudsters with regards to the use of these applications [ST19].

The responses above clearly show that the use of online payment platforms comes with a lot of challenges including poor connectivity issues, an increasing rate of fraudsters, and agents having limited cash at the point of transaction. This finding is consistent with Ovia [29] whose finding established that providing basic information technology infrastructures is a major challenge. The finding is also supported by von Solms and van Niekerk [17] whose study found that security is also one of the major challenges of e-payment systems.

5 Conclusions and Recommendations

The study makes the following conclusions based on the objectives and research questions of the study.

The findings indicate that the outbreak of the COVID-19 pandemic increased the level of appreciation of online payment platforms as most users started using or increased their usage of the platforms as a result of physical movement restrictions. The findings also indicate that the online payment platforms' system quality, security quality, and service quality indeed influence their usage by the respondents due to the systems' user-friendliness, easy accessibility, and also very secure. However,

the findings indicate that the use of online payment platforms comes with a lot of challenges including poor connectivity issues, an increasing rate of fraudsters, and agents having limited cash at the point of transaction.

5.1 Implications for Research

The current study has broadened the understanding of how online payments have been used during the outbreak of the COVID-19 pandemic through the lens of the updated DeLone and McLean IS success model. This has therefore enriched the IS literature in terms of online payments from a developing country context.

5.2 Implications for Practice

In terms of implications for practice, this study has demonstrated that, practically, users of the online payments system in Ghana are mainly for money transfers and withdrawals. The study also demonstrated that, practically, users face some challenges like network connectivity and fraud. Therefore, managers and government agencies should devise strategies that will curtail this menace facing online payments.

5.3 Implications for Policy

Regarding policy implications, the study has broadened the understanding of the real issues including the benefits and challenges of the current online payment platforms in Ghana. The study suggested that the management of online payment platforms as well as telecommunication companies should establish policies and strategies to address the issues of network challenges and cyber security threats of online payments to win the trust of the users and reduce the security challenges with online payments. The study further suggests that the government through the ministry of communication and other relevant state agencies should provide a better cyber security infrastructure in the country which could be used by online payment companies to secure online payments in the country.

5.4 Limitations and Suggestions for Future Studies

Just like any other study, this study encountered some limitations. The study was purely qualitative. The researcher suggests that future research can use a quantitative approach and expand the number of respondents for easy generalization of the Ghanaian context.

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Leveraging Internet of Things Technologies to Drive Societal-Based Decarbonisation in the Transport Sector: Green Mobile Application

Marcia Mkansi, Aaron Luntala Nsakanda, and Jean Paul Roux

Abstract The global challenge of carbon dioxide emissions has been widely recognised by the UN Framework Convention on Climate Change and the 21st Conference of the Parties. There is a pressing need for sustainable transport systems, as the type of transportation used contributes significantly to greenhouse gas emissions. This challenge is exacerbated by the lack of integrated heterogeneous human-centred innovations in the transport mode decision-making process. This preliminary work presents a mobile application called 'Green' that exploits the current advanced state of Internet of Things technologies to track and monitor the carbon emission footprint of individuals based on their choice of transportation mode in the completion of their daily activities. To alter human behaviour and build loyalty towards a decarbonised society, the paper discusses the integration of Green within a loyalty reward programme that uses CO_2 emission reduction as a currency.

Keywords Decarbonisation · Greenhouse gas emission reduction · Internet of Things · Goal-setting theory · Loyalty reward programmes

1 Introduction

The threat to global security caused by climate change and the global challenge of CO_2 emissions and other greenhouse gases (GHGs) have been widely acknowledged by the United Nations Framework Convention on Climate Change (UNFCCC) and the 21st Conference of the Parties (COP21). The 2019 United Nations (UN) Secretary

M. Mkansi (✉) · A. L. Nsakanda · J. P. Roux
University of South Africa, Muckleneuk, Pretoria 0002, Republic of South Africa
e-mail: mkansm@unisa.ac.za

A. L. Nsakanda
e-mail: aaronnsakanda@CUNET.CARLETON.CA

J. P. Roux
e-mail: 10002561@mylife.unisa.ac.za

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General's Climate Action Summit concluded that despite the increased global focus on climate change, global GHG emissions are on the increase. For example, carbon emissions from fossil fuels that were growing at an estimated 1.6% per year up to 2017 were expected to accelerate to around 2.7% in 2018 [1, 2], and are expected to account for 80% of global GHGs by 2050 [3]. Current levels of CO_2 in the atmosphere are around 147% of pre-industrial levels (prior to 1750) [4]. During COP21, 196 member countries of the UN agreed under the Paris Agreement to keep the rise in the world's average temperature below 2°C, and preferably below 1.5°C, by 2050 or earlier. To meet this goal, progress needs to be accelerated in various areas, including the reduction of global GHG emissions to net-zero through intense and aggressive decarbonisation programmes across all sectors; the transformation of farming and other land activities to carbon storage areas; engagement in large-scale reforestation activities and forest, wetland and peatland management; and the development of other robust carbon storage solutions [5].

One of the largest GHG-emitting sectors is the transport sector, which is reported to be responsible for nearly 25% of global energy-related carbon emissions [6], and which is the second-highest carbon emission producing industry in the world [7]. Hence, the development of innovative pathways for decarbonisation in this sector is critical to address the global challenge of net-zero GHG emissions by the middle of this century. A variety of instruments driven by government and corporate policies have been developed to promote societal changes towards decarbonisation. Examples include carbon pricing, strict emission standards, technology phase-out mandates (e.g. policies to ban light-duty vehicles that emit GHG), green tax, incentives for technological innovation (e.g. switching to renewable and zero-emission sources of energy) or the increase of carbon sink capacities and innovation subsidies [5, 8]. Most of the existing initiatives focus on organisations, and the few that target individuals do not have an adequate incentive structure for their timely implementation on a large scale [5]. However, to legitimise decarbonisation, societies need to be mobilised to establish social cohesion towards the common goal of accepting sustainable transformation [9].

In the transport sector, over 70% of GHG emissions occur in urban areas because of short trips within and around cities [5, 10]. Although different levels of urbanisation exist between nations and within a country, about 55% of the world's population currently lives in urban areas. In 1950, the rate of urbanisation was only about 30%, but it is expected to rise to 68% by 2050 and to 80% by 2100. Thus, the world's population living in urban cities will have increased from less than 1 million in 1950 to 9 billion by 2100 [11]. These figures indicate that rapid urbanisation will continue to challenge efforts to reduce GHG emissions from the transport sector. They also point to the possibility for society at large to participate in the decarbonisation efforts of the transport sector through an appropriate incentive structure.

While there is increasing discourse concerning carbon tax, the advocates of decarbonisation have pointed out that there is a lack of society-based initiatives related to the climate change agenda. In particular, there is a need for a carbon currency to justify to all individuals and organisations in society that the burden for carbon tax is enough drive to save the planet from the brink of dissolution and ruin. The

world needs a comprehensive all-in-one integrated political, economic, social, technological, legal and environmental innovative currency solution that binds industry, society and government towards a common decarbonisation goal.

This paper seeks to contribute to this gap by proposing a society-based decarbonisation platform that considers a balance between environmental, social and governance (ESG) principles through the presentation of a mobile application called 'Green'. This application exploits the current advanced state of Internet of Things (IoT) technologies to track and monitor in real time the carbon emission footprint of individuals (and society at large) resulting from their choice of transportation mode in the completion of their daily activities. Furthermore, to motivate and encourage individuals and society at large to alter their behaviour and to become fully engaged in the decarbonisation journey, the paper discusses the integration of the Green mobile application to a loyalty reward programme (LRP) that uses CO_2 emission savings as a currency to build loyalty towards a decarbonised society.

In addition to the introduction, this paper contains four sections. The next section presents the theoretical and practical insights that underpin the Green mobile application. It is followed by a section discussing how to build engagement and loyalty to a decarbonised society. The last section presents our conclusions related to the potential offered by the platform discussed in this paper.

2 Theoretical Insights of Green Mobile Application: Internet of Things and Goal Theory

The Green mobile application innovation draws on design science's IoT and the goal-setting theory (henceforth, goal theory) to demonstrate how a mobile application supported innovation can drive industrial innovation design and encourage societal decarbonisation towards a high-performance cycle. Goal theory serves as a lens for exploring the use of persuasive technologies in combination with an IoT framework to address the problem of carbon emissions in the context of a decarbonised society. The IoT refers to a network of interconnected objects of various kinds such as sensory technologies that form a holistic intelligent ecosystem that could be managed via the Internet or telecommunications network, and which allows the control and collection of real-time data to fulfil the purpose of the system as a whole Li [12]. The relevance of IoT to the Green mobile innovation is its ability to serve as a mechanism and moderator of goal theory. The Green application integrates IoT's network and application layer (i.e., Microsoft Azure/Amazon AWS/Google Cloud), sensor layers (i.e., GPS, smartphones, wearable technologies) and network layer (e.g., Wi-Fi, HSDPA, HSPDA+, 3G, 4G, 5G) to track personal carbon emissions and influence lifestyle choices to achieve the goal core (decarbonised society). Hence, the integration of the goal theory and IoT, as depicted in Fig. 1.

The goal theory posits that to establish whether changes to human behaviour would achieve a positive outcome when executing a certain action, one needs to establish

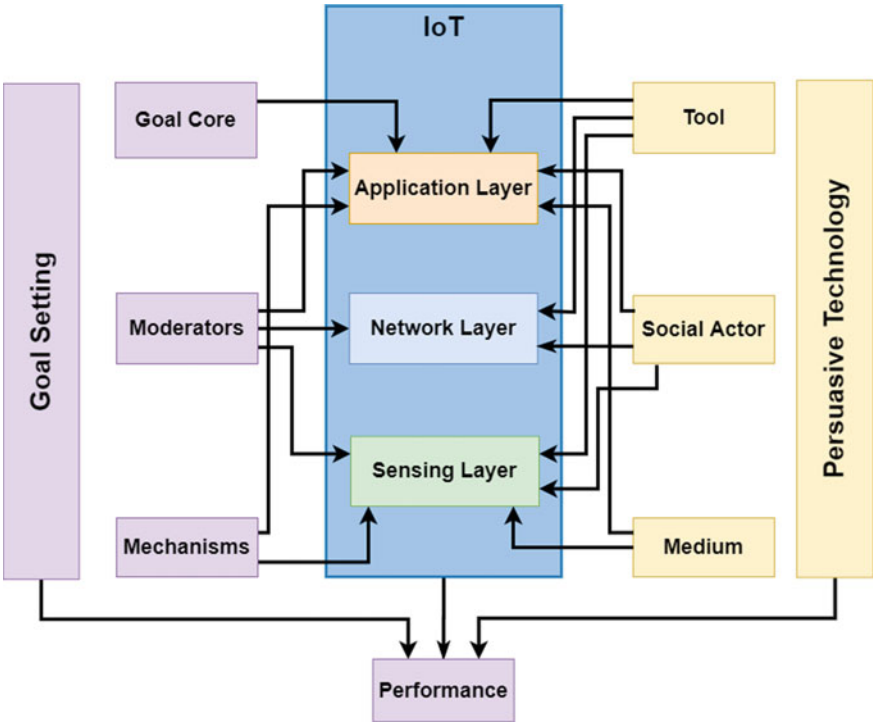


Fig. 1 Integration of goal theory and IoT

a baseline of whether changes to an activity would have an effect on a person. The latter premise of goal theory was explored in a 2017 study by Ewald et al. [13], who investigated the link between daily step count and the need for hospital care among a population of people between the ages of 55 and 85 in New South Wales, Australia. The study found that the participants who recorded at least 8,800 steps per day spent 30% less time in hospital for cancer or diabetes-related health issues than people taking 4,500 steps [13]. Based on Ewald et al.'s [13] study, we propose that to change the behaviour of people to mitigate their carbon emissions, it may be necessary to present a need or a goal to persuade them of the benefits of lower carbon emissions, such as the health benefits found by the above study.

The Green mobile application innovation presented in this paper builds on the health belief model (HBM) to propose a theoretical model that could explain the need for carbon tax rebates, carbon tax credits or other incentives or rewards. We argue that when industry and society are confronted with the perceived susceptibility to and severity of a carbon tax, and/or the opportunity to earn carbon currency (i.e., carbon credits), they are more likely to act on it to increase their chances of a reward (e.g., a carbon tax rebate tax incentive, a product or a service). If we relate this to reducing personal carbon emissions, it can be argued that given enough facts about the negative effect of carbon emissions and the need to lower it, and the opportunity

for a reward by trading tax credits, a strong argument can be presented towards a lower carbon emission lifestyle. Socially constructed norms and social influences have also been studied, and it has been found that they play a significant role in technology usage [14]. Figure 1 presents a graphical illustration of the integration of goal theory and IoT as relevant to this paper.

3 Green Mobile Application Development: Design Science Methodology

The mobile application development followed the design science methodology, which constitute the following stages: defining problem relevance, approaching design as a search process, design as an artefact, design evaluation, research rigour, research contribution, and its communication. The design methodology has been extensively researched Hevner et al. [15]. Its strength is in the combination of the different, but complementary, behavioural aspects of goal theory and computer design science.

3.1 Problem Model

The problem relevance emerged from recent study and policy papers and organisations which point to the effects of climate change that are mostly linked to different GHGs, that include carbon emissions [1, 2]. The common view from the latter scholars and organisation such as the World Meteorological Organisation (WMO) is that CO_2 emissions due to anthropogenic activity contribute approximately 65.8% of the radiative forcing (reflection of sunlight back to earth from the atmosphere). One of the major sources of carbon emissions is transportation, which currently leads the total GHG emissions, with an estimated 23% of global energy-related CO_2 emissions that account for about 65% of global oil demand [2]. Much has been done to address carbon emissions from a policy and industrial perspective, both by international and national governing bodies, through frameworks, agreements and greener technologies. However, there has been a lack of focus on the individual and societal impact that humans have on global carbon emissions as a result of their transport choices. Therefore, the call for research to integrate the heterogeneous human nature when investigating ways towards a decarbonised society [16]. This study responds to the call through the development of the Green mobile application.

3.2 Approaching Design as a Search Process

The design process of Green involved evaluating the design science tools, suitable solutions, technologies, software development frameworks and methodologies, platforms and similar technologies in order to find a unique approach to carbon emission tracking. Complementary to the design tools was the behavioural leg of design methodology which involved evaluating goal-setting theory tools as part of the aim to reduce personal carbon emissions. This resulted in various development methodologies and frameworks that can be broadly categorised as heavyweight (i.e., Waterfall, Spiral Model and Unified Process (UP) and agile (such as XP, Scrum and Lean)) [17].

Based on the research, XP proved to be a highly suitable fit for this project. XP allows for a more irregular cadence during the development phase which, due to circumstances, would be the norm during the development of this project. XP also caters for exploration and planning to happen where it is required, thus when development cannot continue due to certain blockers, the developer could stop development and explore other avenues in order to overcome those blockers. In terms of database, the study considered Google Firebase that runs on Google Cloud Compute which is a flexible NoSQL document type database that stores data in JSON format. It allows flexibility in the data model, as well as built-in rules to manage the access to various collections that will also take a lot of effort off the developer. Further, Google Firebase allows a developer to quickly create a mobile application with the necessary cloud infrastructure, including databases, authentication, hosting, computing resources, etc. with minimal effort. The coding language utilised for Green belongs to the class of hybrid mobile applications, which are installed applications just like native applications, but wrapped in a container that acts as the bridge between the application and the underlying platform [18, 19].

3.3 Design as an Artefact

The model architecture followed an IoT framework which encompasses the total scope of this application, the selected architecture also needs to adhere to this framework, as depicted in Fig. 2. The IoT refers to a network of interconnected objects of various kinds such as sensory technologies that form a holistic intelligent ecosystem that could be managed via the Internet or telecommunications network, and which allows for the control and collection of real-time data to fulfil the purpose of the system as a whole. It can be arranged in the following stages: identity, sensing, processing and information transmission [12]. The sensing stage consists of the various sensory technologies that gather the required data or execute control of the device it is monitoring. The network layer encompasses any transmission medium, including the wireless or cabled mediums used in access networks or core networks in a two-way transmission mode that would transport the data to and from the sensing

layer and the application layer. The application layer consists of the applications that would gather, process and store the data from the sensory layer and execute control over the sensory and network layers. Figure 2 illustrates the process.

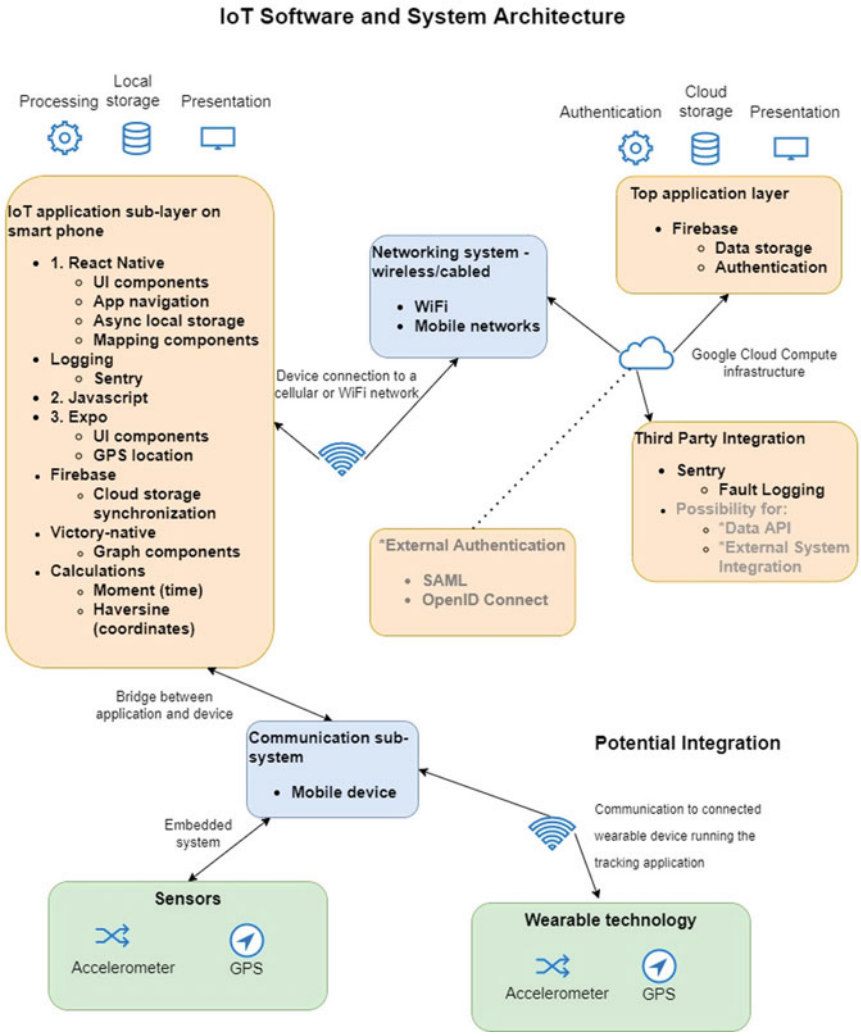


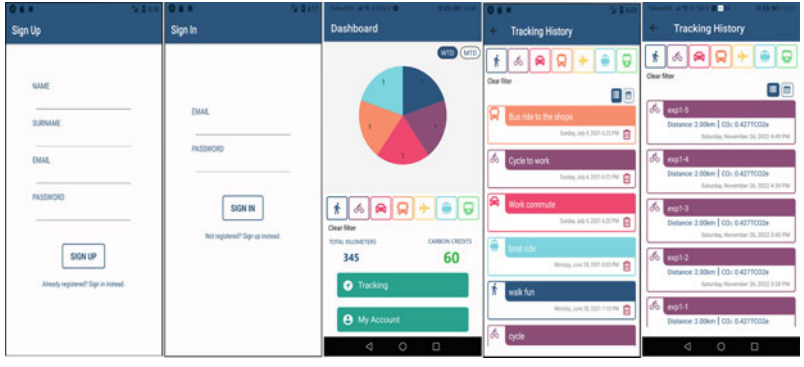
Fig. 2 Green mobile application IoT framework

4 Development Results: Operationalising IoT and Goal Theory

The development results encompass the last stages of design science, such as design evaluation, research rigour, contribution and communication. In terms of design evaluation and research rigour, the Green mobile application operationalises IoT and goal theory into a practical decarbonisation platform as shown in Table 1. The application interacts with the users for various major tasks, such as: download Green; register; login; view carbon emission tracking activities per different transport choices, dates, month, years, geography and carbon credits generated; and logout. The mobile-based innovation serves as a carbon tax credits currency tool, a data hub and a critical input measure of the FTSE4Good Index on how its users contribute to alleviating the UN sustainability goals towards the environment (reduction of road CO_2 emission, noise and congestion), while encouraging social and governance policy design for industries and the society at large. The strength of the Green digital mobile application is its ability to aggregate the data that will enable business, society and government to address several environmental (climate change, biodiversity, pollution, noise, congestion), societal (responsibility, health and safety, human resources and community, labour standards and supply chain) and governance (tax transparency, corporate governance and risk management) challenges simultaneously. The carbon emission data from reputable sources serves as inputs for the accuracy of the mobile application. The computer experiment and testing of major features of the Green mobile application are displayed in Table 1.

The Green mobile application can contribute to the communication of theory, practice and methods. In practice, environmental stewards in charge of carbon emission policies in various countries can use the Green mobile application (IoT framework) as a carbon tax currency to encourage industries and society to engage in decarbonisation (the CO_2 carbon reduction goal) through their choice of transportation mode. Members of society can trade their carbon credits directly for carbon tax rebates from their government, or indirectly, through carbon tax rebates at their workplace. Industry can aggregate all carbon credits from their employees for accumulative carbon tax rebates from the government. Hence, governments can aggregate various industries and society's carbon tax credits for carbon tax reduction reporting, evidence and compliance purposes to the UNFCCC and COP21. Subsequently, the cumulative CO_2 reduction can lead to a great input measure for the FTSE4Good Index, and ultimately, reduce global warming below 2°C. The reduction will be a significant increase to the nationally determined contribution (NDC) commitment targets in light of the 1.5°C goal. Health insurance can use the Green mobile application to exchange carbon tax currency for health rebates with their members, which they can later claim against their carbon tax bill from the government. In terms of theory and methods, this article advances the goal theory of Ewald et al. [13], and IoT studies, such as that of Li [12], by providing tangible evidence of the combination of behavioural and design science in real time to solve global problems [15].

Table 1 Mobile operationalisation of IoT and goal theory towards decarbonisation and carbon credits

Test case ID	Use case	Scenario/Condition	Data	Expected results	Pass/Fail
TC1-5	Download screen and logo on Android	Register and login	View data per date, month, year, etc.	View carbon tax credits, against carbon emission racked	Logout
Screenshots					

5 Integrating Green Decarbonisation Innovation Within a Full-Service Loyalty Reward Programme

The Green mobile application also offers the possibility of altering people's behaviour on their decarbonisation journey by integrating it into a loyalty reward programme. As reported by Nsakanda et al. [20], loyalty reward programmes (LRPs) are marketing programmes aimed at rewarding customers for repeat business. In turn, these rewards (or the likelihood of receiving one) serve as an incentive for customers to continue buying the firm's product or service rather than switching to a competitor. Loyalty reward programmes are prevalent across many industries (e.g., travel, hotel, retail, telecommunications, banking, gasoline) and have become the most effective means of finding, nurturing and sustaining long-term relationships with the company's most profitable customers [20, 21].

Within the context of society's contributions to decarbonisation efforts, similar to how existing LRPs work, individuals become members by subscribing to a CO_2 emission reduction LRP. Following a pre-established accumulation scheme, members earn points (i.e., carbon credits) through the Green mobile application tracking system on their repeated choices of modes of transportation that emit much less CO_2 than conventional modes (e.g., carpooling, public transportation). These points can then be fully or partially redeemed following a pre-established reward scheme, which can be a reward such as a product or a service.

At the core of the LRP, a founding (host) firm is responsible for trading at a standard price the total carbon offsets by its members during a given period, which corresponds to the LRP issued points, as well as for rewarding members at cost when redeeming points for rewards. Furthermore, as Nsakanda et al. [22] noted, the operation of such a firm requires, at a minimum, a promotional currency (e.g., points or miles); the definition of single or multiple reward tier(s) and a comprehensive database of individual consumers' demographics and detailed transaction information. In addition, advanced technology is required to manage the programme (e.g., facilitate the redemption of rewards directly or through Internet), operate the contact centre and analyse the members' database. Overall, the backbone of the Green mobile application innovation and the LRP lies in the use of advanced technologies and fully functioning large-scale information systems. They offer an integrated solution for societal-based decarbonisation efforts where a massive amount of information can be gathered, stored, aggregated and converted into knowledge at various scales and for various stakeholders.

Figure 3 shows a partial representation of the interactions of these applications with the various stakeholders. Contrary to the discussion in the previous section, society can no longer trade carbon credits directly with the various stakeholders, but solely through the LRP host firm. In addition, this option offers the benefit of becoming the only entry point for governments, corporations and other organisations to cost-effectively obtain aggregate and personalised data to address some of their needs.

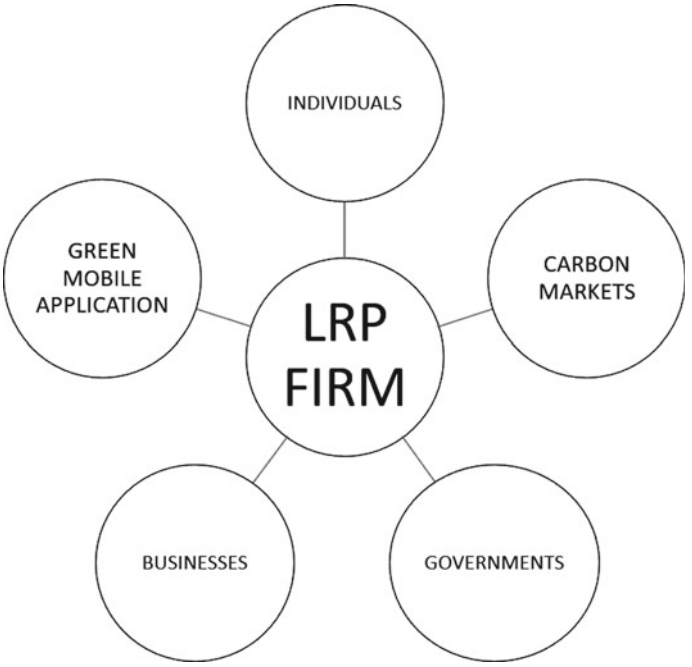


Fig. 3 Green mobile application integration within an LRP

6 Conclusions

Carbon emissions from transport activities are a growing concern and show no signs of slowing down. Various actions, methods and agreements have been adopted to counter the effect of carbon emissions, such as cleaner energy solutions, more efficient transport vehicles, better manufacturing practices, and even legislation and carbon emission goals on an international and governmental level. However, the focus has not been on an approach to assist individuals towards establishing a decarbonised society. The current technological landscape has changed dramatically, and thus, it provides an appropriate platform to address the issue of a decarbonised society.

This preliminary work presents a mobile application called 'Green' that exploits the current advanced state of IoT technologies to track, monitor and display the carbon emission footprint of individuals as per their transportation decisions. To alter human behaviour and build their loyalty towards a decarbonised society, the paper also discusses the integration of Green within a loyalty reward programme that uses CO_2 emission reduction as a currency and offers a sole entry point for various stakeholders (e.g., governments, corporations and other private, public for-profit or for non-profit organisations) to gather at cost a large amount of aggregated and customised data to promote, nurture and sustain decarbonisation initiatives.

In practice, the platform discussed in this work could be used to actively influence society's transportation choices and lifestyle behaviour towards a lower carbon emission society. It could also serve as a reflection tool for people to view and reflect on the impact that their transportation choices have on the environment. In addition, it could serve as a basis for other studies in the field of carbon emission monitoring regarding the lifestyle choices that influence carbon emissions, decarbonised societies, transport behaviour, etc. However, the feasibility of the platform's implementation remains to be tested and evaluated.

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Wireless Sensor Network-Based Streetlight Monitoring System with Theft Detection Features

Arjay R. Alba and Noel B. Linsangan

Abstract Street lighting systems are essential for rural and urban development as they provide safety for motorists and pedestrians. It is also forecasted the emergence of intelligent street lighting as part of the development of smart cities. However, streetlights are prone to infrastructure theft and electricity pilferage, especially those installed in poor urban regions where cabled streetlights are commonly used. In this study, the researchers developed a prototype application-specific device called Intelligent Monitoring System for Streetlights with Theft Identification Feature (iMoSSTIF). This device is capable of monitoring the different electrical parameters associated with the health of the street lighting it monitors. Moreover, the device can detect the following events: (a) power cable theft and its location; (b) lamp theft and its location; (c) burnt-out lamp and its location; and (d) electricity theft and the size of the overloading. This is done by deploying various sensors in the street lighting system using the wireless sensor network (WSN) technology. Moreover, the system is equipped with an alarm feature when such activities are detected. GSM module is also installed in the device so that it can text streetlight administrators responsible for streetlight monitoring when strange incidents occur. Finally, the researchers tested the device through a prototype street lighting system. The result shows that the iMoSSTIF is 100% accurate in detecting the aforementioned illegal activities.

Keywords Street lighting · Power cable theft · Anti-electricity pilferage · Raspberry Pi · Wireless sensor network · Arduino

A. R. Alba (✉)
Bulacan State University, City of Malolos, Philippines
e-mail: arjay.alba@bulsu.edu.ph

N. B. Linsangan
Mapua University, Manila, Philippines
e-mail: nblinsangan@mapua.edu.ph

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1 Introduction

Street lighting is an essential part of public service that provides a safer night-time environment for commuters and pedestrians. Proper use of street lighting can be considered a protective method that provides social benefits to people, including eliminating night-time accidents. Roads with low illumination are attributed to night-time vehicular and pedestrian accidents. A study in China shows that 93.49% of accidents, looking at illumination as an attribute, occur on streets with no street light [1]. In addition, a study determining the effects perceived by a community for the absence of streetlights revealed that the community worried about peace in the lack of streetlights [2]. Furthermore, the study shows that it is inconvenient for a community to live in a place without streetlights. On the other hand, a published study in Japan depicts that street lighting may offer a 43% reduction in night-time accidents [3].

Having said its importance, streetlight has become one of the priority projects of every nation. Some researchers said that intelligent streetlights would soon become integral to smart cities [2, 4]. However, streetlight monitoring and security are challenging because of their exposure to the general public, specifically in poor urban regions. They become prone to both electricity pilferage and streetlight infrastructure theft, such as power cable and lamp theft, which are illegal.

1.1 Purpose of the Study

In this study, the researchers' objective is to develop a prototype device called an intelligent monitoring system for streetlights with theft identification features (iMoSSTIF) capable of monitoring the health of the streetlight's electrical system and detecting acts of theft in the streetlight infrastructure. Specifically, the device must be able to identify the illegal activity of power cable theft and lamp theft. In these cases, the device must be able to locate the fault location. In addition, the system must also detect electricity theft. Moreover, the iMoSSTIF must report illegal activity through text messages and other output mechanisms to the local authorities.

2 Related Works

2.1 Power Cable Theft

Current methodologies in detecting power cable theft evolve from the capacitance current measurement method and the fault location method, which were both tested to be effective.

The streetlight lamps were modeled as capacitors in the capacitance current measurement method. Hence, when a fault occurs due to cable stealing, the size

of the capacitance is reduced. By this mechanism, a power cable theft is identified Patel et al. [5].

The fault location method also models the streetlight lamps as capacitors. However, in this method, an inductor and resistor are inserted into the streetlight's electrical system to produce an in-phase system. The capacitance is reduced when a fault occurs due to power cable theft. Hence, the phase angle of the system is changed. Whenever the phase angle changes, the system will detect this as an event of power cable theft. In addition, from the change in phase angle, the location of the fault is calculated Wang et al. [6].

2.2 Electricity Theft Detection

Moreover, the electricity pilferage detection method was analyzed, too. Three studies reviewed use the power measurement method in their detection method. The other two reviewed use current sensing methods to detect electricity theft. Electricity theft is generally detected when there is a significant increase in the power or current measured from the secondary side of the transformer and the service drop entrance. All materials reviewed feature an alarm system to notify electric distributors of the illegal activities of their customers [7–11].

2.3 Synthesis

The power cable theft method is an effective method for detecting cable theft. Unfortunately, the mechanisms involve measuring the impedance of the street lighting system, which could change significantly over time. Moreover, this kind of methodology is easily affected by various environmental factors. Hence, the researchers are motivated to look for a sensor that could monitor the cable of street lighting systems.

The methods used in electricity theft detection were designed and tested for residential use only, and the power measurement method can be adopted in the development of the iMoSSTIF. This can help the proposed device detect electricity theft in streetlights and lamps.

With the broad applicability of the Internet of Things (IoT), wireless sensor networks (WSN), and embedded systems [12–18], the researchers are confident that the iMoSSTIF can smartly monitor streetlights and detect infrastructure-related theft.

3 Methodology

The general approach used by the researchers in this study is the Conceive-Design-Implement-Operate (CDIO) framework. However, the operationalization of the device is not yet included as the proposed device is a prototype model only.

3.1 Conceive Phase

In the conceiving phase, the researchers conceptualize the system requirements, the process, and the iMoSSTIF device's desired output. Also, the technology to be considered is developed at this phase.

System Input Requirements. One of the specific functionalities of the iMoSSTIF is its ability to detect power cable theft in cabled streetlights. For this, the researchers considered using optocouplers (OC), an electronic device capable of generating output signals whenever the input signals are high. Here, the OC's input terminals are to be connected to the streetlight's terminals. Thus, OC produced a high signal (OC = 1) whenever the inputs were high. When power cable theft occurs, the input signal to the OC is interrupted. Hence, OC = 0 will occur. This scenario is to be identified by the iMoSSTIF as power-cabled theft.

The other source of input to the iMoSSTIF is the power analyzer reading (P_A), which is regularly monitored by a multi-functional device capable of reading various electrical parameters. In addition, the expected power (P_E) of the streetlight is also required. P_E is a user-defined input that is based on the electrical design of the street lighting system. Thus, the iMoSSTIF must have an LCD touchscreen display that the streetlight administrators can use to enter the P_E.

A sensor that can detect lamp theft is needed for lamp theft detection. In this study, the researchers consider using light-dependent resistors (LDR) to detect burnt-out lamps. It is important to consider this so that the iMoSSTIF will not be confused between a lamp theft and a burnt-out lamp. On the other hand, an improvised sensor the researchers simply called shorted wire (SW) is used for lamp theft detection.

All the sensors mentioned here are designed to be placed and connected to the street lighting system. The WSN technology sends all the signals and information collected to the iMoSSTIF for further processing.

System Process and Output. After defining the system input requirements, the processes needed are then carefully crafted. The iMoSSTIF must compare the values of P_A and P_E and analyze other signals from the WSN. The iMoSSTIF can identify various events depending on the signal received and processed.

Normal Operating Condition. Under normal conditions, the optocoupler signal must be high (OC = 1), meaning the power cable lines are unbroken. Also, since all the lamps are working and there is no additional load due to the illegal connection to the streetlights, the power analyzer reading is the same as the expected power of

the streetlight ($P_A = P_E$). In this case, the iMoSSTIF displays electrical parameters measured by a multiple electrical parameter measuring device.

Power Cable Theft. In the case of an OC = 0, the device must detect this scenario as a power cable theft. The lamps connected beyond the fault's location due to stolen cables will no longer light up. Hence, $P_A < P_E$. The system can compute the location of the fault by computing the number of working lamps (n) after the incident using the formula

$$n = N(P_A) \big/ P_E \tag{1}$$

where N is the total number of installed lamps in the streetlight being monitored. Hence, the location of the stolen cable is between n and $n + 1$ from the streetlight's terminal.

Lamp Theft or Burnt-out Lamp. Lamp theft or burnt-out lamp may occur whenever OC = 1 but with $P_A < P_E$. For lamp theft, whenever someone attempts to remove the lamp, the end of the SW sensor strategically placed between the lamp and receptacle is removed, too. In this case, the signal sent to the sensor node's microcontroller unit (MCU) is altered from high to low; hence, the event can be detected. Moreover, the system must identify it as a case of a burnt-out lamp when the LDR signal is changed from high to low without any change in the signal coming from the shorted wire.

Electricity Theft. Electricity theft is detected whenever OC = 1 but with $P_A > P_E$. In this case, the system gives feedback on the detected event with the size of the overloading ($P_A - P_E$).

The researchers derived the conceptual framework from this discussion which is shown in Fig. 1.

Table 1, on the other hand, summarizes the conditions of the OC and the comparison of power and its corresponding event.

3.2 Design Phase

During the design phase, the researchers developed the architecture of the iMoSSTIF, shown in Fig. 2, and the different design considerations. Here, Raspberry Pi (RPi) 3 is considered the brain of the proposed device for its powerful processor, dual-band wireless LAN, and faster ethernet.

Systems Input Design Consideration. As discussed in the conceptualization phase, the input P_E is a user-defined input. Therefore, the researchers considered using a 7-in LCD touchscreen panel as an input device for this matter. This panel will also display the output of the iMoSSTIF device.

Another critical input to the system is the actual load power (P_A) of the streetlight being monitored. Here, PZEM-004T is used to monitor power and other electrical parameters attributed to the streetlights' health. This power analyzer is connected

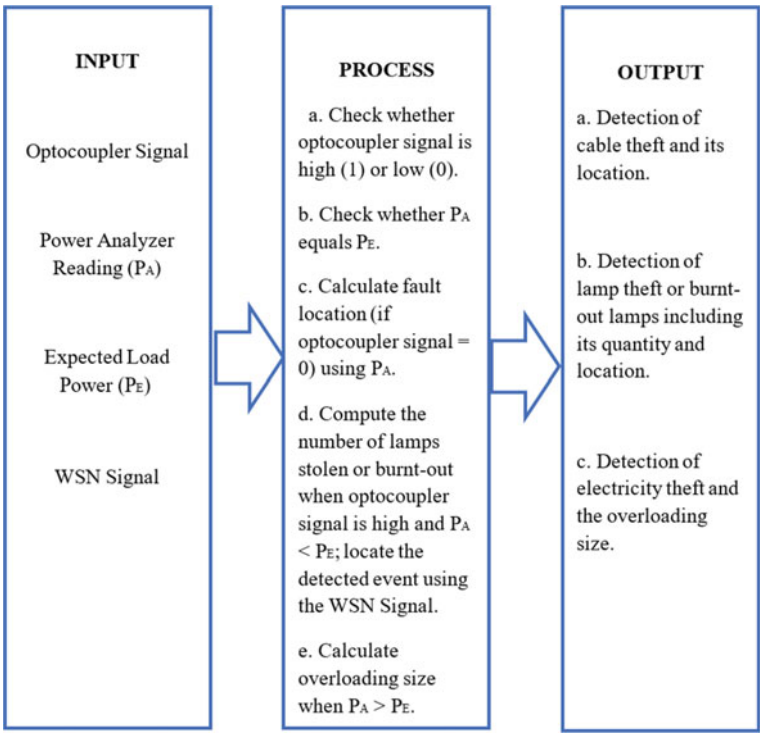

Fig. 1 Conceptual framework of the study

Table 1 Summary of conditions and the corresponding event that can occur

OC	Power	Event
1	$P_A = P_E$	None (normal operation)
0	$P_A < P_E$	Power cable theft
1	$P_A < P_E$	Lamp theft if LDR = 1 or 0 and SW = 0; Burnt-out if LDR = 0 and SW = 1
1	$P_A > P_E$	Electricity theft

directly to the terminals of the streetlight. The output of PZEM-004T device is connected to the MCU of the WSN sensor node named Node 0 in Fig. 2.

For the detection of power cable theft, three optocouplers are considered. This will help the iMoSSTIF further identify power cable theft from power interruption and a switched-off system. The first optocoupler (OC1) is tasked with monitoring power interruption. If the OC1 signal is high (OC1 = 1), there is no power interruption in the system. Hence, power failure and cable theft can be appropriately differentiated. The second optocoupler (OC2) is responsible for differentiating between a switched-off system and a cable theft case. In the case of OC2 = 0, the streetlights are switched

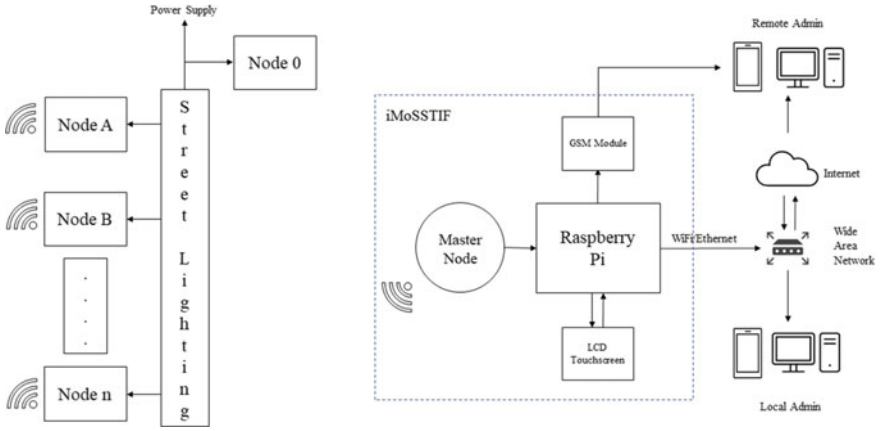

Fig. 2 System architecture of the iMoSSTIF

off. The third optocoupler (OC), the one that is discussed in the system input requirements, is responsible for detecting power cable theft. The third optocoupler signal remains high (OC = 1) as long as there is no interruption to the streetlight's power cable. However, this signal is altered to low (OC = 0) when cable theft occurs. The output of these optocouplers is also fed to the Node 0 of the WSN.

Lastly, sensor nodes where the LDR and SW are connected are in Nodes A and B, and their number depends on the number of lamps installed in the streetlights.

Figure 3 reveals the WSN block diagram developed in this study. Node 0 contains the optocoupler and the PZEM-004T device. The MCU considered to be used is the Arduino nano, especially since converting analog signals to digital is more straightforward in Arduino. For the data transmission, the researchers consider the use of nRF24L01 single chip, a 2.4 GHz transceiver with an on-air data rate of up to 2 Mbps. Also, this transceiver consumes very low power during its operation. On the other hand, nodes attached close to the lamp contain Arduino nano as the MCU, the sensors LDR and SW, the nRF24L01 transceiver, and a buzzer for an immediate alarm should there be an attempt to steal the lamp. The master node receives all the data transmitted by the sensor node and is equipped with an nRF24L01 transceiver, too. Its MCU, the Arduino nano will feed the data to the RPi, the central processor of the iMoSSTIF (Fig. 4).

Systems Output Design Consideration. As depicted in Fig. 2, iMoSSTIF has various ways of informing the authorities of the status of the streetlights and events detected. The device is equipped with LCD touchscreen that displays different electrical parameters during normal conditions. The screen will also show the event detected in case of an anomalous event. In addition, the device is equipped with a SIM800L module for sending text reports to the remote admin. The text message contains the information about the event detected and the link to the website to review the possible capturing of the event through the optional IP cameras installed within

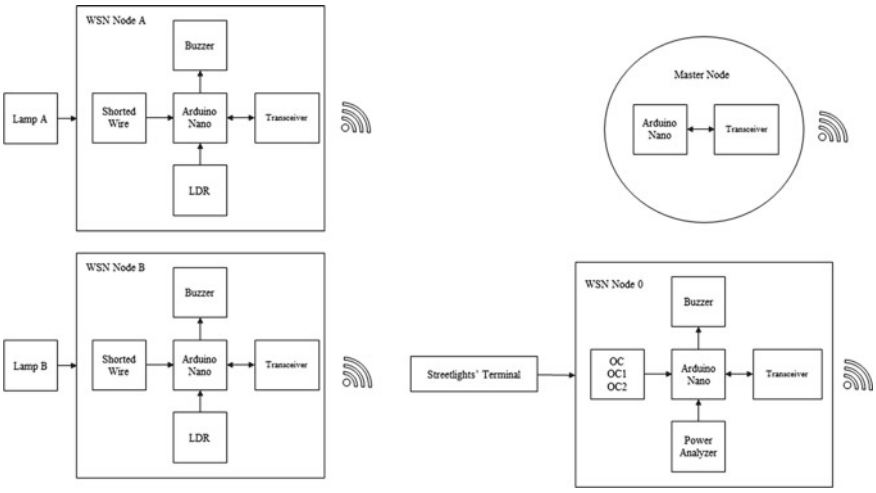

Fig. 3 Diagram for the WSN of the iMoSSTIF

the streetlight perimeter. The iMoSSTIF is also capable of connecting to the internet, and through an application programming interface (API), the data is fed to a website dedicated to monitoring the streetlight. The website logs the electrical parameters read by the device and the event by which an anomalous activity occurred.

3.3 Implement Phase

In the implementation phase of the study, the researchers transform the design into a prototype device.

Hardware Development and Assembly. The researchers gathered all the necessary equipment and materials needed for the study. All connections were set according to the required operation and structure. All the components directly connected to the RPi are temporarily housed in a white case with a dimension of 15 mm × 150 mm × 70 mm, and an IP 65 rating, as shown in Fig. 5.

Programming and Website Development. The researchers installed the latest Raspbian Operating System (OS) for the programming part. Python programming language is then used to develop the system's instruction set. For the WSN, the Arduino found in sensor nodes was programmed to convert analog signals to digital from the LDR sensor and to transmit the data to the master node. On the other hand, the website was developed using programming languages such as HTML, CSS, JavaScript, PHP, and SQL.

Prototype Implementation and Testing. For the implementation and testing of the iMoSSTIF, the researchers developed a prototype streetlight of four lamps, each rated

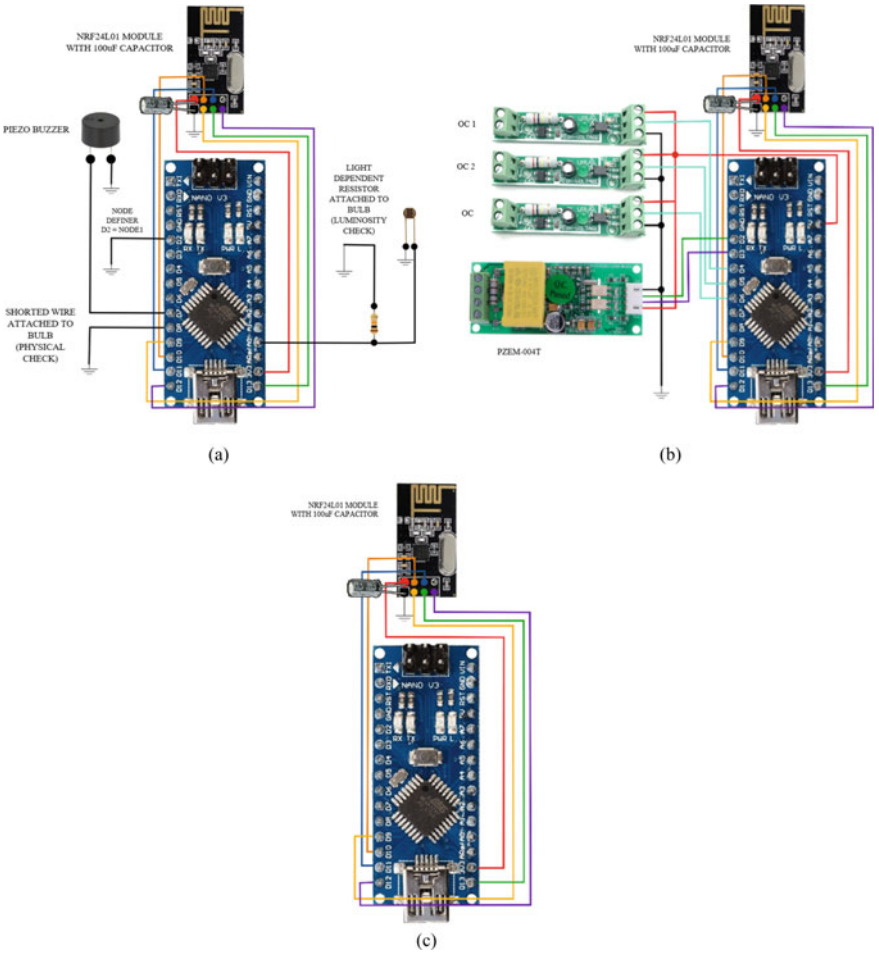

Fig. 4 Wiring diagram of the: **a** sensor node for lamp theft and burnt-out lamp detection; **b** power cable theft detection; and **c** the master node

at 5 W. Sensor nodes are placed 1 inch from the receptacle of the lamp, while the SW intended to detect lamp theft is embedded in the receptacle. For the iMoSSTIF, all the necessary connections from the sources of inputs are appropriately placed. Also, the researchers entered the P_E by providing in the device's GUI the number of lamps on the streetlight and the power rating of each lamp, as shown in Fig. 6.

The researchers then tested the iMoSSTIF's ability to detect power cable theft, lamp theft, and electricity pilferage. In addition, its ability to notify the local administrators of the streetlights is also tested. The researchers were guided by the experimental design set-up shown in Fig. 7.

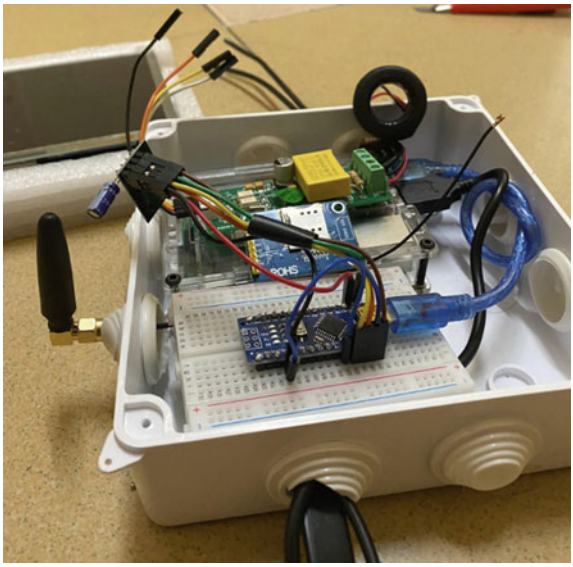

Fig. 5 IMoSSTIF prototype device

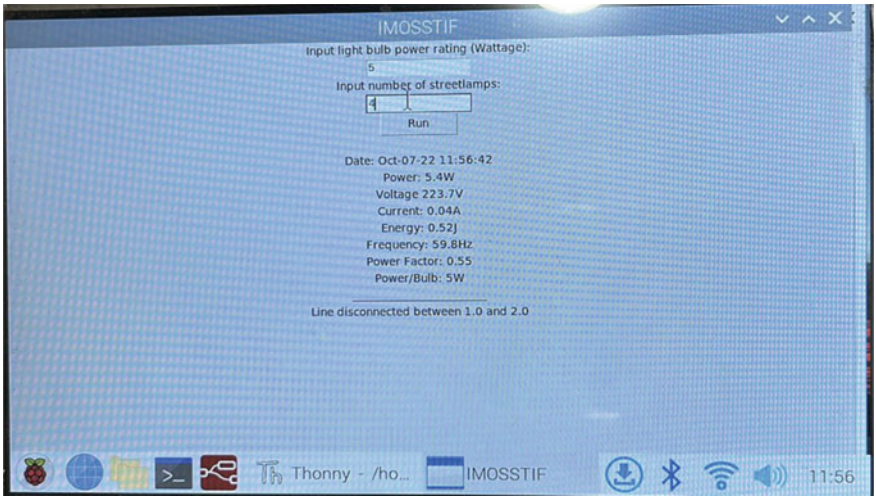

Fig. 6 iMoSSTIF's LCD for entering input parameters. The picture also shows the electrical parameters monitored by the device in normal condition

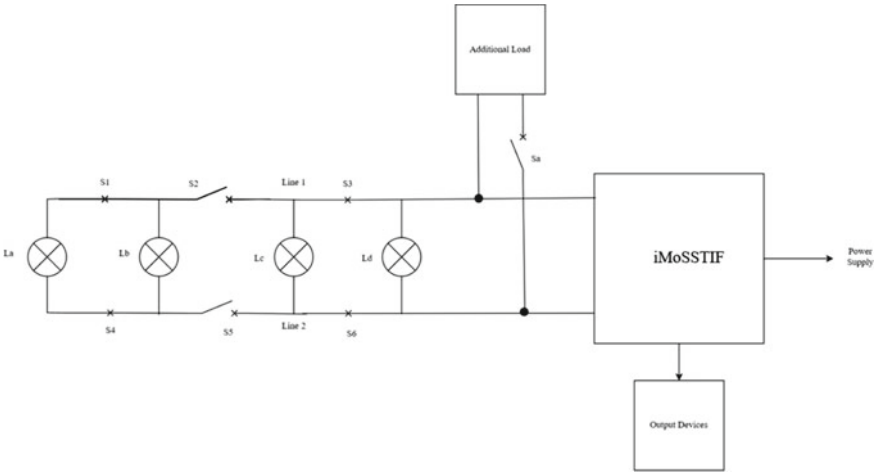

Fig. 7 Experimental design set-up

Power Cable Theft Detection Test. During this test, the researchers evaluate the ability of the iMoSSTIF to detect power cable theft. Table 2 shows the number of trials to be conducted and the expected output from the device. A trial is successful if the iMoSSTIF can detect the event and give the authorities detailed event information containing the time stamp and fault location through the built-in device display, the developed website, and text messages. In addition to the 9 trials presented in Table 2, the researchers will also test if the device can identify and differentiate power failure and streetlight switching state from power cable theft.

Lamp Theft and Burnt-out Lamp Detection Test. The test for lamp theft and burnt-out lamp detection contains four different trials, as presented in Table 3. A successful trial is only considered if the iMoSSTIF can provide the expected output shown in Table 3 through the display of the iMoSSTIF, the website, and text messages. In addition,

Table 2 Expected device output during cable theft

Streetlight condition	Fault location
S1 is open	Between La and Lb
S2 is open	Between Lb and Lc
S3 is open	Between Lc and Ld
S4 is open	Between La and Lb
S5 is open	Between Lb and Lc
S6 is open	Between Lb and Lc
S1 and S4 open	Between La and Lb
S2 and S5 open	Between Lb and Lc
S3 and S6 open	Between Lc and Ld

Table 3 Expected device output for lamp and burnt-out detection

Street light condition	Expected output
La detached	Lamp "a" stolen
Lb and Ld detached	Lamp "b" and "d" stolen
Lc busted	Lamp "c" is burnt-out
All lamps detached	All lamps detached

Table 4 Expected device output for electricity pilferage

Street light condition	Expected output	Size of overloading
1–5 W lamp added	Illegal connection detected	5 W
2–5 W lamp added	Illegal connection detected	10 W

the buzzer installed near the lamp of the streetlight should produce an alarm in case of lamp theft.

Electricity Pilferage Test. In this test, the additional load is connected to the streetlight's electrical system to simulate electricity theft. The trial is successful only if the iMoSSTIF is able to detect an illegal connection to the streetlight's grid and give the size of the unwanted load in Watts, as shown in Table 4. The information is expected to be delivered by the iMoSSTIF through the device's display, website, and text message.

4 Results and Discussion

After the test, the researchers confirmed that the iMoSSTIF is 100% accurate in detecting power cable theft, lamp theft and burnt-out lamp, and electricity pilferage. In Table 5, the researchers summarize the system's latency to notify administrators of anomalous activity.

For the power cable theft, it can be seen that the iMoSSTIF took an average of 2.27 s for the LCD to display the detected event. On the other hand, the average time for the website to update and show the event is 2.51 s, and an average of 2.70 s for texting the remote admin.

Analyzing the result for lamp theft and burnt-out lamp detection, the average time for the LCD to display the event is 2.65 s. The website took an average of 2.75 s to display the event, while 3.13 s for the text message before the notification entered the administrator's phone. A screenshot of the website and the text message received by the remote admin is shown in Fig. 8.

For the electricity pilferage, it took an average of 2.00 s for the iMoSSTIF to update its built-in display of the status of the streetlight. On the other hand, the

Table 5 Latency performance of the iMoSSTIF

Tests	Streetlight condition	Latency (s)		
		LCD	Website	Text
Test 1: Power cable theft	S1 is open	2.3	2.5	2.7
	S2 is open	2.2	2.4	2.6
	S3 is open	2.2	2.5	2.5
	S4 is open	2.3	2.5	2.7
	S5 is open	2.2	2.6	2.8
	S6 is open	2.1	2.5	2.7
	S1 and S4 open	2.4	2.5	2.7
	S2 and S5 open	2.3	2.6	2.8
	S3 and S6 open	2.4	2.5	2.8
	Average	**2.27**	**2.51**	**2.70**
Test 2: Lamp theft and burnt-out lamp	La detached	2.5	2.7	3.1
	Lb and Ld detached	2.9	2.8	3.2
	Lc busted	2.5	2.7	3.0
	All lamps detached	2.7	2.8	3.2
	Average	**2.65**	**2.75**	**3.13**
Test 3: Electricity pilferage	1–5 W lamp added	2.0	2.3	2.4
	2–5 W lamp added	2.0	2.4	2.4
	Average	**2.0**	**2.35**	**2.40**

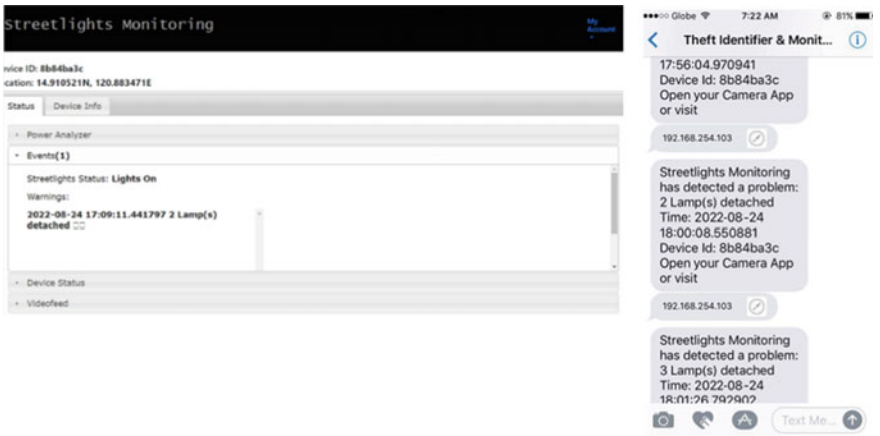

Fig. 8 Example output of the iMoSSTIF: (left) website bearing the information of the detected event and (right) text message bearing the event's information

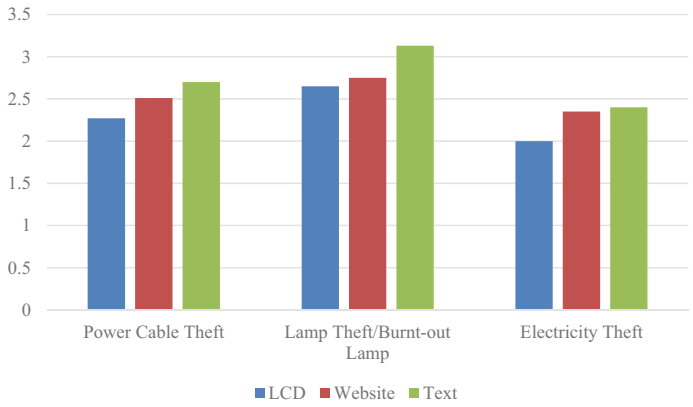

Fig. 9 Comparison of average latency per test conducted and output device

website was updated 2.35 s after the unwanted load was added to the streetlight grid. Lastly, it took an average of 2.40 s for the text message to arrive at the administrator's mobile phone.

It can also be observed from the graph in Fig. 9 that the iMoSSTIF has its best latency in detecting electricity pilferage. On the contrary, the latency of lamp theft and burnt-out lamp detection is high.

The test results also conclude that the iMoSSTIF is intelligent enough to classify lamp theft from a burn-out lamp. Also, using three optocouplers effectively classifies cases of power cable theft from power interruption and a switched-off system.

5 Conclusion

The researchers successfully developed a prototype device capable of intelligent monitoring of the streetlight's electrical parameters. Events such as power cable theft, lamp theft, and electricity pilferage were correctly detected by the iMoSSTIF. The device accurately determined the location of the fault due to stolen wires and lamp theft. iMoSSTIF can also differentiate between a case of lamp theft and a burnt-out lamp. In addition, the device was also able to differentiate power cable theft from power interruption and a switched-off streetlight status. More so, the device was able to inform local administrators of the streetlight of the event detected in less than 4.00 s.

6 Recommendations

Future work on the consideration of multi-hop WSN can be conducted primarily for long street lighting systems. Also, interested researchers may explore the integration of IoT and multi-hop WSN for smarter monitoring and control of streetlights. Lastly, the authors recommend applying AI cameras that could detect and identify persons involved in the illegal act of stealing lamps, power cable, and electricity in public streetlights.

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High-Sensitivity Transimpedance Amplifier for MEMS Microsensor Readout in Acetone Vapor Detection

S. E. Ramírez-Domínguez, N. J. Montes de Oca-Mora, R. M. Woo-García, S. E. Vázquez-Valdes, D. Mata-Hernandez, C. A. Cerón-Álvarez, and F. López-Huerta

Abstract The microelectromechanical systems (MEMS) technology has been successful in yielding high-performance sensors for the measurement of pressure, vibration, inclination, and position. It is making progressive inroads in the gas sensing field for healthcare monitoring systems. This technology yields miniaturized sensors with reduced power consumption, faster response times, and lower unit costs in high volumes. This paper presents a brief introduction to exhaled breath acetone sensors based on MEMS and a study of a low-current front-end circuit for healthcare systems implementation for the detection of acetone vapor. The proposed capacitive sensor includes a high-sensitivity current-to-voltage converter, also known as a transimpedance circuit (TIA) is suggested. The advantage of t-network topology is that high gain and high sensitivity (1 V/1 nA) can be obtained by using kilo-range resistors, which are appropriate for on-chip circuitry. The obtained results offer a non-invasive alternative way the diagnosis of diabetic patients through exhaled breath analysis.

Keywords Acetone vapor detection · Amplifier · CMOS · MEMS · TIA

S. E. Ramírez-Domínguez · N. J. M. de Oca-Mora
Micro and Nanotechnology Research Center, Universidad Veracruzana, Ruiz Cortines 455, Boca del Río, 94294 Veracruz, Mexico

R. M. Woo-García · C. A. Cerón-Álvarez · F. López-Huerta (✉)
Faculty of Electrical and Electronic Engineering, Universidad Veracruzana, Ruiz Cortines 455, Boca del Río, 94294 Veracruz, Mexico
e-mail: frlopez@uv.mx

R. M. Woo-García · S. E. Vázquez-Valdes · F. López-Huerta
Faculty of Construction and Habitat Engineering, Universidad Veracruzana, Ruiz Cortines 455, Boca del Río, 94294 Veracruz, Mexico

D. Mata-Hernandez
Electronic Engineering Department, Universitat Politècnica de Catalunya, Barcelona, Spain

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1 Introduction

Diabetes mellitus (DM), or just diabetes, is a chronic metabolic disorder caused by pancreas malfunction. Type 1 diabetes (T1DM) is generated by an autoimmune reaction in which the body destroys pancreatic β cells responsible for insulin secretion. Type 2 diabetes (T2DM) is characterized by insulin resistance, which is related to obesity, physical inactivity, and inappropriate diet. Insulin is the hormone responsible for carrying glucose from the blood to the cells where it is converted into energy. Therefore, lack of it, or the inability of cells to respond to it, derives in elevated blood glucose concentration, which is a clinical indicator of diabetes [1]. If the disease is not well treated, it can lead to severe health problems such as cardiovascular disease, diabetic retinopathy, limb amputation, neuropathy, nerve damage, and a poor life quality [2]. So far, there is no cure for it; therefore, people with diabetes need to be treated throughout their lives.

Early diagnosis and constant diabetes management is key to achieve success in treatment. At present, the used method is through blood glucose concentration monitoring. It is accurate, but it implies an invasive, expensive, painful, and risk for infection process. To reduce these difficulties, the current research is focused on building a non-invasive biosensor for diabetes diagnosis [3–6]. A developing strategy in non-invasive healthcare devices lies in the detection of volatile organic compounds (VOCs) in exhaled breath. Throughout illness, a wide range of physical and chemical processes occur, followed by fluctuations in the metabolic state. As a response, exhaled breath composition is modified, and different exhaled gases can be used as informative biomarkers for certain diseases [7]. Exhaled breath analysis offers real-time diagnosis, sample accessibility, and user-friendliness compared to urine or blood test. In diabetics, an increased amount of glucose in the blood (hyperglycemia) changes the rate of acetone (CH_3COCH_3) production. As insulin levels in diabetics are low, the liver breaks down fatty acids to supply energy for the body. This process is known as diabetic ketoacidosis, and it produces an accumulation of ketone bodies: acetone, acetoacetate (AcAc), and β-hydroxybutyrate (3BH). Acetone is a minor product in this process, but the second highest VOC presents in human breath. It is brought into the blood, and when it reaches the lungs, it is breath out. Therefore, acetone has been identified as a potential diabetes biomarker. That is, detection of alterations in acetone concentration may reflect variations in insulin and glucose levels [8].

1.1 Literature Survey

The ideal gas biosensor for exhaled breath acetone must detect down to the sub-part per million level since exhaled breath acetone concentration is very low. In healthy individuals, the range varies from 0.3 ppm to 0.8 ppm, in T2DM patients: > 1.71 ppm and for T1DM patients: > 2.19 ppm [9]. Over 90% of the gas biosensors

reported are built on electrochemical/electrical principles [10], that is, measurement of change in electrical properties of the sensing layer. Different nanomaterials can be implemented, including metal oxides, polymers, and carbon-based. Metal oxide semiconductors (MOS) are the most used because they can achieve fast response time in the adsorption and desorption process, usually at high temperatures (≈400 °C). However, factors such as desired sensitivity for diabetes diagnosis, poor stability in humid atmospheres, as conditions found in breath, and high working temperatures are major challenges [11]. To solve the shortcomings of MOS biosensors, mass sensitive microelectromechanical systems (MEMSs) are a potential tool because of their intrinsic high sensitivity due to their small dimensions. Functionalizing the structure with a specific sensing layer that merely interacts with the analyte of interest makes highly selective mass biosensors possible. Mass sensitive devices detect mass' variations at the surface and transform the information into a change of current, voltage, or frequency.

This paper reports the study and design of a microsensor circuit topology for CMOS-MEMS integration. MEMS biosensors integrate sensing layers, mechanical components for sensing and actuation, and electronics on a common silicon substrate through microfabrication technology. CMOS circuitry is the foremost candidate for electronic stages, due to its ability to integrate the sensing transducer and circuitry on a single chip. The use of CMOS-MEMS technology offers key advantages, such as mass production, miniaturization feasibilities, and low power consumption [12].

2 Research Design and Methods

In the on-chip CMOS-MEMS integration perspective, there are few proposals for this application. Table 1 presents state-of-the-art MEMS gas sensors for exhaled breath acetone [13–16]. On this basis, a transimpedance amplifier (TIA) is proposed as a readout circuit of a MEMS device based on mass loading principle.

The considered system in Fig. 1 is defined as a parallel-plate MEMS capacitive sensor. Capacitive sensing is the most common method in MEMS applications due to its simplicity in design, high sensitivity, and low-temperature effect [17]. Top moving plate (rotor) is coated with selective sensing material, and it is suspended above a fixed plate (stator) for actuation and sensing capacitors. It is biased to a fixed DC voltage V_{DC} and actuated by a superimposed small amplitude AC driving voltage $V_{AC}(t) = v_c \sin(\omega_c t)$, all values referenced to common ground. As sensing material is exposed to the analyte, acetone molecules are adsorbed causing mass loading. Thus, capacitive changes generated due to displacement of the moving electrode on the x-axis can be sensed in the form of an electrical signal by the circuitry.

Table 1 State-of-the-art acetone exhaled breath MEMS-based sensor

Authors	Sensing layer	LOD (ppm)	Heater	Working temperature	Actuation principle	Sensing principle	Circuitry	On-chip
Yang et al. (2014)	α-Fe_2O_3	1	Yes	265 °C	Electrochemical	Capacitive (Δf)	Ring oscillator	Yes
Dennis et al. (2016)	Chitosan	0.4	No	R.T	Electrostatic	Capacitive (Δf)	N/A	No
Rabih et al. (2018)	Chitosan/PEG	0.05 - 5	Yes	577 °C	Electrothermal	Capacitive (ΔC)	MS3110 IC	No
Perelló-Roig et al. (2021)	P4V alcohol	0.02	No	R.T	Electrostatic	Capacitive (Δf)	CMOS amplifier	Yes

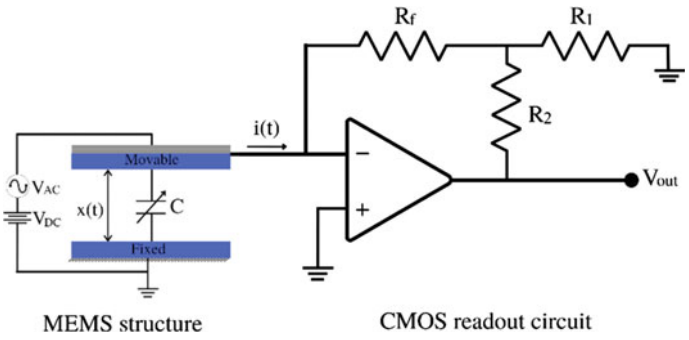

Fig. 1 CMOS-MEMS biosensor topology for exhaled breath acetone detection

2.1 Microelectromechanical Device Model

For circuit design purposes, a microsensor model is needed. Based on MEMS structure in Fig. 1, the system is defined as electrically linear, due to the vacuum being the dielectric between the plates. Geometry variation is only dependent on mechanical displacement $x(t)$ with respect to a fixed reference. Considering the previous, charge can be written in the form:

$$q(v, x) = C[x(t)] \cdot v_c(t) \tag{1}$$

Equation (1) indicates charge which is a function dependent on v and x variables, which are functions of time. Capacitance contains dependence on geometry, when an actuation signal is applied on the test mass, current flows, and it is obtained as follows:

$$qi(t) = \frac{\mathrm{d}q(t)}{\mathrm{d}t} = C(x)\frac{\mathrm{d}v}{\mathrm{d}t} + \frac{\mathrm{d}C}{\mathrm{d}x}v\frac{\mathrm{d}x}{\mathrm{d}t} \tag{2}$$

In Eq. (2), the first term refers to displacement measurement, and the second term refers to rate of change measurement. At low frequencies, the latter is small, so it becomes negligible.

For MEMS devices, electrostatic actuation is a suitable method for electronically sensing the motion of a mechanical device [19]. The total voltage across the sensor is $V_s(t) = V_{\mathrm{DC}} + v_c \sin(\omega_c t)$, motion modulates capacitance defined as $C(x)$, where x is referred to displacement, and input current $i_{\mathrm{in}}(t) = \frac{\mathrm{d}q(t)}{\mathrm{d}t}$ is generated.

Figure 2 presents an equivalent circuit for MEMS device modeling [18]. Simulation was performed for different values of capacitance and displacement using Mentor Graphics Tanner S-Edit v16.0 64-bit tool.

For proper modeling and simulation of CMOS readout circuit, physical dimensions and behavioral characteristics of reported parallel-plate MEMS sensors in Table 2 were used.

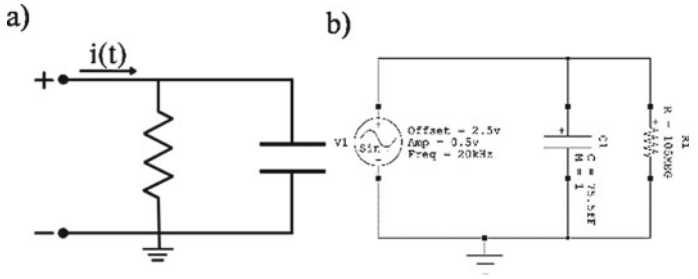

Fig. 2 **a** Equivalent circuit of a MEMS capacitive sensor. **b** Schematic circuit modeled in Tanner S-Edit

Table 2 Main parameters of the CMOS-MEMS sensor simulation

Authors	Area	x_0 (μm)	C_0 (fF)	Initial $i(t)$ (nA)	Generated $i(t)$	Final $i(t)$ (nA)
[14]	360 × 166 μ m^2	9	58.76	3.8	1.2 nA	5
		8	66.15	4.15	980 pA	5.1
		7	75.6	7.5	790 pA	8.29
		6	88.2	5.5	820 pA	6.3
		5	105.84	6.6	1.070 nA	7.7
[15]	412 × 412 μ m^2	4.75	316	20	2.3 nA	22

In this sense, this work is aimed to develop a circuit topology which is able to detect current variations in capacitive MEMS sensors in the femto-farad range, for further CMOS-MEMS integration. Capacitive sensor is electrostatically driven, which leads to a non-resonant dynamic implementation. This means an AC signal with lower frequency than its resonance frequency is used. For this model, a 2.5 AC voltage signal with 20 kHz frequency, and a superimposed 5 DC voltage is used. The DC voltage establishes the static equilibrium of the structure, and the AC voltage drives it to stable oscillations. According to obtained sensor simulations, the proposed circuit must detect a minimum measurement range of 5 nA.

2.2 Circuit Topology Simulation

The current signal amplitude $i_{in}(t)$ is in the nano ampere range, and this is because of bias voltage and mechanical displacement constrains and the high impedance node [19]. Consequently, high gain and small input-referred noise circuit is desired, to overcome this relationship, CMOS continuous-time voltage approach is used [20]. A high-sensitivity current-to-voltage converter, also known as transimpedance circuit

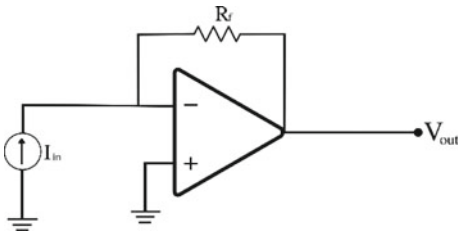

Fig. 3 Basic TIA topology

(TIA), is suggested. This analog circuit takes the sensed current $\boldsymbol{i}_{\text{in}}(\boldsymbol{t})$ and produces a voltage at the amplifier's output $\boldsymbol{v_o}(\boldsymbol{t})$ for subsequent stages. TIA topology consists of a voltage amplifier with transfer function set by $\boldsymbol{A}(\boldsymbol{s})$, and shunt-shunt feedback $\boldsymbol{R}_f$ across it to set the gain, its output voltage is given by (Fig. 3).

$$\boldsymbol{v_o} = -\boldsymbol{R_F} \cdot \boldsymbol{i}_{\text{in}} \tag{3}$$

For extremely low-current detection, an unrealistically large resistor may be required for desired gain. A 5 nA current needs a 1 GΩ resistor for a 1 V/1nA sensitivity. Although this value is market possible, it is not suitable for CMOS on-chip systems due to its large area consumption. To avoid such drawback, a T-network architecture is presented to achieve high sensitivity without compromising a large circuit area (Fig. 4).

$$\boldsymbol{v_o} = -\boldsymbol{k} \cdot \boldsymbol{R_F} \cdot \boldsymbol{i}_{\text{in}} \tag{4}$$

$$\boldsymbol{k} = 1 + \frac{\boldsymbol{R}_2}{\boldsymbol{R}_1} + \frac{\boldsymbol{R}_2}{\boldsymbol{R}} \tag{5}$$

The numerical simulation was executed using Mentor Graphics Tanner T-Spice v16.0 software, in which an ideal amplifier macro-model (VCVS) was implemented. The circuit above represents a differential amplifier with 2 K gain, a single pole filter, and unity gain output buffer. The benefit of creating a simpler model is that

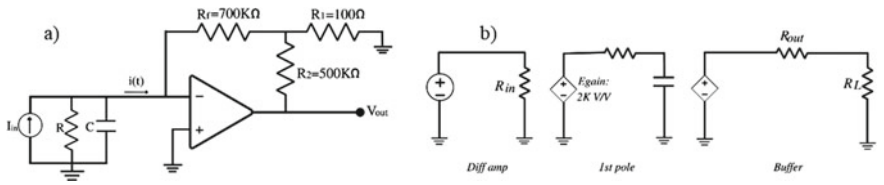

Fig. 4 **a** Proposed t-network topology for a MEMS capacitive biosensor readout circuit. **b** Equivalent macro-model for proposed circuit amplifier

the amplifier's behavior can be reproduced faster and using less components without sacrificing the required accuracy.

3 Results and Discussion

Based on theoretical analysis and simulation results, the t-network feedback topology can achieve the desired sensitivity with smaller on-chip fabricated resistors than a typical TIA circuit. Amplifier's output $v_o(t)$ gain increases by the multiplicative factor k and can thus achieve high sensitivity with reasonable values of integrated resistors.

Implementing CMOS-MEMS microsensors for physiological variables detection and monitoring involves innovation in micro- and nanodevices, currently, the biomedical industry has benefited from its advantages. This paper presents the study of a low-current front-end circuit for healthcare systems implementation that helps engineers and scientist to design the accurate microsensor for non-invasive diabetes diagnosis (Figs. 5 and 6).

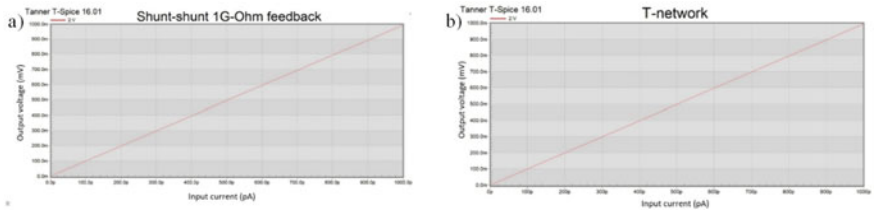

Fig. 5 Comparative *I-V* response of readout circuit. **a** Using classic shunt-shunt feedback and **b** using t-network architecture

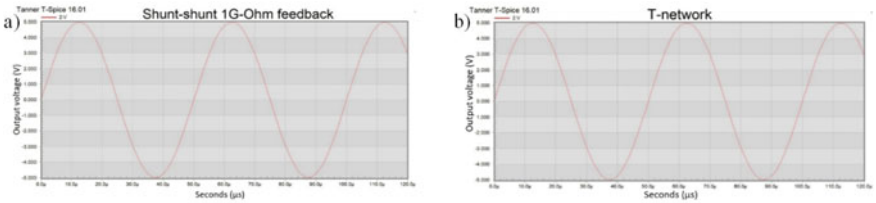

Fig. 6 Comparative V_{out} amplifier's response of readout circuit. **a** Using classic shunt–shunt feedback and **b** Using t-network architecture

4 Conclusions

Having a full-costume readout CMOS circuit, monolithically integrated with the microsensor, allows real-time detection, low-noise, low package cost, and high performance of the system. To develop a non-invasive microsensor, it allows better acceptance by diabetic patients to perform constant monitoring, which results in better treatment of disease and life quality.

Detection of low-current signals requires a high-sensitivity readout circuit; this study proves it is possible to implement an on-chip low current-to-voltage amplifier without sacrificing large area consumption. The advantage of t-network topology is that high gain and high sensitivity (1 V/1nA) can be obtained by using kilo-range resistors, which are appropriate for on-chip circuitry.

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Smiley Antenna: Design of a SWB Antenna Based on an UWB Antenna Modifications

Lizbeth M. Naranjo-Mora, Alex C. Ochoa-Siavichay, Luis F. Guerrero-Vásquez, Jorge O. Ordoñez-Ordoñez, and Paul A. Chasi-Pesantez

Abstract This chapter shows the modifying process of an ultra-wideband (UWB) antenna to become a superwideband (SWB) antenna. Based on a design previously existing in the literature, modifications were made to patch geometry and feed line. Modifications consisted mainly of insertion of circular, rectangular, and U-shaped slots. With modifications made, a bandwidth of 2.6–30 GHz was achieved. Subsequently, antenna was manufactured and characterized with laboratory equipment, where results were observed according to simulations. Finally, modifications made to antenna generate a shape similar to a face with a smile; for that reason, we have decided to call our work "Smile Antenna."

Keywords SWB antenna · UWB antenna · Patch antenna · Slots · Microstrip

1 Introduction

The growing demand for wireless communications services has generated requirements for devices with greater performance. A fundamental part of this scheme of information transmission is antennas that play an essential role by transforming electrical signals into electromagnetic waves and allowing communication over long

L. M. Naranjo-Mora · A. C. Ochoa-Siavichay · L. F. Guerrero-Vásquez (✉) · J. O. Ordoñez-Ordoñez · P. A. Chasi-Pesantez
Universidad Politécnica Salesiana, Cuenca, Ecuador
e-mail: lguerrero@ups.edu.ec

L. M. Naranjo-Mora
e-mail: lnaranjom2@est.ups.edu.ec

A. C. Ochoa-Siavichay
e-mail: aochoas@est.ups.edu.ec

J. O. Ordoñez-Ordoñez
e-mail: jordonezo@ups.edu.ec

P. A. Chasi-Pesantez
e-mail: pchasi@ups.edu.ec

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distances [1]. With new communications technologies deployment, including the fifth generation of mobile networks (5G), much wider bandwidths are required, with the possibility of covering many applications with different resonance frequencies, with operating ranges ranging from 800 MHz to 11 GHz [2], and even higher values in 5G networks [3].

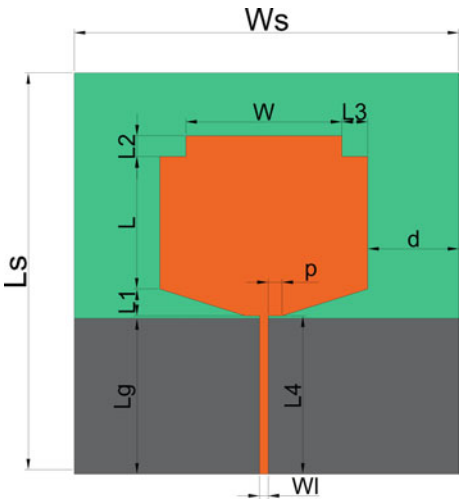
In addition, by working on communications new generations, coverage range decreases, and it is necessary to install a greater number of small cells with several antennas. Thus, in recent years a series of technological advances have been generated regarding the design of new antennas types. Even Federal Communications Commission (FCC) has seen the need to establish standards that group antennas types based on their behavior [4], thus generating multi-resonant antennas, broadband antennas, UWB antennas, SWB antennas [5], among others. Antennas working in operating ranges ranging from 3.1 to 10.7 GHz are called UWB antennas. UWB technology has several characteristics that motivate it to be used in short-range communication systems, due to its high transmission rate and data, combined with a low power required and low sensitivity to multipath losses. However, there are designs that extend that operation range, with bandwidths greater than 10 GHz and are called SWB antennas [6, 7]. Patch antennas are presented as an excellent alternative to cover these requirements, since with light and simple modifications in designs, good performance is obtained. In addition, they are antennas with low production costs and reduced dimensions with geometric shapes that allow to improve miniaturization [8].

In this context, patch antennas or microstrip are characterized by having a patch that will have a radiant effect on a dielectric substrate [9–11]. There are several geometric shapes used in the manufacture of these antennas and stand out among these, for being the most used, square, rectangular, circular, elliptical, triangular, triangular sector, circular ring, ring sector, among others [11]. However, the use of new forms is constantly proposed, demonstrating that it is not necessary to restrict design to these basic forms. In fact, excellent results have been seen with fractal shapes, fill curves, and inserting slots in both the patch and ground plane [12].

In order to reach wide bandwidth ranges, several techniques have been developed that include modifications to designs. Using these techniques, it is intended to obtain before with UWB or SWB characteristics, that can be used in applications related to deployment of new generations of communications. One of the techniques used to obtain SWB consists in the insertion of slots of different shapes, located in path, feeder, or ground plane. Among the most common shapes, we find slots U, L, T, H, C, square, circular, among others [3, 13]. Specifically, U-shaped slots were introduced by Huynh Lee in 1995 [14], and recent studies reveal that they are not only suitable for broadband applications, but also in double and triple bands [14, 15]. Currently, SWB antennas have been widely developed, having as their characteristic their monopole planes with small dimensions and their easy integration with monolithic microwave circuits. One example is a monopole circular antenna with a peculiar design in the ground plane with a trapezoid shape [16, 17].

Thus, this document proposes the insertion of various slots and geometric figures in an antenna with UWB characteristics presented in [2]. Through the new proposal,

Fig. 1 Initial antenna design



antenna is designed to operate from 2.85 GHz to values above 10 GHz, thus entering the SWB range. A behavior analysis is performed for each new element inserted into antenna.

The paper is organized as follows. Section 2 details characteristics and dimensions of initial antenna and describes the process for antenna modification detailed as iterations. Section 3 contains the final design with modifications consisting of U-slots and inserts into shapes such as circles and rectangles on transmission line. In addition, ground plan is already optimized as in [2], which had UWB characteristics. In Sect. 4, results are detailed and analyzed by a comparison between simulated and measured parameters. In addition, images of manufactured antenna and characterization results developed in our laboratory are included. Finally, Sect. 5 summarizes the main conclusions drawn from this work.

2 Antenna Design

Initial design consists of a printed rectangular monopole antenna powered by a microtape line of width $W_1 = 3.164$ mm and length $L_1 = 11.5$ mm. Patch is shaped like a rectangle, with a conical section at lower end. This narrowing is used to improve antenna coupling, and this also expands its bandwidth. Additionally, two slots have been inserted in two upper ends and a partial ground plane on the other side of substrate of length $L_g = 11.3$ mm. These variations in antenna geometry contribute to increasing resonance frequency and decreasing reflection coefficient. Substrate used is FR4 with a relative permittivity $\varepsilon_r = 4.25$ and a thickness $h = 1.6$ mm. Antenna dimensions are shown in Fig. 1, and values are detailed in Table 1.

Antenna design modification process is summarized in Fig. 2, where an empirical process is presented. To obtain the final design, three interactions are made in match

Table 1 Initial design antenna dimensions

Variable	Value (mm)
Ws	138.75
Ls	144.75
W	75
*L*1	9.7
*L*2	7.5
*L*3	9.375
*L*4	57.2
Lg	3.164
Wl	3.164
h	1.6
p	5

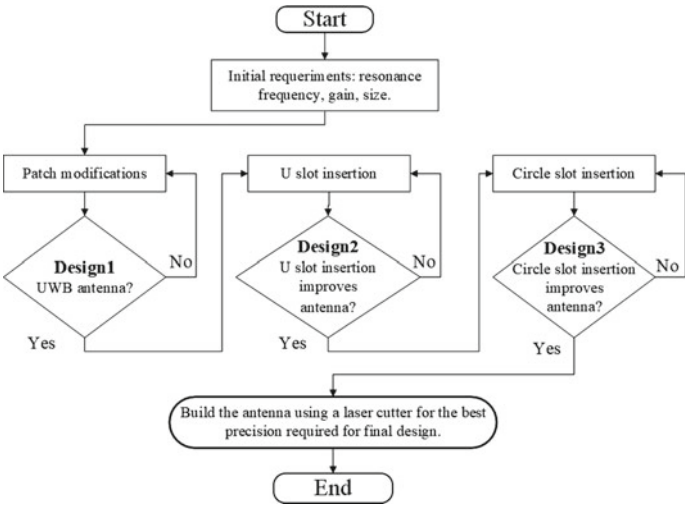


Fig. 2 Process antenna design

as seen in Fig. 3. It is worth mentioning that exteriors of the same are not modified. In first iteration, two rectangle slots are made on transmission line. Then, in iteration 2, an insertion is made with a U-shaped. Finally, final iteration consists of an insertion of four circle shapes, which in addition to improving bandwidth, simulate antenna eyes.

In Fig. 4, the results of each modifications are observed and how bandwidth range was expanded. Initial design has a bandwidth of 16 GHz, with an operating range that starts at 2.83 GHz up to 18.91 GHz. Then, next iteration generates a bandwidth from 2.1 to 12.4 GHz with a bandwidth of 9.40 GHz. Additionally, a U-slot is inserted, which causes a frequency range that starts at 2.77 GHz.

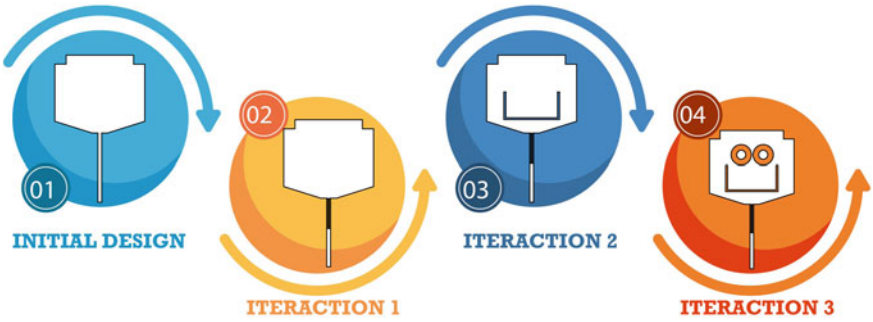


Fig. 3 Process design

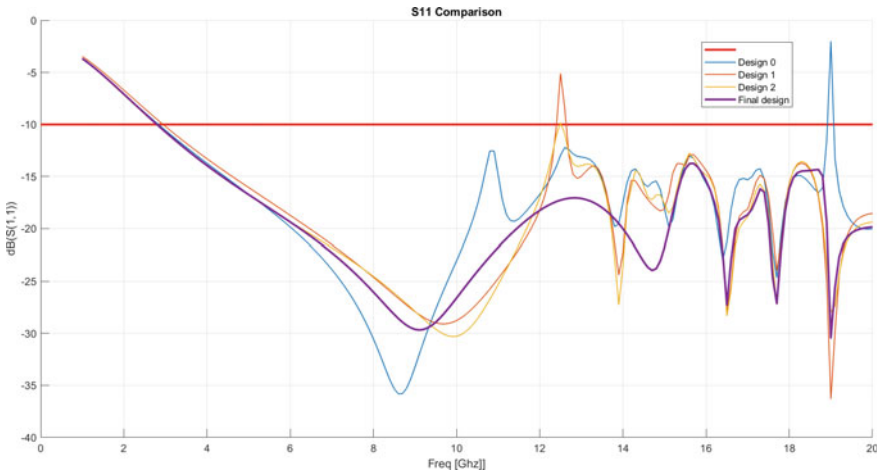


Fig. 4 S11 iteration comparison

3 Final Design

Final design is to keep rectangular monopole antenna and patch ends as seen in Fig. 1. Additionally, a U-shaped slots have been inserted into the patch with a length of $M_1 = 1.75$ mm, $M_2 = 43$ mm, $M_3 = 46.5$ mm, $M_4 = 21.5$ mm, and $M_5 = 23$ mm. In addition, two slots of two circles with diameters of $D_1 = 8$ mm and $D_2 = 18$ mm. Finally, two slots that have a rectangle shape $C_1 = 1.1$ mm and $C_2 = 25$. As we see in more detail in Fig. 5 and Table 2. In Fig. 7, we can see that bandwidth starts from 2.8 GHz exceeding the 10 GHz range, thus achieving SWB.

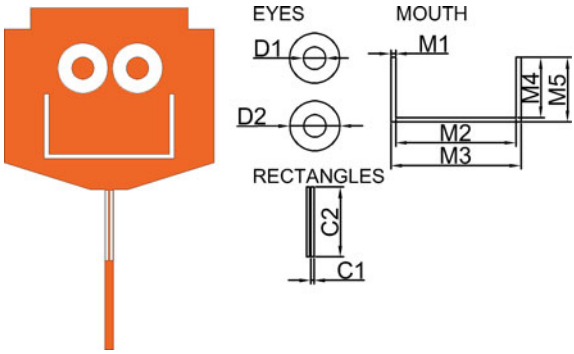


Fig. 5 Measurements of final patch

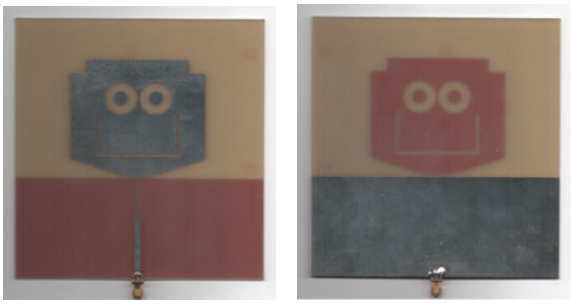
Table 2 Final patch dimensions

Variable	Value (mm)
D_1	8
D_2	18
M_1	1.75
M_2	43
M_3	46.5
M_4	21.5
M_5	23
C_1	1.1
C_2	25

4 Measurements and Results

Final design was manufactured for characterization, result is shown in Fig. 6. Comparison of measured results with respect to simulated results is performed. First parameter analyzed is S11, which is observed in Fig. 7. Bandwidth is measured at − 10 dB, in the diagram. A vector network analyzer (VNA) was used to antenna measure, with an operating range of 5 kHz–15 GHz. Manufactured antenna operates in a wide range of frequencies from 0.46 to 15 GHz, considerably increasing the range in relation to the simulated model, which operates from 2.8 GHz. In both cases, bandwidth exceeds 10 GHz, thus being able to consider them SWB antennas.

Additionally, antenna behavior is analyzed according to radiation pattern generated. Due to wide operating range of antenna, we decided to make measurements in frequencies of 2, 3, and 4 GHz. It is not possible, within our context, to expand the range of tests because we do not have transceivers that work in larger ranges. In Fig. 8, a comparison is observed between measured and simulated radiation patterns in azimuth and elevation planes. Simulated 3D pattern is also displayed. Antenna radiant characteristics are striking by increasing operating frequency. In low frequencies (2 GHz), an omnidirectional pattern typical of a monopole patch antenna



(a) Top part. (b) Bottom part.

Fig. 6 Fabricated proposed SWB antenna

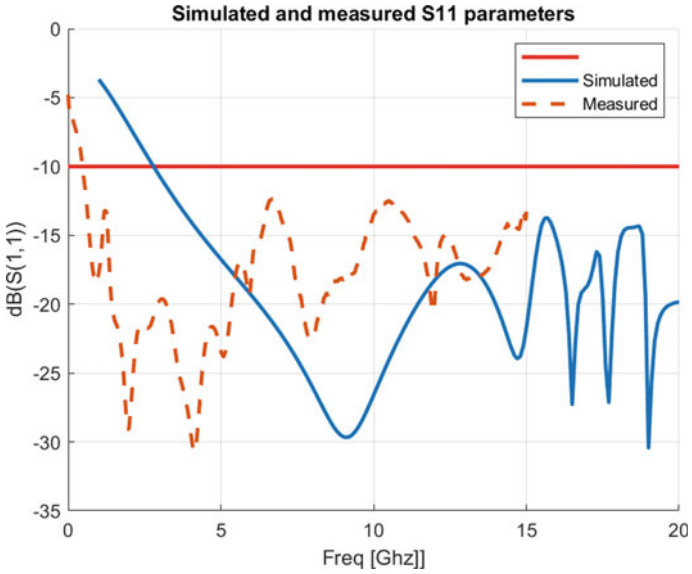
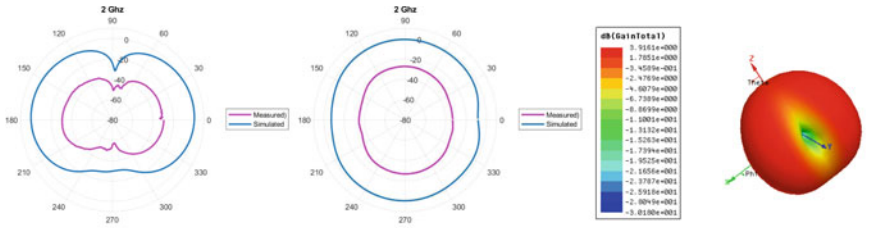
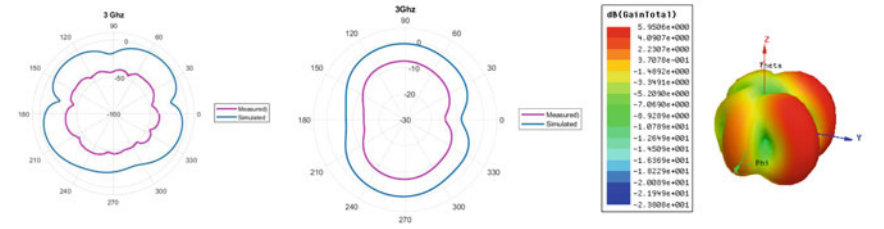


Fig. 7 Simulated and measured S11 parameters of final antenna

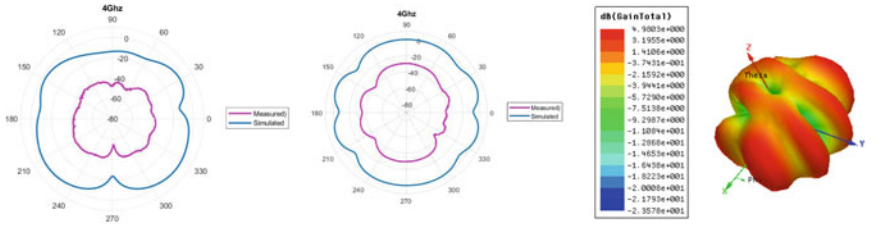
is observed. However, as operation frequency increases, the pattern begins to show the appearance of lobes, which although gain is not diminished, in higher ranges could cause dark areas without coverage. It is very important considering the type and quality of the material used for the manufacturing of the antenna, since at certain frequencies the resonance may present variations in the results.



(a) Azimuth plane $f_r = 2GHz$. (b) Elevation plane $f_r = 2GHz$. (c) 3D radiation pattern $f_r = 2GHz$.



(d) Azimuth plane $f_r = 3GHz$. (e) Elevation plane $f_r = 3GHz$. (f) 3D radiation pattern $f_r = 3GHz$.



(g) Azimuth plane $f_r = 4GHz$. (h) Elevation plane $f_r = 4GHz$. (i) 3D radiation pattern $f_r = 4GHz$.

Fig. 8 Azimuth plane, elevation plane, and 3D radiation pattern in different reference frequencies (blue circled dot simulated, violet circled dot measured)

5 Conclusions

The main result of our work is to demonstrate that, with simple modifications, it's possible to expand antenna bandwidth. In this case, we managed to transform a UWB antenna into a SWB, with slots insertion of different geometric shapes. Additionally, we were able to place slots in such a way that final design appears to be smiling, which motivated antenna name.

Although the objectives set are met, there are differences between measured and simulated results. In Fig. 7, it is observed that according to S_{11} parameter, operating ranges vary with a difference greater than 2.34 GHz. On the one hand, these variations are due to different conditions that occur at time of antenna building, such as material type and manufacturing process. On the other hand, the slots inserted into antenna

feeder have specific and reduced dimensions. Slight variations in the dimensions of these grooves cause differences in results.

Measured and simulated radiation patterns exhibit variations mainly related to gain. This is due to conditions in which antenna was characterized, without having an anechoic chamber. Although there are differences, shape and lobes of radiation match enough to state that the manufactured antenna is consistent with respect to the simulated design.

It is recommended to manufacture antenna with laser cutting. The precision offered by this process allows millimeter grooves to be made. Prior to final design, other antennas were manufactured with artisanal manufacturing processes and expected results were not obtained.

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New Data Novelty Check and Distributed Learning for IoT Data Anomaly Detection

Ons Jelassi, Naman S. Negi, and Hakima Chaouchi

Abstract The Internet of things (IoT) is set to fundamentally change our daily lives with massive numbers of connected devices, generating large volumes of data every second. Data acquisition and data correctness verification for different processes have become of increasing concern. IoT data anomaly detection performance relies on accuracy and response time and both can be enhanced with a distributed learning and adaptive "online" update of the model. Retraining the model only when the distribution of the new collected data differs from the distribution of the data used to learn the model greatly streamlines the computational resources of the distributed learning infrastructure. It also improves learning data accuracy as the model is updated regularly rather than waiting for the retraining period, which is usually a fixed value and is set up manually. It's a well-established fact that a machine learning model accurately predicts if the distribution of new data, on which predictions are made, is similar to the distribution of the model training data. However, over time, the new data retrieved may hold additional information that was not initially identified by the model when it was trained. Therefore, model deployment should not be a one-time exercise, but rather a continuous process. In this article, we propose a scalable, robust, and sustainable IoT data anomaly detection framework based on distributed learning and an efficient online model update. First, we investigate the distributed learning of different anomaly detection models, namely RNN, LSTM, and k-means clustering. These models are trained for anomaly detection tasks on two different IoT data use cases: ECG sensor data for the health industry and connected cars for the automotive industry. Then, we study the significance of identifying new data at an early stage to determine when to retrain the model for the purpose of improving anomaly detection accu-

O. Jelassi (✉) · N. S. Negi
LTCI, Télécom Paris, Institut Polytechnique de Paris, 19 place Marguerite Perey, Palaiseau 91120, France
e-mail: ons.jelassi@telecom-paris.fr

H. Chaouchi
SAMOVAR, Télécom SudParis, Institut Polytechnique de Paris, 9 rue Charles Fourier, Evry 91000, France
e-mail: hakima.chaouchi@telecom-sudparis.fr

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racy. The research thus focuses on the ideal moment to retrain a model based on the data novelty detection in order to establish an efficient automated retraining module.

Keywords Anomaly · Anomaly detection · Deep neural networks · Recurrent neural

1 Introduction

Today, the large amount of data generated in the Internet of things from highly connected devices helps to understand different systems and processes, but it also reveals the problem of data anomalies. As a result, data anomaly detection study has attracted special attention among researchers and industrialists [1]. Detecting anomalous data patterns not only helps in preventing hazardous situations but also tracks the changes in the trend of the system or process being analyzed. It's worth noting that several IoT processes require real-time prediction and data anomaly detection such as in the real-time decision making in self-driving cars. However, previous research [2] has shown that existing approaches to detect anomalies in real time are not very effective. The first challenge is the amount, scalability, and evolution of data being collected in the amount of short time through connected devices. Therefore, it is important to provide a framework that effectively handles a large amount of online data processing and detects anomalies in real time. The second challenge is the effectiveness of the anomaly detection system over time with new data arriving every second. In fact, anomaly detection algorithms make the hypothesis that new collected data will be similar to previously observed data. But this assumption is often not the reality, and the system must adapt. Accuracy of anomaly detection models may deteriorate along time and is often referred to as model drift. The proposed architecture in this work takes these two aspects into account. The rest of the article is organized as follows. Section 2 gives a short overview of existing anomaly detection algorithms in the literature. Section 3 describes different techniques for distributing the training phase of machine learning in general. Section 4 defines model drift and model retraining. Section 5 describes three anomaly detection methods, k-means, RNN, and LSTM and shows how to implement them in a distributed way. Section 6 presents our proposed architecture for distributed learning and online model updates. Finally, Sect. 7 gives a summary of the results.

2 Anomaly Detection Brief Literature Review

Recent studies have shown the use of parametric and nonparametric statistical models, data clustering, rule-based systems, mixture models, and support vector machines (SVMs) for anomaly detection [3, 4]. In [5], the authors use the k-nearest neighbors (kNN) algorithm to compute the anomaly score of each data sample based on the

average distance to its k-nearest neighbors. In [6], clustering models are used to make different clusters of data samples and detect anomalies via a predefined outlier score. In [7], one-class SVM is used to find the density distribution of previously observed data and classifies new data as without anomalies or with anomalies. However, traditional models often fall short of fully capturing complex structures in the data or may experience difficulties in dealing with large volumes of data. In order to address these issues, the use anomaly detection algorithms based on deep learning is becoming more and more popular [8]. These algorithms are first trained on data from which they learn the complex patterns. Then, we extract the hidden layer representations from the trained network. These representations are used to feed traditional anomaly detection algorithms [9, 10].

While these methods have shown promising results in various applications, they fail to capture the temporal dependencies appropriately and therefore do not necessarily perform well with data including time dependency. Anomaly detection algorithms suited to time series are often based on either prediction errors or on reconstruction errors. Methods using prediction errors first predict next values of time series, and then anomaly detection is carried out by verifying the prediction errors from past data [11, 12]. Methods using reconstruction errors first build a model to rebuild the time series, frequently with an autoencoder [9] and then do anomaly detection by verifying the reconstruction errors for past data. Often used time series anomaly detection methods have been based on temporal prediction methods such as models based on an autoregressive moving average (ARMA), which finds anomalies by simulating stationary time sequences over a time window (see [13, 14]). These models are sensitive to noise and hence can have a high false positive rate. Classic methods also use methods based on correlation [15] and ensemble methods [16]. The Kalman filter [17, 18] algorithm has been used for detecting anomalies using optimal estimation of the system states. Recently, long short-term memory (LSTM) [19] was also used to perform anomaly detection [11, 12]. An LSTM network is a recurrent neural network, which goes beyond gradient vanishing problems by using memory cells. The LSTM network is designed for sequential data [20, 21]. An LSTM encoder–decoder [22] models time series by LSTM networks and improves generalization capabilities.

In this study, we investigate the benefit of novel data detection to trigger the model update, and we also follow the merits of distributed learning to gain in response time, especially with large datasets. Therefore, we focus on three algorithms: k-means clustering, RNN, and LSTM. K-means clustering, which is based anomaly detection, is relatively faster than other machine learning techniques and also helps reduce the computational complexity in large datasets. On the other hand, RNN and LSTM help capture the temporal characteristics of the data. This study intends to compare these algorithms on large datasets on connected devices (e.g., connected vehicles), which have both spatial and temporal characteristics.

3 Distributed Learning

As the amount of data increases, data manipulation, storage, and transmission are the biggest bottlenecks. The challenge is how to extract information from the data in an efficient way and at low latency. However, designing machine learning algorithms that scale with large amounts of data are yet another challenge as the models tend to become larger (more parameters) and more complex, which makes model training incredibly challenging. A centralized approach is suitable to datasets of small size. Here, the machine learning model is straightforward and training the model is possible on a single machine. But this centralized approach becomes inefficient with important drawbacks when training a complex machine learning model with large datasets that cannot be processed by one machine. Therefore, we suggest to use a distributed learning process by performing a distributed training for these models on a cluster of cores. References [23, 24] have demonstrated the performance of using training distribution to make neural models handle big datasets.

Distribution is performed by data parallelism [25] or model parallelism [26].

Data parallelism consists of producing replicas of the entire model distributed over various servers, but training the copies of the model with several parts of the data. In this way,

- The approach spreads the data between different machines, which handle the model copy.
- Each machine estimates on its side the parameters.
- Machines finally send each other the estimates or to a server that centralizes the parameters in order to estimate the aggregate parameters for each stage.

Model parallelism consists of dividing the model on smaller replicas shared on diverse computers, where each replica is trained with the same dataset, but is made up of different parts of the model. In this process,

- The complete dataset is sent to all the computers.
- Each computer estimates its own set of parameters depending on the part of the model it has.
- Machines finally their estimates send each other the estimates or to a server that centralizes the parameters in order to estimate the aggregate parameters for each stage.

A distributed learning approach using multiple machines helps when the requested computation exceeds the capabilities of a single machine. But training with several servers originates overhead. In particular, the overhead generated by the need to update parameters through several servers. The overhead increases with the number of servers. This overhead won't be critic if the computation cycle (one forward step plus one backward step) takes long enough to "hide" the overhead. However, if the computation cycle is short, updating the parameters may take more time and become the bottleneck of the training. The demand of the computation is increased when we use a larger and more complex model (more computation per data sample), or a larger batch size (a larger training set).

4 Model Drift and Model Retraining

When a machine learning algorithm is trained and deployed, it starts degrading due to the presence of new coming data generated continuously; the type of the data tends to change continuously. Therefore, the model must adapt. Machine learning models need to be retrained if the data distributions are significantly different from those of the training dataset. This is the model drift or concept drift [27]. Model drift occurs when a model's predictive performance degrades due to a change in the environment that is inconsistent with the hypothesis of the model. To handle this issue, the solution is to create schemes for detecting and handling concept drift [28]. The question is how to see model drift and how often the model has to be trained to correct it [29]. In practice, the following two approaches are generally employed:

- Based on time, the model is retrained periodically with a manually pre-defined period. There is no need to check for model performance. But it may lead to model retraining even when it is not required.
- Based on model performance, this more advanced technique monitors the model performance along with the distribution of the new data to trigger the time for retraining.

The next challenge is how and when to retrain the model. There are three methods to do this:

- Online: When we have a new available observation, this single new point serves for the training of the model. The model will therefore be more affected by the new observations than by older ones. This might be useful when the model needs to continuously adapt to new patterns in data or when dealing with very large datasets for which training on everything all at once is not possible.
- Offline: Add each new data to the initial dataset that was already trained and entirely retrain the model on the augmented dataset. In this case, we have a more accurate global approximation. However, it is unpractical for large datasets or when new observations occur.
- Batch: Wait until a batch of new data occurs and train the model on this whole batch. Note that, online learning is a batch method with batch sizes equal to 1 and offline learning is a batch method with batch sizes to the size of the entire dataset.

Today, most models are constructed on the batch or mini-batch approaches. The batch size is chosen depending on the application. Choosing the right size consists of choosing the right frequency with which to retrain the algorithm. In recent years, this area of research has gained traction and a lot of promising work has been done on retraining and updating the model. A model performance evaluation-based automated retraining method was proposed by [30]. Recently, Amazon introduced SageMaker Model Monitor, a system that continuously monitors the ML models in order to find deviations in the model performance. Actions to correct these deviations, such as retraining models, can then be taken in a more efficient and automated manner [31]. In more advanced studies, [32] argues that when retraining the models on

many various new datasets, the efficiency is improved by caching information on the training process on the initial data and calculating the "updates." Similar propositions were also proposed by [33–35]. In this study, we have followed a similar approach to [30].

In the following sections, we focus on three anomaly detection models: k-means, RNN, and especially, LSTM; note that other models can also be analyzed following our approach. The K-means clustering method was chosen for its simplicity, speed, and scalability, as well as for its straightforward adaptation to new data and ability to identify nonlinear structures in the dataset. RNN and LSTM were chosen for the learning model accuracy when dealing with time series data by using the sequential information present in IoT data applications. In a traditional neural network, we suppose that all inputs (and outputs) don't depend on each other. This is not always true. RNN and LSTM take the sequential information in the input data, i.e., dependency between the past data points in the times series while predicting the future values.

5 Distributing Anomaly Detection Models

5.1 K-Means Clustering

Clustering is a well-known exploratory data analysis technique used to divide the whole dataset into groups (also known as clusters) based on the patterns in the data [36]. It identifies subgroups in the data. Each subgroup (cluster) contains data points with very similar features while data points belonging to different clusters have different features. The process to implement k-means clustering on time series data involves the following steps:

- **Training Phase**

– Segmentation—Split the time series data into small segments of predefined size and with a predefined horizontal translation,
– Windowing—Multiply the time series segments from Step 1 by a windowing function to truncate the dataset before and after the window,
– Clustering—Group similar windowed segments and determine the centers.

- **Testing Phase**

– Reconstruction—Reconstruct the test data time series using the cluster centroids found in the training phase,
– Error—Calculate the reconstruction error associated with the output of the time series prediction,
– Anomaly Detection—Rise anomaly when facing poor reconstruction errors (greater than a certain value) on any individual segment.

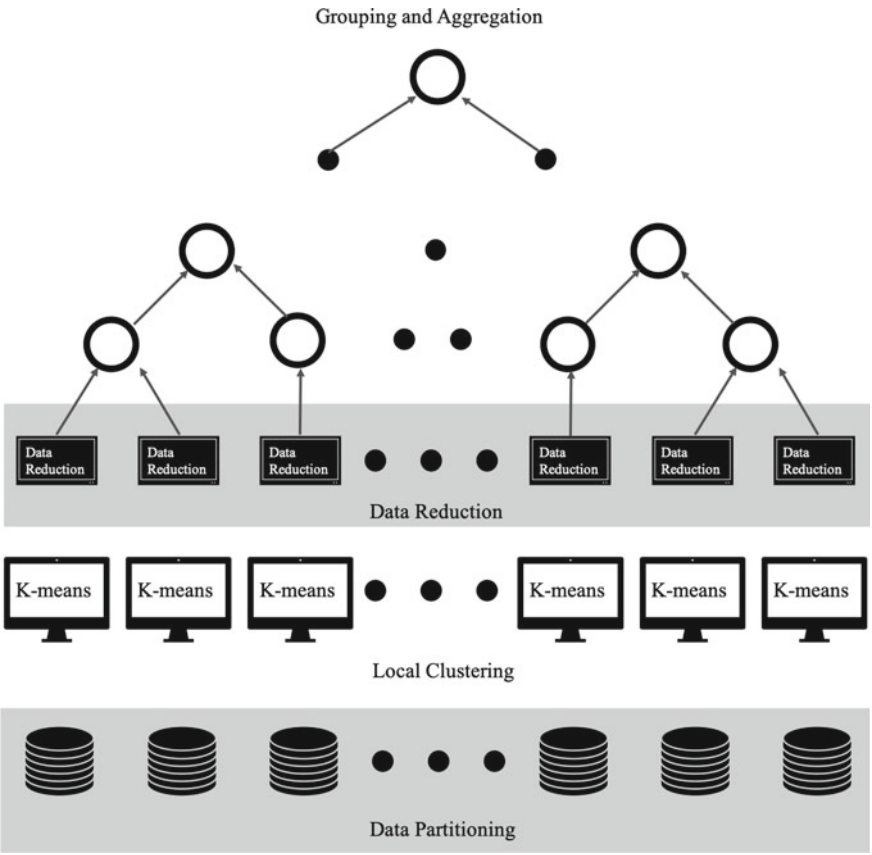

Fig. 1 Distributed clustering architecture

This centralized technique can be applied in a distributed manner by dividing the datasets and carrying out the clustering process (training phase) on the individual subsets. Compared to a central clustering of the entire dataset, clustering of the local models can be performed much faster (Fig. 1). However, exchanging the local clusters through network nodes can create important overheads and slow down the process. This is one of the most important issues of the main distributed clustering techniques. To address this problem, it is important to minimize the data communication and computational time in order to minimize the overheads due to the data exchange. Thus instead of exchanging the entire local cluster between nodes, it is important to first apply some data reduction techniques to find points that can be used to represent a cluster, for example, its shape and density [37].

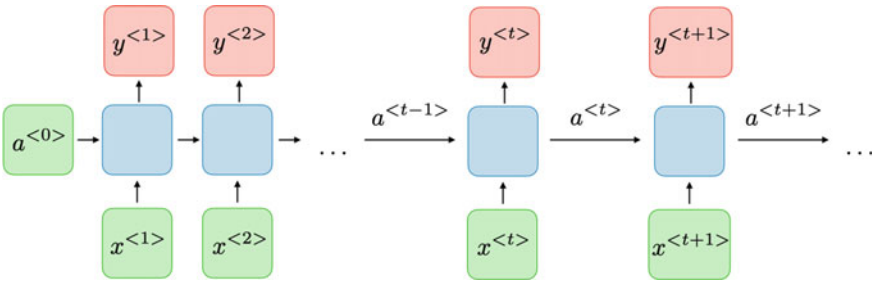

Fig. 2 Recurrent neural networks

5.2 RNN and LSTM

An RNN is a specific type of neural network suitable for processing sequential datasets. In sequential data, such as time series data, any point in the data is dependent on the past history. RNNs perform predictions of every element of a sequence based on the past computations. Therefore, RNNs have a "memory" which captures information on the previous calculations [38]. Figure 2 shows the architecture of a traditional RNN. For each time step t, the activation $a^{<t>}$ and the output $y^{<t>}$ are expressed as follows:

$$a^{<t>} = g_1\left(W_{aa}a^{<t-1>} + W_{ax}x^{<t>} + b_a\right)$$

$$y^{<t>} = g_2\left(W_{ya}a^{<t>} + b_y\right),$$

where W_{ax}, W_{aa}, W_{ya}, b_a, b_y are coefficients that are shared temporally and g_1, g_2 activation functions.

Theoretically, RNNs can use data in arbitrarily long sequences; however in practice, they can look back only a few steps. LSTM is a form of RNN which can learn long-time dependencies by using a complex structure called a memory cell in hidden layers [19]. In Fig. 3, we can see the memory cell of an LSTM. The LSTM module has three gates: the Forget gate, the Input gate, and the Output gate. The memory cell can maintain its state over time, consisting of explicit memory (also called the cell state vector) and gates. Gates regulate the flow of data in and out of the memory.

Figure 4 shows the distributed learning architecture for an RNN and an LSTM. In the figure, there are "n" workers. Each worker has a copy of the entire RNN or LSTM model. The workers execute in a data parallel manner, meaning they work at one partition of the training data, going through it in mini-batches to make model parameter optimizing. Each worker asynchronously looks for an update copy of its model parameters "w" from the parameter server and then processes a mini-batch. After processing a mini-batch and computing parameter gradients, Δw, each model copy asynchronously pushes these gradients to the parameter server upon which it updates the model parameters using these gradients.

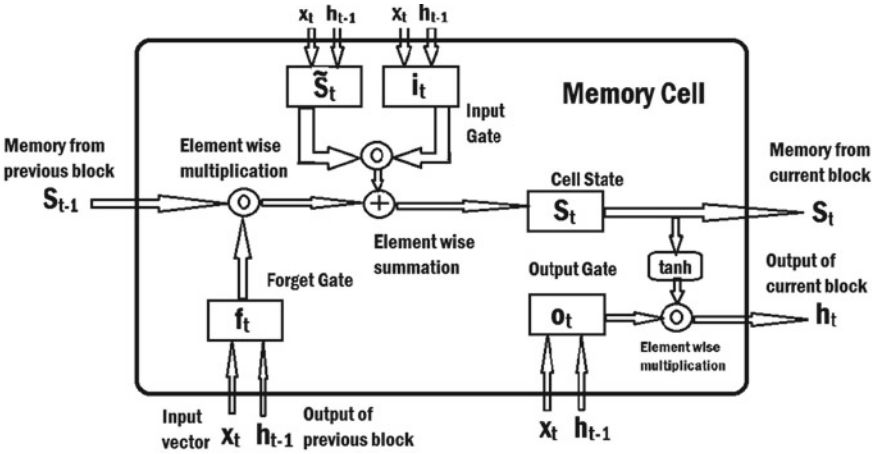

Fig. 3 Long short-term memory

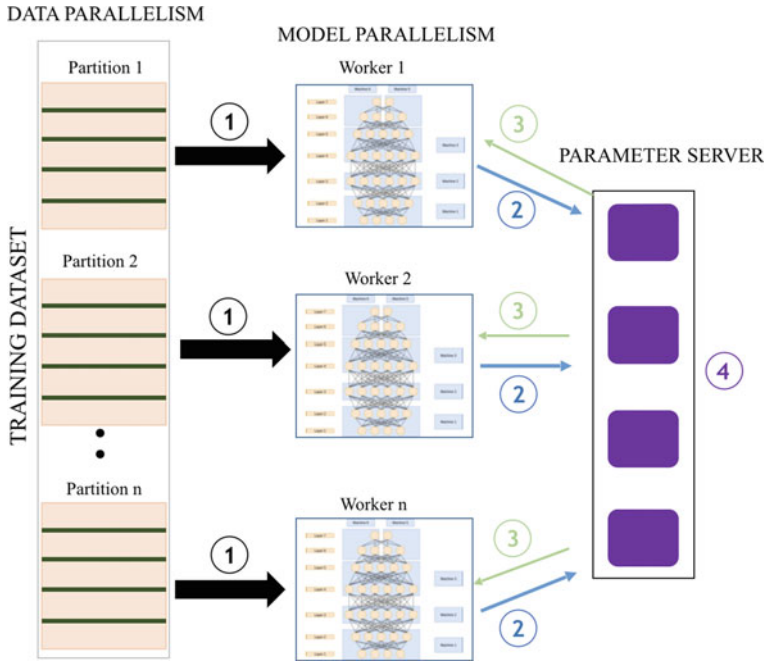

Fig. 4 Distributed RNN and LSTM architecture

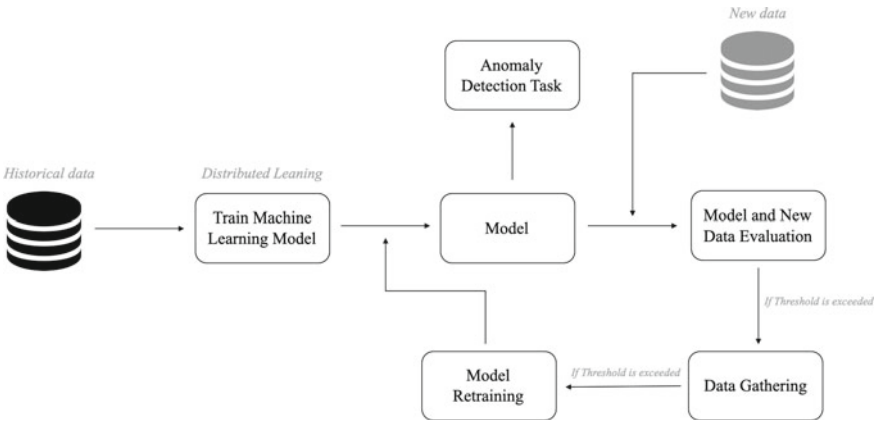

Fig. 5 Distributed and online retraining architecture

6 Distributed and Online Updated Model for IoT Data

Implementing high-performance distributed machine learning models is a challenging problem as programs (codes) have become more complex. We also have to address the communication and synchronization between different machines. If we're not careful with handling the system bottlenecks (e.g., load imbalance, network bandwidth, and latency), we can end up with a system which is slower than a centralized one. Similarly, retraining models when they become outdated can be time-consuming mainly for complex models and large datasets.

Therefore, in this paper, we focus on the aforementioned issues for which we suggest:

- A distributed online data anomaly detection framework,
- A model retraining framework.

Our proposed architecture is presented in Fig. 5. First, the machine learning model is trained using the historical data in a distributed manner. This model is then used for the anomaly detection task on the system level. The new data that is being generated by different processes and systems are evaluated using the predefined model from the previous step. The data gathered for retraining is used to optimize the model in the model retraining step presented in the next section.

The method to diagnose model drift uses model performance metrics.

6.1 Model Performance Degradation

Identifying model drift means to determine that predictive performance has worsened and to quantify this decline. Measuring the accuracy of a deployed model on

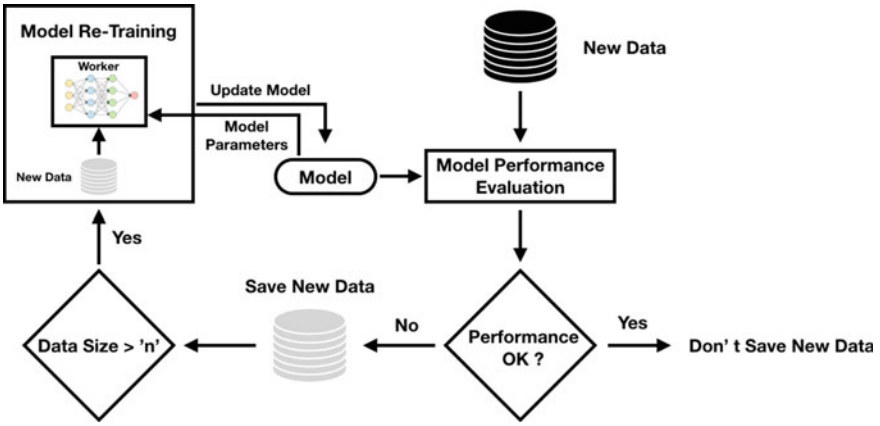

Fig. 6 Model retraining framework

streaming data is a challenging problem, especially for anomaly detection data. This difficulty arises because it's important to know whether the new data is normal (without any anomalies) or abnormal (with anomalies). To verify the novelty of the new data, the prediction error distribution is calculated for the training dataset; a new dataset is similar to the training data, and a new dataset is different from the training data. Kullback–Leibler divergence is used to quantify the difference between the distributions.

6.2 Model Retraining Framework

After the initial training phase, we noticed that there is a need to retrain the model with the arrival of new datasets. In this section, we provide a framework to automate this process of updating the model. The underlying concept is to use a batch retraining process, wherein we collect and store the data where the model was not able to predict accurately. Once enough data is collected, it is then used to update the model parameters. The proposed framework allows us to measure for the susceptibility of anomaly detection algorithms to model drift. Our study discusses how to detect and address model drift through model retraining (Fig. 6).

The model retraining framework includes the following steps:

- Model performance evaluation: The pre-trained model is tested with the incoming data in a real-time manner. If the performance of the model goes below a predefined value (Prediction Error > Threshold), then the data is considered "new" and is stored. This selected threshold will depend on the domain in which the process is being applied and rely on the following factors:

– If the threshold is too low, the retraining is too frequent, which would increase the overhead of compute cost,
– Too high a threshold might result in not retraining often enough, which would lead to a suboptimal model that provides inaccurate predictions.

An ROC curve can be used to pick thresholds that meet a specific criteria for a specific domain, for example, maximizing true positives or minimizing false negatives.

- Data Storage: We store the new data, and the size of the stored data is checked. When its size becomes greater than a predefined batch size "*n*," the retraining module is triggered.
- Model Retraining: Once the model retraining is triggered, the stored data is sent to a worker station along with parameters of the existing model. We use the new data to optimize the model parameters. The updated parameters are then sent to the model server. Depending on the rate of the new incoming data, we can either have a single worker to retrain the models (for a low rate) or multiple worker stations (for a high rate). In the event of multiple workers, an algorithmic system has to be defined to determine the number of workers required and to efficiently schedule jobs such that computational resources are maximized and model retraining can be completed in the minimum time.

To improve the data anomaly detection accuracy, but also the use of computing resources and network exchanges, two parameters must be optimized in this framework: The threshold for model performance evaluation needed as a model retraining trigger and the batch size "*n*" for model retraining. These two parameters will depend on the dataset type and the types of anomalies.

7 Experiments and Results

At the start of our approach, RNN, LSTM, and k-means clustering were used to classify anomalous behavior; then the performances were analyzed. A distributed approach was used to train these models. The experiment (the code of which is available on [39]) focused on the efficiency and limits of the corresponding models in predicting anomalies in the dataset. The second step involved modifying the input values and testing the data with the existing model.

7.1 Datasets Presentation

Three datasets were chosen for this study. Two were from the automotive industry, where one was collected from experiments performed on a treadmill-like autonomous car simulator at the University of Waterloo, Canada ([Simulator, 2018]) and a second

was generated from real vehicle equipped with sensors. The third dataset concerned health data. To achieve our goals, we used Python and its various machine learning libraries.

7.1.1 Simulator Data

The first dataset was from an autonomous car simulator. This demonstrator is a laboratory research and validation platform for real-time safety-critical systems in the context of autonomous driving algorithms. For this study, we focused on the vehicle lateral acceleration and jerk during various driving scenarios. Data was recorded for 15 min with a sampling frequency 30 Hz.

7.1.2 Vehicle Data

The second dataset comprised the real vehicle lateral acceleration and steering angle data. Data recording is done for 15 min with a sampling frequency 100 Hz.

7.1.3 ECG Data

The third dataset was electrocardiogram (ECG) data, which represents the cardiac activity of the heart in the form of electrical signals. Data was recorded for 15 min with a sampling frequency of 1000 Hz.

7.2 Distributed Model Training Experiments

The parameters used for the various algorithms are mentioned in Table 1. The models training was done using a dataset without anomalies to identify the normal behavior. Then, the model was used to predict the next values. A significant deviation between predicted and future values shows an anomaly. We understand for this approach that the model is trained on normal instances, and therefore, it learns to rebuild the normal behavior of the system. If the model learns from a dataset that already contains anomalies, the normal signal reconstruction won't be efficient. This leads to detect false anomalies and hence to high prediction errors. Prediction errors are calculated at each time step using the following formula:

$$\text{Error} = \sqrt{(y_{\text{observed}} - y_{\text{predicted}})^2}$$

Table 1 Hyperparameters

	Simulator data	Vehicle data	ECG data
RNN	Training window: 10 Predict ahead: 1 Epochs: 10	Training window: 10 Predict ahead: 1 Epochs: 10	Training window: 100 Predict ahead: 1 Epochs: 10
LSTM	Training window: 10 Predict ahead: 1 Epochs: 10	Training window: 10 Predict ahead: 1 Epochs: 10	Training window: 100 Predict ahead: 1 Epochs: 10
K-Means	Segment size: 30 Step size: 10	Segment size: 30 Step size: 10	Segment size: 500 Step size: 100

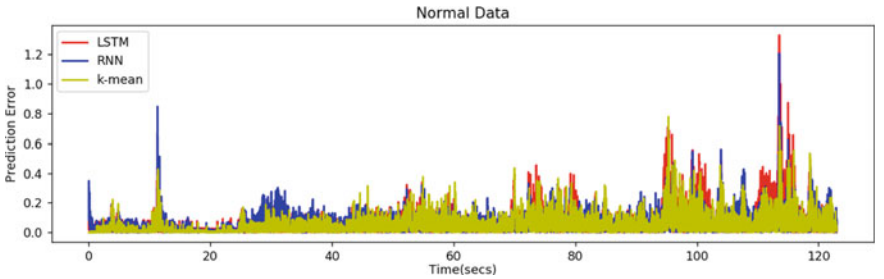

Fig. 7 Prediction error vehicle data

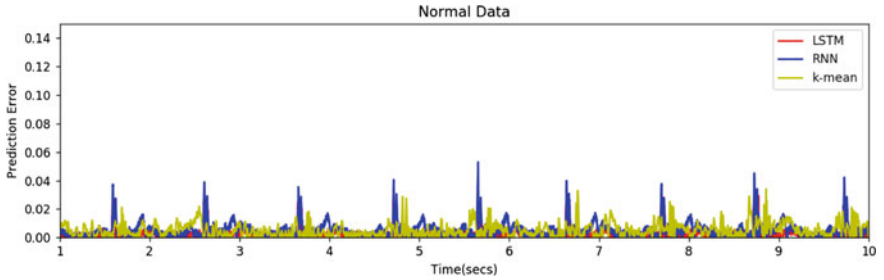

Fig. 8 Prediction error ECG data

The algorithms were first tested in a centralized manner. Figures 7 and 8 show the results for the three algorithms for different datasets. In Fig. 7, we can see the prediction error for real vehicle data.

Similarly, the prediction error for ECG data is shown in Fig. 8.

A more detailed analysis was done on the simulator data. In Fig. 9, we can see the prediction error for anomalous data is higher than for normal data. Therefore, an error threshold can be used to detect anomalies. Figure 10 shows a closeup of the results of the different algorithms. Similar results are represented for vehicle data and ECG data.

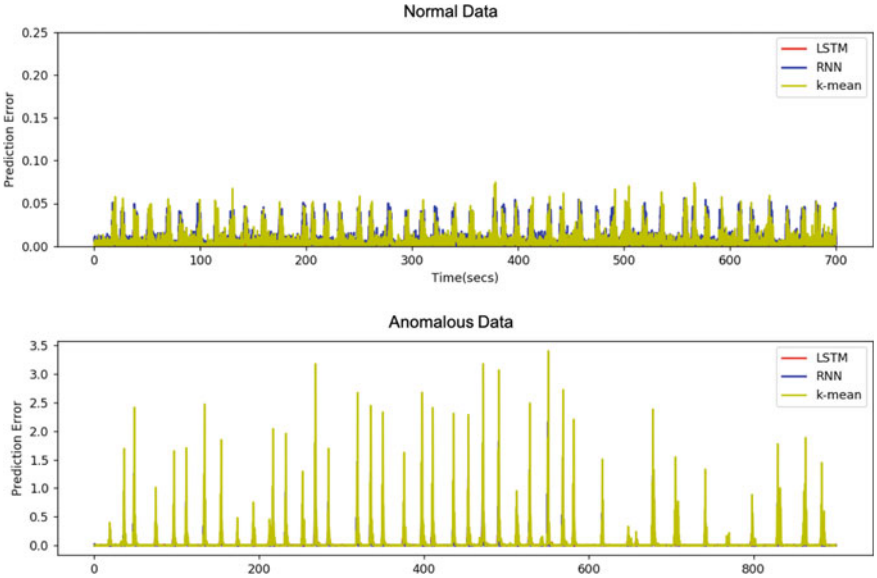

Fig. 9 Prediction error simulator data

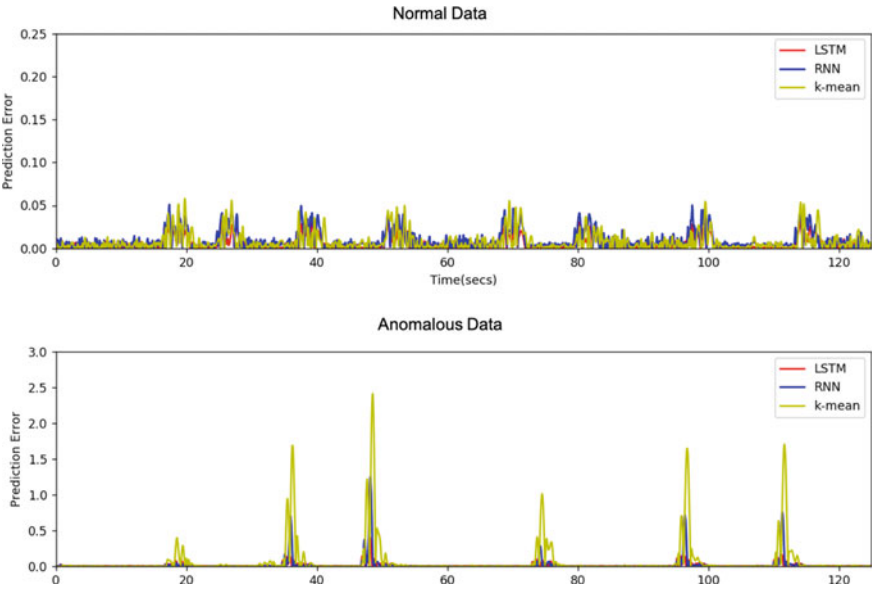

Fig. 10 Prediction error simulator data

Table 2 Training time (min) for simulator data

	Centralized	5 machines	10 machines
RNN	49	53	42
LSTM	49	53	42
K-Means	0.5	0.25	0.15

Table 3 Training time (min) for ECG data

	Centralized	5 machines	10 machines
RNN	150	135	120
LSTM	220	200	176
K-Means	2.5	1.25	0.5

Past research [12, 40, 41] has shown the effectiveness of using LSTM to detect anomalies in time series data. Therefore, the focus of this research was not on optimizing the hyperparameters of the algorithm, but to implement the algorithms in a distributed manner to handle the increase in the size of the dataset and to reduce the model training time.

In Table 2, we can see the result of distributed learning for the simulator data. For the training phase, 15 min of data from the simulator were used.

Table 3 shows the result for the ECG data. For the training phase, 15 min of ECG data were used.

A distributed learning approach shows improvement in the model training time; however, this only helps when a single machine cannot handle the requested computation. In fact, distributed training over multiple machines leads to overheads. In particular, communication between machines and parameter/cluster updates through multiple nodes. The greater number of machines that are used, the larger the overhead. This is not an issue if the computation cycle lasts a sufficient period to "erase" the overhead. If the computation step isn't long, the overheads become the bottleneck for the training. For machine learning algorithms, we can have more computation demands while relying on a better network (more computation per data sample), or by increasing the batch size (more samples per training step). The parameters and results described above are optimized for the used datasets, but will need further optimization depending on the specifications of data available, the model complexity, and the data batch characteristics.

7.3 Datasets Distributions Comparison

Here, we evaluate the distributions between similar datasets and new datasets to identify the moment when we have unseen data and thus require model retraining.

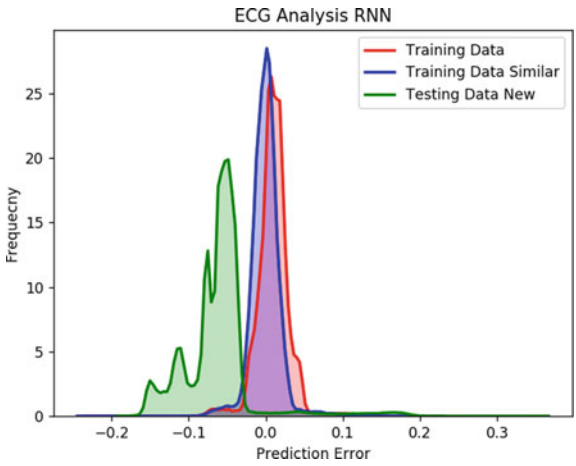

Fig. 11 Prediction error distribution

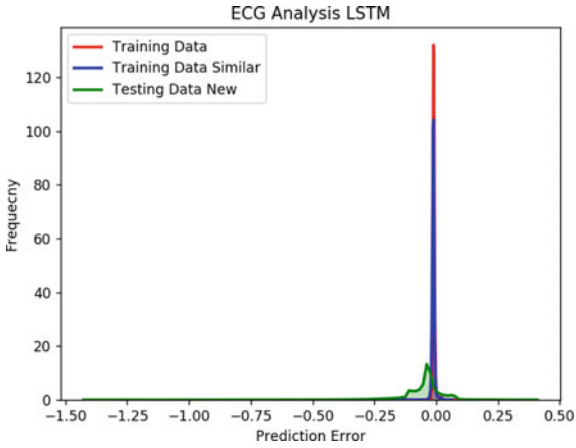

Fig. 12 Prediction error distribution

We can see in Fig. 11 the prediction error distribution for the RNN model. As shown, the training data and the similar data have overlapping distributions with a mean error close to zero. On the other hand, new data shows different behavior with a higher mean error.

In Fig. 12, we can see the prediction error distribution for the LSTM implementation. Here, that prediction error is smaller than in the RNN implementation. Similar to RNN, LSTM also shows different behavior for new data.

Figure 13 shows similar performance results for a k-means clustering model.

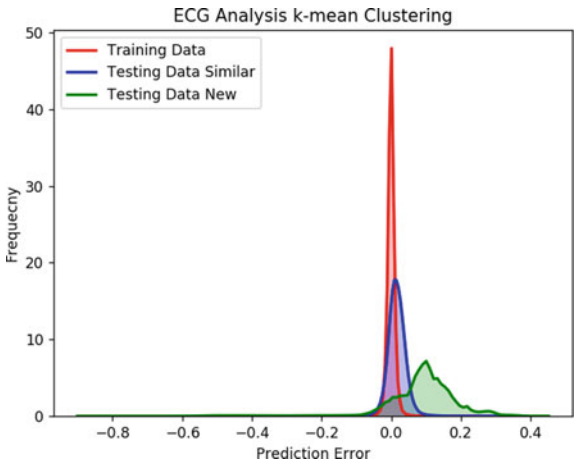

Fig. 13 Prediction error distribution

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Analytical Cyclic Division of Dataset for an ANN-Type Model: A Case Study in Air Quality Prediction in Sub-tropical Area

Benedito Chi Man Tam, Su-Kit Tang, and Alberto Cardoso

Abstract This research intends to show how an analytical cyclic division of a dataset can improve ANN-type models in predicting future situation of different air pollutants in small-sized urban cities. Similar to other sub-tropical cities, the four seasons are not significant but climate characteristics of Macao obviously includes warm and cold seasons. These make it difficult to train the models well. Thus, an effective analytical way of cyclic division of the dataset for a seasonal LSTM modeling can improve the prediction of air quality with the meteorological data. We used data from 2016 to 2020 as input, and the model was trained on a 24-h basis, weekly oscillation frequency and finally grouped into 2 warm and cold seasons. A small-sized urban city was selected to demonstrate this study with 21 meteorological variables, and wavelet decomposition was used to clearly see the obvious oscillation and cycle patterns. The contributions include using LSTM for the prediction of time series with multivariate inputs in Macao and observing how the 2 cyclic division of the time series dataset of air pollutants and meteorological conditions look like. It is also intended to show, using some indicators, why the multivariate dataset should be divided according to the 2 cold/warm seasons. Finally, the result of predicting the concentrations of air pollutants is presented.

Keywords Air quality · LSTM · Cyclic · Dataset division

B. C. M. Tam · A. Cardoso (✉)
Department of Informatics Engineering, Centre for Informatics and Systems of the University of Coimbra (CISUC), University of Coimbra, Coimbra, Portugal
e-mail: alberto@dei.uc.pt

B. C. M. Tam
e-mail: uc2019246674@student.uc.pt

B. C. M. Tam · S.-K. Tang
Faculty of Applied Sciences, Macao Polytechnic University, Macao SAR, China
e-mail: sktang@mpu.edu.mo

S.-K. Tang
Engineering Research Centre of Applied Technology on Machine Translation and Artificial Intelligence of Ministry of Education, Macao Polytechnic University, Macao SAR, China

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1 Introduction

This research intends to discuss how to analytically divide the cyclic divisions of a whole yearly dataset for multivariate ANN-type models in air quality prediction. The assessment of air quality is mainly related to the concentration of two major types of air pollutants, i.e., particulate matter (PM10 and PM2.5) and chemical gases (NO, SO, CO, and Ozone) [1]. In most urban cities like Macao, air quality index is issued to the public for planning outdoor activities, and the monitoring networks are used. The bottle neck of the traditional meteorological dynamic/chemical model is the limited number of equations. As an innovative alternative, deep learning models can accurately capture the patterns and build connections with multivariate inputs even if there are no sufficient equations. The air quality index (AQI) [2] will be defined as the highest sub-index among the pollutants, i.e.:

$$\mathrm{AQI} = \max(\mathrm{IPM}_{10}, \mathrm{IPM}_{2.5}, \mathrm{ISO}_2, \mathrm{INO}_2, \mathrm{IO}_3, \mathrm{ICO})(\mathrm{Ixxx}: \text{ Sub-index of pollutant } xxx) \quad (1)$$

2 The Contributions of This Research

This research aims to verify how influential is the seasonality of time series data of the concentrations of air pollutants and meteorological data in small urban cities. A half-year cycle is found, as well as the yearly oscillations. 4-season and 2-cycle cold/warm subsets are compared. To raise the accuracy, some other complementary atmospheric phenomenon data besides air temperature, rain rate and wind data, such as cloud and solar radiation are added to a multivariate long short-term memory (LSTM) model. Finally, the time series data of the above from these recent years are used in a selected small-sized urban city, Macao. The LSTM performance evaluation allows the identification of the best combination of datasets to predict future air quality as an assistance in an adaptive system for public services.

3 State of the Art

The current state of the art seeks to combine different components of artificial neural networks and different datasets, as well as to optimize the algorithms of deep learning networks. In meteorological research fields, some basic weather elements such as air temperature, humidity, and winds are commonly used as multivariate inputs. The more external information added, the more accurate the result will be. To predict the future air quality situation, the air quality index itself can be directly predicted, or firstly find out the concentration of each constituent pollutant and then recombine them to forecast the air quality.

3.1 Literature Review Synthesis

Most time series data exhibit a cycled behavior that can be considered to divide them into subsets. For ANN models, two main aspects are needed to be balanced, execution efficiency and accuracy. Convolutional neural network (CNN) models improve accuracy but consume more resources and are more complex. They are faster if implemented with LSTM. In many reports, LSTM performs even better, and the accuracy is very close to CNN-LSTM. LSTMs are called "long short-term memory" because of the gates that store patterns explored during long runs, so as to alleviate the gradient vanishing problem [3]. In many industrial and scientific applications, solutions based on LSTM are proposed. The accuracy can be greatly improved because the dispersion of air pollutants can be conveyed or blocked by different weather phenomenon [4].

3.2 ANN-Type Model as an Alternative

In the nature, there are too many unknown variables. If a mathematical model runs with all the necessary equations, all the unknown variables could be estimated accurately. Alternatively, ANN-type models can assist to estimate the approximate solution. Remote sensing can monitor precisely with intensive time intervals. The problem is that not all those measured nature elements can be used directly in a conventional model. In unsupervised learning, almost any type and any source of measured variable can be fed into an ANN model. These approaches allow helping to estimate any new measured variable that is too complicated to handle with formulae or equations.

3.3 Air Pollutant Diffusions and Concentrations

The periodicity and oscillation of the concentration of air pollutants are very consistent in meteorological data. The concentration depends mainly on its own source of emission, but also on the meteorological phenomena that help diffusion and transmission. When ANN-type models are used to predict the concentration of air pollutants, more meteorological data should be introduced. Since various weather phenomena affect the concentration of different air pollutants, such as the washing effect of precipitation and the chemical effect of solar radiation, and given that air pollutants are trapped in the atmospheric boundary layer, these will not be described in detail here [5].

4 Methodology

After considering the performance and accuracy indicators, a multivariate LSTM was adopted. A 3-layer architectures, namely input layer, hidden layer, and output layer, are interconnected by synaptic weights and activation functions. Like all ANNs, it maps complex nonlinear functions with different numbers of node units to obtain required accuracy. It is very flexible to perform seasonal forecasting in research [6, 7]. The model is run with the whole dataset and some subsets, i.e., two cycles with cold (September to February) and warm (March to August) seasons, and based on Spring (March to May), Summer (June to August), Autumn (September to November), and Winter (December to February).

Conventionally, the training set and the test set are divided with the ratio of 8:2. The research is focused on medium to small-sized urban cities. In order to bring this abstract plan into reality, considering feasibility, accessibility and data availability, Macao was chosen due to the network of observation stations monitoring air quality and all those data are published hourly [8]. Macao is developing rapidly in all perspectives and has good meteorological services. In many contexts, local specialties and facilities are very similar to western cities such as in Portugal and in other European countries. Air quality monitoring has been carried out for decades. There are 6 air pollutants to be monitored, i.e., PM10, PM2.5, CO, NO_2, SO_2, and Ozone in the 15-min intervals. Figure 1 shows the geographical locations of those six stations. They are: High Density Residential Area (Macao), Roadside (Macao), High Density Residential Area (Taipa), Ambient (Taipa), Roadside (Ká-Hó), Ambient (Coloane). In Macao's southern district Ka-Ho of Coloane, there are the concrete cement producing industries, so residents are very concerned about the air quality. They made several petitions to the government. This was also one of the motivations of this work.

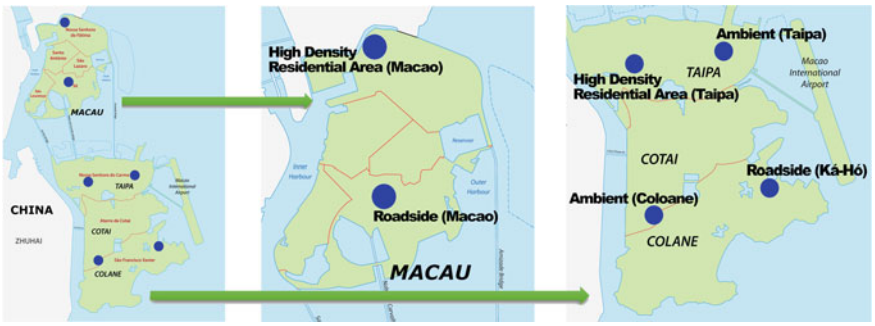

Fig. 1 Six air quality monitoring stations in Macao

5 Cyclic Division of the Dataset

To carry out this case study, firstly, the whole yearly dataset is used to assess the performance of the approach. Then, the result was compared with the dataset divided according to the four conventional meteorological seasons, i.e., spring, summer, autumn, and winter. In the following section, the comparison metrics show that the result is not good as it is obtained with the whole yearly dataset. Finally, by exploiting the seasonality and oscillation of the air quality and climate datasets, there is a 2-cycle or 2-oscillations throughout the year. Therefore, the experiments are performed again. To better understand the characteristics of the concentration of air pollutants, several interviews were conducted with experts in meteorology. The experiences tell that the concentration mainly has two significant annual changes, namely in the cold and warm seasons.

5.1 Data Sources

The concentration of air pollutants extracted from the internet sources has been released to the public every hour daily in recent years. Other parameters of atmospheric phenomena, including cloud base height, cloud cover, and surface solar radiation, are obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) data centers. The above data are all released to the public and are very suitable for research [9–11]. Final selected experimental data include meteorological elements, air temperature, humidity, rainfall rate, wind, sea-level pressure, visibility, cloud, solar radiation, air pollutants, four gas elements, and suspended particles.

5.2 Dataset Division Factors

The seasons to consider in the approach correspond approximately to the 4 seasons, Spring, Summer, Autumn, and Winter, each with 3 months. Another factor to consider when dividing the dataset is the climatic characteristics. Table 1 shows the climate for 30 years starting from 1991 with the Macao climate report data of 2021. In summary, the warm/wet season from March to September is characterized by warmer, more humid, prevailing mainly south winds, more thunderstorms, a continuous trend of increasing temperature and rainfall, and dropping sea-level pressure; the cold/dry season from October to February is characterized by colder and drier climate, the prevailing wind is northerly, the temperature and rainfall have a continuous downward trend, and the sea-level pressure increases. Macao is surrounded by the sea on three sides and exposed to direct solar radiation twice a year with a sub-tropical oceanic monsoon climate that is characterized by intense radiation, exuberant evaporation, intense heat, adequate moisture, high temperature, and abundant rainfall [12].

Table 1 Macao climate

t	*h*	*r*	*rd*	*w*	*tsd*	*t*	*h*	*R*	*rd*	*w*	*tsd*
Warm season: March–August						Cold Season: September–February					
21.4	***85.0***	80	11.4	***ESE***	2.0	30.8	78.3	228	12.3	N	6.6
25.1	***86.3***	154	11.6	***ESE***	3.8	28.5	72.5	75	6.2	NNE	0.9
28.7	***84.9***	***286***	***14.1***	***S***	***7.0***	24.7	72.6	39	4.9	N	0.1
30.5	***84.6***	***374***	***17.7***	***S***	***10.0***	20.3	70.8	31	5.0	N	0.1
31.4	***82.7***	***291***	***16.6***	***S***	***9.0***	18.6	74.9	34	5.8	N	0.1
31.5	***82.1***	***331***	***16.2***	***S***	***10.5***	19.2	80.5	44	8.9	N	0.7

5.3 Analytical Division of Appropriate Cyclic Dataset

Analytically, some basic guidelines are needed to consider the different possible cyclic dataset segments to further define those divisions. The most effective and feasible method is finding out the different reasonable oscillations of the whole dataset. In this case, the whole yearly dataset is divided into 4 seasons based on common knowledge, and the split of 2 cold/warm cycles. In the following section, it is verified that the results are not good or even worse when breaking down the whole dataset into the 4 conventional meteorological seasons. The explanation is as follows, choosing the air quality and meteorological data to prove this concept. Both, the air quality and meteorological data have the characteristics according to the four meteorological seasons as the rotation of the earth around the sun. Thus, all of them have the 4-season cycles affected by the earth's seasonal phenomenon.

In Table 1, the data are from the report issued by Meteorological Bureau at 2021–03-18, where *t*: air temperature (C), *h*: humidity (%), *r*: precipitation (mm), *rd*: rainy day, *w*: prevailing wind direction, *tsd*: thunderstorm days. Those values in italic are with characteristics for warm season while underlined for cold season. Table 1 also shows the annual temperature cycle depicted by the 30-year (1991–2020) monthly mean temperatures in Macao (Table 1, data source from Macao Meteorological Bureau Climate Data [12]), i.e., June, July, and August are usually the three warmest months, while December, January, and February are the three coldest months in a year. With the seasonality analysis, from Table 1, it is verified that there are the most obvious 2-cycle patterns, where the cold and warm cycles span over the five years dataset. If only the 12-month average data are examined, it seems that the changes in air temperature (*t*) correspond very closely to the four meteorological seasons, 3 months for each meteorological season, like in Table 1. If the analysis is extended to a spanning of 5 years, a 2-cycle oscillation is much more obvious, even in different weather elements (air temperature: yellow, humidity: pink, rainfall: blue and sea-level air pressure: green), as shown in Fig. 2.

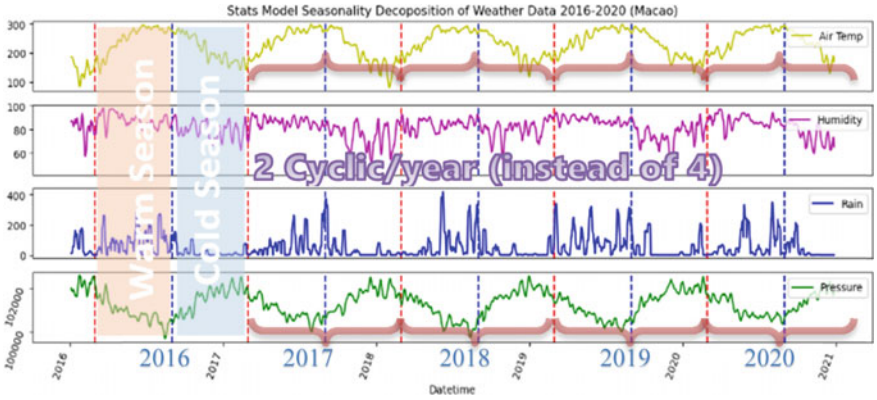

Fig. 2 Two cold/warm cycles spanning 5 years

6 Modeling with 4 and 2-Seasons Datasets

Two main approaches correspond to the division of the whole dataset into 4 seasons and only 2 cold/warm seasons, respectively. To do experiments as a proof of concept, the deep learning model is built. Based on the literature review, the LSTM is finally chosen. The number of node units in the hidden layer is defined, as well as the selection of activation functions, forward and backward propagations, and loss functions. The core concept of the artificial neural network is mainly the mathematical regression equation. The first layer is for storing the collected dataset values so called x, i.e., features, and the middle layer is used to find the regression equations of the sequence of the data, being each assigned to a polynomial coefficient, i.e., the weight w, and the last layer found the parsed output y.

7 Results and Evaluations

In the proposed LSTM model, the nodes of the first hidden layer and of the 2 hidden layers are increased from the initial 16 to the eventual 256, and the nodes of the second hidden layer are increased from 128 to the eventual 256. In total, many different experiments were carried out, with trade-offs of different settings and designs. More nodes will get higher accuracy, but this is not inevitable for all cases due to the overfitting situation. The data include 21 multivariate inputs, 19 of which are input layer features, and 1 output node. After building the model, different training rates varying from 0.0025 to 0.0005 were tested and run for 500 to 3000 epochs, with the ReLU() activation function. Finally, the 2000-epoch setting was used, given the training loss curve is almost flat. Smaller MSE's errors are used to find the better combinations for accuracy.

Table 2 PM_{10} and $PM_{2.5}$ metrics (4-Season Evaluation)

MSE	Annual (Dec–Nov)	Winter (Dec–Feb)	Spring (Mar–May)	Summer (Jun–Aug)	Autumn (Sep–Nov)
PM 10					
2016	0.00618	0.00778#	0.00421	0.00245	0.00429
2017	0.00465	0.00513#	0.00426#	0.00176	0.00357
2018	0.00197	0.00272#	0.00190	0.00306#	0.00271#
2019	0.00211	0.00477#	0.00504#	0.00214#	0.00189
2020	0.00184	0.00202#	0.00289#	0.00077	0.00320#
PM2.5					
2016	0.00497	0.00649#	0.00349	0.00257	0.00360
2017	0.00344	0.00280	0.00295	0.00109	0.00159
2018	0.00122	0.00130#	0.00406#	0.00106	0.00245#
2019	0.00231	0.00214	0.00395#	0.00116	0.00228
2020	0.00178	0.00150	0.00429#	0.00078	0.00404#
Elements of 2020					
PM10	0.00184	0.00202#	0.00289#	0.00077	0.00320#
PM2.5	0.00178	0.00150	0.00429#	0.00078	0.00404#
SO_2	0.00149	0.00113	0.00132	0.00067	0.00281#
NO_2	0.00368	0.00439#	0.00381#	0.00096	0.00362
CO	0.00740	0.00684	0.00375	0.00293	0.00643
Ozone	0.00440	0.00503#	0.00352	0.00066	0.00501#

In Table 2, model was run with hidden layers: 16/128, 21 multivariate inputs; "#" indicates worse results. Sometimes, periodic patterns cannot be explored when the dataset is too small, not enough data exists for the model to be trained, and it is difficult for the neural network to explore the potential patterns and repeat the oscillations.

7.1 Result Metrics Discussion

After comparing and analyzing the metrics, the following results were achieved. In Table 2, in most cases, it was not positive to have the model running based on the 4-meteorological dataset division. In Table 3, run with hidden layers with 32/256 nodes and 21 multivariate inputs; values marked with "*" indicate better results. The comparisons between annual dataset and the 2-cycle cold/warm dataset of each air pollutant element can also be observed in Table 3. It can be seen that in most cases, the accuracy is improved, allowing to conclude that if a good and appropriate cyclic division of the dataset is performed, this can significantly contribute to the

Table 3 PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, and Ozone Metrics (2-Season: cold/warm)

Year/MSE	Annual Sep–Aug	Cold Sep–Feb	Warm Mar–Aug	Annual Sep–Aug	Cold Sep–Feb	Warm Mar–Aug
	PM_{10}			NO_2		
2016	0.00382	0.00318*	0.00160*	0.00400	0.00243*	0.00293*
2017	0.00285	0.00243*	0.00137*	0.00433	0.00308*	0.00355*
2018	0.00109	0.00100*	0.00054*	0.00289	0.00241*	0.00334
2019	0.00189	0.00184*	0.00198	0.00335	0.00241*	0.00220*
2020	0.00122	0.00115*	0.00071*	0.00321	0.00274*	0.00170*
	$PM_{2.5}$			CO		
2016	0.00511	0.00465*	0.00229*	0.00233	0.00207*	0.00126*
2017	0.00270	0.00221*	0.00171*	0.00317	0.00335	0.00120*
2018	0.00113	0.00098*	0.00186	0.00465	0.00298*	0.00189*
2019	0.00226	0.00193*	0.00190*	0.00034	0.00024*	0.00107
2020	0.00185	0.00178*	0.00255	0.00310	0.00268*	0.00252*
	SO_2			Ozone		
2016	0.00200	0.00108*	0.00128*	0.00246	0.00232*	0.00106*
2017	0.00086	0.00046*	0.00066*	0.00193	0.00192*	0.00099*
2018	0.00197	0.00134*	0.00071*	0.00168	0.00116*	0.00146*
2019	0.00250	0.00174*	0.00144*	0.00239	0.00277	0.00090*
2020	0.00089	0.00079*	0.00095	0.00153	0.00143*	0.00156

improvement of accuracy, when running a multivariate ANN-type model for time series data prediction.

7.2 Two Yearly Cold/Warm Seasons Increasing Accuracy

Finally, after carrying out the presented methodology, an ideal LSTM model is built and tuned. The results show that the predictions improved as the dataset was divided into 2 cold/warm seasons, rather than using the whole yearly data. The model is good enough to predict the trend and the 24-h oscillation patterns. With this fundamental information and framework, an effective predicting model can be built for short term forecast and nowcast on the air quality. This is helpful for institutions to provide some real-time alert services to the public. Table 3 shows the improved prediction metrics for air pollutant elements PM10, PM2.5, SO_2, NO_2, CO, and Ozone, respectively. Figure 3 shows, for example, the $PM_{2.5}$ curves, demonstrating the relevant performance of the model (the yellow curves with the predicted data are very close to the blue curves with the Actual Data). The cold season spans 6 months from Autumn to Winter (September to February), while warm season spans 6 months from Spring

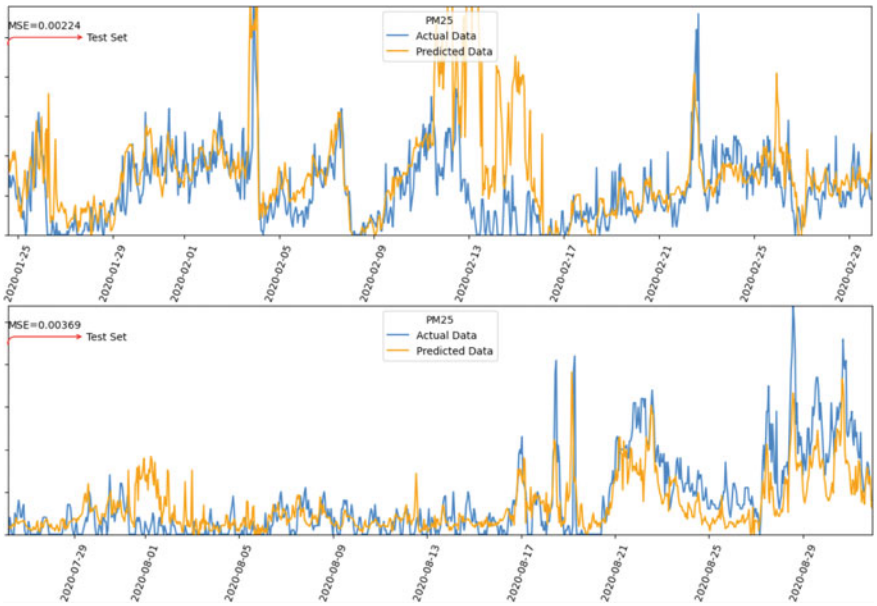

Fig. 3 $PM_{2.5}$ concentration prediction test set result from the 2020 cold and warm dataset

to Summer (March to August). Table 3 obviously shows that model accuracy can be improved by considering 2 cold/warm seasons instead of annual data or data with 4 seasons.

8 Conclusion and Future Works

With the results obtained in this work, it can be concluded that an analytical cyclic division of the dataset and an appropriate subset of the cyclic data division can improve ANN-type models in predicting the future situation of different air pollutants in small-sized urban cities (although some division may make the result even worse than with the whole dataset). In most real cases, due to the oscillations, there will be a canceling-out effect, where the dataset can be divided into too small parts so that some crucial patterns are not kept. In the presented case study for air quality prediction in a sub-tropical city, among the 3 kinds of datasets, i.e., whole yearly dataset, 4-season meteorological dataset, 2-cycle cold/warm seasons divided dataset, this 2-cycle approach presents the best results, and even the whole yearly is better than the 4-season one. Therefore, it is concluded that the time series dataset is useful to be appropriately divided into analytical cyclic subsets. This is due to the fact that, in different seasons, the weather is affected by climate behaviors on a totally different

planetary scale, such as the monsoon system, typhoon system, cold and dry high-pressure system, and the warm and wet rainy system, which present very different behaviors.

To focus on the research subject and make the analysis more comprehensive, rigorous, and easy to implement, the experiment was directed only to general weather situations. However, when some severe weather condition occurs, such as monsoons, strong convective rainfall and sandstorms, the chemical degradation and dynamic diffusion of pollutants will be completely different and difficult to grasp. Therefore, these aspects will be deepened in future work, including filtering the conditions of severe weather phenomena. There will also be research on the different degrees of delay of the influence of different elements on each other, so that the periodicity can be more consistent, and the accuracy of the results can be greater.

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BCAP-SA—Towards a Blockchain-Based Cryptocurrency Adoption Model as a Payment Method in Saudi Arabia

Ahmed Alrehaili, Martin White, and Natalia Beloff

Abstract Online transactions have grown to gain significant attention from various stakeholders in governments, business, and research practitioners all over the world. A decade ago, the first cryptocurrency transaction was executed to pave the way for a new era of online transactions. However, there is a relatively low adoption of blockchain-based cryptocurrency transactions as a payment method by service providers, organizations, and customers. Further, there is no study investigating the adoption of cryptocurrency technology as a payment method in Saudi Arabia. Therefore, this research proposes a new adoption model to investigate the acceptance of a blockchain-based cryptocurrency as a payment method in Saudi Arabia (BCAP-SA). A thorough research of the literature has yielded only a few studies covering external factors over a range of technical, economic, personal, and environmental aspects in different parts of the world. Hypotheses have been developed for each factor which will be examined by both qualitative (interviews) and quantitative (surveys) methods. The proposed study aims to offer service providers with insights about which factors customers would concentrate on if they were to accept blockchain-based cryptocurrency as a payment method.

Keywords Cryptocurrency · Technology Acceptance Model · Blockchain-based technology · Cryptocurrency adoption · Technology acceptance · Saudi Arabia

A. Alrehaili · M. White (✉) · N. Beloff
Department of Informatics, University of Sussex, Falmer, Brighton BN1 9QT, UK
e-mail: m.white@sussex.ac.uk

A. Alrehaili
e-mail: aa2709@sussex.ac.uk

N. Beloff
e-mail: n.beloff@sussex.ac.uk

A. Alrehaili
Faculty of Computer and Information Systems, Islamic University of Madinah, Medina 42351, KSA, Saudi Arabia

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1 Introduction

In recent years, consumers' demand has been growing where online marketing and transactions have expanded to an unprecedented level. Online services depend on electronic transactions as a payment method where customers pay for their goods and services online. Thus, consumers are looking for flexible, convenient, and time-efficient payment methods [1]. One of the most promising technology innovations during past years is the evolution of digitally distributed currencies, i.e., cryptocurrency.

Cryptocurrency is a digital currency that runs on a distributed (peer-2-peer) P2P network where transactions are recorded and validated (using cryptography methods) on a distributed public ledger (called a blockchain) that does not rely on a trusted third party (such as a bank) to verify the transaction, hence it is a trustless system [2]. Cryptocurrencies originated as replacement currencies for fiat currencies, to permits users to perform electronic payment for services and goods without the necessity of a central third party [3]. It can be seen as a new form of currency platform that is digitally governed based on computer cryptography and decentralized network [4]. The platform creates transparent transactions that are saved on the blockchain [5].

Consumers can obtain cryptocurrency in their digital wallets via various ways. They can register with several internet-based platforms which offer the opportunity to exchange national fiat currencies with cryptocurrencies [6]. However, due to legal constraints in some countries, some customers tend to trade cryptocurrencies in national fiat currencies through unofficial internet-based exchange platforms [4]. Other consumers can get cryptocurrency through specialized open-source programs sponsored by cryptocurrency platforms. These programs offer to customers a specified cryptocurrency amount in trade for certain tasks performed by the customers to the operation on the digital cryptocurrency platform [4]. Then, consumers can do a set of operations on these cryptocurrencies such as transfer them to other digital wallets or use them to pay for services and goods if there is a seller who accepts trading with cryptocurrencies.

Due to its popularity, significant interest has been focused on cryptocurrencies. The volume of the cryptocurrency market has raised from $1.5 billion in 2013 to over $795 in the next five years [7]. Globally, more than two thousand cryptocurrencies vary in their demand and prices [8]. Bitcoin is considered one of the most known cryptocurrencies where it gained a great deal of attention in the media in recent years. It was the first cryptocurrency platform that was published in a paper by Nakamoto [9]. Technically, it permits customers to send and receive payments in a few minutes without the necessity of a trusted central third party to governor such transactions and operations [9].

This research will focus on understanding and examining variables (factors) that may affect services providers and customers' acceptance and usage of a blockchain-based cryptocurrency as a payment method in Saudi Arabia. We are interested in investigating the acceptance of cryptocurrency transactions from two different perspectives; that of customers and that of service providers who are eager to accept

such technology as a payment method in their businesses or organizations. Furthermore, we aim to investigate external factors in four critical contexts, namely technical, personal, economic, and environmental. The scope of this research does not cover other contexts such as design aspects [2], usability dimensions [6], tourism-related issues [10], and banking prospective [4].

This research intends to offer the knowledge required to guarantee a high degree of acceptance and usage when deploying cryptocurrency while describing the various components of a new model utilized to perform this research. Furthermore, our research method will focus on deploying a mixed quantitative and qualitative research to assess and validate the proposed model.

2 Background and Context

Blockchain technology and cryptocurrency payments are considered as an evolution in technology innovation that can intervene in how customers can pay for services and goods [11]. While some researchers have investigated the effect of blockchain-based cryptocurrency in economy and tourism fields [10, 12–14], there is not enough empirical studies investigating cryptocurrencies as a payment method from both consumers and service provider perspectives in general context. We believe that cryptocurrency is an evolution in technology that can lead the way as a standard payment method in the near future.

A thorough analysis of the relevant literature indicates that there is a significant knowledge gap regarding in what way external variables could impact the acceptance and deployment of cryptocurrency as a payment method. Furthermore, there is no study investigating this issue in Saudi Arabia. This research intends to fill this gap by proposing an adapted conceptual model which will be basis of experimental study in the field.

The study findings arising from the proposed model will offer useful knowledge concerning the key variables (factors) influencing adoption of blockchain-based cryptocurrencies. Understanding how these factors influence the adoption of cryptocurrency as a payment method will provide useful insights for various parties involve in the technology. Such understanding will indicate to service providers the factors that are most important to consider if they wish to utilize the technology that would facilitate faster and more efficient payment methods. Furthermore, the study will offer useful knowledge for researchers and businesses working on the cryptocurrency industry.

Blockchain technology and cryptocurrency payment methods have seen a dramatic rise in recent years. The model proposed in this research is based on the well-tried and tested Technology Acceptance Model (TAM) (see Fig. 1) which has proven itself as a suitable model to investigate the influence of adopting a blockchain-based cryptocurrency as a payment method [15]. Studies performed in different parts of the world have utilized TAM as a base where they have added personal, economic, environmental, and technical "external variables" (or factors) to the TAM to explain what

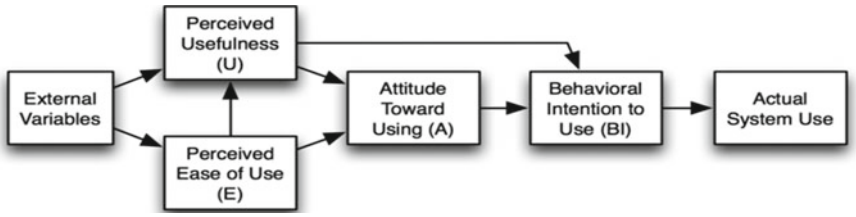

Fig. 1 Technology acceptance model [15]

affects customers' intention to use and deploy of a blockchain-based cryptocurrency as a payment method [16].

Personal and economic factors such as knowledge and low transaction fee have been demonstrated to be of strategic value by researchers that investigated the acceptance of cryptocurrency as payment method [48, 55]. Other studies have analyzed the impact of environmental and technical factors such as governmental regulatory and decentralization that have been proven to be critical aspects of adopting the technology [16].

Though the literature on the adoption of a blockchain-based cryptocurrency as a payment method is still fairly restricted, nonetheless research in this field has emphasized the importance of using TAM as a base model and deploy of factors such as trust to investigate the extent to which using cryptocurrency as a payment method is perceived as being efficient and reliable payment method by both service providers and customers.

There is a necessity to perform further investigation into cryptocurrency adoption as a payment method. A thorough research of relevant studies yielded there are no empirical studies in Saudi Arabia that investigate the impact of technical factors, namely decentralization, transparency, and anonymity into account, or examined personal factors such as knowledge and culture in the context of deploying cryptocurrency as a payment method from the perspectives of the service providers, organizations, and customers.

3 Technology Adoption Theories and Models

There are several models that are currently used to investigate the acceptance of technologies. These models analyze the variables that affect the adoption of technology in specific contexts and under certain circumstances. While the Technology Acceptance Model (TAM) is deemed as one of the standards of acceptance models and theories [15], there are other theories and models namely the Diffusion of Innovation (DOI) [17], the Unified Theory of Acceptance and Use of Technology (UTAUT) [18], and the Theory of Reasoned Action (TRA) [19]. Many studies regarding the acceptance and utilization of a blockchain-based cryptocurrency as a payment method deploy

the Technology Acceptance Model as a base model either in its original form or combined with extra external factors.

The intention to adopt blockchain-based cryptocurrency as a payment method is the main interest of this research. To accomplish this, we have adapted the TAM with external factors because the TAM core constructs alone cannot be the only variables to get a precise assessment. The Technology Acceptance Model (TAM) is built on top of the Theory of Reasoned Action (TRA) model [19]. The Theory of Reasoned Action (TRA) is a model to explain the information technology adoption in different situations and scenarios. These models, namely TRA and TAM, describe that individual's behaviour is identified by their intention to perform the specified behaviour.

Given the TAM (see Fig. 1) as a model to clarify the motivation for the widespread acceptance of new technologies by customers, we will primarily investigate the Perceived Usefulness (PU), Perceived Ease of Use (PEOU) and Behavioural Intention (BI) [15]. Earlier studies have indicated that the TAM core constructs of PU and PEoU offers critical initial view of investigating the intention to adopt cryptocurrency as a payment method [16]. However, more research is required to recognize what are the factors that work as enablers to utilize the technology as a payment method. Therefore, we are investigating a set of four important groups of external variables plus perceived trust. The basis of the model is the combination of two core factors from the TAM, perceived trust, and a group of technical, economic, personal, and environmental variables which have been identified in the literature as critical variables for our study.

4 Conceptual Framework

As already implied, our model is based on TAM with this addition of factors (external variables) that may impact the acceptance of blockchain-based cryptocurrency as a payment method. These factors have been classified into four categories which signify the independent variables of the suggested conceptual model. For each variable, a hypothesis is defined to indicate the probable association to the dependent factor, i.e., "Intention to Adopt cryptocurrency as a payment method (ITA)." The framework has various layers of variables which has influence on the dependent variable, (see Fig. 2). The effect on this variable by intermediate variables represents the aim of the research. Consequently, these intermediate variables are influenced by the independent variables in the model.

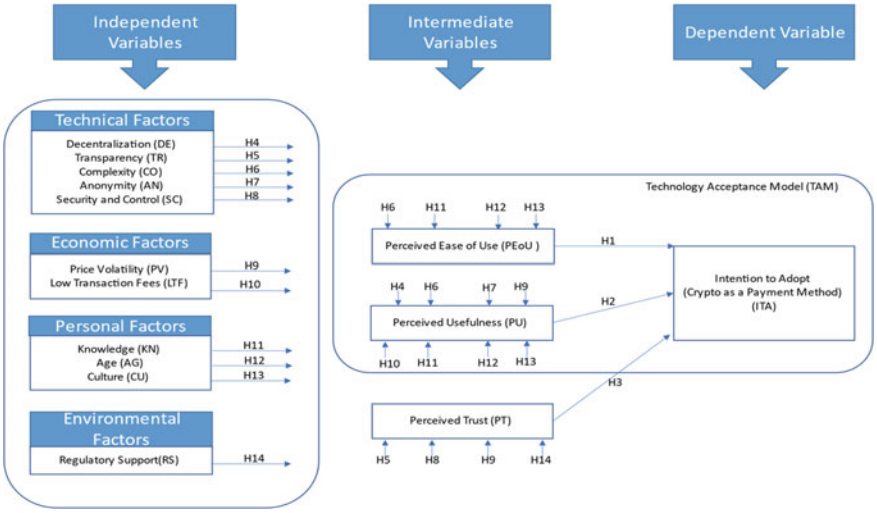

Fig. 2 The conceptual framework for the adoption of blockchain-based cryptocurrency as a payment method in Saudi Arabia (BCAP-SA)

4.1 Intermediate Variables

Intermediate Factors: These factors refer to TAM core constructs that impact the behaviour of individuals with regard to their attitude to accept and use a new technology. Two factors from TAM factors are the Perceived Ease of Use (PEoU) and the Perceived Usefulness (PU). Furthermore, it comprises an important external factor named Perceived Trust Factor (PT). These factors determine how helpful, useful, how easy and the trustworthy cryptocurrency technology is as a payment method.

Perceived Ease of Use (PEoU)

PEoU is described by Davis et al. as "the degree to which a person believes that using a particular system would be free of effort" [20]. It is the level of an individual's understanding about a service or technology to be free of efforts [15]. Consequently, it has a direct impact on user behavioural intention to adopt the technology. It is a TAM core construct which has been extensively studied [16, 21]. It is advised by Gould J and Lewis C to make the system friendly and flexible to users while maintaining its responsiveness and simplicity so it can be easily used by end users [22].

PEoU is highly related to an individual acceptance of a technology, so fulfilling this factor is an important goal to be achieved. However, PEoU of an individual can be impacted by various reasons such as external factors, then these reasons might lead to an individual changing their opinions about the technology. Tan G and Ooi K claimed that when individuals discover a technology that has high PEoU and do not need much effort to learn, they will utilize it more [23].

In this research, we consider PEoU as an intermediate variable, which has a direct impact on the intention to accept blockchain-based cryptocurrency as a payment method. Hence, it is hypothesized that:

H1: Increasing the **perceived ease of use** of blockchain-based cryptocurrency increases users' **intention to adopt blockchain-based cryptocurrency as a payment method**.

In the hypothesis above, the independent (or intermediate) variable is highlighted in bold followed by the dependent variable also highlighted in bold. All further hypotheses are formatted the same way for clarity.

Perceived Usefulness (PU)

PU is described by Davis et al. as "the degree to which a person believes that use of the system will enhance their performance" [15]. Indeed, it implies individual perceptions about the possible advantages of adopting a certain technology. As a result, it has a direct impact on user behavioural intention to accept a technology [20]. It is a TAM core construct which has been extensively studied [16, 21]. It been suggested that the level to which an individual discovers the system usefulness leads to a substantial effect on the intention to adopt a technology.

PU for an individual can be impacted by various causes such as external factors, then these causes might lead to an individual changing their beliefs about the technology. Chenhall and Morris indicated that contextual factors of decentralization and perceived environmental uncertainty impact the PU [24]. However, Igbaria M., et al. suggest while PU and fun have comparable effect on number of times of using a technology, yet computer anxiety has major and significant effects on fun compared with its effect on PU [25]. It shows that there is a direct impact of PU on adopting a technology.

In this research, we consider perceived usefulness as an intermediate variable, which has a direct impact on the intention to accept blockchain-based cryptocurrency as a payment method. Hence, it is hypothesized that:

H2: Increasing the **perceived usefulness** of blockchain-based cryptocurrency increases users' **intention to adopt blockchain-based cryptocurrency as a payment method**.

Perceived Trust (PT)

PT can be described as the level of person's confidence and anticipation that another entity will accomplish certain activities that are significant for the trustor in the lack of trustor management over the trustee's performance [26]. In the context of blockchain acceptance, PT is a fundamental factor that is required to ensure the relationship between parties within the network.

Trust is one of the critical variables that influences the adoption of a technology either directly or indirectly [27]. It has a substantial direct impact on customer behaviour while conducting online purchases or other activities on the internet [28]. Practically, increasing trust leads to decreasing risks, so PT contributes to easing dangers. Online transactions and e-commerce require establishing a solid trust relationship between parties. Consequently, trading partners start evolving confidence

and reduce the danger of risks [29]. An earlier study by McCloskey claimed that trust has a considerable positive impact on the PEoU [28]. Obviously, the decline of trust leads to customers and service providers become more reluctant to adopt a technology. Kesharwani and Bisht suggested that trust can cause a change in customers' intention toward the adoption of any technology or service [31].

In the context of blockchain-based cryptocurrency, risks should be maintained at low level and maximize trust to a higher level. Therefore, PT may have a direct influence on the intention to accept and use the technology. Blockchain technology has still got some misconceptions and has been underestimated. Therefore, people still believe that its benefits cannot overcome risks related to it [32]. Various attempts been made to enforce trust in the technology such as deploying trusted management protocols or the creating constraints such as the setting in the IBM Hyperledger platform [30–33].

In this research, we consider PT as an intermediate variable which has a direct impact on the intention to accept blockchain-based cryptocurrency as a payment method. Hence, it is hypothesized that:

H3: Increasing the **perceived trust** of blockchain-based cryptocurrency increases users' **intention to adopt blockchain-based cryptocurrency as a payment method**.

4.2 Independent Variables

Independent variables: These factors are external factors which are grouped in four sets. These sets represent four aspects of external impacts namely technical, economic, personal, and environmental factors.

Technical Factors

Technical factors are factors that represent the core technology behind cryptocurrency. Each factor represents an aspect of the underlining technology blockchain. This construct consists of five substantial variables that are likely to impact the acceptance of blockchain-based cryptocurrency as a payment method: decentralization, transparency, complexity, anonymity, and security and control.

Decentralization (DC)

DC is the main technological feature of cryptocurrency. It is defined as distributed environment which is independence from central authorities [34]. Indeed, it is based on a collective effort by various parties around the world, so no single point of failure. A thorough research in relevant literature revealed that only a few studies investigating the important of such feature in utilizing blockchain-based cryptocurrency as payment method. Krombholz et al. indicated that many of their interviewees mentioned DC as one of main reasons that lured them to adopt Bitcoin [35]. In contrast, Abramova S and Bohme R in a quantitative study claimed that the DC has a weak effect on adopting the technology by their sample [34].

In this research, we consider DC as an independent variable that does not have a direct impact on the intention to accept blockchain-based cryptocurrency as a payment method. We assume there is a direct relationship between DC and one of the TAM core constructs; namely PU. Hence, it is hypothesized that:

H4: The **decentralization** of blockchain-based cryptocurrency increases **PU** of blockchain-based cryptocurrency as a payment method.

Transparency (TR)

TR is a valuable feature of underling technology of cryptocurrency. It is described as how firmly individuals believe that the transactions of cryptocurrency are understandable, available, and communicable [36]. While security matters are tackled by encryption algorithms, implementing a clear peer-to-peer mechanism was facilitated supporting TR in cryptocurrencies [37]. Pardo M, et al. suggested that TR is deemed as an irreplaceable component of international trading procedures [38]. There are not enough studies in the literature examining the impact of TR in influencing the use of the technology as payment method. Hoxha V and Sadiku suggested that TR is the most prominent factor that impacts the intention to accept blockchain-based technology in real-estate transactions [39]. Bharadwaj K et al. highlighted that blockchain TR has a positive impact on PT in adopting cryptocurrency [20]. Furthermore, Sobhanifard, Y. and Sadatfarizani, S believe that cryptocurrency acceptance will lead to more trust since all transactions are observed in full transparency mood [42].

In this research, we consider TR as an independent variable that does not have direct impact on the intention to accept blockchain-based cryptocurrency as a payment method. We assume there is a direct relationship between TR and PT. Hence, it is hypothesized that:

H5: The **transparency** of blockchain-based cryptocurrency increases **PT** of blockchain-based cryptocurrency as a payment method.

Complexity (CO)

CO is described by Cheung, et al. as "the degree to which an innovation is considered and perceived difficult to understand and utilize" [41]. It is defined as the degree of difficulty that an individual perceives in realizing innovation and operating technology [40]. There is a study that highlights CP is not a significant factor in affecting consumers' intentions to adopt the technology [43]. Agustina D claimed that CO substantially impacts the PEoU, yet it has no significant impact on PU [44]. In contrast, there are some studies confirmed that PEoU and PU are substantially impacted by CO [42]. Obviously, CO signifies the contrary of PEoU and PU, so we can assume that it has direct effect on both PEoU and PU.

In this research, we consider CO as an independent variable that does not have a direct impact on the intention to accept blockchain-based cryptocurrency as a payment method. We assume there is a direct relationship between CO and TAM core constructs; namely, PEoU and PU. Hence, it is hypothesized that:

H6a: The **complexity** of blockchain-based cryptocurrency decreases **PEoU** of blockchain-based cryptocurrency as a payment method.

H6b: The **complexity** of blockchain-based cryptocurrency decreases **PU** of blockchain-based cryptocurrency as a payment method.

Anonymity (AN)

AN is described by Wallace K. as "noncoordinatability of traits in a given respect "[45]. It is described as being a pseudonymity in cryptocurrency rather than full AN of individuals [46]. The identity of cryptocurrency transactions is associated with digital numbers within cryptocurrency platforms. Identity is only revealed if users' attempt to cash out or transfer their funds into a traditional bank account [47]. Alqaryouti O., et al. indicated that many of their interviewees are convinced that AN is one of the main enablers of cryptocurrency that lured them to adopt the technology [48].

In this research, we consider AN as an independent variable that does not have a direct impact on the intention to accept blockchain-based cryptocurrency as a payment method. We assume there is a direct relationship between AN and one of the TAM core constructs; namely PU. Hence, it is hypothesized that:

H7: The **anonymity** of blockchain-based cryptocurrency increases **PU** of blockchain-based cryptocurrency as a payment method.

Security and Control (SC)

SC is described as the perception of general safety of cryptocurrency environment and controlling the privacy [49]. Security is described as the incidents, or situations with the likelihood to trigger financial difficulty to platform assets or data in the form of limitation, alteration, exposure or restriction of data, breach of privacy, fraud, neglect, and misuse [50, 51]. Controlling privacy has positive and negative aspects, so no entity can identify if it would encourage or discourage the adoption of the technology. Surprisingly, Nadeem M, et al. claims that the intention to accept the technology is not significantly affected by SC factor [52]. However, Almarashdeh I. highlighted that SC is negatively correlated with the intention to utilize the technology as payment method [49].

In this research, we consider SC as an independent variable that does not have a direct impact on the intention to accept blockchain-based cryptocurrency as a payment method. We assume there is a direct relationship between SC and PT. Hence, it is hypothesized that:

H8: The **security and control** of blockchain-based cryptocurrency increases **PT** of blockchain-based cryptocurrency as a payment method.

Economic Factors

Economic factors are factors that represent financial-related factors. Each factor represents an economic aspect of cryptocurrency. This construct consists of two economic variables that are highly likely to impact the adoption of blockchain-based cryptocurrency as a payment method: price volatility and low transaction fee.

Price Volatility (PV)

PV is described as the perception of individuals to price variation over time. It is called squishiness of prices, which calculates how cryptocurrency prices can fluctuate widely over time [53]. It is extremely associated with the intention to accept and utilize the technology since it affects individuals from financial point of view. Many studies have indicated that PV has a strong effect on individuals' satisfaction which impacts their PU [53, 54]. Many qualitative studies have indicated that experts and service providers consider PV as a major obstacle to (their intention to) adopt the technology [5, 55, 56]. However, other studies claimed that PV has no impact on the confidence of individuals if the market can bring the price to a higher level at some time [57].

In this research, we consider PV as an independent variable that does not have a direct impact on the intention to accept blockchain-based cryptocurrency as a payment method. We assume there is a direct relationship between PV and PT and one of the TAM core constructs; namely PU. Hence, it is hypothesized that:

H9a: The **price volatility** of blockchain-based cryptocurrency decreases **PU** of blockchain-based cryptocurrency as a payment method.

H9b: The **price volatility** of blockchain-based cryptocurrency decreases **PT** of blockchain-based cryptocurrency as a payment method.

Low Transaction Fees (LTF)

LTF is described as the perception of related fees of a transaction. It is argued that LTF means decreasing the difficulties in adopting the technology [58]. Alqaryouti O., et al. indicated that many of their interviewees are convinced that the LTF is one of the main enablers of cryptocurrency that lured them to adopt the technology [48]. Furthermore, other studies have indicated that LTF has a major impact on individual intention to accept a technology [54].

In this research, we consider LTF as an independent variable that does not have a direct impact on the intention to adopt the blockchain-based cryptocurrency as a payment method. We assume there is a direct relationship between LTF and one of the TAM core constructs; namely PU. Hence, it is hypothesized that:

H10: The **low transactions fees** of blockchain-based cryptocurrency increases **PU** of blockchain-based cryptocurrency as a payment method.

Personal Factors

Personal factors relate to users in general who are possibly eager to utilize and accept blockchain-based cryptocurrency as a payment method to buy or sell goods and services. Individuals can be customers, merchants, service providers, and company executives, among others. This construct consists of three substantial variables that are highly likely to impact the acceptance and usage of blockchain-based cryptocurrency as a payment method: knowledge, age, and culture.

Knowledge (KN)

KN is described as the overall perception of the technology. It can affect the final decision of adopting a technology or not. As mentioned earlier, the TAM was established over the basis of the Theory of Reasoned Action (TRA), which stated that the overall perception of an individual regarding a technology is a learned behaviour [59]. Therefore, it is considered as a growth of KN, which is acquired through experience. While many TAM-based studies deployed experience to represent KN, yet other examined individuals' KN directly by investigating their relative competence with the technology [60–62]. Other studies have investigated KN by examining its dimensions namely IT skills, education, and awareness. We will also investigate this factor from various dimensions, including IT skills, education, and awareness.

In this research, we consider KN as an independent variable that does not have a direct impact on the intention to accept blockchain-based cryptocurrency as a payment method. We assume there is a direct relationship between KN and TAM core constructs; namely PEoU and PU. Hence, it is hypothesized that:

H11a: Increasing users' **knowledge** in terms of IT skills, education, and technology awareness of blockchain-based cryptocurrency will increase users' **PEoU** of blockchain-based cryptocurrency as a payment method.

H11b: Increasing users' **knowledge** in term of IT skills, education, and technology awareness of blockchain-based cryptocurrency will increase users' **PU** of blockchain-based cryptocurrency as a payment method.

Age (AG)

AG is described as how old are the individuals who believe that cryptocurrency is a feasible way to perform payment operations. The utilization of a newly invented technology can be affected by how old the intended user is. Various studies highlighted the influence of AG when it comes in the utilization of technologies [23]. While some studies showed the significant impact of AG on the adoption of a technology, yet others highlighted AG has low impact on the intention to accept and use a technology [62].

In this research, we consider AG as an independent variable that does not have a direct impact on the intention to accept the blockchain-based cryptocurrency as a payment method. We assume there is a direct relationship between AG and TAM core constructs; namely PEoU and PU. Hence, it is hypothesized that:

H12a: Increased users' **age** decreases **PEoU** of blockchain-based cryptocurrency as a payment method.

H12b: Increased users' **age** decreases **PU** of blockchain-based cryptocurrency as a payment method.

Culture (CU)

CU refers to a tradition and common ways of a society. It has different aspects involving individualism, collectivism, masculinity and femininity, and others. Therefore, these multidimensional aspects made it difficult and hard to specifically define CU [63, 65]. CU has been investigated in the acceptance of various technologies and

services [63, 65]. A thorough research in relevant literature yielded a few research that has examined the impact of CU on the adoption of the technology as a payment method. Cristofaro M. et al. investigated whether behaviour or CU has more impact on the technologies used in the USA and China [64]. However, CU dimensions decreased the identified relationships and had different impacts: encouraging impact on results from the USA and discouraging impact on results from China [64]. Other studies have investigated CU by examining social image factor as a representative of culture [65, 73]. It implies to which degree an individual believes that utilizing a technology would increase their social status [65]. We will investigate this factor as representative of CU.

In this research, we consider CU as an independent variable that does not have a direct impact on the intention to adopt blockchain-based cryptocurrency as a payment method. We assume there is a direct relationship between CU and TAM core constructs; namely PEoU and PU. Hence, it is hypothesized that:

H13a: Increased users' **social image** increases **PEoU** of blockchain-based cryptocurrency as a payment method.

H13b: Increased users' **social image** increases **PU** of blockchain-based cryptocurrency as a payment method.

Environmental Factors

Environmental factors refer to ecosystem surrounding merchants and customers who are eager to utilize and accept blockchain-based cryptocurrency as a payment method to buy or sell goods and services. The government has a significant role to support a new technology. This construct consists of one significant factor that is highly to influence the adoption and utilization of blockchain-based cryptocurrency as a payment method: regulatory support.

Regulatory Support (RS)

RS indicates to authorized constitution that have being recognized by governmental institute to control and guarantee that all parties within the operation of selling and buying are adhered to rules and regulations without any violation of rights [16]. Governmental approval and RS are critical aspects when dealing with a new trend in e-business [66, 68]. Consequently, laws and regulations are set to control the quality of the service and fairness among are interested parties. Blockchain-based cryptocurrency is a similar technology that needs to be regulated to decrease the undesirable outcomes [66, 67]. There are many issues concerned with regulating technology around the world where such RS and laws can influence individuals' intention to trust the utilization of the technology [66, 70].

In this research, we consider RS as an independent variable that does not have a direct impact on the intention to adopt the blockchain-based cryptocurrency as a payment method. We assume there is a direct relationship between RS and PT. Hence, it is hypothesized that:

H14: Providing governmental **regulatory support** increases **PT** of blockchain-based cryptocurrency as a payment method.

5 Proposed Methodology

The proposed study will deploy combined research approaches where both qualitative and quantitative research methods will be adapted in investigating the acceptance of blockchain-based cryptocurrency as an efficient payment method. The two research methods will be complementary to each other. It becomes more common to deploy a mix of both qualitative and quantitative research methods rather than deploying one of them [69, 71].

The quantitative research method of the research will involve the development of a survey questionnaire designed to anticipate how consumer's pay their goods and services through a blockchain-based cryptocurrency and the potential difficulties they might face. The primary aim of deploying the questionnaire is the ability to distribute them online and obtain general overview of outcomes. Since the population of Saudi Arabia is around 34 million, we aim to follow the suggestion by Saunders et al. and make the confidence level at 95% with 5% confidence intervals [72–74]. As a result, we aim to get at least 384 responses so we can have reliable results. Since Saudi Arabia citizens are ethnically Arabs, so these results represent an appropriate view of same ethnical group about the acceptance of the technology. The finding of the quantitative study will be evaluated together with the proposed conceptual model using descriptive statistics, namely regularities, percentages, means, variations, and correlation assessments. Furthermore, the data will be evaluated and tested by Partial Least Squares-Structural Equation Modelling (PLS-SEM).

The qualitative research approach of the study will be performed as a case study, which involves interviews with experts in the field of blockchain and service providers who are eager to deploy the technology to determine their perspective of adopting blockchain-based cryptocurrency as a payment method. The interviews will be conducted in a semi-structured way to get the perspective of service providers. This will enable us to recognize the variables that impact the adoption of blockchain-based cryptocurrency as a payment method from the service provider perspective. Furthermore, it will allow us to investigate the benefits of deploying such technology in different sectors.

6 Conclusion

The research intends to examine and evaluate external variables that can influence users' acceptance of blockchain-based cryptocurrency as a payment method. As a result, the conceptual framework for the adoption of blockchain-based cryptocurrency as a payment method in Saudi Arabia (BCAP-SA) is utilized as a foundation for future empirical work. BCAP-SA combines the Technology Acceptance Model (TAM) with a group of technological, economic, personal, and environmental variables. These variables are mainly driven from a thorough analysis of other important conceptual models. As part of this study, BCAP-SA will be verified with citizens from

Saudi Arabia to examine and comprehend their perception about blockchain-based cryptocurrency as a payment method.

We anticipate facing some challenges especially when investigating the acceptance of the technology between business to business due to privacy and confidentiality reasons. Furthermore, we are aware that our target audience need to understand the underline concept of cryptocurrency before investigating their opinions to get accurate judgment about the effect of technical factors on the acceptance of the technology. However, we are confident the findings of such research will offer valuable information regarding the key variables influencing the acceptance of blockchain-based cryptocurrency as a payment method, which will provide insights for service providers who wish to increase their exposure and provide more efficient and accessible payment method. Furthermore, the finding of the research will provide useful knowledge for researchers and businesses working on cryptocurrency industry.

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Design Consideration for LC Analog Filters: Inductor ESR Compensation, Mutual Inductance Effect and Variable Center Frequency

Misaki Takagi, Takayuki Nakatani, Shogo Katayama, Daisuke Iimori, Gaku Ogihara, Yujie Zhao, Anna Kuwana, Keno Sato, Takashi Ishida, Toshiyuki Okamoto, Tamotsu Ichikawa, Kentaroh Katoh, Kazumi Hatayama, and Haruo Kobayashi

Abstract This paper presents several considerations of LC analog filter design. First, we propose an inductor equivalent series resistance (ESR) compensation technique for LC analog band-pass filters (BPFs) and band-elimination filters (BEF) for low-cost analog/mixed-signal IC test systems. The proposed technique uses an

M. Takagi (✉) · T. Nakatani · S. Katayama · D. Iimori · G. Ogihara · Y. Zhao · A. Kuwana · K. Katoh · K. Hatayama · H. Kobayashi
Division of Electronics and Informatics, Gunma University, 1-5-1 Tenjin-cho, Kiryu, Gunma 376-8515, Japan
e-mail: t221d0146@gunma-u.ac.jp

S. Katayama
e-mail: t15304906@gunma-u.ac.jp

D. Iimori
e-mail: t170d011@gunma-u.ac.jp

G. Ogihara
e-mail: t160d031@gunma-u.ac.jp

Y. Zhao
e-mail: t181d041@gunma-u.ac.jp

A. Kuwana
e-mail: kuwana.anna@gunma-u.ac.jp

H. Kobayashi
e-mail: koba@gunma-u.ac.jp

K. Sato · T. Ishida · T. Okamoto · T. Ichikawa
ROHM Semiconductor, 2-4-8 Shin-Yokohama, Kouhoku-Ku, Yokohama 222-8575, Japan
e-mail: keno.sato@dsn.rohm.co.jp

T. Ishida
e-mail: takashi.ishida@lsi.rohm.co.jp

T. Okamoto
e-mail: toshiyuki.okamoto@lsi.rohm.co.jp

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instrumentation amplifier and a few resistors. Also, the technique can be extended to the variable inductor implementation for variable center frequency. They were verified with simulation and measurement results. Further, we show in simulation and experiment that mutual inductance between two inductors in the BPF degrade its stop band characteristics, and this problem can be alleviated by the perpendicular placement of the inductors.

Keywords LC analog filter · ESR compensation · Band-pass filter · Band-elimination filter · Mutual inductance effect · Variable inductor

1 Introduction

Analog BPF and BEF are important components for pure sine wave signal generation and total harmonic distortion measurement in analog/mixed-signal IC testing systems [1–4]. They are implemented with dedicated devices in [3]; they have superior performance, but they are very costly. We describe here an inductor ESR compensation technique to enable the usage of inductors on the shelf to realize LC BPF and BEF with good performance at low cost. We also investigate parasitic mutual inductor effects to the filters and show their countermeasure. Furthermore, we show the application of the proposed circuit technique to the variable inductor implementation, which can realize variable center frequency BPF and BEF.

2 Proposed Inductor ESR Compensation Method

Figure 1a shows our proposed inductor ESR compensation circuit. There an instrumentation amplifier (LT1167) is used and its gain G can be controlled by the resistor R_g. Then we have the followings:

$$V_2 = G(V_2 - V_1), \quad R_m I = V_1 - V_2 = V_1/(1 - G). \tag{1}$$

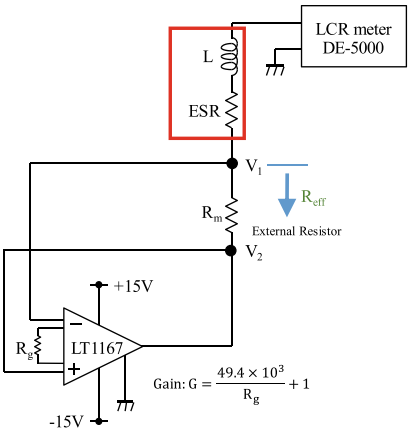
We have the effective resistor from the node V_1:

$$R_{\text{eff}} = V_1/I = (1 - G)R_m. \tag{2}$$

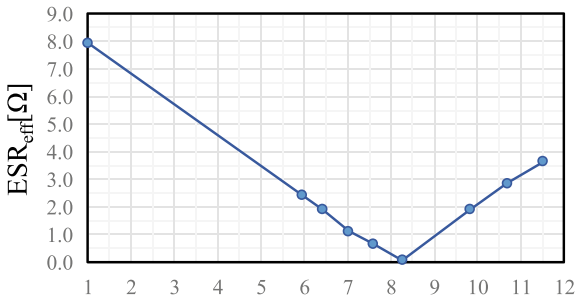
The effective ESR for small R_m is given by

$$\text{ESR}_{\text{eff}} = \text{ESR} + R_{\text{eff}}. \tag{3}$$

T. Ichikawa
e-mail: tamotsu.ichikawa@lsi.rohm.co.jp



(a)



(b)

Fig. 1 Proposed inductor ESR compensation. **a** Circuit. **b** Measured result

Notice that $R_{\text{eff}} < 0$ when $G > 1$, and by adjusting G, ESR_{eff} can be zero. Figure 1b shows the measured result; we see that ESR_{eff} is close to zero with amplifier gain of 8.

3 Application to LC BPF

Figure 2 shows an ideal LC BPF under investigation. Its transfer function is as follows:

$$G(s) = \frac{V_{\text{OUT}}}{V_{\text{IN}}} = \frac{s^3 R_t L^2 C_C}{s^4 R_i R_t L^2 C(2C_C + C) + s^3 L^2 (C + C_C)(R_i + R_t) + s^2 L\{2R_i R_t (C_C + C) + L\} + sL(R_i + R_t) + R_i R_t}. \quad (4)$$

However, in reality, the inductor L has an ESR. Figure 3 shows an LC BPF with the ESR compensation, and Fig. 4 shows its simulation results; Q is enhanced and the gain is attenuated by the proposed ESR compensation.

We have implemented a prototype BPF (Fig. 5). When its inductors L_1, L_2 are placed in parallel, the measurement result shows that Q is not well enhanced, and the attenuation in the stop bands is not enough (Fig. 6). We have found in simulation and measurement that it is due to the mutual inductance effect. Simulation result in Fig. 7 explains the mutual inductance effects to the BPF gain characteristics. On the other hand, L_1, L_2 are placed in a perpendicular manner for their mutual inductance reduction, the stop band attenuation is improved (Fig. 8) and Q is enhanced (Fig. 9).

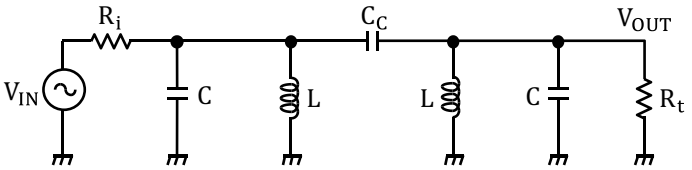


Fig. 2 Ideal LC BPF under investigation

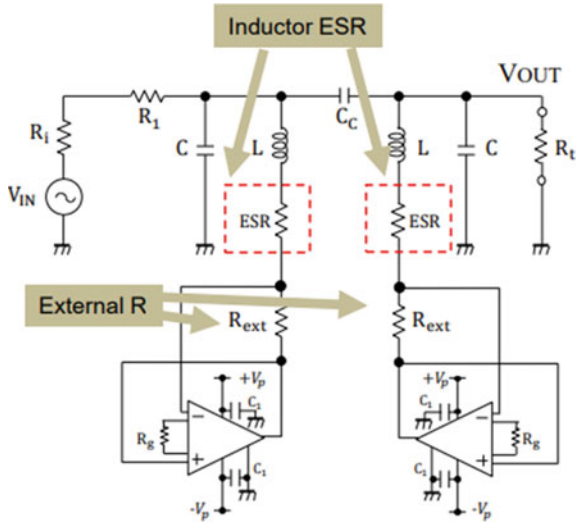


Fig. 3 LC analog BPF with the proposed inductor ESR compensation

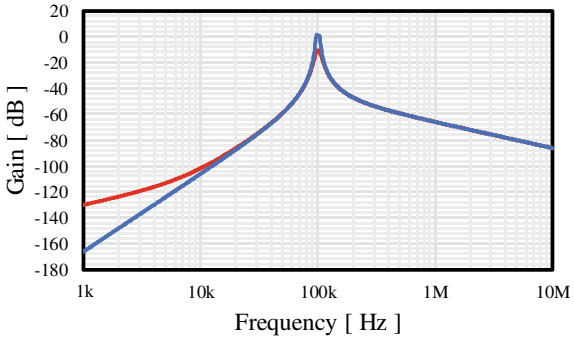


Fig. 4 Simulated BPF gain characteristics with (blue line) and without (red line) the inductor ESR compensation

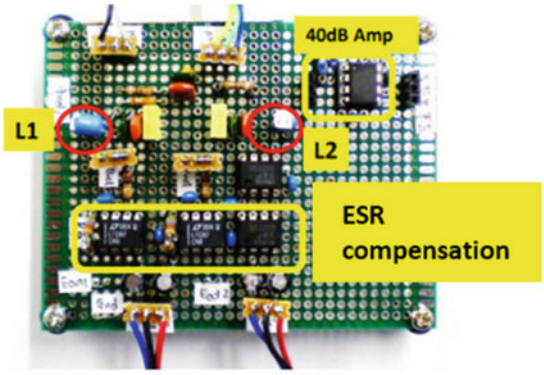


Fig. 5 LC BPF prototype with ESR compensation

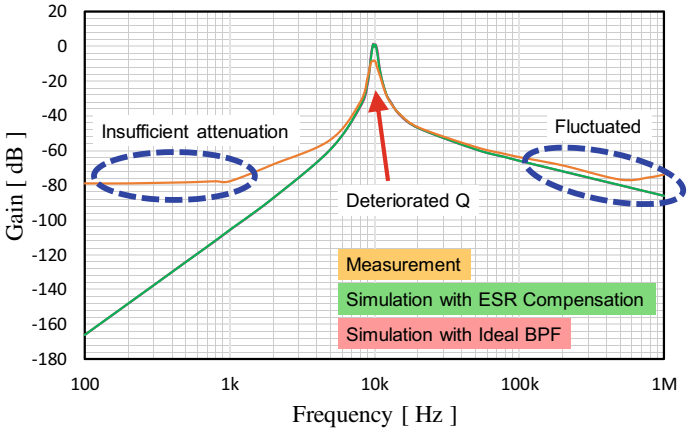


Fig. 6 Measurement result of the BPF prototype with ESR compensation, where L_1, L_2 are placed in parallel

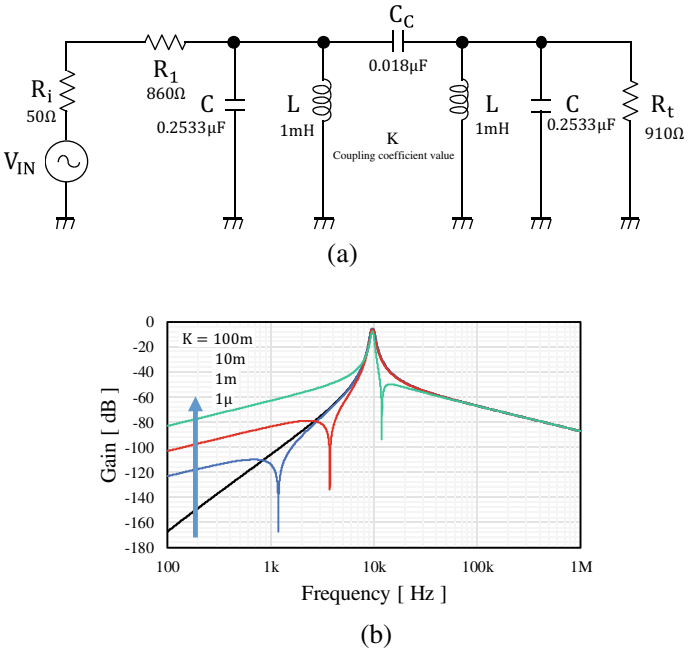


Fig. 7 Simulated mutual inductance effect to the BPF gain characteristics. **a** Circuit. **b** Simulation result with various coupling coefficient values of K

4 Application to LC BEF

Figure 10 shows an ideal LC BEF under investigation. Its transfer function is as follows:

$$G(s) = \frac{V_o}{V_s} = \frac{(s^2L_1C_1+1)(s^2L_fC_f+1)(s^2R_tL_2C_2+R_t)}{(s^2R_sL_1C_1+sL_1+R_s)\{(s^2L_fC_f+1)(s^2L_2C_2+1)+sC_f(s^2R_tL_2C_2+sL_2+R_t)\} + (s^2L_1C_1+1)(s^2L_fC_f+1)(s^2R_tL_2C_2+sL_2+R_t)} \quad (5)$$

We apply the ESR compensation technique in the BEF filter to the inductor L_3 in Fig. 11a; the ESR of L_3 is dominant to the overall BEF performance while that of L_1. or L_2 is not so much. As Fig. 11b, c shows, the notch becomes sharper, thanks to the ESR compensation. Figure 11d shows the BEF prototype photo.

Notice that BEF is used for the total harmonic distortion (THD) measurement of the device under test (DUT) [3]; the low-distortion sinusoidal signal is applied the DUT, and the fundamental component is removed by the BEF. Then the harmonic components are amplified and measured; then high dynamic range THD measurement can be achieved.

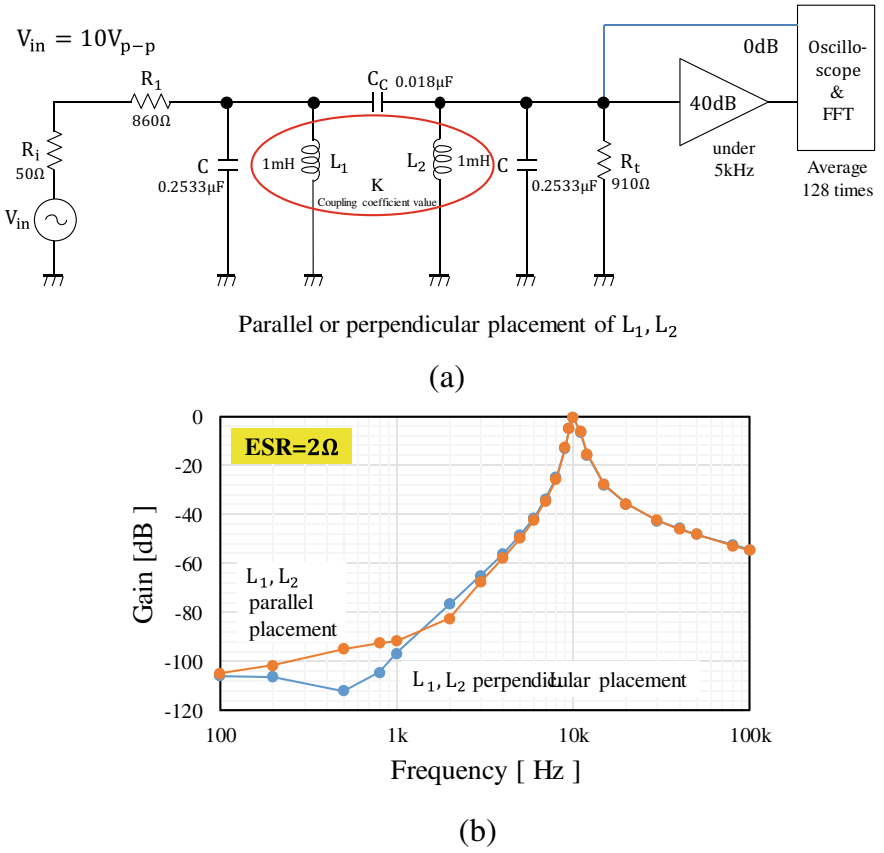


Fig. 8 BPF measurement result. **a** Measurement system with an amplifier of 40 dB gain under 5 kHz and 128 times averaging for accurate measurement in the stop bands. **b** Measured BPF gain characteristics of L_1, L_2 perpendicular or parallel placement

5 Application to Variable Inductor Realization

The proposed technique can be extended to realize a variable inductor in Fig. 12a for variable center frequency BPF and BEF. There neglect ESR and we have:

$$V_2 = G(V_2 - V_1), \quad j\omega L_m I = V_1 - V_2 = V_1/(1 - \mathrm{G}). \tag{6}$$

Then we have the effective inductor from the node V_1:

$$L_{\mathrm{eff}} = V_1/(\mathrm{j}\omega I) = (1 - G)L_m. \tag{7}$$

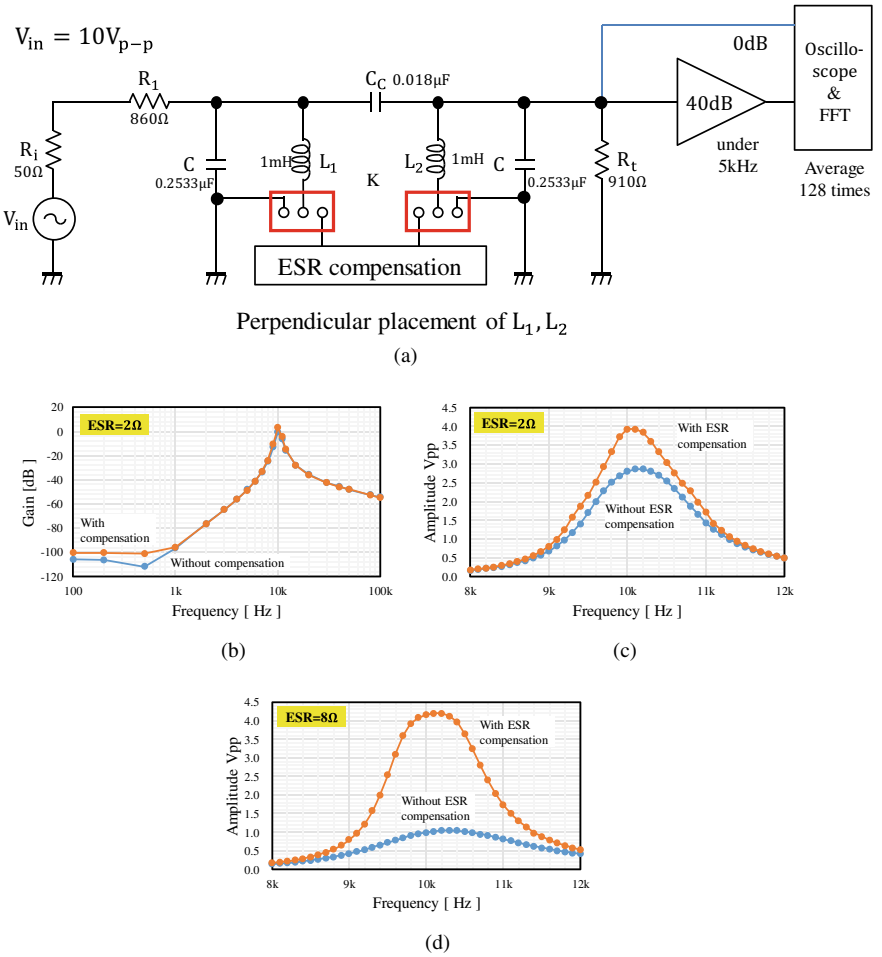
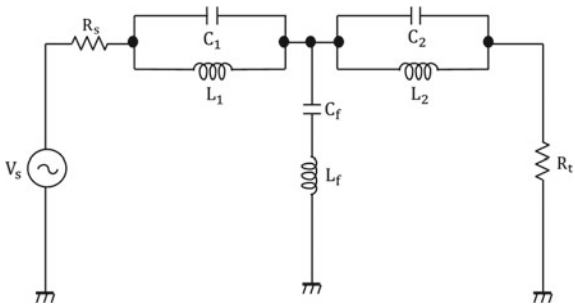


Fig. 9 Measurement of the second BPF prototype with the inductor ESR compensation. **a** Circuit. **b** Measured result with ESR of 2 Ω. **c** Enlarged one with ESR of 2 Ω. **d** Enlarged one with ESR of 8 Ω

Fig. 10 Ideal LC BEF under investigation



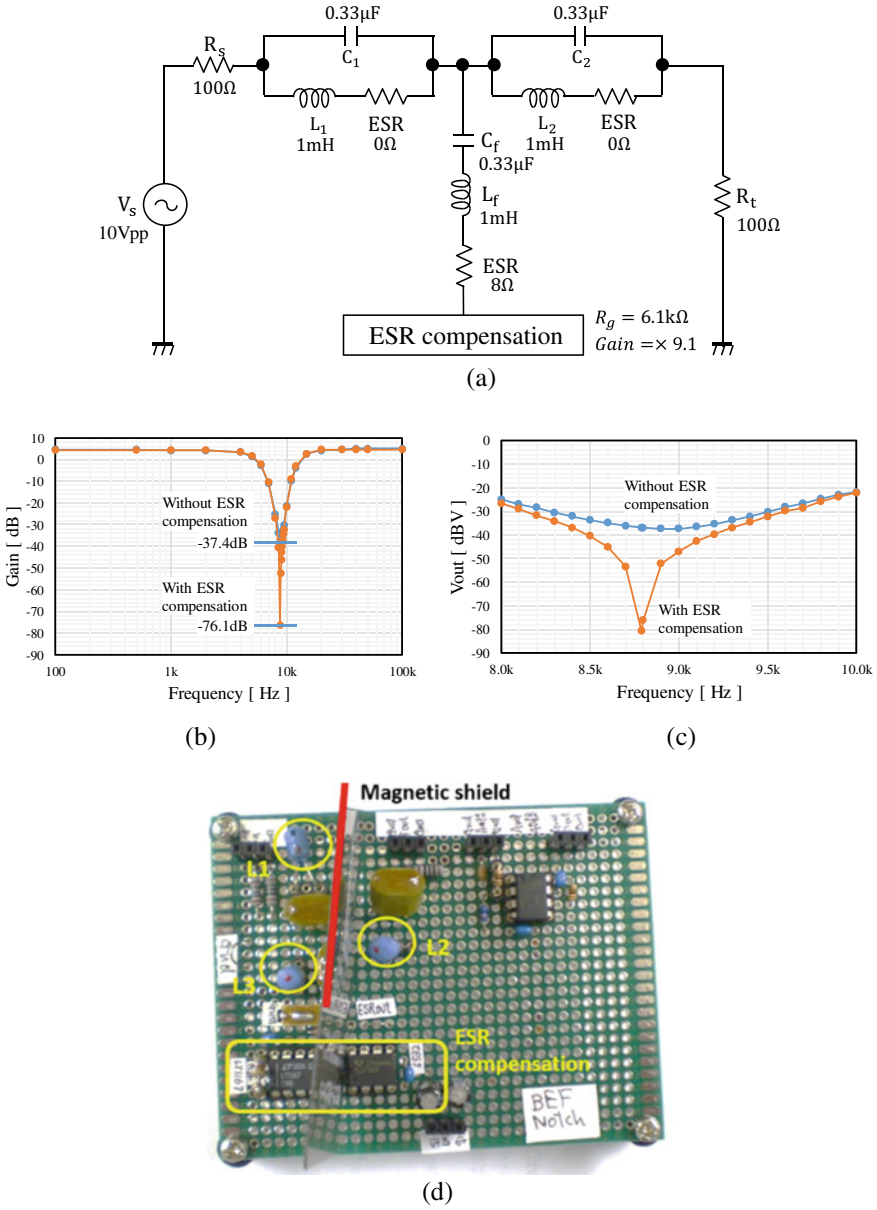


Fig. 11 BEF prototype with the inductor ESR compensation. **a** Circuit. **b** Measured result. **c** Enlarged one. **d** Board photo

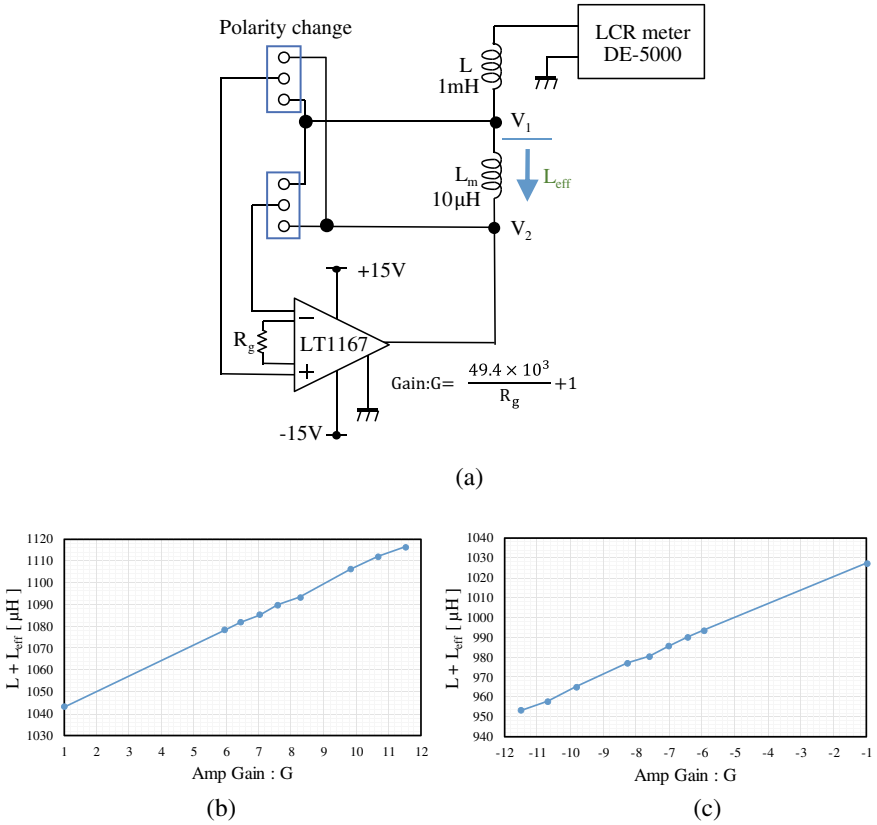


Fig. 12 Variable inductor implementation. **a** Circuit. **b** Measured results with polarity switch change. Inductor increase case ($G > 0$). **c** Inductor decrease case ($G < 0$)

G can be positive or negative by the polarity change switch (Fig. 12a). The total inductor is given by

$$L_{\text{total}} = L_{\text{eff}} + L. \tag{8}$$

Figure 12b, c shows the measurement verification.

6 Conclusion

We have shown an inductor ESR compensation technique for BPF and BEF with high Q to realize an analog/mixed-signal testing system at low cost, and its extension to a variable inductor realization for variable center frequency BPFs and BEFs. We have also investigated parasitic mutual inductance effects. These were verified with

simulation and experimental results. These are useful to generate the low-distortion sinusoidal signal and measure the THD at low cost for LSI test systems.

Acknowledgements Mr. Michio Shibuya is acknowledged for his advice on LTspice usage.

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Classification Performance in the Bio-inspired Asymmetric and Symmetric Networks

Naohiro Ishii, Kazunori Iwata, Naoto Mukai, Kazuya Odagiri, and Tokuro Matsuo

Abstract Recent developments of deep learning, machine learning, and artificial intelligence have a great influence on the wide areas of technologies. Classification is a core technology in their processing. This paper aims to make clear the classification performance for the bio-inspired asymmetric and symmetric networks. First, the bio-inspired asymmetric network is shown to have superior performance for tracing features compared to the symmetric one. Second, the classification characteristics of the asymmetric and symmetric networks are derived based on the independence of their outputs. Further, it is shown that generation of extended bases in the bio-inspired layered networks improves classification performance. Finally, the higher-dimensional mapping code generated as the extended bases are applied to the modified XOR problem.

Keywords Asymmetric network · Symmetric network · Independence for classification · Classification performance · Tracing for features

N. Ishii (✉) · T. Matsuo
Advanced Institute of Industrial Technology, Tokyo 140-0011, Japan
e-mail: nishii@acm.org

T. Matsuo
e-mail: matsuo@aiit.ac.jp

K. Iwata
Aichi University, Nagoya 453-8777, Japan
e-mail: kazunori@aichi-u.ac.jp

N. Mukai · K. Odagiri
Sugiyama Jyogakuen University, Nagoya 464-8622, Japan
e-mail: naoto@sugiyama-u.ac.jp

K. Odagiri
e-mail: kodagiri@sugiyama-u.ac.jp

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1 Introduction

Tremendous progress has been developed using deep learning, machine learning, and artificial intelligence [1–3]. Despite their results, computational models for understanding, transparency, and explainability are expected for their intelligent processing [3]. Classification is a core technology in their processing. This paper aims to make clear the classification performance for the bio-inspired asymmetric and symmetric networks. First, the asymmetric network is derived from the biological network of the catfish retina. Second, the classification characteristics in the asymmetric and symmetric networks are analyzed, which are based on the independent of the networks outputs. The determinants of output matrices of asymmetric and symmetric networks are computed for the evaluation of the independence. Further, the bio-inspired extended layered networks with nonlinearity improve the classification performance greatly. Finally, the higher-dimensional code in the extended layer is generated for the classification, which is applied to the modified XOR problems. Thus, the orthogonal bases and subspaces generated in the bio-inspired asymmetric networks [4, 5] are shown to be useful for the tracing and classification performance, which show an explainable design in the layered networks.

2 Bio-inspired Retinal Neural Networks

2.1 Structure of Bio-inspired Asymmetric Networks

Naka et al. [6] proposed a simplified, but fundamental networks of catfish retina as shown in Fig. 1.

Catfish retinal network consists of the bipolar cell B, amacrine cells, C and D in Fig. 1. The C cell has a squaring function [6, 7]. Then, the network in Fig. 1 is composed of a linear pathway and a nonlinear pathway with the cell C, which shows an asymmetric structure of the network. Thus, the network is called the asymmetric network.

3 Behavior of Asymmetric Networks

The impulse response functions, $h_1(t)$ and $h_1'(t)$ in Fig. 1, are replaced with Gabor filters as shown in Eq. (1)

$$G_s(t') = \frac{1}{\sqrt{2\pi}\sigma} \mathrm{e}^{-\frac{t'^2}{2\sigma^2\xi^2}} \sin(t') \quad G_c(t') = \frac{1}{\sqrt{2\pi}\sigma} \mathrm{e}^{-\frac{t'^2}{2\sigma^2\xi^2}} \cos(t') \tag{1}$$

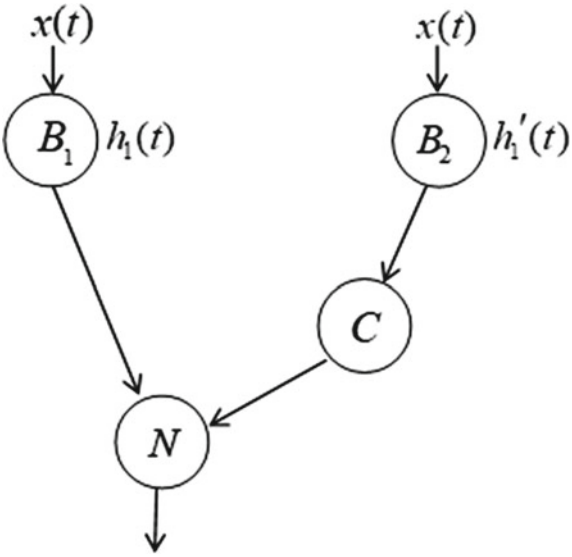

Fig. 1 Biological retinal network with asymmetric structure

The output of the network in Fig. 2 is described in Eq. (2), where h_1 is Gaussian term in Eq. (1). The tracing for the input $y = x$ is experimented in the network units in Fig. 2. The tracing results in the asymmetric network are shown in Fig. 3 [5]. The output of the second layer of the asymmetric network units is described in Eq. (3).

$$y_1 = (h_1 \sin(x_1) + h_1^2 \cos(x_2)^2) + (h_1 \cos(x_3) + h_1^2 \sin(x_4)^2) \tag{2}$$

$$y_2 = (h_1 \sin(x_1) + h_1^2 \cos(x_2)^2) + (h_1 \cos(x_3) + h_1^2 \sin(x_4)^2) + h_1^2 \sin(x_1) \cos(x_3) \tag{3}$$

The second layer of the asymmetric networks shows to trace the input well as shown in Fig. 3.

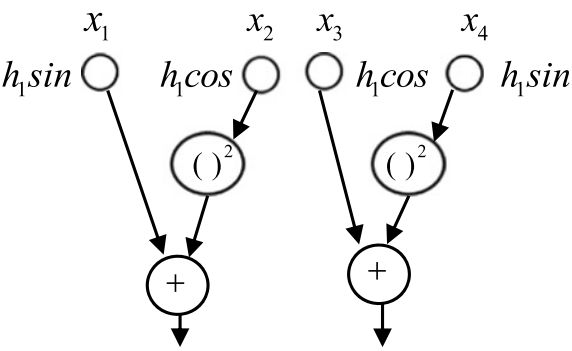

Fig. 2 Asymmetric network units derived from network in Fig. 1

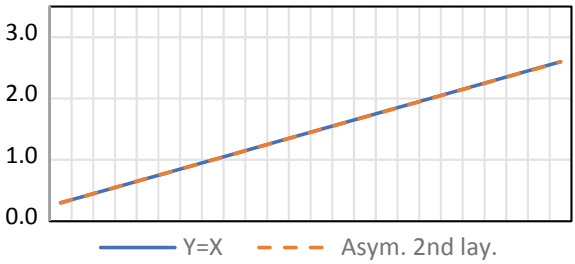

Fig. 3 Tracing results for $y = x$ in the second layer of asymmetric networks

The symmetric network is called energy model, which shows a symmetric structure in Fig. 4 [8]. The tracing for $y = x$ in the symmetric networks is experimented. The output results adapt well to the input $y = x$ as shown in Fig. 5.

The output of the symmetric network units in Fig. 4, which is in the first layer, is described as

$$y_1 = (h_1^2 \sin(x_1)^2 + h_1^2 \cos(x_2)^2) + (h_1^2 \cos(x_3)^2 + h_1^2 \sin(x_4)^2) \tag{4}$$

while the second layer of the symmetric network is described in the following equation.

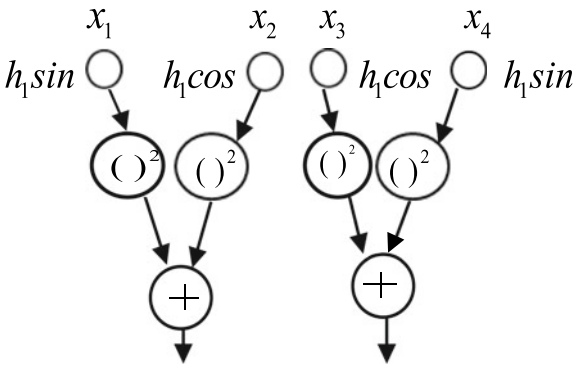

Fig. 4 Energy model units, which are called here symmetric network units

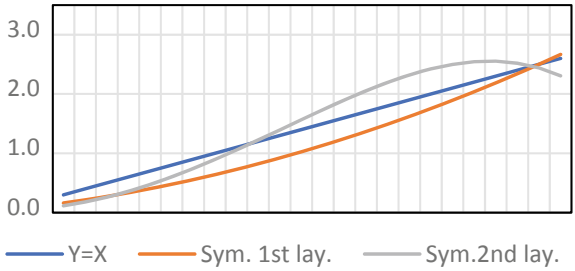

Fig. 5 Tracing results for $y = x$ in the symmetric networks

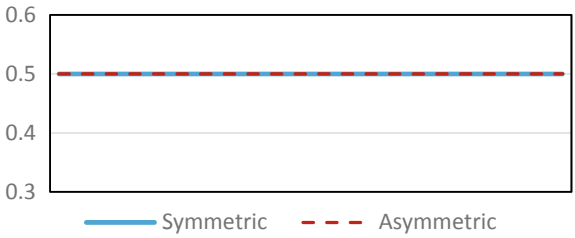

Fig. 6 Tracing results for $y = 0.5$ in the asymmetric and symmetric networks

$$y_2 = (h_1^2 \sin(x_1)^2 + h_1^2 \cos(x_2)^2) + (h_1^2 \cos(x_3)^2 + h_1^2 \sin(x_4)^2) + h_1^4 \sin(x_1)^2 \cos(x_3)^2 \tag{5}$$

Figures 3 and 5 show that tracing characteristics are different between the asymmetric and the symmetric networks, respectively. The orthogonal properties [5] in the second layer of the asymmetric networks make the tracking performance smoothly compared with the symmetric networks. In case of the tracing for $y = 0.5$, the asymmetric and the symmetric networks show to be same tracing results as shown in Fig. 6.

4 Comparison of Classification Performance Between Asymmetric and Symmetric Networks

Independence is an important factor for the classification scheme [9, 10]. The independence of the network outputs is measured by their determinant of the matrix. We compare the classification performance between asymmetric networks in Fig. 2 and the symmetric networks in Fig. 4. We assume the four-dimensional input, $X_1 = (x_{11}\, x_{12}\, x_{13}\, x_{14})$, which is the first row of the input matrix $X = [X_1\, X_2\, X_3\, X_4]$. The X is described in four-dimensional input matrix as Eq. (6). Further, we assume a simple four-dimensional example with components value $\{x_{ij}\} = \{0, 1\}$ as the third term in Eq. (6). The output of the network in Fig. 3 becomes $\{\sin(x_1),\ \cos^2(x_2),\ \cos(x_3), \sin^2(x_4)\}$ for the input $\{x_1, x_2, x_3, x_4\}$, in which h_1 to be 1 for the simplicity. We assume $a = \sin(x_i)$ and $b = \cos(x_j)$.

$$X = \begin{bmatrix} x_{11} & \cdots & x_{14} \\ \vdots & \ddots & \vdots \\ x_{41} & \cdots & x_{44} \end{bmatrix} \left(\equiv \begin{bmatrix} 1\,0 & 0\,1 \\ 0\,1 & 1\,0 \\ 0\,0 & 1\,1 \\ 1\,1 & 0\,0 \end{bmatrix} \right) \tag{6}$$

The determinant of the outputs of asymmetric networks for Eq. (6) is shown in Eq. (7).

$$\|\text{Asym.}N.\| \text{ for Eq.(6)} = \begin{Vmatrix} a & 1 & 1 & a^2 \\ 0 & b^2 & b & 0 \\ a & 1 & b & a^2 \\ 0 & b^2 & 1 & 0 \end{Vmatrix} \tag{7}$$

The determinant of the outputs of asymmetrical networks including Eq. (7) is represented as

$$\|\text{Asym.}N.\| = \left(a^3\right)\{(\pm b)[Z_1] + (\pm 1)[Z_2]\} \tag{8}$$

where $[Z_1]$ shows the summed determinants of matrices by the cofactor, variable $\pm b$ expansion across the third column in Eq. (7) and $[Z_2]$ shows those by the cofactor ± 1 expansion across the third column in Eq. (7). Similarly, the determinant of symmetric networks for inputs in Eq. (6) is shown in Eq. (9).

$$\|\text{Sym.}N.\| \text{ for Eq.(6)} = \begin{Vmatrix} a^2 & 1 & 1 & a^2 \\ 0 & b^2 & b^2 & 0 \\ a^2 & 1 & b^2 & a^2 \\ 0 & b^2 & 1 & 0 \end{Vmatrix} \tag{9}$$

The determinant of the output of symmetrical networks including Eq. (9) is represented as

$$\|Sym.N.\| = \left(a^4\right)\left\{\left(\pm b^2\right)[Z_1] + (\pm 1)[Z_2]\right\} \tag{10}$$

Note here the determinant $\{[Z_1] + (\pm 1)[Z_2]\}$ is same in both Eqs. (9) and (10). Then the following theorems are derived.

Theorem 1 Under the condition $[Z_1] \neq 0$, the determinant of asymmetric networks $\|Asym.N.\| \neq 0$ holds.

This is proved as follows. The first term, $(\pm b)[Z_1]$ in the determinant of asymmetric networks in Eq. (8), has the odd order exponentiation of the variable b, while the second term $(\pm 1)[Z_2]$ has the even order exponentiation of the variable b. Thus, these terms do not generate the summation to be zero.

Corollary 2 Under the condition $[Z_1] \neq 0$, if the determinant of symmetric networks, $\|Sym.N.\| = 0$, then that of asymmetric networks, $\|Asym.N.\| \neq 0$.

This is proved as follows. If $\|Sym.\| = 0$, then from Eq. (10) the equality equation $\left(\pm b^2\right)[Z_1] = -[Z_2]$ holds. This equation is substituted in Eq. (8). Thus, Eq. (11) holds

$$\left\{\left(\pm b^2\right) - (\pm b)\right\}[Z_1] \tag{11}$$

Since Eq. (11) $\neq 0$ holds under the condition $[Z_1] \neq 0$, the determinant of asymmetric networks, $\|Asym.\| \neq 0$.

Corollary 3 Under the condition $[Z_1] \neq 0$ and $[Z_2] = 0$ the determinant of symmetric networks, $\|Sym.N.\| \neq 0$, and that of asymmetric networks, $\|Asym.N.\| \neq 0$.

Theorem 4 Under the condition $[Z_1] = 0$ if the determinant of asymmetric networks, $\|Asym.N.\| = 0$, then the symmetric one, $\|Sym.N.\| = 0$ is satisfied.

Since Eq. (8) $= 0$ holds, then $[Z_2] = 0$ which are satisfied in Eq. (10) in the symmetric networks.

To compare the classification ability experimentally between the asymmetric networks in Fig. 2 and the symmetric network in Fig. 4, the four-dimensional input matrices $\{X\}$ in Eq. (6) are generated with components {0,1}. We define the symmetrical input patterns, X in the following.

Lemma 5 The determinants $[Z_1]$ and $[Z_2]$ in the asymmetric and symmetric network are described in a quadratic polynomial of variable b in the following.

$$[Z_1] = mb^2 + l \text{ and } [Z_2] = kb^2 + n \tag{12}$$

where m, l, k, and n are numerical coefficients.

This is proved from the definition of the matrix. Since $[Z_1]$ and $[Z_2]$ are computed by the cofactor of expansion across the third column in the four-dimensional matrix, variable b^2 exists only in the second column of the matrix. Since only one variable in the second column is used in the each expansion term from the definition of the determinant, the expansion terms consist of the quadratic polynomial in Eq. (12).

Theorem 6 A necessary and sufficient condition for $\|Asym.N.\| = 0$ is $m = 0, l = 0, k = 0$ and $n = 0$. Similarly, this condition for $\|Sym.N.\| = 0$ is $m = 0, (l + k) = 0$, and$n = 0$.

Definition 7 Symmetric pattern X is defined to have the following rows (1) or (2) in the four-dimensional matrix.

(1) $X_i = (x_{i1}\, x_{i2}\, x_{i3}\, x_{i4})$ and $X_j = (x_{j1}\, x_{j2}\, x_{j3}\, x_{j4})$, in which $x_{j1} = x_{i4}$, $x_{j2} = x_{i3}$,

$$x_{j3} = x_{i2} \text{ and } x_{j4} = x_{i1} \text{ are satisfied.} \tag{13}$$

(B) $X_k = (x_{k1}\, x_{k2}\, x_{k3}\, x_{k4}) = (x_{k4}\, x_{k3}\, x_{k2}\, x_{k1})$ (14)

(e.g., the matrix with elements {0.1} in Eq. (6) is a symmetric pattern) The first and second rows show from (2) in Definition 7, while the third and fourth rows show from (1) in Definition 7. Total of 24 symmetric patterns are generated, in which classification independence performance is evaluated between asymmetric and symmetric networks using the determinants of the respective networks, in Eqs. (8) and

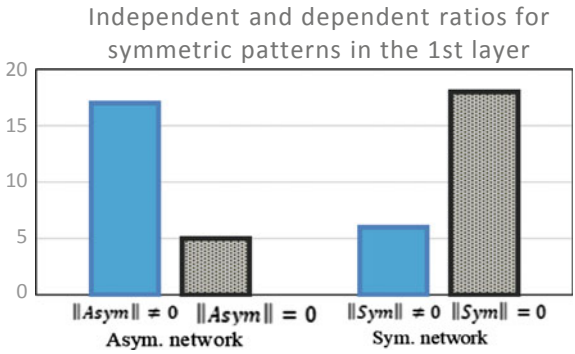

Fig. 7 Independent and dependent ratios for classification in the first layer of asymmetric and symmetric networks

(10), respectively. The determinant to be not 0 shows the independence of the output pattern matrix, while that to be 0 shows the dependence of the matrix. The dependence implies that the weights in the networks are not computed in the classification. Thud, the independence is expected in the networks. The asymmetric networks show that the classification performance is superior to the symmetric networks as shown in Fig. 7. These experimental results are explainable using theorems derived in this section.

5 Extended Layered Networks from the Bio-inspired Networks

Layered developments of the asymmetric and symmetric networks are useful for the classification performance. The layered network is also a bio-inspired model of the brain cortex, which is a neural network with the nonlinearity of a half-wave rectification [11]. The nonlinear operation of the half-wave rectification in Fig. 8 is approximated in Eq. (14).

$$f(x) = \frac{1}{1 + \mathrm{e}^{-\eta(x-\theta)}} \tag{14}$$

By Taylor expansion of Eq. (14) at $x = \theta$,

$$\begin{aligned} f(x)_{x=\theta} &= f(\theta) + f'(\theta)(x-\theta) + \frac{1}{2!} f''(\theta)(x-\theta)^2 + \cdots \\ &= \frac{1}{2} + \frac{\eta}{4}(x-\theta) + \frac{1}{2!}\left(-\frac{\eta^2}{4} + \frac{\eta^2 \mathrm{e}^{-\eta\theta}}{2}\right)(x-\theta) + \cdots \end{aligned} \tag{15}$$

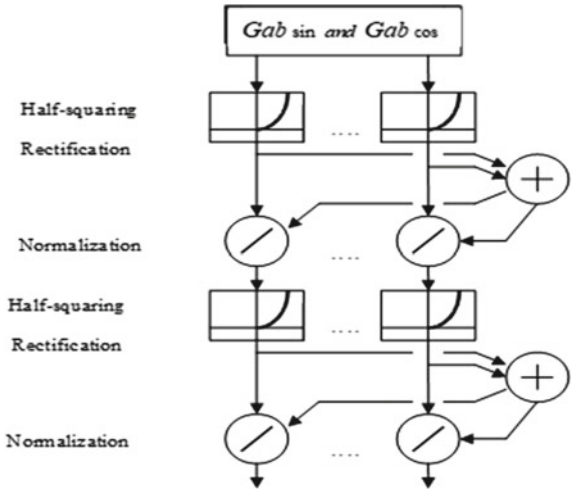

Fig. 8 Neural networks model, V1 and MT of the cortex [11]

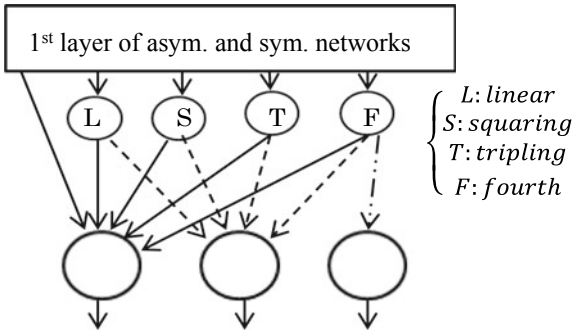

Fig. 9 Second layer network created from first layer one

The nonlinear variables $\{x^2, x^3, x^4, ...\}$ are created from Eq. (15), which are schematically described in Fig. 9. Then, the combination of the product terms of the first layer outputs is generated in the second layer.

5.1 Generation of Independent Subspaces

To improve the classification performance, the layered networks are developed based on the bio-inspired cortex model in Fig. 9. The combinations of the output terms are created using linear(L) and nonlinear operations of squaring(S), tripling(T), fourth(F) …. From these combined terms, optimized terms are selected for good performance of the classification. Thus, selective independent subspace is created using these wavelet orthogonal bases.

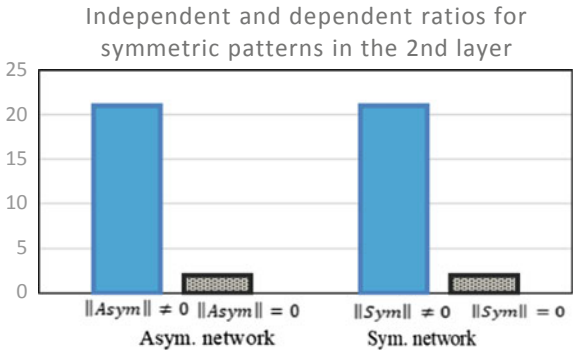

Fig. 10 Independent and dependent ratios in second layer of networks

5.2 *Higher-Dimensional Mapping Code in the Layered Networks*

For the outlier data from the classification class, new independence is useful, which is often called the sparse coding [12, 13]. Higher-dimensional codes realized in the extended layered networks are made of the product of atoms in the first layer network. As example, atoms in the first layer in Fig. 2 are described in wavelet basis set $\{h_1 \sin(x_1), h_1^2 \cos^2(x_2), h_1 \cos(x_3), h_1^2 \sin^2(x(t_4)\}$. We assume here the data $\{x(t)\}$ is normalized or binary valued. Then, the atoms in the first layer asymmetric network become

$$\{h_1 \sin(x_1), h_1^2 \cos^2(x_2), h_1 \cos(x_3), h_1^2 \sin^2(x_4)\} \tag{16}$$

The independence of input matrix including the higher-dimensional mapping term is a useful factor in the network. The modified XOR problem shows a transition from Fig. 11a, b. The problem is applied to the asymmetric networks. The target input (111) in Fig. 11 is changed to the class with white circles by generating the higher-dimensional bases in Table 1, in which $x_2 = x_3$ is assumed. To realize this operation, two higher-dimensional codes are generated, which are summed as follows.

$$w_1 \cdot \sin(x_1) \sin(x_4)^2 + w_2 \cdot \sin(x_1) \cos(x_2) sin(x_4)^2 \tag{17}$$

The two codes(bases) are given in their summation. In this case, only (101) is the nearest neighbor input, which generates independent relation with (111) in Fig. 11. Then, the optimized weights $w_1 = -1.96$ and $w_2 = 1.96$ are obtained.

Next, the class of the input (000) is changed by the creation of the higher-dimensional three bases.

$$w_1 \cdot \cos(x') \cos(x')^2 + w_2 \cdot \sin(x) cos(x') + w_3 \cdot \cos(x') \sin(x'')^2 \tag{18}$$

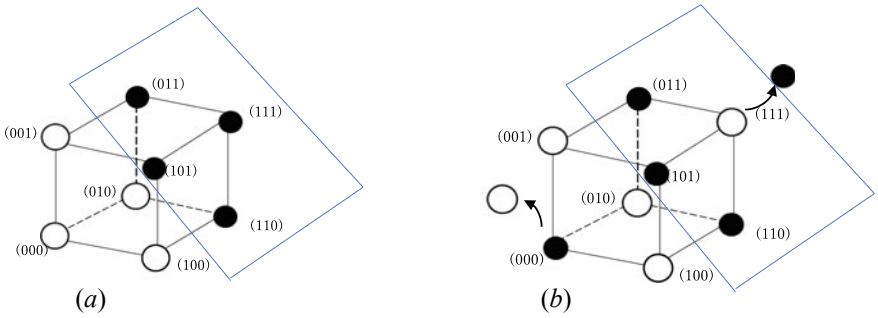

Fig.11 Modified XOR problems. **a** linearly separated, **b** mapping steps from (**a**)

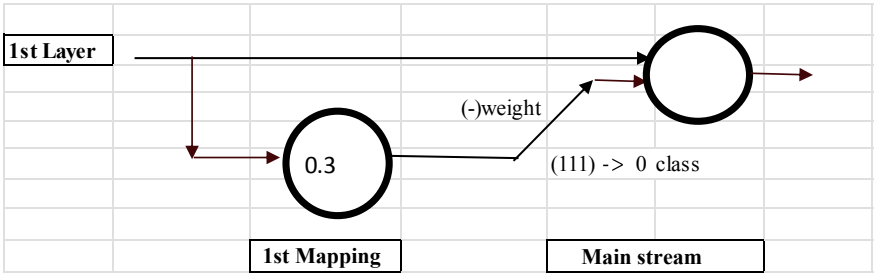

Fig. 12 First mapping by higher-dimensional bases for (111)

Table 1 Higher-dimensional bases for target input (111)

Input	$\sin(x)\sin(x'')^2$	$\sin(x)\cos(x')\sin(x'')^2$
101	0.59582324	0.595823237
011	0	0
110	0	0
111	0.5958232	0.321924669
000	0	0
100	0	0
010	0	0
001	0	0

Similarly, the determinant of three-dimensional matrix for target input (000) becomes to be nonzero. Thus, the independent relation produces the optimized w_1, w_2, and w_3.In Fig. 13, the firing of the second threshold element contributes (+) large weight of the mainstream element, which passes input (000) to the class 0. Thus, the combined the first and second threshold elements in the subnetworks make the change of the class for the input (111) and (000).

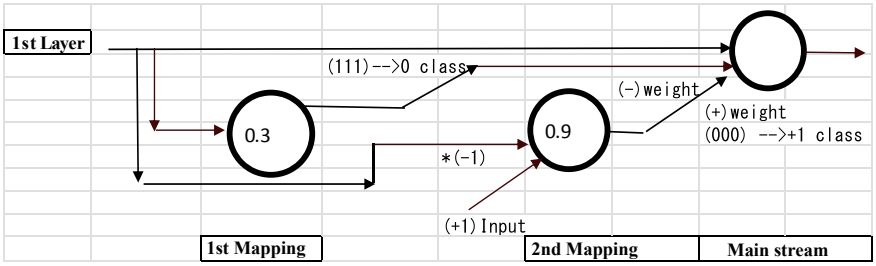

Fig. 13 Combined subnetworks for class change of the input (111) and the (000)

6 Conclusion

This paper aims to make clear the classification performance for the asymmetric and the symmetric networks, which are created based on the biological networks. First, tracing performance is discussed from the input–output relations through networks. Next, classification characteristics of the asymmetric and symmetric networks are analyzed and experimented based on independence of their networks outputs. To improve the classification performance in the networks, the bio-inspired layered networks are proposed, which show better performance for classification. Finally, the higher-dimensional mapping in the layered asymmetric network is created for the modified XOR problems. New functions are expected in the asymmetric networks.

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Deep-Aware Network for Removing Single Haze

Ruxi Xiang, Xifang Zhu, Feng Wu, Qinquan Xu, and Longan Zhang

Abstract Some dehazing methods based on traditional statistical theory are prone to suffering from the higher complexity and resulting in some lower degeneration phenomenon such as a few halo with discontinuities and low contrast. To tackle these issues, we present an effective and efficient end-to-end method based on deep-aware channel information for single image removal haze. We compute an effective feature map by integrating the deep-aware channel attention mechanism with multi-scale residual connection to build a feature aware attention block, and then more these blocks are combined to form the final feature block for directly learning the statistical information of some haze-free images. In some pubic synthetic datasets and some real-world haze images, extensive experimental results show that the proposed model is not only superior than some state-of-the-art models including some traditional dehazing methods and methods based on convolutional neural network, but also achieves better image quality than other models such as high contrast, better details, and vivid color. Meanwhile, we argue that our model is a lightweight and low computation cost network.

Keywords Dehazing method · Channel aware · Deep learning

1 Introduction

Images acquired in the haze conditions are prone to producing some degradation phenomenon such as low contrast, blurry, less details, and color degradation because of the scatter and absorption effect of some small particles from the atmosphere, which serious influence some subsequent computer vison tasks including object

R. Xiang (✉) · X. Zhu · F. Wu · Q. Xu · L. Zhang
School of Electrical and Information Engineering, Changzhou Institute of Technology Changzhou, Changzhou, China
e-mail: xiangrx@czu.cn

X. Zhu
e-mail: zhuxf@czu.cn

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detection, object recognition, and image understanding. In order to improve the quality of these images, some works have been proposed for removing the fog or haze [1–7]. At present, these methods can be roughly divided into two categories: methods based on classical statistical theory [1–3] and neural network [4–6], and these methods can achieve better results on some test datasets. However, the former is more difficult and requires higher requirements such as some prior information, and solving this kind of problem is still a dilemma, without accurate solution. Researchers make different prior information assumptions for solving a suitable and effective solution, such as Kaiming's dark channel prior theory [1], Fattal's prior information that the chromaticity information in local area and color line [2], and Zhu's prior information of color attenuation [3]. These prior information have their limitations, for instance, dark channel theory is easy to fail to process the haze with gray target [1], Fattal's method with color line can't deal with monochromatic images without color information [2], and Zhu's color attenuation theory can't deal with the effect of dense fog [3]. The methods above are all based on the monochromatic atmospheric scattering model [8] and need to estimate the atmospheric ambient light and atmospheric transmittance parameters. There are some errors in the estimation due to the fact that they need to rely on some prior information. For reducing the influence of the prior assumption, researchers have proposed some removal haze methods based on deep learning [4–7]. For example, Cai proposes an end-to-end deep learning model for dehazing [4], and Ren introduces an end-to-end multi-scale convolution neural network for learning atmospheric transmittance [7]. Zhang proposes a fame-net method for removing the haze based on convolutional neural network [5]. These methods train the better network parameters by some larger training sets. For some simple scenes, the performance of the neural network-based dehazing method is better than the performance of dehazing for complex scenes, and their training time is longer.

In this paper, we present a faster and effective end-to-end method based on deep-aware channel for single image removal haze, which introduce a deep-aware channel attention of the image feature to enhance the ability of the represent of the feature. Specifically, we first compute effective feature maps by combing the visual aware mechanism and residual connection to form a feature attention block, and following by some feature aware blocks are integrated to form the final feature block for directly learning the statistical information of some haze-free images. In some pubic synthetic datasets and some real-world haze images, experimental results argue that our model is superior to some state-of-the-art models and achieve the better image quality with respect to qualitative and quantitative view, such as high contrast, better details, and vivid color. Simultaneously, we also show our model is a lightweight and low computation cost.

The main contributions of this paper can be details as

1. We design a faster and effective deep-aware-channel based removal haze network, which can implicitly learn some image features by fusing the deep-aware channel attention for improving the image quality.
2. Our model has some advantages such as lightweight and less training time.

3. Substantial experiments are conducted on various image datasets with haze and free haze to show the effectiveness of the proposed deep-aware channel dehazing network.

The rest of this paper consists of the following sections. First, we review the related works on removal haze method in Sect. 2, Following by the architecture and details of the proposed are deep-aware channel dehazing network introduced in Sect. 3. In Sect. 4, we evaluate the performance of the proposed method and compare our method with other state-of-the-art methods.

2 Related Work

FAMED-NET method [5] introduces two submodules K-encode and K-decode to estimate the variable K merged the transmission into ambient light introduced by Li et al. [6], followed by the reflection image is recovered by the Eq. (1) which is formulated as

$$R^c(x) = K^c(x)I^c(x) - K^c(x) + 1, \tag{1}$$

$$K^c(x) = \frac{\frac{1}{t(x)}(I^c(x) - A^c) + A^c - 1}{I^c(x) - 1}, \tag{2}$$

where R denotes a reflection image with free haze, I represents an input images with haze, t represents the haze transmission map, A represents the ambient light, c is the index of the image channel, and x represents pixel location. The architecture of the FAMED-NET is shown in Fig. 1, which consists of K-encode and K-decode submodules. K-encode model is combined by several convolutional blocks with kernel size 1×1 and several pooling blocks with different kernel size, and K-decode model is computed by Eq. (1).

We usually does not capture some specified partial scene information from the whole image but grasp a whole scene information at once, because visual attention

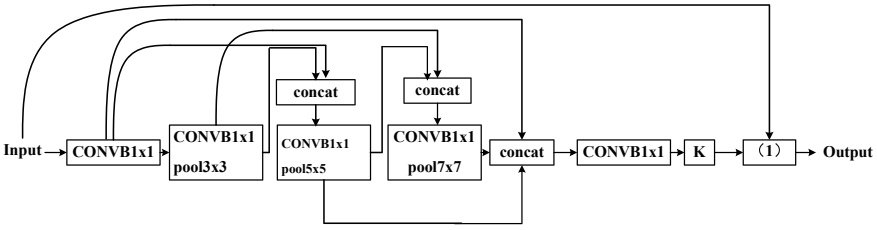

Fig. 1 Architecture of the FAMED-NET. Noting that Conv1 $\times$ 1 denotes convolutional operation with kernel size of 1 $\times$ 1, poolsxs denotes pool operation with kernel size of sxs, where s is set 3,5,7 respectively and concat represents concatenating operation

plays an essential role in human vison [9–12] since visual attention can not only quickly scratch the global image to obtain salient information that needs to be focused on but also suppress other irrelevant information.

Some researchers have proposed some classical attention methods for improving the ability of the feature represent, which can be simply divided into four categories: channel attention, spatial attention, branch attention, and channel and spatial attention. For instance, squeeze and excitation method [13], named SENet, learns the attention of each channel to improve the performance the networks, which is composed of two main operations: global average pooling (GAP) and convolution block (CONVB). CBAM [14] takes into not only the attention of each channel but also the spatial attention of each channel account, which is consisted of global average pooling (GAP), global maximum pooling (GMP), and convolution block (CONVB). When it is combined with some state-of-the-art methods to tackle some vision tasks such as object detection, image generation [15, 16]. ECA-Net [17] introduced by Wang can effectively reduce the complexity by combing the local cross-channel interaction strategy. GSoP-Net applies with a second-order pooling to abstract richer feature information, detailed of the GSoP-Net refers to [18].

3 Method

Since it is easier to extract some significant attention-aware information feature from the image channels, we tend to combine these information for improving the quality of the removal haze or fog. We design a new and effective dehazing model based on deep-aware channel attention which integrates several deep-aware channel attention blocks with sample blocks by dense concatenation networks to obtain the better channel aware attention information, as shown in Fig. 2.

Deep-aware channel attention block is a feature channel perception module, which is used to enhance the channel weight that has a greater impact on the feature and improve the effectiveness of feature extracted. A dense concatenation network for predicting pseudo-transmittance is constructed, which contains several channel

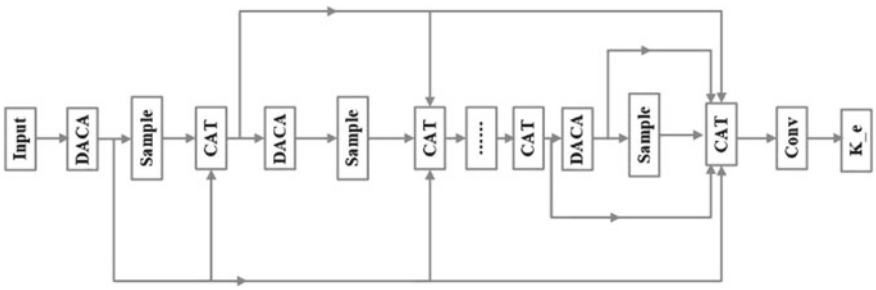

Fig. 2 Dedicated architecture based on DACA for removing the haze

aware modules, dense connections, and sampling modules. Given a haze image, it is passed through overall dehazing network to obtain a pseudo-transmission map, following by it is restored by the reformulated haze removal block. The following Sect. 3.1 describes the deep-aware channel attention module.

3.1 Deep-Aware Channel Attention Module

The proposed deep-aware channel module, named DACA, is composed of two blocks: left block and right block, as shown in Fig. 3. The left block is a block contains a convolutional module, batch normalization module, and pooling module with different kernel size. The right block is the feature channel fusion module, which is used to aggregate the features of different channels to obtain as much more feature information as possible. Specifically, the module DACA includes three submodules, namely GMP, FC, and sigmoid. GMP is a global maximum pooling module, FC is a full connection module which maps the learned distributed feature representation space to the sample tag space, and sigmoid is an activation module, which constrains the output result the range from 0 to 1. We describe the mathematical detailed of the proposed module MACA in the following chapters.

DACA module is composed of four branches: three branches in the left of the red line and one branch in the right. The left focuses on obtaining different direction

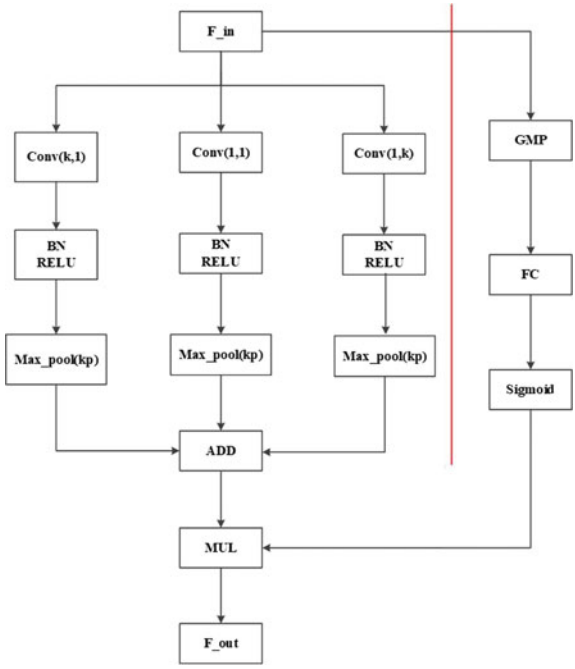

Fig. 3 Flowchart of the deep-aware channel attention block (MACA)

convolutional information features. However, the right computes the corresponding aware channel attention of the input feature. Specifically, each branch is firstly passed by a convolution block which consists of one convolution layer with the kernel width (ks, 1), one batch normalization layer, and one maximum pooling layer with kernel width (l, ks), where ks is empirically set 5 in the leftmost branch and the left branch near the red line and the middle ks is set 1 in practice. Mathematically, each branch is formulated as

$$F_{\mathrm{r}} = \max\_\mathrm{pool}_r(\mathrm{RELU}_r(\mathrm{BN}_r(\mathrm{conv}_r(F\_\mathrm{in})))), \tag{3}$$

where conv(.), BN(.), RELU(.), and max_pool(.) represent a convolution function, batch normalization function, linear rectification activation function, and maximum function, respectively. The subscript r is the index of the branch, which is ranged from 1 to 3 in this paper. Following by we compute the channel aware attention of the feature in the same way, which is expressed as

$$F_4 = \sigma(\mathrm{FC}(\mathrm{GMP}(F\_\mathrm{in}))), \tag{4}$$

where GMP(.), FC(.) and σ(.) denote a global maximum pooling function, fully connected function and sigmoid function, respectively. After each branch feature is computed, the final output feature $F_$out is formulated as

$$F\_\mathrm{out} = F_4 \otimes \sum_{r=1}^{3} F_r, \tag{5}$$

where ⊗ represents an element-wise multiplication operation.

3.2 Deep Dense Residual Network Based on DACA

The deep dense residual aware network of the pseudo-transmittance is composed of several DACA modules and a sampling block including two submodules: upper sampling and lower sampling.

The method based on the deep dense residual aware network of the pseudo-transmittance is expressed as

$$K\_e = f(\mathrm{Input}, \theta), \tag{6}$$

where $f(.)$ is a depth aware network function, input is an input image to be processed, and θ is training parameters of the depth aware network $f(.)$. The deep dense residual aware network of the pseudo-transmittance includes several channel aware sensing

module DACA, sampling blocks a convolution module and cascade operations. The output of the ith channel aware module is fci. The input of the first MFCA module comes from the input image and the corresponding output is fc1. The input of the *i*th ($i > 1$) MFCA module derives from the new feature after cascading operation, which is expressed as

$$\mathrm{fc}_i = \mathrm{concat}(\mathrm{fc}_k, \mathrm{fs}_k), \quad k = 1 \cdots i-1, i < N-1. \tag{7}$$

Here, fc_i is the visual output feature of MCFA in layer i, fs_k is the output feature after the kth sampling block, concat is a cascade operation function, and the variable n is the number of MCFA blocks. The sampling block is composed of two submodules: Up and Down, which is expressed as

$$\mathrm{Sample} = \big[\mathrm{Up}, \mathrm{Down}\big], \tag{8}$$

where Up sampling is a transpose convolution module and Down module is a convolution module to eliminate the blur phenomenon caused by the outdoor image as far as possible. The convolution operation with 3×3 convolution kernel after the deep dense residual aware network of the pseudo-transmittance mainly balances the time complexity and the precision of defogging. The model of haze removal is predicted by the image defogging model rewritten by Zhang [5], which is formulated as

$$K^c\_e = \frac{\frac{1}{t(x)}(I^c(x) - A^c) + A^c - 1}{I^c(x) - 1}; \tag{9}$$

$$J^c(x) = K^c\_e(x) I^c(x) - K\_\,\mathrm{e}^c(x) + 1, \tag{10}$$

where J denotes a clear image without haze, I represents an input image with haze, x denotes the pixel coordinates of the image, c denotes the number of image channels, and K_e is the pseudo-transmittance. In our experiments, we use multi-kernel guided filter [16] to refine them and focus on the haze removal of the single scale image. In the future, we would like to extend the proposed method to the haze removal of multi-scale image.

3.3 Training

We train our network on substantial image patches randomly cropped from different scenes which are taken from the publicly benchmark dataset RESIDE [19] whose details will be described in Sect. 4.

Learning the map relation of the deep dense residual aware network between the image with the haze and the clear image is achieved by minimizing the L1 loss function between the dehazing results $f(I, w)$ estimated by our network and the

clear images J, which is expressed as

$$w^* = \arg\min||J - f(I; w)||_1 + \lambda||w||_1, \tag{11}$$

where w denotes the learning parameters of the network, w^* represents the parameters learned by optimization method, and λ aims to balance the relation between the fidelity term and the regularization term.

4 Experiments and Discussion

We evaluate our method on the standard benchmark dataset RSIDE [19] widely used for removal haze due to its diverse data sources and image content which consists of 72,315 synthetic haze outdoor images for training and 400 hazy images for ablation. In order to evaluate the proposed method performance, we compare it with state-of-the-art dehazing methods including FPC-Net [20], AOD-Net [6], and FAMED-NET [5]. All experiments have been implemented using PyTorch frame on a PC equipped with NVIDIA GeForce GTX 1080Ti, and the optimizer adopted is Adam optimizer with initial learning rate 0.001.

To thoroughly evaluate the effectiveness of the proposed method, we first conduct extensive ablation experiments in terms of different parameters, which consists of the results with batch normalization, without batch normalization, and the size of training images. Following by we argue that our method outperforms other dehazing methods in terms of quantitative and qualitative analysis.

4.1 Ablation Studies

In this section, we demonstrate the effectiveness of our parameters choice. We adopt the same data augmentation scheme with [5] for training and validation. During the network training time, the learning rate is set to range from 0.00005 to 0.0001. The momentum is set to 0.9. We trained a total of 160 times of network in our experiment.

Table 1 shows comparison of our method with different parameters with FAMED-Net-GP with different parameters on RSIDE dataset [19]. As one can see, our method achieves the better performance in terms of PSNR and SSIM than all compared methods in the smaller training data and the less training epoch, especially it surpass the state-of-the-art model FAMED-Net-GP-MaxP which has adopted all training data and implemented 400000 iterations with respect to SSIM by up to 0.02. However, the proposed method is on par with the FAMED-Net [5] in terms of the metric PSNR due to the fact that we make fully advantage of the deep-aware channel information. Simultaneously, we also observe that the performance is related to two factors: the size of cropped image size and the size of training data set, the larger the size of the cropped image and the training data set are, the better the performance achieve.

Table 1 Comparison of our method with different parameters with FAMED-Net-GP with different parameters on RSIDE dataset

Model	Training data	Size	Iterations	PSNR	SSIM
DED-NET (normalization)	40,000	128 × 128	160	27.88	**0.9753**
DED-NET-N-ER	40,000	128 × 128	160	27.51	0.9732
FAMED-Net-GP-3 × 3	All (424,450)	128 × 128	400,000	27.86	0.9520
FAMED-Net-GP-MaxP	All (424,450)	128 × 128	400,000	**28.67**	0.9555
DED-NET-N-ER	40,000	200 × 200	160	**28.72**	**0.9768**

Fig. 4 Performance comparison of different methods on an image with haze **a** input, **b** AOD-Net, **c** FPC-Net, **d** FAMED-Net, and **e** proposed method

Figures 4 and 5 show the performance comparison of state-of-the-art methods including FAMED-Net [5], AOD-Net [6], and FPC-Net [20] on two different images from the test data of FAMED-Net, which are designed on the basis of convolutional neural network. As one can see, the removal haze results obtained by the AOD-Net method are darker than other results and also have over-saturated phenomenon. Besides, we also find that FPC-Net can achieve better results than the AOD-Net, while it is prone to producing slight color distortions phenomenon. In contrast, the proposed method outperforms performance the FAMED-Net. Specifically, our method not only produces visually pleasant results but also takes advantage of the less training time and training data to train the model because we adopt deep-aware channel information to obtain more detailed information for recovering d edges covered by the haze. Especially, the men indicated by pink in Fig. 4 and the far building indicated by pink in Fig. 5 are obvious.

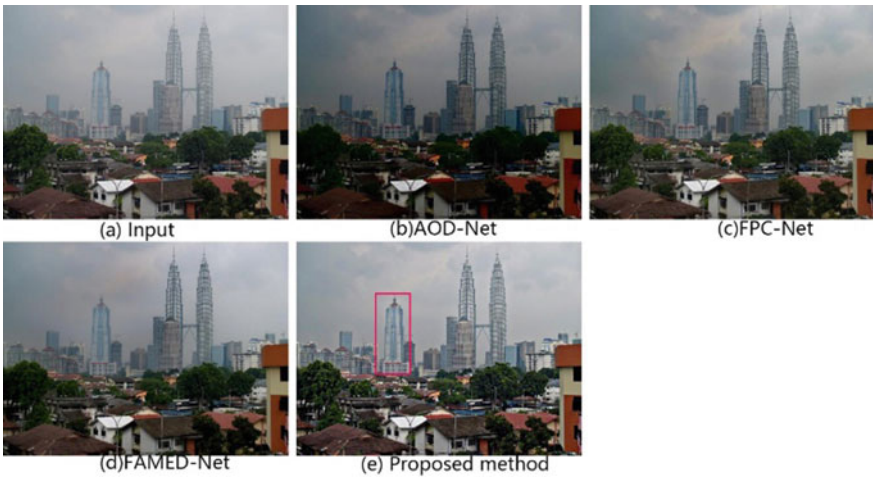

Fig. 5 Performance comparison of different methods on image "highquality06" **a** input, **b** AOD-Net, **c** FPC-Net, **d** FAMED-Net, and **e** proposed method

5 Conclusion

In this paper, we propose an effectively and efficiently end-to-end method based on deep-aware channel information for single image removal haze. We compute effective feature maps by integrating the deep-aware channel attention mechanism with multi-scale residual connection to form a feature aware attention block, and then more feature aware attention blocks are combined to form the final feature block for directly learning the statistical information of some haze-free images. Meanwhile, we also show our model is a lightweight and low computation cost. In some pubic synthetic datasets and some real-world haze images, experimental results demonstrate that our model outperform some classical state-of-the-art models and achieve better image quality than other models such as high contrast, better details, and vivid color. However, we also find that the results obtained by all implemented methods have slight blur including our method, which is left for the future to process.

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Research on a Multi-agent System That Mimics Ant Foraging Behavior

Koumei Imai and Atsushi Okuyama

Abstract Artificial life is a research field that uses artificial systems, such as computer simulations, to reproduce life phenomena to expand our understanding of life. Artificial life research focuses primarily on emergent behavior using multi-agent systems, which is a part of artificial intelligence research. In conventional research on artificial life, simulation studies have been conducted using models of organisms that behave in groups, such as fish, birds and insects. Studying pheromone communication in ants focuses on the organized behavior of ants that use pheromones to communicate with their fellow ants and efficiently transport food during foraging. Ants have low individual abilities and behave according to simple behavioral principles. In this study, we focus on the efficient activities of ants and apply the ant foraging behavior to establish an algorithm that mimics this behavior in a multi-agent system using their organized behavior. The purpose of this study is to confirm that pheromone trail formation and foraging behavior are emergent in multiple ants and pheromone volatilization rate affects pheromone trails.

Keywords Artificial life · Multi-agent system · Ant foraging behavior · Unity · Pheromone trail

1 Introduction

Artificial life is a research field that broadens our understanding of life by reproducing life phenomenon using artificial systems, such as computer simulations [1]. Research on artificial life focuses primarily on emergent behavior using multi-agent systems and is a part of artificial intelligence research [2]. Emergence is 'a process in which a whole emerges as a result of local interactions among parts, and the whole becomes an environment for the parts, thereby forming a new order; it is said to be the essence that governs various life phenomena, such as the development, behavior, and evolution,

K. Imai (✉) · A. Okuyama
Tokai University, 4-1-1, Kitakaname, Hiratsuka-City, Kanagawa 2591292, Japan
e-mail: 1cemm007@mail.u-tokai.ac.jp

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from an individual to entire societies and ecosystems' [3]. In conventional research on artificial life, simulation studies have been conducted using models of organisms that engage in collective behavior, such as fish, birds and insects. In the study of ant pheromone communication, there have been studies of line tracing with pheromones, but whether the behavior can be realized has not been examined. Therefore, we focus on the organized behavior of ants that use pheromones to communicate with their mates during foraging and transport. Individual ants have little behavioral ability and act based on simple behavioral principles. However, ants use pheromones to generate organized behaviors, such as guiding each other to a food source and bringing back a single food item as a group.

In this research, we focused on ants' organizational behavior, particularly their foraging behavior, and established an algorithm that mimics it. Accordingly, we aimed to improve the efficiency of cooperative behavior in a multi-agent system. As a preliminary step, we simulated the formation of pheromone trails between multiple ants. We confirmed that pheromone trails are formed by the proposed model, based on which foraging behavior emerged. Additionally, we confirmed that an increase or decrease in the pheromone volatilization rate influences the pheromone trail.

2 Foraging Behavior of Ants

2.1 Overview of Foraging Behavior

Ants communicate through the secretions of pheromones, and they use various types of pheromones depending on the situation. When ants return to their nest after finding food, they emit feeding pheromones (called trail pheromones in numerous studies; however, here, they are referred to as feeding pheromones to distinguish them from homing pheromones). Fellow ants can reach the food from the nest by following the feeding pheromone trail. However, how they return to the nest from the food is unknown. Presumably, they may recognize the location of their nest or use a homing pheromone that functions similar to the feeding pheromone. In this study, we assume that they emit a homing pheromone when they leave the nest to reach the food, similar to the feeding pheromone. By following this homing pheromone, a fellow ant can return to the nest from the food. At this time, this fellow ant, like the ants described above, also emits feeding and homing pheromones as it travels. This creates a pheromone trail between the nest and food. Figure 1 shows an image of a pheromone trail. The repetition of this process generates the foraging behavior.

Fig. 1 Pheromone trail

2.2 Feeding and Homing Pheromone

The feeding and homing pheromones are the primary volatile compounds secreted from the tail end. They are dispersed as ants pass by, thus increasing the concentration of pheromones along the path from the nest to the food. As ants choose the path with the highest pheromone concentration, they can forage without hesitation. In addition, because the pheromone is volatile, it is not dispersed when the food is lost, and the trail fizzles out over time. Figure 2 depicts the effect of the pheromone concentration on generated pheromone trails generated.

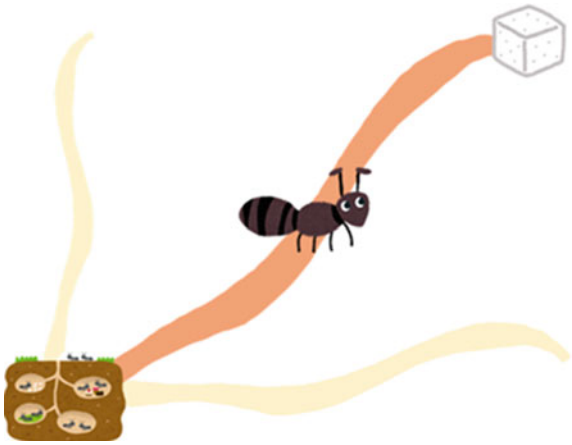

Fig. 2 Effect of pheromone concentration

3 Ant Model Overview

In this research, ants were modelled using Unity (2019 3.13f1) and Visual Studio (2019 16.3.1), which allows easy configuration of the physical behavior. In this section, first, we describe the models (object) of feeding and homing pheromones, and then the model (object) of an ant with sensors to detect them.

3.1 Pheromone Model

Figure 3 shows a diagram of a pheromone trail with different pheromones functions, and Fig. 4 shows the changes in the pheromones. Pheromone objects were created as cone-shaped objects and placed at locations where ants passed at regular intervals when the ant objects returned to their nests. This created a single trail, as shown in Fig. 3. The model proposed in this study attempts to express the concentration of prey pheromones based on the height of a cone-shaped object, as demonstrated below.

Height of conical object = concentration of pheromone

In particular, the four states of pheromone, namely release, diffusion, volatilization and evaporation, are expressed as changes in conical objects, as shown in Fig. 4. The color of the cone object is yellow for the feeding pheromone and purple for the homing pheromone, to ensure that the pheromone can be distinguished from the others.

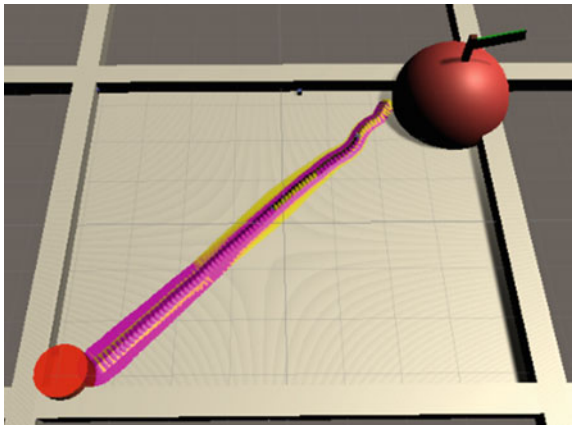

Fig. 3 Pheromone trail with different pheromone functions

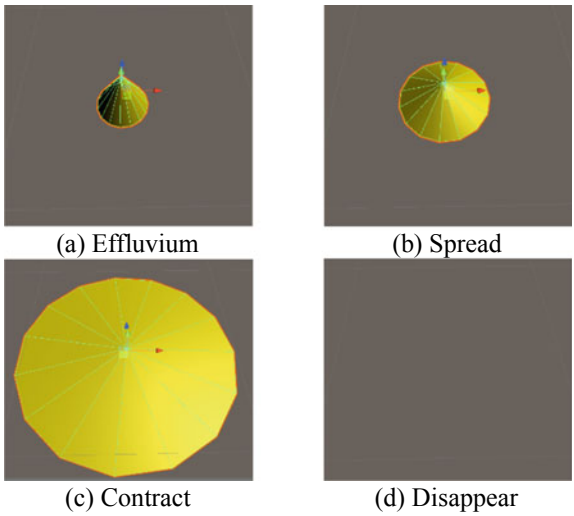

Fig. 4 Changes in feeding pheromone

3.2 Ant Model

Figure 5 shows the ant model used in this study, and Fig. 6 shows the operation of the pheromone sensor. The cube in the figure denotes the ant body, and the front right side is the front. Cylindrical objects placed on the front face, two on each side, were sensors that detect pheromones.

The pheromone sensor consists of 10 small sensors, each of which outputs a value of 1/0 according to the contact/non-contact with the prey pheromone object. Therefore, the pheromone sensor has a resolution of 11 steps in the height direction, and outputs sensor values ranging from 0 (no contact with the pheromone) to 10 (maximum value when in contact with the pheromone). This sensor configuration

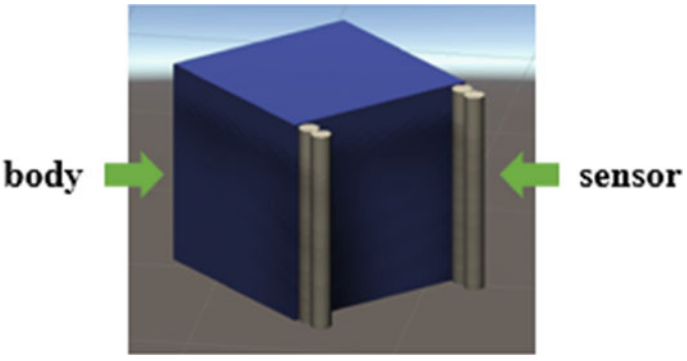

Fig. 5 Ant model

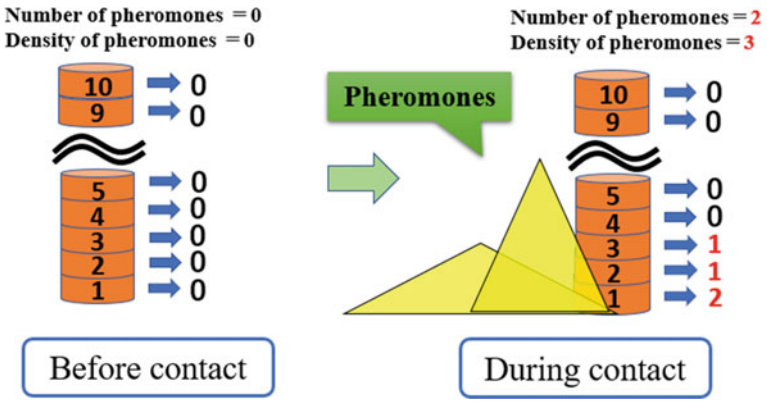

Fig. 6 Working of pheromone sensor

enables detecting the height of the pheromone object, which denotes the pheromone concentration.

The ant model performs forward and rotational movements by directly specifying the position coordinates and rotation angle. In particular, the control algorithm described below calculates the position coordinates and rotation angle for each step. By specifying these values for each movement, the ant model moves forward and rotates.

3.3 Control Algorithm

Figure 7 shows the angle at which the ants rotate. The following equations characterize how the ants rotate; herein, the travel direction is denoted by the angle θ, the speed of the ants is v, the sampling period is T_s, and number of pheromones in contact with the sensor is R_s on the right side and L_s on the left side.

$$x[k] = x[k-1] + v\cos(\theta[k])T_s \tag{1}$$

$$z[k] = z[k-1] + v\sin(\theta[k])T_s \tag{2}$$

$$\theta[k] = \theta[k-1] + \begin{cases} 1[\deg] & \text{if } R_s > L_s \\ 0[\deg] & \text{if} R_s = L_s \\ -1[\deg] & \text{if} R_s < L_s \end{cases} \tag{3}$$

When an ant contacts a pheromone, it rotates by 1° per sample towards the pheromone with a higher total value denoting contact with the left and right sensors,

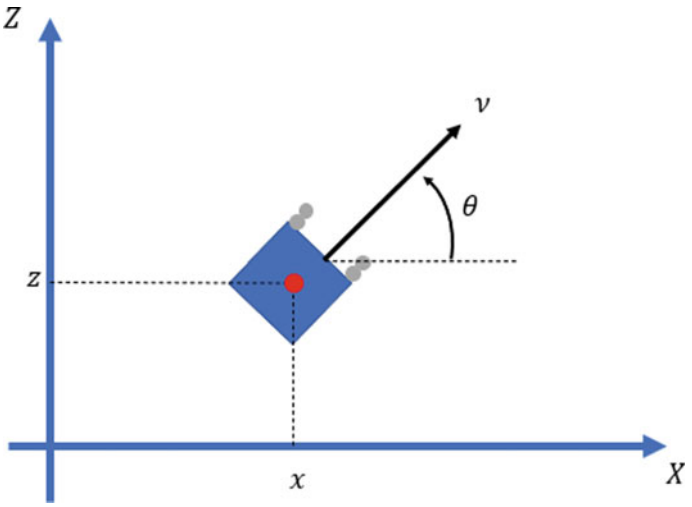

Fig. 7 Ant direction and angle

as shown in Eq. (3). When the total values of the left and right pheromones are the same, the rotation angle is 0° and the ant moves straight ahead.

4 Simulation Overview

4.1 Simulation Objective

The purpose of this research was to confirm whether the proposed model can create pheromone trails between multiple ants, thereby generating foraging behavior. Accordingly, we aimed to confirm the effect of increasing or decreasing the volatilization rate of pheromones on pheromone trails.

4.2 Simulation Conditions

Figure 8 shows the initial conditions. The red cylindrical object in the foreground denotes the nest, whereas the apple-shaped object in the background denotes the food. The nest diameter was 30 mm, and the food diameter was 75 mm. As described in Sect. 3, five ants were placed near the nest, each at an angle of 15°. The size of an ants was assumed to be 3 mm, which is the actual size of the ants. After 5 min, the ants were returned to their initial state, pheromone volatilization time was changed, and ants were moved again for another 5 min. This process was repeated thrice. When

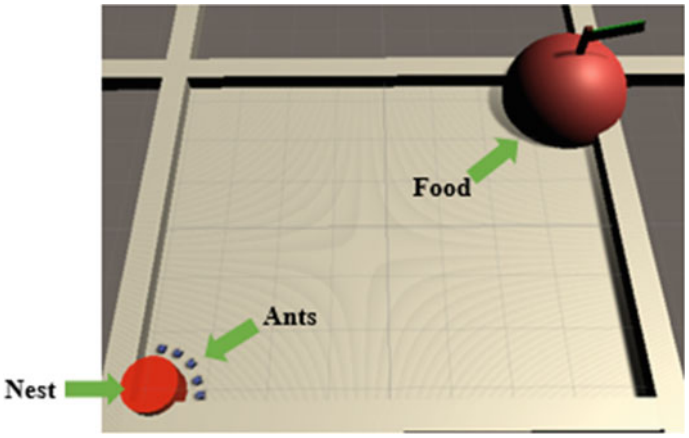

Fig. 8 Initial state

ants collided with nests or food, they reversed their direction of movement; when they contacted each other, they passed through each other. In addition, if the simulation range was the same as that of actual ants, the simulation would be significantly time-consuming owing to the large range. Therefore, we limited the simulation range to 300 mm, which was set to 1/1000 of an ants' original range of behavior, by enclosing the domain with a wall. When an ant collided with a wall, it rotated at a right angle depending on the collision angle.

5 Results and Discussion

Figures 9, 10 and 11 show the simulation results with pheromone volatilization times set to 1 min 30 s, 2 min, and 2 min 30 s, respectively. The simulation time was set to 1 min and 30 s in Fig. 9 because the pheromone volatilization rate of the actual ants was 1 min and 30 s. Pheromone trails were formed by 3–5 ants under the condition that the volatilization time was 1 min and 30 s, which is the same as the actual ants. We assumed that the pheromone trail was not formed because the pheromones volatilized before the pheromone trail was formed when the volatilization time was set to 1 min. However, when the volatilization time was set to 2 min, an inappropriate trail was formed and ants detected it. As described above, setting an appropriate volatilization time is necessary to form a pheromone trail from the nest to prey.

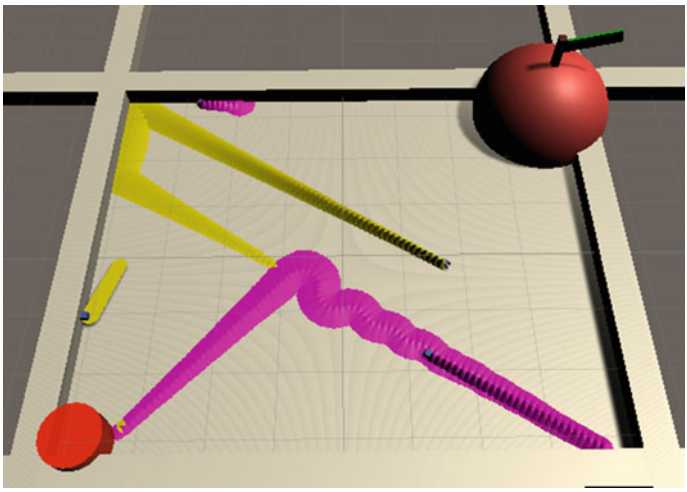

Fig. 9 Simulation result obtained with a volatilization time of 1 min 30 s

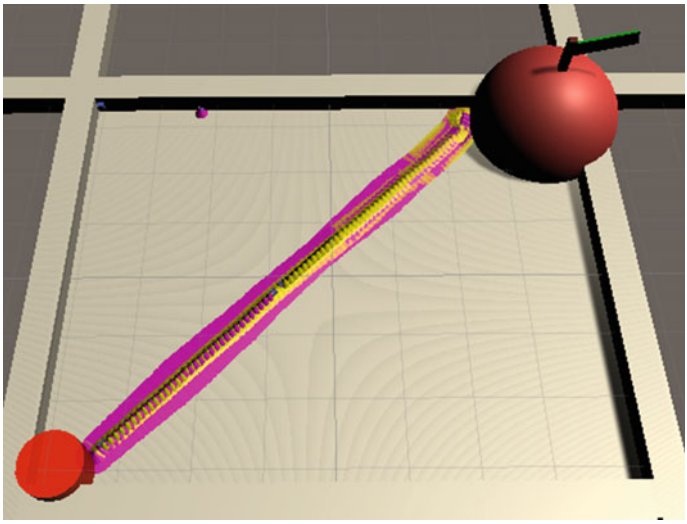

Fig. 10 Simulation result obtained with a volatilization time of 2 min

Figures 12 and 13 show the graphs for the time evolution of each coordinate when the experiment was conducted under the conditions depicted in Fig. 10. The horizontal axis represents time, and vertical axis represents coordinates. The black solid lines in Figs. 12 and 13 indicate the coordinates of the nest, whereas the black dotted lines indicate the coordinates of the prey. 'Unity' uses a left-handed coordinate system; thus, the horizontal direction in Fig. 8 corresponds to the x-coordinate, whereas the vertical direction corresponds to the z-coordinate. The origin

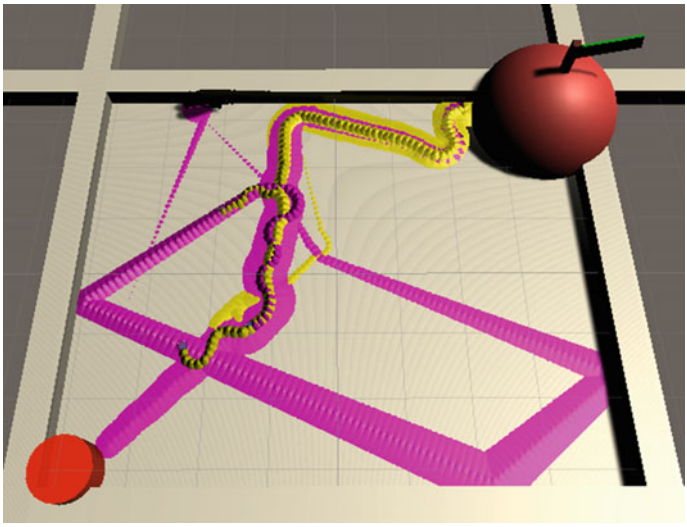

Fig. 11 Simulation result obtained with a volatilization time of 2 min 30 s

is at the centre of the field in Fig. 8. The x-coordinate of the food was 37.1, and the z-coordinate was 30.0. Whereas the x-coordinate of the nest was –37.7, and z-coordinate was –30.2. Figures 12 and 13 show that Ant 3 returned to the nest after it reached the food at 40 s. At 110 s, Ant 4 detected the pheromone of Ant 3, and Ant 5 began to follow the pheromone of Ant 3 as it returned to the nest; thus, a pheromone trail was formed. The reason Ants 1 and 2 did not behave normally could be because their movement method was based on a series of short warps.

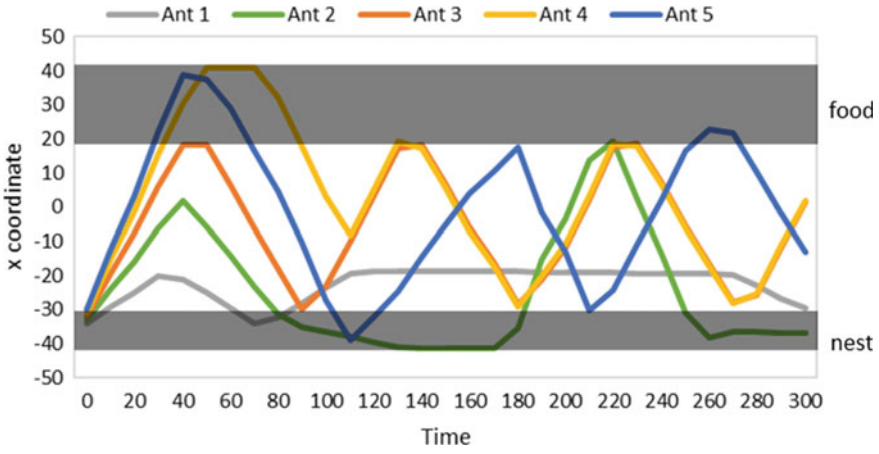

Fig. 12 Transition of x-coordinate of ants with respect to time

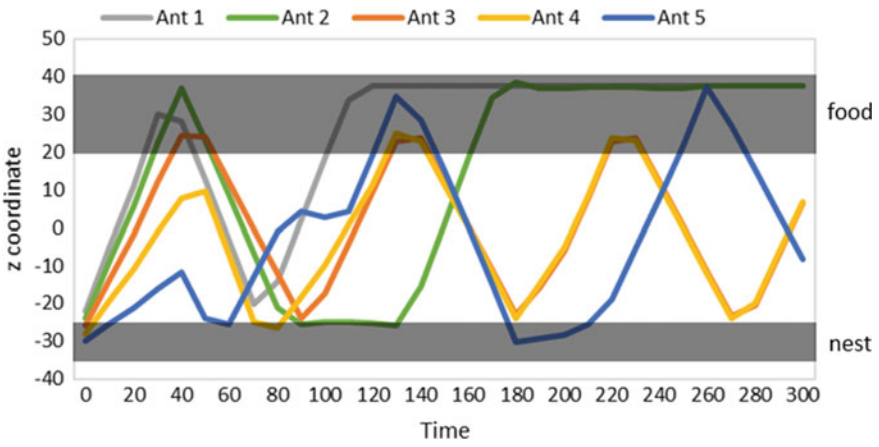

Fig. 13 Transition of z-coordinate of ants with respect to time

6 Conclusion

In this research, we focused on organizational behavior of ants, particularly their foraging behavior, and established an algorithm that mimics it, with the aim to improve the efficiency of cooperative behavior in a multi-agent system. As a preliminary step, we simulated the formation of pheromone trails between multiple ants. Consequently, we confirmed that the proposed model can form pheromone trails with multiple ants, foraging behavior emerges and pheromone trails change depending on the increase or decrease in the pheromone volatilization rate.

In future, we will construct a cooperative control algorithm applied to a multi-agent system and study its simulation. This is because in the current study, we confirmed that pheromone trails can be formed and foraging behavior can emerge using multiple ant models.

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Contemporary Research Trends in Mobile Learning

Cansu Cigdem EKIN and Salah Eddin Algabsi

Abstract This study attempts to conduct a bibliometric analysis of the structure and development of mobile learning research. For this, 7829 publications included in the Elsevier SCOPUS database between 1984 and 2021 were examined using bibliometric analysis by identifying key research areas, most influential authors, co-authorship status of countries, and organizations. As a result of this study, most topics related to mobile learning were Computer Science. "Mobile Learning" was the most used keyword followed by "e-learning" and "higher education". Top performing organizations were in Taiwan. Taiwan was the major contributor in m-learning publications' co-citation with other co-authorship countries.

Keywords Bibliometric analysis · Systematic review · Mobile learning · Data mining

1 Introduction

The late twentieth century witnessed the great invention of mobile communication technology that emerged in many applications; recently, it has changed almost every aspect of people's lifestyle, resulted in a significant impact on the traditional education systems [1]. The Internet nowadays is more accessible and probably less expensive than ever; in addition, the successive advancements in smartphones features, such as wireless connectivity coupled with their ubiquity, have led to an increased interest in leveraging mobile devices to develop a new paradigm of modern education [2].

Mobile learning (m-learning) is emerged as a natural evolution and upgrade of distance learning (d-Learning) and electronic learning (e-Learning), as it affords

C. C. EKIN (✉) · S. E. Algabsi
Computer Engineering Department, Atilim University, Ankara, Turkey
e-mail: cansu.aydin@atilim.edu.tr

S. E. Algabsi
Graduate School of Natural and Applied Sciences, Atilim University, Ankara, Turkey

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portability and mobility features for the mobile devices and learning content; thus, replacing books and notes with small devices, filled with tailor-made learning contents; therefore, it is believed that "*Mobile learning encourages a pedagogic shift from a teacher centric model to a learner-centric approach*" [3]. In the past two decades, scholars have relied on several different aspects to review the literature related to mobile learning and ubiquitous learning. In these studies, diverse outcomes were concluded using different research methods, such as systematic reviews, bibliometric analysis, content analysis, and meta-analysis. Traditionally, these approaches are conducted using techniques such as surveys, experiments, and statistical tools. *Bibliometric analysis* method is used to assess the research-based literature to determine specific patterns by summarizing publications and quantifying those using quantitative data statistics, such as the yearly growth of studies and their citations [4]. Scientists use bibliometric analyses to determine the impact of published academic papers and to contrast the contribution of individual authors, organizations, and nations [5].

In the literature, one of the most notable early studies in the field of mobile learning covering an earlier period was conducted by Chiang at all (2016). In this study, samples and manual data coding and analysis were used to examine patents related to m-learning between 1976 and 2013 and created a detailed view of m-learning trends from the aspect of patents using top authoritative social sciences databases: CNIPR, USPTO, and Espacenet. Hwang and Tsai [6] conducted a systematic review of journals in the *Social Science Citation Index* database (SSCI) between 2001 and 2010, identifying 154 articles on mobile and ubiquitous learning as well as stating the number of publications, study sample groups chosen, learning areas studied, and publishing countries. Among the key results were:

- The number of publications on the field of *Mobile and Ubiquitous Learning* significantly increased between 2006 and 2010; and
- The majority of studies focused on examining the students' encouragements, intuitions, and preferences toward mobile and ubiquitous learning, as well as oriented-courses for engineering, languages, arts, and science.

Goksu [7] used a bibliometric mapping of mobile learning in 5167 bibliometric studies by following the Web of Science (WoS) database. In this study, co-authorship, bibliographic association, co-existence, and citation analysis were used to reveal mobile learning trends from 2015 to 2019, considering authors, publications, keywords, journals, and countries, universities, and citations variables.

2 Purpose of the Study

The main research objective of this study is to examine the status of academic publications in the field of mobile learning from its existence to the present time. For this purpose, bibliometric analysis tools were used to analyze the statistical distributions of m-learning publications with a broad-spectrum literature review.

3 Data Collection and Research Method

In order to evaluate research trends on mobile learning, the current study combines relational and evaluative bibliometric approaches. The Scopus database was used for the search. DOCTYPE: ("ar") AND TOPIC: ("Mobile learning") OR TOPIC: ("m-learning") OR TOPIC: ("mlearning") was the search term entered into the search field. For the goal of this work, the bibliographical data of published papers in the mobile learning from 1968 to 2021 was used to create and visualize bibliometric mapping. Titles, keywords, abstracts, authors, references, and citations were included as a bibliographic information. The VOSviewer default parameters were used, but only terms that appeared more than 50 times and "author keywords" that appeared more than 20 times were examined. The bibliometric analysis, which combine the number of publications and their citations with the co-word analysis to depict the relationship maps between documents, such as the co-occurrences of author keywords and co-authorships of authors, countries, and organizations.

4 Results

4.1 Documents by Year Distributions in Mobile Learning

According to statistics, the year 1968 marked the beginning of articles published in this field with just one document, as shown by the line chart in Fig. 1; however, this number nearly remained constant without a significant increase until the years 2002–2003, at which point it then started to slightly increase. The number of publications then climbed linearly starting in 2004 with more than 50 documents, peaking in 2018–2019 with around 750 documents. There was a considerable decrease in the number of publications with fewer than 400 till this study was done in May 2021.

4.2 Documents by Subject Area Distributions in Mobile Learning

As demonstrated in Fig. 2, within the analyzed documents in the corpus, the top three subject areas in which most of their publications addressed topics related to m-learning are Computer Science (39.6%), Social Science (27.1%), and Engineering (12.5%), with a total proportion of 79.2% of all documents. Whereas the bottom-most three subject areas whose publications discussed m-learning topics are Medicine (1.6%), Psychology (1.5%), and Physics and Astronomy (1.4).

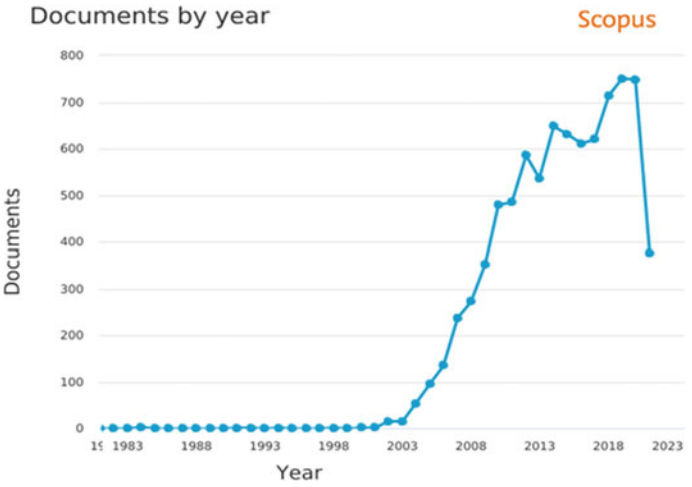

Fig. 1 Visualization of documents by year distributions in mobile learning

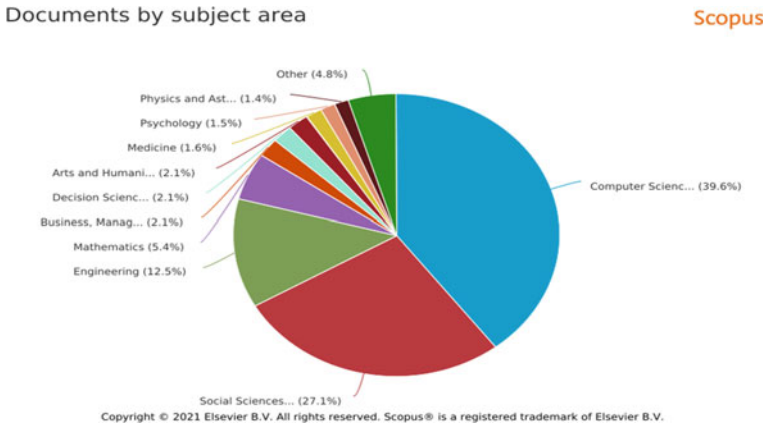

Fig. 2 Visualization of documents by subject area distributions in mobile learning

4.3 Co-occurrence Analysis Results for Keywords

The dataset had 12,187 distinct author keywords that were all evaluated. Only 170 keywords remained after lowering the minimum number of occurrences criteria to 20. Table 1 displays the top 10 terms that appear alongside other keywords the most frequently. The visualization map of the 170 author keywords' co-occurrence is shown in Fig. 3. Five separate color clusters are present. Relevant keywords are frequently provided together, as may be seen in the same cluster. The connections between two circles signify the combined use of the related keywords. It can be seen

Table 1 Co-occurrences of the top 10 author keywords in mobile learning

Author keywords	Occurrences	Link strength
Mobile learning	3975	4880
e-learning	544	1115
Higher education	285	573
Augmented reality	257	452
Education	206	455
m-learning	188	315
Ubiquitous learning	186	385
Mobile technology	183	336
Collaborative learning	156	273
Blended learning	137	268

that among the top frequent terms are "*mobile learning"*, "e-*learning", "higher education", and "augmented reality*".

4.4 Co-authorship of Authors According to the Number of Papers

The dataset included 14,427 unique authors in total when it was evaluated. Only 140 authors remain after lowering the papers'/documents' cutoff number to 10. For this analysis, only the 140 co-authors were taken into account.

Table 2 lists the top 10 co-authors who have each published at least 10 papers. Figure 4 shows the co-authorship networks among the 140, demonstrating the collaboration between the various groups of co-authors within the corpus.

4.5 Co-authorship of Authors According to the Number of Citations

When analyzed, in total, there were 14,427 different *Authors* in the dataset. After limiting the papers and citations' threshold to 10, only 183 authors are left. Among the 138, only co-authors were taken into consideration for this analysis. The top 20 co-authors according to the number of citations are listed in Table 3. Among the 138, Fig. 5 illustrates the co-authorship networks, showing the co-citations cooperation among the different groups of co-authors within the corpus.

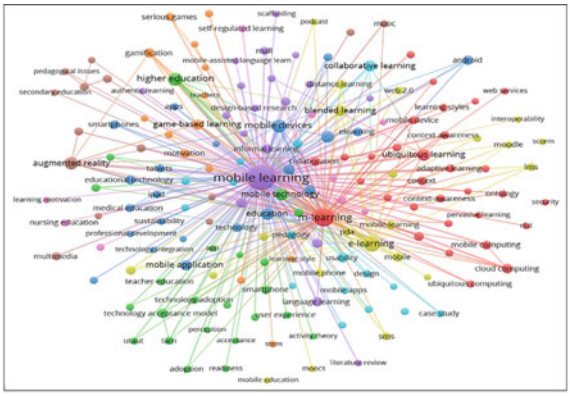

Fig. 3 Visualization map of the co-occurrences of author keywords. **a** among all author keywords, **b** among the top 10 keywords

Table 2 Top 20 co-authors by the number of papers in mobile learning

Authors	Number of documents
G.-J. Hwang	85
Y.-M. Huang	45
H. Ogata	41
J. Wang	38
C.-K. Looi	35
M. Specht	31
M. Milrad	29
D. Parsons	25
Y. Yano	25
P. Seow	22

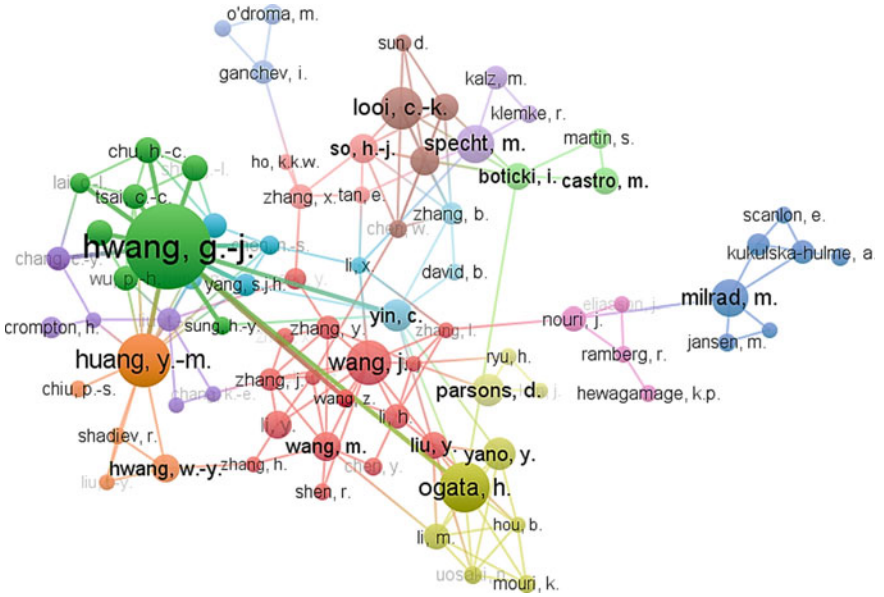

Fig. 4 Visualization map of the co-authorship of authors by the number of papers in mobile learning

Table 3 Top 20 co-authors by the number of citations in mobile learning

Authors	# of documents	# of citations
G.-J. Hwang	85	3652
A. Kukulska-hulme	16	1330
C.-K. Looi	35	1276
M. Sharples	15	1239
L.-H. Wong	19	1096
Y.-M. Huang	45	1068
P. Seow	22	967
T.-C. Liu	16	870
W. Chen	12	831
H.-C. Chu	16	765

4.6 Co-authorship of Countries According to the Number of Citations

When analyzed, in total, there were 148 different *Countries* in the dataset. After limiting the papers and citations' threshold to 10, only 83 countries are left. Among the 83, only countries with co-authorships were taken into consideration. The top 20 co-authorship countries by Citations' number are listed in Table 4. Among the 83,

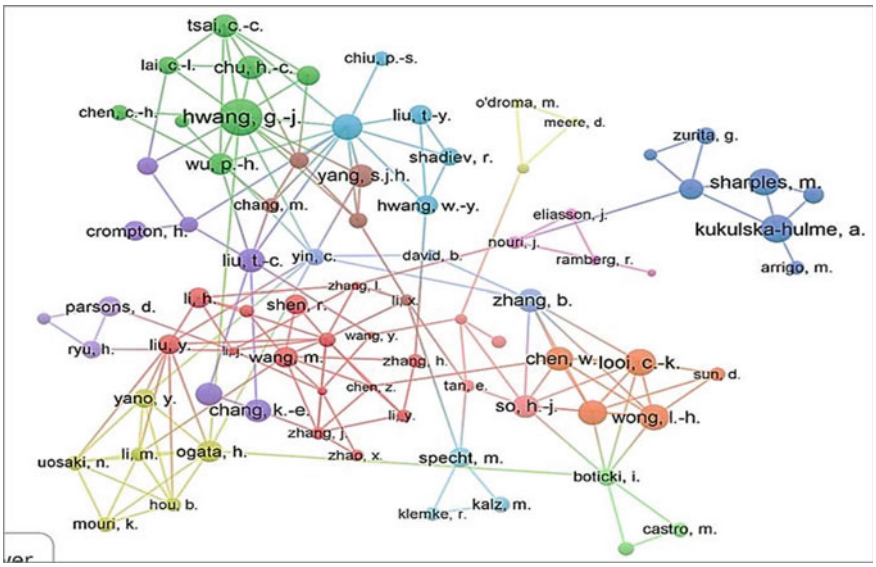

Fig. 5 Visualization map of the co-authorship of authors by the number of citations in mobile learning

Fig. 6 illustrates the co-authorship networks, showing the co-citations cooperation among the different groups of countries within the corpus.

Among 148 countries in the raw dataset, only 83 countries having a minimum of 10 papers and citations were analyzed with VOSviewer Co-Authorship Networks, as depicted by the visualization map in Fig. 6, showing the co-citation cooperation among the different groups of countries within the corpus. Table 4 lists the top 20 *Co-Authorship Countries* according to the number of citation in mobile learning. These

Table 4 Top 20 co-authorship countries by the number of citations in mobile learning

Country	# of documents	# of citations
Taiwan	650	14,725
United States	718	13,563
United Kingdom	573	10,794
Australia	370	4285
China	696	3737
Spain	391	3727
Turkey	161	2728
Malaysia	470	2697
Canada	228	2622
Greece	169	2168

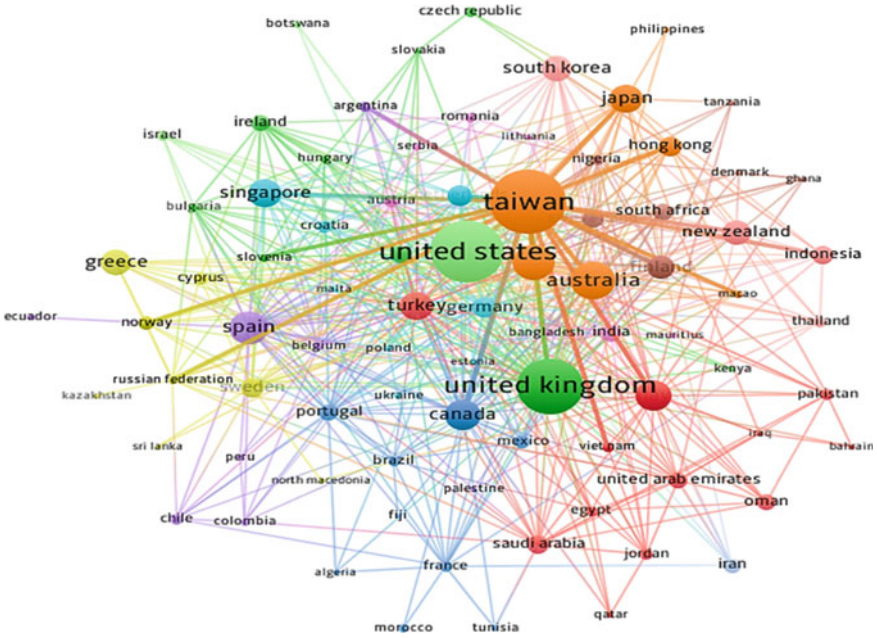

Fig. 6 Visualization map of the co-authorship of countries by the number of citations in mobile learning

results show that *Taiwan* was the major contributor in m-learning publications' co-citation with other co-authorship countries, with 14,725 citations, followed by the *United States* with 13,563, and the *United Kingdom* with 10,794 citations.

4.7 Co-authorship of Organizations According to the Number of Citations

When analyzed, in total, there were 3934 different *Organizations* in the dataset. After limiting the papers and citations' threshold to 20, only 79 organizations are left.

Among the 79, only organizations with co-authorships were taken into consideration.

The top 15 co-authorship countries by citations' number are listed in Table 5.

Among the 79, Fig. 7 illustrates the co-authorship networks, showing the co-citations cooperation among the different groups of organizations within the corpus.

Table 5 shows the top 10 affiliations to which the most m-learning publications belonged. Among these institutions, the *National Taiwan University of Science and Technology* (Taiwan) was first with nearly 100 documents (1.28% of total articles),

Table 5 Co-authorship of the top 20 organizations by citations in m-learning

Organization	#of documents	#of citations
National Taiwan University of Science and Technology Taipei, Taiwan	92	4613
National Central University Taiwan, Chung-Li, Taiwan	79	2889
National University of Tainan, Taiwan, Tainan, Taiwan	65	2698
National Taiwan Normal University, Taipei, Taiwan	73	2379
The Open University Milton Keynes, United Kingdom	58	2271
National Cheng Kung University, Tainan, Taiwan	62	1628
National Institute of Education, Singapore City, Singapore	56	1606
Athabasca University, Athabasca, Canada	79	1094
University of Technology Sydney, Sydney, Australia	42	870
University of Wolverhampton, Wolverhampton, United Kingdom	22	787

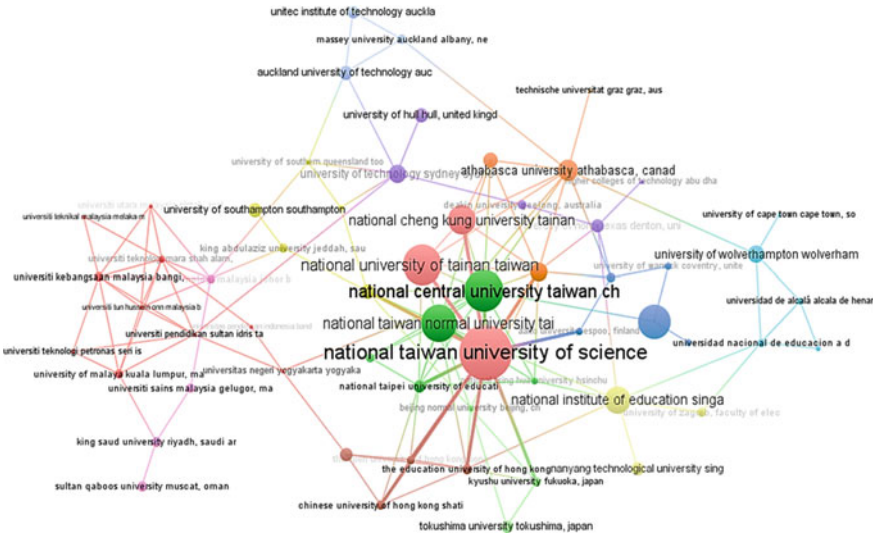

Fig. 7 Visualization map of the co-authorship of organizations by the number of citations in mobile learning

followed by *Athabasca University* (Canada) with nearly 85 documents (1.1%) and *National Central University* (Taiwan) with nearly 80 documents (1.0%), respectively.

5 Conclusion and Limitations

By applying bibliometric analysis, this paper gives a broad review of the state of the art and emerging trends in mobile learning research. To examine excluded data, two efficient bibliometric tools, VOSviewer and Scopus Analysis Tool, are used. Mobile-based education and m-learning are now firmly established as a solid basis in pedagogy, running parallel to the daily technical advances and advancements. The contribution of academics, journals, and institutions to understanding and advancing m-learning research in the disciplines of instruction and education is discussed in great detail.

There are some limitations in the current study. First, since our investigation is limited to English-language journals, it is certain that some crucial information from publications in other languages would be missed. Second, based on a review of 7829 publications, analysis was conducted on mobile learning in the educational sector. The study used a specific term combination, but it's feasible that using another search combination could have produced entirely different results. Other keywords may be used in early research investigations in the future to extract more publications.

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The Innovative Creation Competency: The Creation of an Exhibition Website Through the Learning Management Model Based on Design Thinking and Applied Drama Process

Pattaranun Waitayasin and Nutteerat Pheeraphan

Abstract Due to the recent COVID-19 pandemic, teaching and learning management and student activities have changed. Likewise, the exhibition on innovative educational works of students in the Bachelor of Education Program could not be carried out as special event according to its goal of disseminating knowledge, technology, and educational innovation. It had to modify the format of the presentation through the website, and the lecturers had to manage learning in a new way by responding to the creation of such websites. Consequently, this research aimed to study the result of implementing the learning management model based on design thinking learning and applied drama process to enhance the innovative creation competency. The researcher implemented the learning management model based on design thinking and applied drama process to promote the innovative creation competency with the sample group of 24 fourth students of Educational Technology Program. The learning management model was retrieved from a review of related literature consisting of concepts, principles, and process of design thinking and applied drama, elements, and attributes of innovative creation competency as well as the development of a learning management plan with design thinking and applied drama process to promote the innovative creation competency. The results of the research found that students' innovative creation competency was statistically significantly higher at the level of 0.01. The results from the behavioral observation showed that students' improvement was higher, and the evaluation results of the students' work or the creation of a website presenting the exhibition were at the excellent level are at a very good level.

Keywords Innovative creation competency · Exhibition website · Learning management model · Design thinking · Applied drama

P. Waitayasin (✉) · N. Pheeraphan
Srinakharinwirot University, Bangkok, Thailand
e-mail: pattaranun@g.swu.ac.th

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1 Introduction

The Future of Education and Skills 2030 of The Organization for Economic Co-operation and Development (OECD) mentioned that the Learning Framework 2030 has been divided into three main parts: knowledge, skills and attitudes and values. This is considered as a challenging framework to create great opportunities in the era of technology and artificial intelligence. The required skills include critical thinking, creative thinking, learning, self-control, social, collaboration, and information technology skills [1]. In addition, Wagner [2: 21] explained innovative creation ability that the foundation of economy was the innovation only, we should become a country creating more advanced and better products, processes, and services. Furthermore, the creativity has been related to innovation because the creativity has been one of the cornerstones of the innovation management movement. In terms of the human resource competency and the country's competitiveness development in the era of globalization, the innovation has become a goal that teachers have had to achieve in teaching and learning to create effective learning results among students [3].

Design thinking is learning by doing to create new ideas at leapfrog. It is commonly used to practice creative development and think outside the box, especially for complex projects and problems as well as for creative problem-solving with a human-centered. It is focusing on hands-on practice and experimental learning, iterative process of human understanding, creativity, and user testing to learn and reduce multiple errors. This would enable to constantly develop new and better ideas and solutions and increase the chances of project success [4]. Also, Stanford Design School [5] described the relationship between the design thinking process and the creativity affecting the innovative creation that the design thinking has not only aimed to solve the desired problem but also led to new discovery that even users have not realized whether they needed it. Once they have tried that innovation, it has been well received. Innovation through the design thinking process is therefore innovative from invaluable creativity that can be used in practice to meet the needs or answer the problems of target audience, and when the innovation is widely accepted, it will lead to an endless continuous development of new innovations. The design thinking process consists of: (1) understanding the target audience in depth, (2) setting the scope of problem, (3) creating ideas, (4) prototyping, and (5) testing [4]. One of the important design thinking processes is understanding the problem, which is the first step of design thinking. Trying to understand the problem, people, or events taking place can lead to the next step. As Berengueres [6] mentioned, one of the key elements of the design thinking process was to exactly reach the consumer behaviors, not only by observing but by studying in-depth consumer behaviors, feelings, and different beliefs.

To understand the problems and needs of the target, audience requires reflection skills and open-mindedness to a wide range of possibilities. If students have little or lack of experience, it will lead to inadequate understanding of the real needs and inappropriate development process. The researcher, as a lecturer of applied drama, is therefore interested in integrating the concepts, theories, and processes of applied

drama with design thinking. Since the applied drama is a tool created from images based on human experience and imagination leading to communicate meaning and understand of human stories in depth [7], it enables students to create a better understanding of the problem and understanding of human beings, promote, and cultivate students' creative innovation competency to be more efficient. The whole process of applied drama helped to create and promote giving learners more experience. This allowed students to perform the design thinking process better [8]. In addition, Anthony Jackson and Chris Vine [9: 10] described that an applied drama developed since 1990 was linked to social and political changes by using drama as a tool to communicate with audiences. Thus, it caused experiential learning through characters, role-playing, as well as learning through the process of drama which led to the educational drama concept. Similarly, Dumrhung [10] proposed that the concept of theater for transformation was the applied theater process for developing the participants.

The process of applied drama can enhance the design thinking process, reach an in-depth understanding of the target audience as well as creating a thought process leading to the creation of prototyping and testing according to the design thinking process. The applied drama process can support each step of the design thinking process from setting up a scope of problem, understanding problems and target audiences, creating ideas, prototyping and testing through expressions, communications, simulations, and role plays. This enabled the researcher to integrate the concept of design thinking with the applied drama process for learning management in subjects relating to display and creation of exhibition or creative media for education which were provided for students in Bachelor of Education Program to promote their innovative creation competency.

According to the COVID-19 pandemic since the end of 2019, the learning management model has been changed from classroom to online teaching, and become blended learning [11]. Blended learning is an integration of classroom learning and learning from various technologies. For examples, the teacher organizes regular activities to stimulate learners and support their learning followed by an additional self-study outside the classroom or a synchronous online learning [12]. Based on the guideline for developing learning management model or the guideline for learning management in the twenty-first century and blended learning approach, the researcher therefore studied the effect of using the learning management model based on design thinking learning and applied drama process to promote the innovative creation competency and the effective process of creating an exhibition website displaying works of students in Bachelor of Education Program who had participated in learning through design thinking and applied drama process during the COVID-19 pandemic.

2 The Learning Management Model Based on Design Thinking and Applied Drama Process or 3I's Model

The researcher has developed a learning management model by studying, analyzing, and synthesizing the concepts, theories, and documents related to learning management design, design thinking, applied drama process, and innovative creation competency. This has led to the design of a learning management plan with details of the learning management model including the design thinking integrated with the drama applied process to promote the innovative creation competency or 3I's Model as follows (Fig. 1):

Input is the science, subject, and knowledge of learners, learning context, and content of each course.

Process is to combine the concept of design thinking with the applied drama process, consisting of three steps as follows:

Step 1 Inquiry: It is to inquire and find a problem, understand a problem and its cause, understand the target audiences as well as understand and think based on target audiences' perspectives. The lecturer has applied the concept of design thinking called "Persona" or an analysis of the characteristics of the target audiences. Then, the students could understand individual feelings, thoughts, and problems which were considered as the primary target audiences required for studying before they created their works. Students were required to observe to gather detailed information

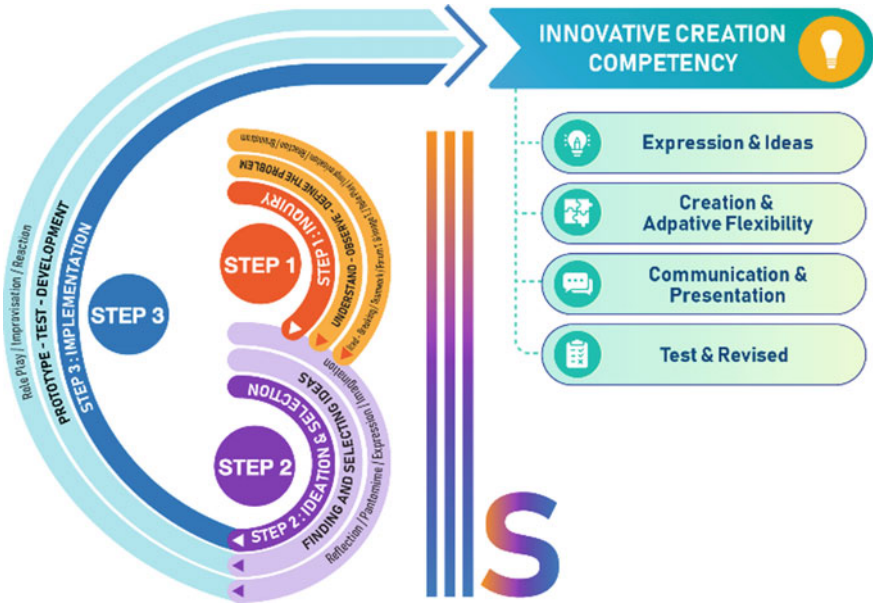

Fig. 1 Learning management model based on design thinking and applied drama process to enhance innovative creation competency

enabling them to define the problem. This included the storytelling, illustration, and description of people's reactions and feelings.

The researcher has applied the process of applied drama to promote and organizes learning activities in order to expand Step 1. The goal was to enable students to study, research, and collect information as well as exchange experiences with the community in the classroom to enhance students' experiences. Also, this would enable students to understand the emotions of the target audiences in depth through applied drama activities which started step by step, respectively.

1. Iced-breaking helped students to relax, made the classroom less stressful, integrated the basic of acting, and enabled students to dare to think and express. This encouraged students to observe their classmates through game activities, scoping problems, determining conditions, and simple situations.
2. Teamwork enabled students to understand the importance of collaborations through games or drama activities by using activities focusing on practice, action, and body movement.
3. Forum theater or image theater was implemented to enable students to share their opinions on various events that happened during the activities.
4. Role-playing and gathering information from the reaction of participants in simulations through the improvisation were conducted by the lecturer after the activities finished. The lecture raised the topics and led the students to express their opinions as well as encouraged them to share their opinions.
5. Brainstorming for conclusions was done by letting students discuss in their group meeting, present their opinions in the classroom to rationally criticize the issues and content.

Step 2 Ideation: It is to create or create an idea starting from bringing information gathered from brainstorming, which may contain a large number of concepts or ideas. The students must search for and select the best or most interesting ideas. The lecturer can act as activity leaders to promote students' thoughts, ask questions leading to criticism, and idea sharing among students which enable students to have a process of finding and selecting ideas. In addition, the retrieved ideas are practical and consistent with the problems identified in Step 1. The applied drama process can be promoted for searching and selecting good practices for real creativities, creating activities for students to summarize and selecting the best ideas by promoting the imagination of students. The lecturer may ask questions using conditional sentences to let student express through actions, movements, and reactions to "pick" the best single idea for the practical creation which can be tested in the next step. The second step started as follows:

1. Imagination
2. Expression
3. Pantomime
4. Reflection of activities promoting classroom learning.

Step 3 Implementation: It is to test and implement the retrieved idea, starting from the creation of model or prototype followed by testing or experimenting to collect

feedback for editing and improving more effectively. In this step, the simulations from applied drama process can be used instead of real implementation or used as close-to-real situation to prove whether ideas and concepts of the work will be able to reach the target audiences. The lecturer and students can collaborate to create situations or role plays in the classroom or appropriate place. In the role plays, students can divide their characters in both improvisation and reaction approaches to test their work for further development based on the creation of learning community in the classroom. This process is considered as retesting and reimplementing to enable students to correct the errors that may occur to make their works become the most effective. In this process, the lecturer will be a facilitator for learning to give students the advices and guidelines.

Output is the students' skills in the innovative creation competency and the work that the students have created. The skills and characteristics of students that promote the innovative creation competency can be divided into four components, which can be measured and assessed from the procedure, step, process of creating work, and product with details as follows:

1. Expression and Idea: Students are able to express their thoughts and explain in detail the concept through various processes while participating in the learning management model based on design thinking and applied drama process. The expression can start with classroom activities about design thinking integrated with applied drama processes. Then, the expressions of thought will be criticized to refine the retrieved opinions and developed as a suitable idea to be used for continuing as real creative works.
2. Creation and Adaptive Flexibility: Students can create as well as adapt creativity appropriately and rationally to the problem or cause of the problem with the ability to implement as practical creative works and can be used in practice leading to the creation of works. When the creativity goes on, the first idea may not be the most suitable; or the students can flexibly solve problems and improve that idea when creative is completely implemented.
3. Communication and Presentation: Students must be able to communicate and present their own ideas to classmates, lecturers, outsiders, and target audiences about the approach to produce their creative works effectively. Also, they must be able to correctly and rationally express opinions to make the primary and secondary target audiences understand their own ideas.
4. Test and Revised: Students can test their works and try it out with their target audiences. Also, they can evaluate their performance, share feedback with classmates and accept suggestions and recommendations to improve their works or process to the test to become the most effective. In addition, students try to fix problems caused by different limitations and conditions.

3 Methodology

This research was conducted using the research and development process and its procedure is as follows:

1. Study, analyze, document, and research related to the creation and development of a learning management model, design thinking process, applied drama, and the innovative creation competency.
2. Summarize data to design and develop a learning management model based on design thinking and applied drama process to enhance the innovative creation competency.
3. Design a learning management plan, create, and measure the quality of the student's learning assessment forms including the innovative creation competency before and after learning assessment, behavioral observation form, performance assessment rubrics, and semi-structured student interview form according to the learning management model based on design thinking and applied drama process to enhance the innovative creation competency in the course entitled EDT 435 Display and Exhibition Techniques for Educational Technology.
4. Implement learning management with a design thinking learning management plan based on design thinking and applied drama process to enhance the innovative creation competency.
5. Study and gather data of the process of creating an exhibition website displaying works of students in Bachelor of Education Program who had participated in learning through design thinking and applied drama process.
6. Study the result of using the learning management model based on design thinking and applied drama process to enhance the innovative creation competency.
7. The population included students of the Faculty of Education or students of the Bachelor of Education Program, Srinakharinwirot University in the second semester, academic year 2020.

The sample group included students studying the course entitled Display and Exhibition Techniques for Educational Technology, Bachelor of Education Program in Educational Technology in the second semester of academic year 2020 at Srinakharinwirot University. The researcher used a purposive sampling approach and selected 1 classroom with 24 students. This course was selected because it aimed to enable students to create exhibition and works related to educational technology which required skills and competency in creating innovations.

The measurement and evaluation of innovative creation competency from the learning management model based on design thinking and applied drama process applied the innovative creation competency measurement (before-after learning) with Wilcoxon signed-rank test. The students' behavioral observation was analyzed by comparing scores before, during, and after learning that the trends of students' improvement seemed higher. The performance assessment rubrics were analyzed based on the total scores. The semi-structured student interview form was analyzed by content analysis approach.

4 Result

After implementing the learning management plan based on design thinking and applied drama process to enhance the innovative creation competency, students had developed the process of creating an exhibition website displaying works of students in the Bachelor of Education Program. The implementation process was described as follows:

1. Providing knowledge and understanding to students on exhibition design and display: During the COVID-19 pandemic, the lecturer provided knowledge for student through the online platform. The online activities included lectures, group discussion, and case studies. Then, the lecturer continued to implement the learning management plan with onsite activities.
2. Implementing the applied drama process: In this stage, students were allowed to participate in ice-breaking and teamwork activities through games with conditions and practice leadership and followership. The design thinking activities also started in this stage by using concept of "Persona" to analyze the target audiences which was aligned with the concept of "Character" in the applied drama process. Students were required to research, observe behaviors of target audiences, and lead the classroom activities according to simulation or role-playing concept. The simulations and role play were based on the character of the selected target audiences to enable students to exactly understand, prove as well as access problems of the target audiences. All these were considered as the "Step 1" of the learning management model based on design thinking and applied drama process to enhance the innovative creation competency called "Inquiry: to inquire and find a problem, understand a problem and its cause, understand the target audiences." The result showed that students were highly cooperative and eager to participate in this 2-week activities.
3. Ideation and Selection: This process was considered as the second step of learning management. The researcher provided simulations for students to practice action and reaction with limited durations. The researcher framed a simple problem that was close to home, such as human behavior, animal, and objects. Practicing through teamwork and various ways of communication enhancing interactions among students retrieved from the applied drama process was also implemented in the classroom. In addition, design thinking process was applied through brainstorming in group activities to encourage students to express their ideas as much as they could. Then, students would continue to comment and discuss to select to best idea in the innovative creation process. The researcher spent 3 weeks in this step to allow student to select the best idea for further process effectively. The classroom atmosphere was not boring. According to the observation of students' leadership and followership, and the applied drama activities could simulate students' thought very well.
4. Determining a goal with students: Due to the COVID-19 pandemic, the onsite activities could not be provided. Therefore, the goal was to create the exhibition website displaying students' works on educational technology which had been

collected throughout their 4 years of education. After the students selected the best idea from brainstorming, the research took action as a "facilitator" for students to practice organizing an exhibition in a website format. This third step was called "Implementation: testing, improving, and implementing the idea." The researcher allowed students to produce a prototype of a website and test it through simulations or role plays based on the applied drama process; it took 4 weeks to complete this activity. Students were divided into different groups acting as target audiences visiting a prototype of website and commenting based on the character of each target audience. This aimed to improve the prototype of website to become more perfect and make the prototype applicable for a real display of creative works in the program. Students could practice organizing their thoughts more systematically as well as test and prove whether their own ideas could be used in practice through simulations in the classroom. The researcher, as the activity leader, provided advice, suggestions, and guidelines to help students develop their work in the right and appropriate direction. In addition to collecting students' work throughout the four years that they had created works, students created additional media to make the display of students' works on educational technology become more perfect. Students also organized a discussion relating to educational technology in COVID-19 pandemic entitled "SOVIVOR: VICTIMS OR SURVIVORS" and a public relations activity via Filter Instagram Story that students had brainstormed and improved exhibition website to become more attractive. The exhibition website could be accessed at https://www.swutechnoshowcase18.com.

The result of students' innovative creation competency assessment (before, during, and after learning) was presented in the following line graph (Fig. 2).

Table 1 shows the result from the analysis using Wilcoxon signed-rank test. The mean of achievement after learning was statistically significantly higher than before learning at 0.01 level. The mean of achievement after learning was higher than after

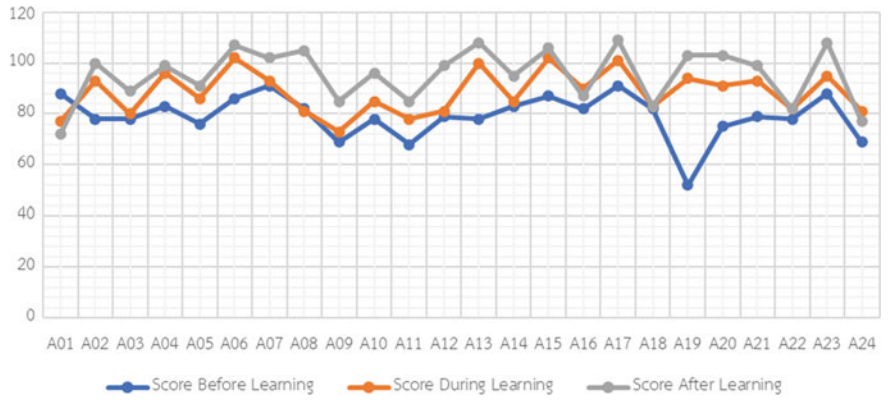

Fig. 2 Line graph presenting the result of students' innovative creation competency assessment (before, during, and after learning)

Table 1 Comparison of a sample group's score before and after learning using Wilcoxon signed-rank test. Table type styles

Learning achievement	*N*	Mean rank	Sum of ranks	*Z*	*p*-value
Before learning	24	9.50	9.50	−4.016**	0.000

** *p*-value < 0.01

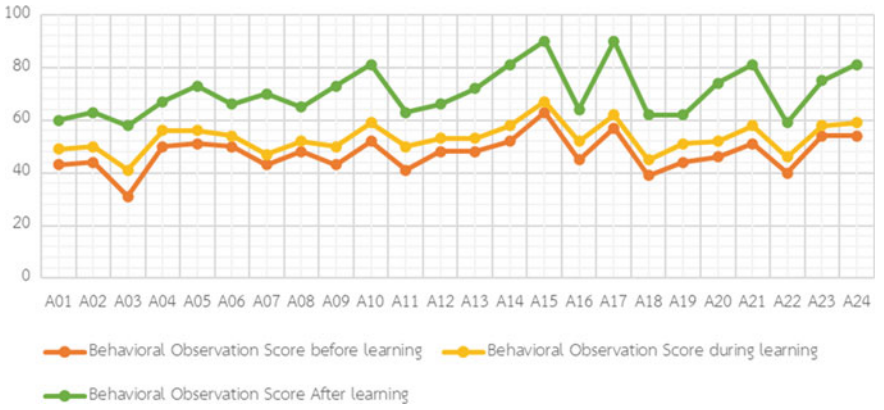

Fig. 3 Line graph presenting the result of the behavioral observation form made by the lecturer (before, during, and after learning)

learning at 12.63 > 9.50. It consequently revealed that students' innovative creation competency was higher after they participated in the learning management based on design thinking and applied drama process.

The result of the behavioral observation form made by the lecturer (before, during, and after learning) was presented in the following line graph (Fig. 3).

5 Conclusion

The results of the learning management based on design thinking and applied dram process to enhance the innovative creation competency were concluded as follows:

1. The process of applied drama allowed some students who were not assertive to express themselves even more as well as encouraged students to dare to think, act, present, and communicate their own ideas. This could be considered as the beginning of the expression of thought leading to the first step to enhance their innovative creation competency.
2. According to the observation of the target audience's behaviors based on the concept of "Persona," students could apply drama activities to create a better understanding of the target audience. They were able to understand their target

audience deeply reasonably and the cause of the problem. Also, they could improve, develop, or apply their creativity more effectively.

3. Teaching based on design thinking and applied drama process enabled students to dare to think, act, present, and communicate their thought without limitations. It gave students opportunities to experiment with challenging tasks. Therefore, students realized how much potential they had for creating works. The first attempt might not be perfect; but they could always improve, experiment, and develop their own work.
4. Before learning, most students had no knowledge and understanding design thinking or applied drama processes. Therefore, students were excited to apply drama activities in their learning and further self-development, apart from developing their innovative creation competency, such as assertiveness and personality development.
5. Students could learn and develop more skills in various fields, which could be summarized as follows:

    - Increasing knowledge and skills in organizing online exhibitions
    - Improving public relations skills
    - Developing self-learning skills by learning on their own through various learning resources to obtain knowledge and information that meet the needs for creating content and discussion topics
    - Enhancing teamwork and collaboration skills that provided opportunities to share knowledge and develop new potentials together.

6 Discussion

According to the study of the result of implementing the learning management model based on design thinking learning and applied drama process to enhance the innovative creation competency, the researcher came up with quite a variety of research results. It showed that students did not develop only the innovative creation competency but also other learning skills. For example, students developed self-learning skills by constructing knowledge from the relationship of what they saw, based on their existing knowledge that they enhanced through psychological processes on their own; and the lecturer could not adjust students' intellectual structure. In this regard, the lecturer performed as a "facilitator for changing a mindset of students who were considered human resource; students were seekers of knowledge who had no idea or experience in seeking knowledge and the lecturer had to challenge students' mindset. Th before. It is a challenge to students' thinking [13]. The researcher did likewise during the implementation the learning management model based on design thinking learning and applied drama process to enhance the innovative creation competency. The researcher, as a lecturer, acted as a person who opened and challenged students' thought, motivated students to become eager to learn and helped students to seek knowledge that they did not know by themselves.

The applied drama activities helped students to break the ice, exercised their body and brain, and created a fascinating atmosphere in the classroom as well as teamwork. Similarly, Dumrhung [10] mentioned the applied drama process that it started from creative and collaborative learning process. It has been focusing on the change of individual and community and serious implementation with concrete goal considered as the strength of the drama, the designed activities are related to the background, cultural, and social capital of the participants in drama activities.

Furthermore, Stein [14] stated that the essentials of applied drama included (1) organizing drama experiences and activities, (2) creating a circle: a safe, equal space where everyone respects each other; (3) building discipline through playing the drama game with rules and regulations resulting in a commitment to play; (4) developing topics and issues suitable for the community; (5) creating a process drama which were integrated into this research, in terms of development of communication (both sending and receiving messages) and simulations or role-playing and (6) exchanging and developing ways to change. Consequently, the whole applied drama process was integrated with the design thinking process and developed as learning management activities.

Due to the COVID-19 pandemic since the end of 2019, learning management of the higher education level has changed. It is necessary to organize online teaching through a remote conferencing system to reduce congestion and face-to-face meeting in the classroom. Therefore, the researcher has designed a blended learning management plan which is an integrated learning based on learning experience of students. It can be generated from collaborative learning with classmates and self-learning. It is possible to arrange a synchronous learning in the classroom and through the online platform and assign out-of-class learning activities, such as reading or browsing other resources by applying technology or different types of teaching materials that the teacher has designed or provided for students. These are flexible and applicable ways of learning suitable for different situations [15]. Then, the researcher has designed a learning management plan that sometimes can be taught online and selected some necessary activities from the plan for teaching in the classroom to reduce the risk of both students and teachers during the spread of COVID-19 pandemic. The researcher found that in the future, the learning management retrieved from the development of a learning management model based on design thinking and applied drama process to enhance the innovative creation competency would be managed as a blended learning, even though it has consisted of practical activities.

7 Suggestion

1. The lecturers and persons who are interested in implementing the learning management model based on design thinking and applied drama process to enhance the innovative creation competency at the higher education level, they should provide fundamentals of the science they are going to teach to students

before implementing the model. In addition, the lecturers should have background or experience in the applied drama process in order to be able to lead to learning activities relating to the applied drama process.

2 The role of a lecturer for leading the learning management model based on design thinking and applied drama process to enhance the innovative creation competency is the activity leader. A lecturer must be a leader who leads the learning activities, gives students opportunities to fully express their opinions, and observes as well as gives advices from a distance, so that students can learn and construct knowledge on their own.

3 The role of students participating in the learning management model based on design thinking and applied drama process to enhance the innovative creation competency is a learner who can construct knowledge and understanding in their specific field of study through a practice based on the step of the learning management integrated with the design thinking concept and applied drama process. If learners lack knowledge or guidelines for creating works, they can study more by themselves and request for advice from lecturers to create a body of knowledge suitable for the course, opportunity, and individual.

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Student Attentiveness Classification Using Geometric Moments Aided Posture Estimation

Gowri Kurthkoti Sridhara Rao and Yanfei Liu

Abstract Body posture provides enough information regarding the current state of mind of a person. This idea is used to implement a system that provides feedback to lecturers on how engaging the class has been by identifying the attentive levels of students. This is carried out using the posture information extracted with the help of Mediapipe. A novel method of extracting features from the key points returned by Mediapipe using geometric moments is proposed. Geometric moments aided features classification performs better than the general distances and angles features classification. In order to extend the single person pose classification to multi-person pose classification, object detection is implemented. Feedback is generated regarding the entire lecture and provided as the output of the system.

Keywords Pose classification · Mediapipe · Geometric moments · Object detection · Attentiveness classification · Random forest classifier · Retina-net

1 Introduction

Classroom learning is very important when it comes to acquiring any professional skill. In a classroom full of students, an instructor can make out how many students are paying attention and how many are not. But this observation must be converted into statistics and has to be analyzed in order to correlate the performance of the classroom and their attentiveness. This analysis if provided to the teacher, will serve as feedback on how to improve the class performance.

G. Kurthkoti Sridhara Rao (✉) · Y. Liu
Purdue University, Fort Wayne, IN 46815, USA
e-mail: gowriks12@gmail.com

Y. Liu
e-mail: liuy@pfw.edu

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There have been good amount of research going on in trying to improve the teacher–student interaction. As stated in [1], having an effective interaction at a younger age provides the kids with emotional support, keeps the classroom organized and instructions of the teachers are better captured by the kids. Similarly, researches at every stage of classroom learning are carried out in [2, 3], which suggest improvements in classroom teaching for teachers. Research carried out at the university level to identify the factors that contribute to improved attention in students is presented in [4]. The active learning classrooms impact is measured, and a report is provided. In this research, surveys are used to capture student engagement, student engagement from the instructor's perspective and from the researcher's perspective. All the surveys and interviews are then analyzed to provide feedback on the improvement of the classroom engagement when active learning classrooms are used.

The traditional ways mentioned are not real-time as it takes time to collect all the surveys, interview the parties involved, analyze all the data collected and create a feedback report. Also, the individuals providing the survey or interview might not be truthful when they are providing the information. This might corrupt the data collected and lead to false interpretations. To overcome these drawbacks of traditional methods a computer vision-based attention identification system is proposed in this research. The visual monitoring system captures the video of the classroom where the session is in progress and identifies the students who are engaged and who aren't based on posture features. By the end of the session, the instructor will be provided with a feedback of engagement level of the classroom in that particular session.

This paper proposes a novel way of extracting features from the key points obtained using Mediapipe. Instead of the general distances and angles features, geometric moments of the posture is used as the features for pose classification. Both the methods were implemented and geometric moments method along with random forest classifier has 92% accuracy while the distances and angles method along with the widely used KNN classifier has 85% accuracy.

The further sections of this paper is organized as follows. Literature review provides the information regarding the previous work that is already carried out for this application. Methodology provides complete information regarding the entire overview of the method and explanation regarding the novel pose feature extraction method proposed. Experimental results presents the results of the method and also a comparison of the proposed method with the other which is followed by the discussion and conclusions section.

2 Literature Review

Capturing the activeness of students in the classroom involves classifying their behavioral features. Behavioral features that can be captured using a camera are head orientation of the students, eye gaze direction, face expressions, and emotions to know if the students are paying attention to the teacher. Student body pose and actions like

hand raising, taking notes, and some other movements can also be considered a set of features that helps in the classification task.

In [5] the OpenFace library is used to capture 31 face features which includes eye gaze movements, head pose movements, and facial action unit features. In E-learning engagement detection applications, face images and videos are used. Face feature extraction and classification is mostly carried out using the deep learning approaches that are discussed in [6] and [7]. For virtual classrooms, face recognition methods seem to provide promising results.

Including face recognition, authors in [8] carry out head and body posture estimation. Head pose estimation is used to identify the gaze direction. Synchronization in the class is another factor they have considered to identify the attentive set of students. Using OpenPose, pose of the students which can be tracked is identified. Concatenating these results with head pose estimation they measure the attention of the class.

In a virtual classroom, web camera is used for capturing the videos and hence, face features can be clearly extracted from these images. In an offline classroom setting, it is hard to capture the face details such as emotions and expressions with the low-resolution surveillance camera. A major drawback of using face expression features to identify attentiveness is that it requires a very high-resolution camera for capturing the video. On the other hand, body posture feature is robust to low quality video and when there are several subjects in the same frame of a video. Although it might seem to not completely provide all the information, it is able to identify an approximate body posture which denoted the state of mind.

Pose classification using Mediapipe can be carried out using deep learning methodologies as well. Yoga pose detection in [9] and [10] both use deep learning algorithms to classify the yoga postures. These methods extract the skeleton posture from each dataset image and train the neural networks to identify the posture. But this can be computationally expensive as neural networks will be used for each posture detection.

Since object detection task is already adding complexity, neural network approach might add more. A less complex version of using key point locations for classification is used in [11]. In this paper, person detection and, skeleton-based pose classification is carried out. But this paper uses the distances between the joints and angles as the feature for classifying the skeleton posture. As presented in the further section of results, proposed method of using geometric moments for the task outperforms this approach. Hence, a novel method of using geometric moment features of regions is presented in this paper.

3 Methodology

The methodology used in this solution follows a top-down approach. The lecture video is first broken down into separate frames. These frames are further processed to identify humans (Students in our application) using object recognition techniques.

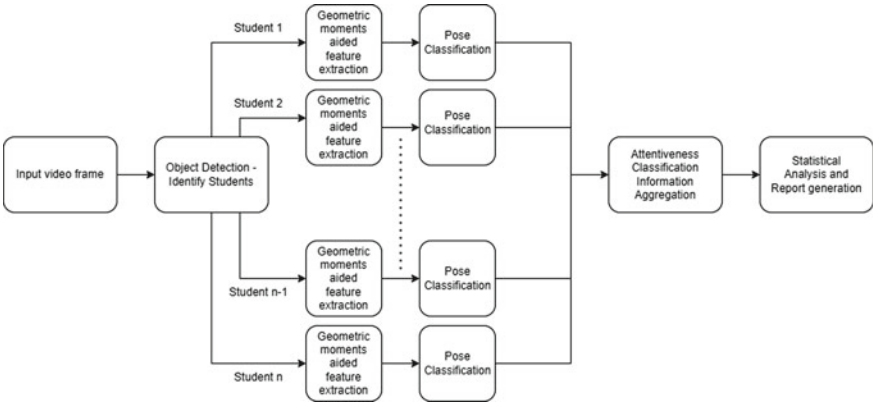

Fig. 1 Block diagram of the proposed methodology

Each human is subjected to human pose estimation. Desired feature from the estimated pose are extracted and they are classified using machine learning techniques. The results are aggregated to compute the feedback report which is the expected end result.

The block diagram in Fig. 1 gives the overview of the solution designed. The input video is broken down into frames, each frame is an input to this system. Object detection is carried out on each of these frames using Retina-Net. The output of the object detection block are the cropped images where each output depicts a student in the frame. For each student in the frame, pose classification is carried out. Pose features are extracted using Mediapipe python library. Pose features are further processed to get more information about the pose using geometric moments and these features are provided as an input to the classifier. The classified attentiveness metric of all students is aggregated, and this is used for report generation.

Pose estimation of the students in the class are carried out using the python library Mediapipe. Mediapipe implements the pose estimation in the state-of-the-art blaze pose [12] architecture. The idea of this architecture is to make the pose estimation algorithm as light weight as possible so that it can be used on mobile phones as well. Since this lightweight architecture helps the application at hand to be used in real-time, Mediapipe is used as the pose estimation library.

In order to be able to identify posture of multiple people in a single frame, object detection is used. Different object detection algorithms [13–15] were tested.

HOG does not use high computation power like the deep learning application but fails to detect the bounding box of the entire person present. YOLOv3 is a fast algorithm and provides accurate results but a part of the human is not inside the bounding box detected. Retina-Net is accurate, and all elements of the person are enclosed within the bounding box but it is slower than YOLOv3. After considering the pros and cons, Retina-Net is used as the object detector for this application.

Table 1
Posture—attentiveness mapping details

Attentiveness grouping	Postures in the group
1. Attentive	Hand raised, hand crossed, sitting straight, taking notes
2. Intermediate 1	Hand on chin, hand on head
3. Intermediate 2	Leaning forward, looking down
4. Inattentive	Looking to the side, sleeping

The dataset used for the classification consists images of a person sitting on a chair and in one of the 10 postures that can be further grouped into attentive, inattentive, or intermediate 1 and 2. The 10 postures are as listed in the Table 1 and it's grouping into one of the three states of minds. A sample set of 100 images for each posture is used for training and validating the classifier.

There are several state-of-the-art techniques that can be used to carry out pose estimation. These state-of-the-art methods are implemented and made into libraries that can be used. OpenPose [16] is one of the famous and widely implemented library. Another such open-source and easy to use pose estimation packages is Mediapipe. Mediapipe uses the state-of-the-art architecture of BlazePose [12] and to identify the key points of the human pose. The Mediapipe library takes image as input and returns 33 key points of the pose as the output. The points returned are the coordinates of the location of the key point. They must be further processed based on the application that it is being used to identify the posture as per the application. Pose classification involves two major steps; first one being pose feature extraction and the second one being the classification using machine learning algorithms.

Pose Feature Extraction

The pose key points that are returned from the Mediapipe library are the x and y coordinates of the point in 2D image space. The relation between each key point must be identified for it to be used for further classification. In the earlier works, pose classification uses the distances between the key points as features to classify the postures. As presented in paper [11], distances between the necessary key points are used as features of the posture for classification.

In this research, a novel method of using geometric moments of regions is tested out in this research. Geometric Moments is the weighted average of the image pixels in a given region or object. Image moments help in gathering simple properties of the region such as area, centroid, orientation. So, instead of using multiple distances and angle, interested area is enclosed in an ellipse and the properties of the ellipse is used to identify the posture.

In case of image, which is a 2D continuous function, the geometric moment is calculated using the formula,

$$M_{pq} = \iint_{-\infty}^{\infty} x^p y^q f(x, y) dx dy \tag{1}$$

For images which have finite number of pixels, this equation can be modified into,

$$M_{ij} = \sum_{x} \sum_{y} x^i y^j I(x, y) \tag{2}$$

Simple image properties or region properties can be derived using the above equation. Area of the region under consideration is calculated by considering i and j as 0 in the above equation (M_{00}). Centroid of the region can be calculated using the formula,

$$\{x_c, y_c\} = \left\{ \frac{M_{10}}{M_{00}}, \frac{M_{01}}{M_{00}} \right\} \tag{3}$$

Similarly, central moments which are translation invariant can be used to compute other features such as angle of orientation, covariance matrix, etc. Central moments are calculated using the formula,

$$\mu_{pq} = \sum_{m}^{p} \sum_{n}^{q} (x - x_c)^p (y - y_c)^q f(x, y) \tag{4}$$

A similar concept is used for identifying the features of a posture in this research. For the feature extraction purposes, 5 regions were identified. Left and right forearms, arms and body. Each region was represented using ellipse and different features of these elliptical regions were used for the classification. Major axis length of the ellipse is similar to the length of the principal axis of the region. Angle of orientation of the principal axis is the angle of orientation of the region. Center of ellipse is the centroid of the region, and area of the ellipse is the M_{00} of the region in terms of image moments. This information is used for the classification using the classifiers.

As depicted in Fig. 2, properties of the ellipses are used as the features. Angle of orientation of each of these regions provides the necessary information with respect to angle and features like major axis, area, and centroid help in identifying the distance between the two points that the region encloses.

Classification

Three different machine learning classifiers were considered for the classification task. K-Nearest Neighbors, Support Vector Machines, and random forest classifier. Table 2 presents the classifier advantages and disadvantages information. Random forest classifier is considered more reliable in classifying the given data due to its' higher accuracy and hence it is chosen for classifying the features that are extracted.

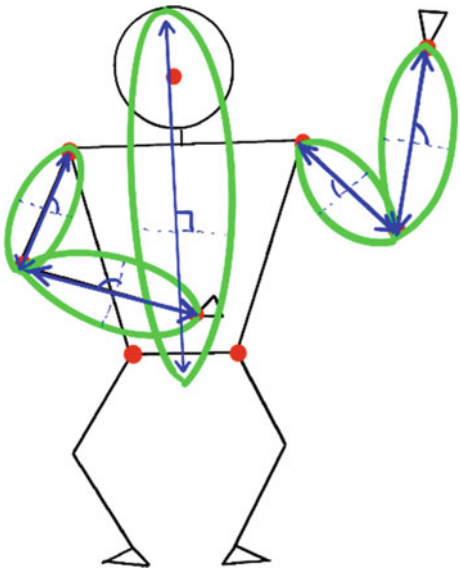

Fig. 2 Geometric moments-based method extracted features

Table 2 Classifiers comparison table

Classifier	Advantages	Disadvantages
K-nearest neighbors (KNN)	Simple and seems to be a perfect fit for the problem statement at hand	Does not function well with high dimensional data
Support vector machines (SVM)	Can handle high dimensional data and classify better even with small train set	Fails when there are overlapping classes
Random forest classifiers (RF)	Can handle high dimensional data and makes sure the classifier doesn't over-fit	Takes more time to train the random forest classifier

The pose that is identified, along with other information such as frame number and object number and classification accuracy is dumped into a data frame as and when they are identified in the video. The pandas data frame is used to perform some basic statistical analysis and get a report on the percentage of the number of students that are grouped into different attentive classes. A pie chart that aggregates the information gathered in the entire classroom session.

4 Experimental Results

The experiment on implementing the methodology to identify the attentive states of the students in a classroom started off with making a list of all the possible distinguishable postures student have during a lecture. These postures were simulated by three different demo students and images were captured to create a dataset. The gathered images were subjected to image augmentation by flipping them left and right. Other image augmentation operations like rotating or vertical flipping were considered but since it only degraded the classifier performance, these operations were excluded. Augmented dataset included 100 images in each class for the further process. Python programming language is used for the implementation of all the blocks in the system.

Single person pose classification involved comparing two different methods of feature extraction and three different types of classifiers. In feature extraction, first one being the one that includes considering the distances and angles formed by each key point similar to the one suggested in [11]. Second one is the novel method presented in this paper which is using the region moments features for classification. Table 3 presents the comparison between the existing framework of distances, angles method, and the proposed region moments method.

Comparing the results presented in Table 3, it is clear that the method proposed in this paper consistently performs better than the other method irrespective of the classifier at hand.

Mediapipe can identify only single person's posture in a frame. To be able to identify postures of all the people in the frame, object detection has to be performed. Each object which in our case is a person has to be cropped out of the frame and this has to be provided as an input to the single person pose classification section.

As mentioned in the methodology chapter, after careful consideration, Retina-Net is used for object detection. Object detection was tested on some classroom images. Figure 3 shows the students detected in a classroom image and their detection confidence percentage. As it can be observed, some objects that are detected are not very clear. Hence, a threshold of 65% will be set to person detection confidence. This prevents human objects that are not very clear to be subjected to classification and it not being able to identify the posture. Figure 4 presents the final results of classification. As it can be observed, for the postures that couldn't be determined, the classifier returns null. Some detection might not be extremely accurate, but the classifications

Table 3 Method classifier accuracy results

Classifier	Distances, angles method accuracy (%)	Region moments method accuracy (%)
KNN	85.66	91.33
SVM	66.17	83.39
Random forest classifier	91.54	92.41

are justifiable considering the posture that is presented to it. The classification information for each frame is stored and converted to a Pandas dataframe that can be used for data analysis. The data extracted from the classification process is summarized a simple visual output of a pie chart and a bar chart. Figure 5 represents a pie chart that will be returned as an output of the entire process.

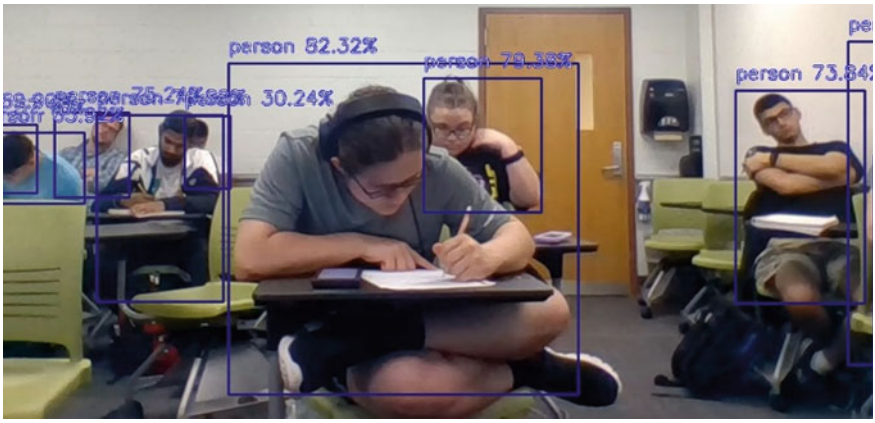

Fig. 3 Classroom image object detection identifying all the students

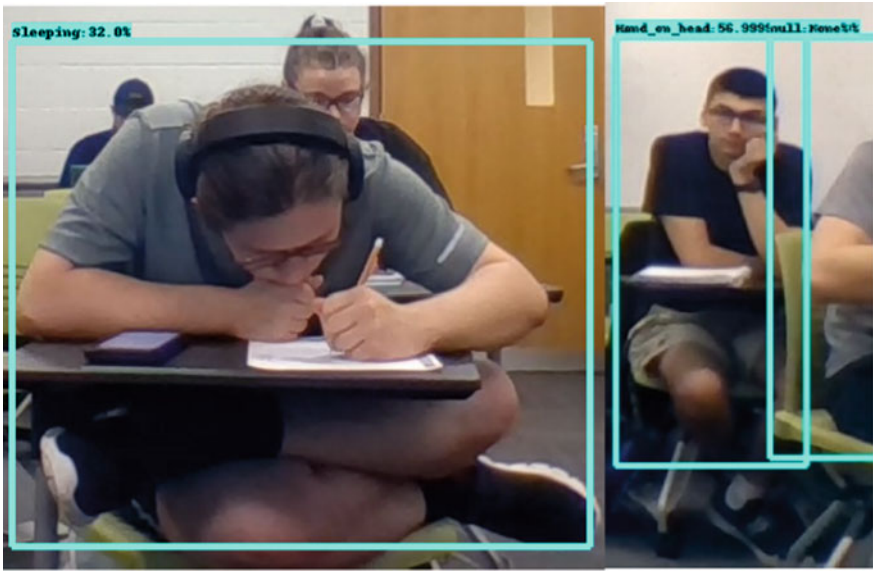

Fig. 4 Multi-person pose classification results

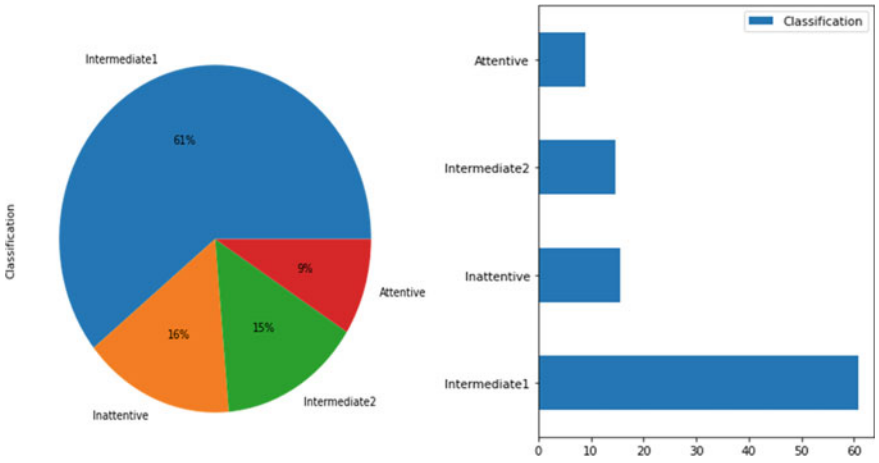

Fig. 5 Visual representation of the attentiveness feedback

5 Discussion and Conclusion

Student attention classification is a very insightful task that can help the lecturers get feedback on how well the students are able to receive the information that they are presented. Using this information, lecturers can plan their coursework to be more interactive or interesting. The method presented in this paper aims to classify the student attention using their posture information. Novelty of this method lies in the way the posture features are extracted from the image and the classifier that is being used.

The proposed method of using geometric moments aided features for the extraction of posture information performed significantly better than the usual distances and angles approach that are usually used. To add to the better performance, random forest classifier is used instead of the KNN classifier which performs better than KNN and avoids overfitting.

The future scope of the research includes experimenting with different quality videos and also with programmable cameras which can provide live feedback to the user. In terms of methodology, action/movement recognition can be extended on top of posture detection to be able to classify the attentive states more accurately.

To conclude, the proposed method is able to correctly classify student posture in a classroom setting and provide feedback in terms of percentage in each classification throughout the entire lecture.

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Low-Resourced Machine Translation for Senegalese Wolof Language

Derguene Mbaye, Moussa Diallo, and Thierno Ibrahima Diop

Abstract Natural language processing (NLP) research has made great advancements in recent years with major breakthroughs that have established new benchmarks. However, these advances have mainly benefited a certain group of languages commonly referred to as resource-rich such as English and French. Majority of other languages with weaker resources are then left behind which is the case for most African languages including Wolof. In this work, we present a parallel Wolof/French corpus of 100,000 sentences on which we conducted experiments on machine translation models based on recurrent neural networks (RNNs) in different data configurations. We noted performance gains with the models trained on subworded data as well as those trained on the French-English language pair compared to those trained on the French-Wolof pair under the same experimental conditions.

Keywords Low resource · Machine translation · African languages · RNN

1 Introduction

A machine translation (MT) system allows to switch from a textual sequence (or an audio source) in a source language, to the same sequence in the target language. For a long time, statistical machine translation (SMT) systems [1] were the most popular approach before neural machine translation (NMT) ones [2] came along and achieved an increasingly higher performance. However, the quality of such systems has always

D. Mbaye (✉) · M. Diallo
Université Cheikh Anta Diop, Dakar, Senegal
e-mail: derguene.mbaye@ucad.edu.sn

M. Diallo
e-mail: moussa.diallo@esp.sn
URL: https://www.ucad.sn/

T. I. Diop
Baamtu, Dakar, Senegal
e-mail: thierno.diop@baamtu.com

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been closely related to the amount of data used in their design [3]. Thus, state-of-the-art MT systems have been developed with sequence-to-sequence models using the attention mechanism [4] as well as the transformer architecture [5]. Languages for which this binding does not represent a constraint, such as English, are said to be resource-rich and have several million sentence pairs; most other languages fall under the concept of "low resource" (LR). However, the term "low resource" can encompass various aspects and can extend beyond the language to domains or tasks where little data is available even if the language is a resource-rich language. This is illustrated in [6] where the concept of "low resource" is defined in three different aspects: availability of task-specific labels, unlabeled language text, and auxiliary data. Most African languages fit into this description [7], which makes the work of researchers difficult and contributes to the low representation of African languages in NLP research [8]. This is particularly the case for Wolof which, beyond the lack of data, is a language for which little work has been done in NLP.

An automatic speech recognition (ASR) dataset on four African languages including Wolof was collected in [9] and used to design the first ASR system in this language. In [10], the design of the first collaborative online dictionary in Wolof adapted to the LMF[1] standard has been initiated. As part of the Dictionnaires Langue Africaine-Français (DiLAF)[2] project, researchers have produced several dictionaries on seven African languages including Wolof. However, at the time of writing, all the dictionaries are available online except Wolof. The authors in [11] explored the development of a finite-state based morphological analyzer for Wolof, the implementation and evaluation of an LFG-based parser for Wolof [12] and the creation of a universal dependency (UD) treebank for Wolof [13] which is the first UD treebank within the Northern Atlantic branch of the Niger-Congo languages. In [14], the authors studied the design of a spellchecker for Wolof by presenting an approach based on a dictionary as a lexicon and a morphological analyzer of the Wolof language.

However, to the best of our knowledge, the only work exploring specifically Wolof French machine translation systems is that in [15] where the authors presented a corpus of 70,000 Wolof French parallel sentences with which Word Embedding models as well as LSTM-based translation models were developed. However, the results were reported in terms of accuracy making it difficult to evaluate the actual translation quality of their systems. Multilingual neural machine translation systems including Wolof have also been developed such as in [16] where authors leveraged existing pre-trained models to create low-resource translation systems for 16 African languages. The Meta's No Language Left Behind project[3] which is capable of translating 200 languages between each other also includes the Wolof language. Nevertheless, beyond Wolof, substantial work has been done on low-resource language NMT (LRL-NMT) in general. The Masakhane community[4] proposes to address the challenge by targeting African languages with a participatory approach [17] including

[1] Lexical Markup Framework.

[2] http://pagesperso.ls2n.fr/~enguehard-c/DiLAF/index.php.

[3] https://ai.facebook.com/research/no-language-left-behind/.

[4] https://www.masakhane.io/.

all relevant resource persons in the process leading to the production of MT datasets and benchmarks for over 30 languages. A detailed study of different approaches has been performed in [18] to address LRL-NMT, and a set of guidelines has been defined to select the possible NMT techniques for a given LRL data setting. A set of experiments has been performed in [19] on different translation systems, both neural and statistical based, to translate from English to Icelandic. Most of these works, however, are based on the transformer architecture, which is very data-intensive. Less recent architectures such as RNNs could perform better in low-resource environments because of the lower parameters required.

In this paper, we present a work in progress of French-Wolof parallel sentence data collection constituting to date, the largest corpus yet collected in this language pair with 100,000 sentences filtered and aligned at the sentence level. We then propose to go further regarding the work in [15] and explore the performance of RNN models on our corpus by evaluating them with the bilingual evaluation understudy (BLEU) metric [20], which is more representative than accuracy. Since subwording, i.e., segmentation of the corpus into words or subwords, tends to improve the performance of translation models [21], we then experimented with the impact of this approach on our models. The paper is organized as follows:

– In Sect. 2, we present a description of the Wolof language.
– The data collection and filtering process are presented in Sect. 3.
– Section 4 presents the experiments performed.
– The results are shown in Sect. 5.
– Section 6 concludes the work.

2 The Wolof Language

As a West-Atlantic language mainly spoken in Senegal and Gambia, Wolof is also used in the Southern part of Mauritania. It belongs to the Atlantic group of the Niger-Congo language family and over seven million people spreading across three West African states is currently speaking Wolof. While only about 40% of the Senegalese population are Wolof, about 90% of the people speak the language as either their first, second or third language.[5]

There are two major geographical varieties of Wolof: one spoken in Senegal and the other spoken in Gambia [22]. Even if people who speaks Wolof understand each other, the Senegalese Wolof and the Gambian Wolof are two distincts languages: both own their ISO 639-3 language code (respectively “WOL” and “WOF”). Although it has a long tradition of writing using the Arabic script known as Ajami or Wolofal, it has also been adapted to Roman script.

Wolof is an agglutinative language [11] whose alphabet is quite close to the French one: We can find all the letters of its alphabet except H, V, and Z [23]. It also

[5] https://www.axl.cefan.ulaval.ca/afrique/senegal.htm.

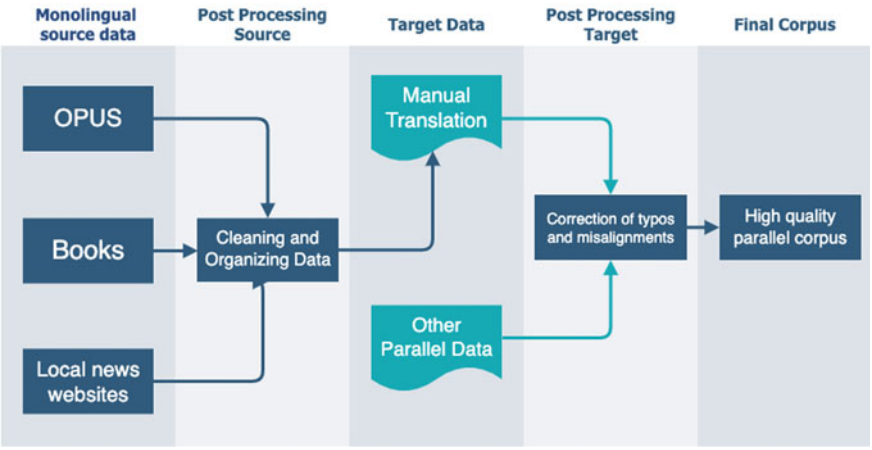

Fig. 1 Data collection pipeline

includes the characters η ("ng") and $\widetilde{N}$ ("gn", as in Spanish). Accents are present, but in limited number ($\grave{A}$, $\grave{E}$, $\dot{A}$, $\grave{O}$). Twenty-nine (29) Roman-based characters are used from the Latin script, and most of them are involved in digraphs standing for geminate and prenasalized stops. Unlike many other Niger-Congo languages, Wolof does not have tones. Nevertheless, Wolof syllables differ in intensity; e.g., long vowels are pronounced with more intensity than short ones. Length is represented by double vowel letters in writing and most Wolof consonants can be also geminated (doubled). However, Wolof is not a standardized language (and some sources exclude the "H" from the alphabet) since no single variety has ever been accepted as the norm. Nonetheless, the Center of Applied Linguistics of Dakar (CLAD) coordinates the orthographic standardization of the Wolof language [9].

3 Data Collection

3.1 Corpus

The construction of a dataset is a tedious and time-consuming task, especially for languages that have yet to be standardized like Wolof. The language is not taught in school, and few people follow the spelling rules, which makes the texts available on sources such as social networks very heterogeneous and difficult to use. We therefore opted to collect data in French, since this is the official language in Senegal since colonization, and to have them translated by competent linguists to build part of the dataset from scratch (Fig. 1).

The linguists used the official Wolof alphabet established by the government[6] to perform the translation. Monolingual French data are collected from existing resources such as Opus and text scraped from online sources that include news sites, religious, and blogs. We used Opus to collect monolingual textual data in French and collected translations of the Quran and the Bible as parallel texts. We also collected data from offline sources such as French books that have been translated into Wolof. We were thus able to collect a corpus of 100,000 parallel French-Wolof sentences, making our corpus the largest collected to date.

For experimental purposes, the overall dataset is divided into three subsets: a training set, a validation set, and a test set. The validation and test sets are kept fixed and separated from the full dataset with 16,000 sentences for the validation set and 7000 for the test set. We only vary the training set from 10,000 to 100,000 sentences in steps of 10,000 sentences.

3.2 Data Filtering

Before distributing the data between the different experimental configurations, we performed a set of post-processing operations. We started by performing stratified sampling to ensure that the validation and test sets were representative of the overall dataset and thus limit sampling bias.

Since the quality of the system depends directly on the quality of the data, we were inspired by the approaches proposed in [24] to then filter our dataset. We have thus removed sentences written in the same language on both sides, duplicate pairs of sentences as well as sentences that are identical on both sides. We also removed special characters, URLs and filtered out sentences that were too long and under-represented in the dataset. We consider a sentence to be too long when its size (number of words) is greater than twice the average size of the sentences in the dataset considered.

4 Experiments

Despite having collected a corpus of 100,000 sentences, we are still in a low-resource configuration for the NMT. We have therefore opted for a medium data-intensive architecture (compared to SMT and transformers) and exploited data manipulations to maximize the performance of the model.

We used OpenNMT [25] to reproduce a similar architecture to that of [15] in order to compare the results. The RNN model is thus composed of an LSTM layer [26] at both the encoder and decoder with 300 hidden units and a dropout layer. The dropout

[6] http://www.jo.gouv.sn/spip.php?article4802.

Table 1 French-Wolof experimentation

Training size	No subword	With subword
100 k	15.22	16.71
90 k	14.41	15.28
80 k	15.12	16.09
70 k	12.76	14.85
60 k	12.11	14.23
50 k	10.45	12.14
40 k	9.35	11.03
30 k	7.33	9.73
20 k	5.58	7.45
10 k	3.94	4.84

rate is set to 0.1 and the embedding size to 128. We have defined an optimizer Adam [27] with a learning rate of 0.001, and the batch size is set to 4096 tokens.

We split our dataset into different size configurations, and in each configuration, the model is trained in the directions Fr → Wo and Fr → En until it reaches convergence. Convergence is considered to be reached when no improvement is observed on the validation set after six checkpoints.

For data subwording, we used SentencePiece [28] with Byte-Pair Encoding (BPE) which offers interesting performance gains in agglutinative languages like Wolof [29]. We then generated a vocabulary on all segments of the considered size configuration's training set and performed an automatic model evaluation using BLEU [20]. BLEU is the most widely used metric in NMT in view of the fairly high correlation it has with human evaluations. We used the SacreBLEU [30] implementation[7] of the BLUE metric to evaluate the models.

5 Results

We compare the same architectures in the same data size configurations (i) when the data are provided to the model in a raw form, i.e., without subwording, compared to when they are subworded before training, (ii) when they are trained on the different language pairs, i.e., Fr → En compared to Fr → Wo. The first case allows us to measure the impact of subwording on the quality of the translations and the second allows us to observe the influence of linguistic properties between languages that can facilitate or hinder translation performance.

Tables 1 and 2 show the results of the translation experiments, and all BLEU scores were computed on the test set.

[7] Version 2.0.0.

Table 2 French-English experimentation

Training size	No subword	With subword
100 k	18.88	22.19
90 k	18.52	21.11
80 k	18.05	20.79
70 k	17.82	20.57
60 k	16.70	19.28
50 k	15.17	18.94
40 k	14.18	17.52
30 k	4.68	16.22
20 k	10.5	14.8
10 k	3.34	10.1

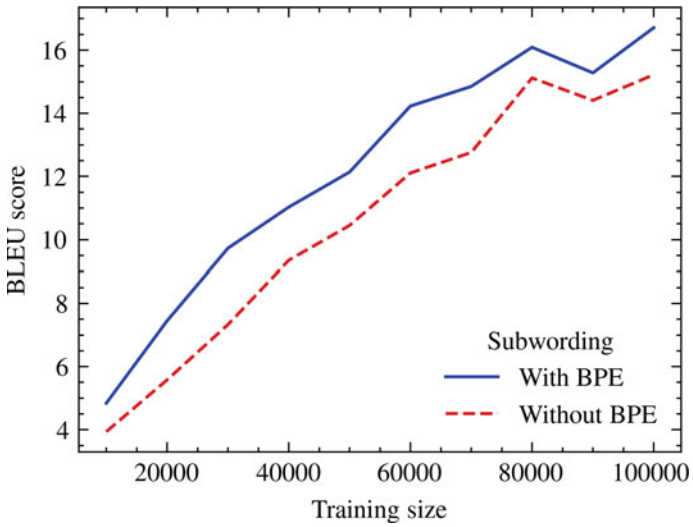

Fig. 2 Performance evolution of Fr → Wo NMT models on subworded and non-subworded data in the same data size configurations

In Table 1, we observe a gain of about 1.6 point of BLEU score between the raw corpus and the subworded one on Fr → Wo data, which can be explained by the fact that the subwords are more frequent and are therefore better learned by the model. This gain is more visible with Fig. 2 where we see that the performance of the model on the subworded data is better at each training checkpoint.

We observe a similar pattern in Table 2 on Fr → En data with a gain of about 4 points of BLUE score this time. When we compare the experimental results between the two language pairs, we also notice that under the same experimental conditions (corpus size and subwording), a gain of about 3.5 is noted on the BLEU score on Fr → En data compared to Fr → Wo.

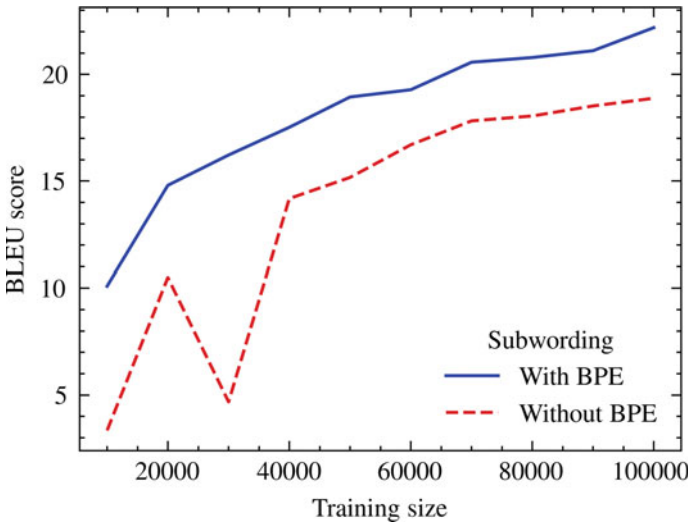

Fig. 3 Performance evolution of Fr → En NMT models on subworded and non-subworded data in the same data size configurations

Figure 3 illustrates well the behavior of the Fr → En models on the different dataset formats with a sharp drop at checkpoint 30 k. This is explained by the quality of the added data segment which contains a lot of artifacts and illustrates the fact that not all data points are useful for training.

In addition to subwording, we wanted to observe whether linguistic properties shared between two languages could influence translation performance. Figures 4 and 5 illustrate the performance of the two models in the same configurations (architecture and data) on the language pairs Fr → Wo and Fr → En.

In general, whether the data is subworded or not, we notice that the performance of the model trained on the Fr → En language pair is better than the one trained on the Fr → Wo language pair at all training checkpoints except the one at 30 k where a sharp drop is observed. This can be explained by the linguistic similarities between French and English which, although belonging to different families, share the same alphabet. They also have a lexical similarity of 27% [22] and words from one language that are found or have their origins in the other language. Our assumption is that the difference in morphology between the language pairs influences the ability of the model to translate one language into the other. The Wolof alphabet has more letters than the French one and Wolof is morphologically richer, which could hinder the ability of the model to capture the specificities of this language.

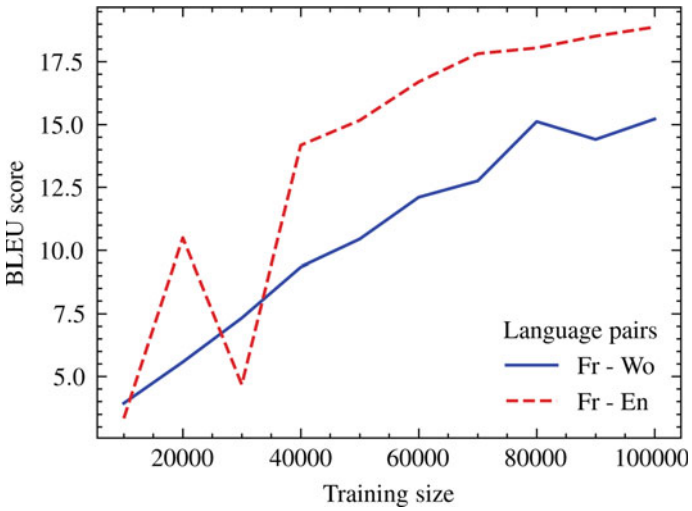

Fig. 4 Performance evolution of Fr → Wo and Fr → En NMT models on raw data in the same data size configurations

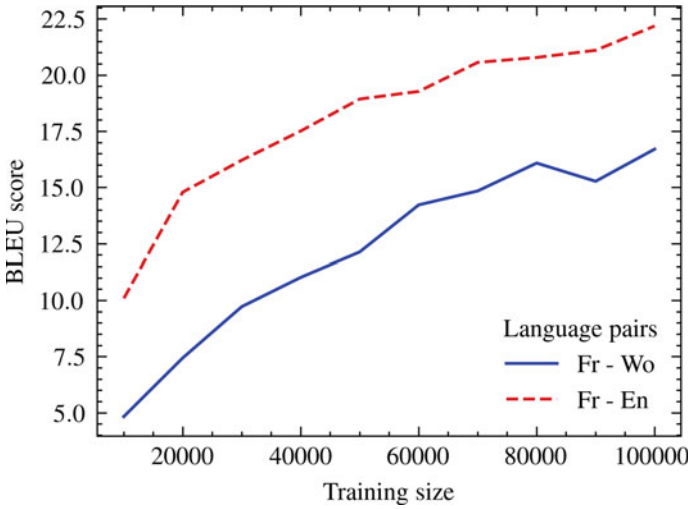

Fig. 5 Performance evolution of Fr → Wo and Fr → En NMT models on subworded data in the same data size configurations

6 Conclusion

In this article, we presented a French-Wolof parallel corpus of 100,000 sentences. This corpus was mostly collected from scratch, as openly accessible resources concerning this pair are scarce. As the collection project is still in progress, the dataset is not yet open. We then conducted experiments on various architectures of LSTM and global attention-based neural machine translation models and showed that these systems were more efficient on subworded data. Further experiments attempted to investigate the impact of linguistic similarity between a language pair on translation performance by comparing systems on two different language pairs under the same experimental conditions: Fr $\rightarrow$ Wo and Fr $\rightarrow$ En.

To the best of our knowledge, our corpus constitutes the largest corpus yet collected in this language pair and it is the first work where LSTM-based machine translation systems specifically for the Fr $\leftrightarrow$ Wo language pair are presenting the performance with the BLEU metric which allows to better appreciate the performance of NMT models.

However, the BLUE metric may induce biases and therefore not be sufficient for a complete evaluation of the actual quality of our systems [31]. Subwording also brought significant gains, but the SentencePiece method is language agnostic and may not be optimal for all languages. On the other hand, RNN systems suffer from the inability to handle long sequences even when LSTM or GRU [26] cells are used. State-of-the-art systems today are mainly based on the transformer architecture which has a better ability to handle longer sequences and allows parallelization as it does not do sequential processing. Cross-lingual transfer learning approaches have also shown very promising results in addressing machine translation for low-resource languages and are thus a relevant direction to explore.

In the future work, we plan to further extend our dataset and explore transformer-based models that, although data-intensive, can be optimized for a limited resource configuration [32]. We will also do a comparative analysis of multilingual models in order to choose the one that has better transfer learning performance with Wolof and perform transfer learning on it.

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The Alleged (Un)regulation of AI Use in Brazil: The Impact Assessment as a Solution

Marco Papp and Cristina Oliveira

Abstract Brazil, despite its recent advances in the regulatory sphere for Privacy and Data Protection, still remains unregulated regarding the use of artificial intelligence. In 2020, two years after the enactment of the General Law on Data Protection (LGPD), a Bill emerged that was the first Brazilian attempt not only to regulate, but also to define, classify, and identify AI-powered tools. However, among confusing meanings and vague typifications, the proposal failed to become the prototype that would generate a regulatory framework that encompasses both preventive compliance methods and possible remedial solutions for eventual disputes. Thus, the need emerges to seek pre-existing solutions in the Brazilian legislation that, although still undefined and precariously implemented, may be consolidated in the future as indispensable tools for the identification of eventual failures. This is where the mandatory implementation of the impact assessment comes in as a potential solution for the detailed analysis of AI-powered systems. Software architectures that are programmed to make automated decisions by means of machine learning techniques, for example, present certain risks, but the level of risk is unknown, precisely because of the lack of transparency about how their internal architectures work. Thus, a continuous and properly documented risk assessment will provide essential analysis both to substantiate a preventive system that survives the wear and tear of time in relation to inexorable technological advancement, and to serve as a broad and precise regulation, which will work as a legal instrument for any legal dispute that may arise in the years to come.

Keywords Ethics and AI · Regulatory framework · Impact assessment

M. Papp (✉) · C. Oliveira
Universidade de São Paulo (USP), São Paulo, Brazil
e-mail: marco.borges.papp@usp.br

C. Oliveira
Center for Artificial Inteligence (C4AI-USP), São Paulo, Brazil

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1 Introduction

In a world where everything is said to be "datafied" in machine language by the proliferation of digital and computational technology based on data analytics and machine learning algorithm systems, the information and communication infrastructure is increasingly dependent on "Big Data Space," that is, the "heterogeneous, decentralized, distributed space–time in which exponential amounts of data are stored and processed." In this way, while access is distributed, accuracy depends on a number of invisible factors.

In this sense, technological applications such as facial recognition, Internet of Things (IoT), smart grids, autonomous cars, virtual personal assistants, and robotics are being developed and used in what is known as the "Big Data Space." In the onlife universe, the communication and information infrastructure emerges and thrives on preemptive computing in light of the use of machine learning techniques in artificial intelligence systems.

Thus, with the increasing use of AI systems integration in our lives and in the scope of Public Administration, it becomes necessary to regulate this emerging phenomenon, considering the existing risks, such as, for example, the use of AI for the monitoring of citizens and their classification by the State, known as the dataveillance regulation [4]. Thus, it is important to analyze the legislative activity in Brazil to discipline the subject of AI, providing a space that inspires more security to its citizens.

For such a problem, the Bill 21/20 was elaborated with the pretension of, besides supplying a legislative lack, making it with the weight of a regulatory legal landmark. However, perhaps due to immaturity in terms of thinking about ethics applied to artificial intelligence and the technical inexperience of Brazilian authorities, this bill proved to be vague, confusing, insufficient, and implicitly copied from European Commission texts, such as the Guidelines on Automated Individual Decision Making and Profiling. However, for analytical purposes, it should be noted that the present work was prepared based on the original text, not considering the parliamentary amendments proposed so far.

It is worth, then, to propose a debate about a potential solution to the problem of the lack of regulation of artificial intelligence systems. This solution, beyond the need for clearer and more efficient legislation, would have at its core not only the implementation of mandatory impact assessments [14], but also a more solid and clear definition for its use in any and all operations that treat personal data in order to influence a society in an automated, uncontrolled, and unattended way.

2 The Brazilian Legislation for Data Protection and Use of AI Systems

With the publication of Law 13.709 of August 14, 2018, the notorious Brazilian General Data Protection Law (Lei Geral de Proteção de Dados Pessoais—LGPD, in the Portuguese acronym), as a central pillar in the system of protection of the rights of the data subject—together with the inclusion of item LXXIX in fifth article of the Brazilian Federal Constitution which, in turn, added to the list of fundamental rights the right to the protection of personal data, in both physical and digital environments—risk analysis as a regulatory approach has emerged as a new legal institute in which the protection of fundamental rights is gradually being regulated by means of prior regulatory instruments, such as licenses, risk analysis, documentation procedures, and accountability of the processing agents—controllers and processors.

This is the so-called preventive system, which was brought by the European experience in its campaign to regulate the growing and unbridled flow of personal data in the virtual seas of the Net in the dependencies of the European Union's jurisdiction.

Regulatory frameworks of the AI pre-existing in Brazil. Although the Brazilian legal system does not have a centralized national regulation for the use of artificial intelligence systems, there are already some guidelines that, transversally, affect AI, such as (a) Presidential Decree n. 10.222 of 2020, which approved the so-called "National Cybersecurity Strategy"; (b) STJ/GP Normative Instruction n. 6 of 2018, which established the pilot project for the application of artificial intelligence solutions in the Brazilian Superior Court of Justice; (c) Resolution n. 332 of 2020, of the Brazilian National Council of Justice (CNJ) that provides for ethics, transparency, and governance in the production and use of Artificial Intelligence in the Judiciary; (d) Decree n. 9.319 of 2018, which established the Brazilian Strategy for Digital Transformation (E-digital); and e) MCTI Ordinance n. 4.617 of April 6, 2021, which established the Brazilian Artificial Intelligence Strategy (EBIA).

2.1 The Supposed Brazilian Legal Framework for the Development and Use of AI: Bill 21/20

In February 2020, the office of Deputy Eduardo Bismarck presented a Bill with the purpose of proposing principles, rights, duties, and governance instruments for the use of artificial intelligence in Brazil, providing guidelines both for state action and for individuals or legal entities.

In order to regulate the incorporation of AI-powered technologies in economic, social, technological, research, and governance activities, Bill 21/20 sought to establish a general and neutral regulation so that the implementation of AI-powered technologies would generate beneficial and sustainable results. However, as every incipient regulation project is subject to immaturity and operational inexperience, both

from authorities and legislators, we will see below some crucial points that are susceptible to criticism due to deliberate omissions, exaggerated subjectivism, and interpretative vagueness.

About the deliberate omission in AI regulation. In the realm of AI applied to ethics (EA2AI), behind all declared eagerness for framing and adequacy of the development and use of systems powered by artificial intelligence, there is a deliberate omission [2] on the part of regulatory movements to avoid excessive restrictions that may generate the feared "anti-value" to the use of such promising technologies. The Brazilian case in the drafting of a Bill on AI use is no exception of deliberate omission.

This bill—which purports to be a regulatory framework—presents a rationale clearly oriented to Brazil's domestic needs, showing itself as a document that compiles numerous different and sparse ideas, clearly inspired by existing European instruments. However, despite the inspiration, the Brazilian Bill adopted the opposite position of the European texts, postulating subjective regulations and restrictions, as we will see later on the civil liability regime, besides questionable semantic definitions about which systems would fit as artificial intelligence.

Like most texts that aim to regulate the use of AI, the Bill lacks clear definitions and, therefore, depending on the interests of the stakeholders, it opens room for a worrying range of different interpretations. Law operators, from lawyers to judges, will be able to interpret each of these subjective definitions in any way they see fit.

About the incomplete definition of the term "AI systems." One can illustrate the interpretative problematics of such vague definitions, for example, by the definition of artificial intelligence itself. The text of the Bill defines artificial intelligence as "a system based on a computational process that can, for a given set of human-defined goals, make predictions and recommendations or make decisions that influence real or virtual environments." This definition is itself controversial, as it assumes that the end goals of AI are predetermined by human action [13], whereas in cases such as in the use of machine learning or deep learning techniques, the AI system has the ability to learn autonomously and thus adjust its end goals in ways unforeseen by the programmers themselves. Such a definition carries with it a naive and misleading perception that AI systems only function based on goals predetermined by human action, as if they were mere tools under the total control of humans. However, a more substantial and lucid definition would be that these technologies tend to have their own dynamics, and may eventually escape human control by influencing society without the possibility of surveillance and control by wholly human actions. Thus, the definition brought by the Bill would immediately disqualify AI systems driven by machine learning techniques [11], such as profiling tools, since these systems inevitably "influence real or virtual environments," but without necessarily being subject to a "certain set of human-defined goals."

Other semantic vagueness. It is also worth mentioning other misused definitions of terms in the Bill's text, such as the use of the word "ethical" in articles 5, 12, and 15, as a preliminary definition erroneously used in place of "beneficial" as if they were equivalent or even synonymous terms. This semantic confusion denotes a real lack of reflection on ethics applied to AI [12].

Similarly, other terms such as "democratic values" and "non-discrimination," present in the fourth article, and "free from prejudice" and "welfare," both in fifth article, are some of several other examples of traditional formulas that are used as sufficiently vague terms to allow for an eventual extensive and flexible interpretation.

A confusing and vague wording like this brings risks to the proper operationalization of a Bill that pretends to be a legal regulatory framework because, considering that human rights—a concept widely invoked in documents that aim to regulate the use of AI—are not yet the product of a universally shared vision, the possibility of this type of document eventually serving as an instrument of treatment for future problems arising from "gray areas" is put in check right from the moment of its issuance.

The lack of characterization and attribution of responsibility. In the text of the bill, the problem of the capacity for self-learning and autonomy in decision making and action of systems or robots was affirmed, which is configured as the biggest challenge for the regulation of the use of AI. To this end, some articles deserve to be highlighted for further analysis. The ninth article establishes the duties of responsibility of AI, while the eighth article recognizes access to the protection and defense of individual and collective interests and rights through access to judicial protection.

Analyzing these provisions, it is remarkable how ambiguous the respective texts are with regard to civil, criminal, and administrative responsibility regarding the problems that the use of AI can bring to the natural person. It was not specified, for example, the type of liability that would be contemplated, whether objective or subjective. This vagueness about the type of liability that is applicable can become an obstacle for those who consider that an interest or right has been damaged by a decision made by the AI, making judicial or administrative protection opaque in cases where the Brazilian Consumer Protection Code is not applicable.

The European Parliament Resolution as a possible recommendation. In this controversial issue, the ethical principles considered by the European Parliament in the treatment of AI-driven systems could have been observed in order to incorporate rules so that AI would be subject to user control, and not the opposite, in order to avoid conferring an "autonomous" power to AI in matters that could harm human rights. In this sense, the model that could have been considered by the legislator is the Resolution of the European Parliament from October 20, 2020, which dealt masterfully with the establishment of civil liability rules for regulating the use of AI based on a risk system as a recommendation to the Commission [8], the European Union's highest authority on data processing and its ramifications in the field of technology.

This resolution carries with it a distinction between high-risk and low-risk systems. For high-risk systems, the strict liability regime would be the best fit without, however, exempting a possible declaration about the exercise of due diligence caused by the autonomy of the program or device powered by AI techniques. For systems that present low risk in the use of AI, the European Parliament resolution recommended a

system that covers subjective liability according to a standardized analysis of intention or failure. Also, for the case of low-risk systems, if the AI system has been activated outside the control and determination of the operator who operationalizes these processes, the program or device can be exonerated. Thus, since the responsibility for taking measures to prevent or mitigate harm lies entirely with the owner, vendor, or operator, they are also required to prove that due diligence has been performed both for the selection of the AI system—with respect to control activities—and for proper support or maintenance. Thus, strict liability could be established for any and all AI systems used in devices—robots or intelligent units—in relation to potential damages in real or virtual activities.

3 On the Implementation of AI Impact Assessment for Risk Prevention

From the regulatory analysis above, it is clear that Brazil is notoriously unprepared to legislate for preventive regulations. The remedial culture is still strong in the Brazilian context. Legislators and jurists still value a legal system that typifies clear and complete provisions in favor of the solution of disputes—and yet they evidently failed to assign the type of responsibility, for example, as shown above. It is necessary to evolve to a legislation focused on the prevention of problems, and not on their remediation. Remediation should exist as a residual solution only for problems that could not be solved before they arose. To this end, one of the most efficient instruments of prevention against the injury of fundamental rights of data subjects is the impact assessment.

The practice of using impact assessment has grown increasingly in the sphere of personal data protection, appearing as the main means of risk analysis for documentation by which the controller—the one with decision-making power in the data processing chain—records the processes involving data processing, as well as the respective tools adopted in favor of mitigating the risk that an operation could entail to the rights of the data subjects [6].

For the European case, protected by the General Data Protection Regulation—in its acronym, GDPR—the controller is obliged to prepare an impact assessment for every operation that represents a high-risk. To this end, there is a list of examples of hypotheses for cases in which an operation may represent high-risk data processing, especially profiling operations, as noted above. In the Brazilian scenario, however, we will have to wait for an eventual imposition of this obligation by the National Data Protection Authority (ANPD), since this obligation is not explicitly stated in the LGPD and, most likely, it will not be in a future regulation on the use of AI either.

3.1 A Regulatory Approach Based on Risk Management

For a better understanding of risk management tools, it is necessary to understand the dichotomy between regulatory approaches based on fundamental rights and those based on risks.

While each and every controller, in order to respect the fundamental rights protected by the Federal Constitution, must observe the principles that govern the discipline of personal data protection through judgments of adequacy, necessity, and reasonableness of data processing according to the specific purpose (rights-based approach), it is also the controller's duty to determine the type of processing and the privacy risks of the data subjects in order to correctly implement accountability measures, such as impact assessment (risk-based approach).

Artificial Intelligence Systems (AIS) risk management. Artificial intelligence systems, such as those used for facial recognition and profiling, have a highly unpredictable character and, therefore, in risk assessments, it becomes complex to level out the risk that an automated decision—or even those resulting from machine learning processes—may imply in specific situations [7], increasing the possibility of catastrophes, besides the possible direct violations (non-compliance) to the fundamental rights and freedoms of data subjects.

Thus, it is understood that the medullary point of risk-based tools must approach in a scalable and proportional way to the controller in favor of a stable and lasting compliance. That is, the greater the risk that a certain data processing may offer according to the range of events that can be foreseen in a certain software architecture that bases its conclusions on artificial intelligence, the greater will be the need for the controller's compliance with the law. Therefore, the level of accountability obligation will be linked to the level of risk that the operation presents.

In this sense, extracting from the principles of security, prevention, and accountability present in the sixth article, the LGPD systematically advocates the obligation to implement minimum security measures that protect the rights of the data subject from the documentation of processing activities—the so-called Register of Processing Activities (ROPA), a document derived from data mapping—regardless of the level of risk of the operation. Thus, the question that arises is: If the factor "high-risk to the data subject" would determine the scalability of the obligation of compliance with the law that the data controller must submit to, what would then be the form of identification of these risks so that they may be duly evaluated and mitigated? The answer provided in the Brazilian legislation would be the risk assessment, a genus in which the Personal Data Protection Impact Assessment (RIPD) is a kind.

The risks of Profiling by AI. Beyond the conceptual differences between privacy and data protection, with important dogmatic consequences, it is necessary to identify the possible threats that automated AI profiling poses even to the basic rights of a data-driven society, in view of privacy rights and recent data protection legislation. The hidden capabilities of preemptive computing and automated decisions based on profiling technology raise individual and collective questions, bringing new nuances

to the assertion about collective data protection, involving the legal protection of so-called "group privacy." Only with an understanding of the possible threats to privacy and the protection of personal data can one move to a more specific level of assessing the risks associated with the use of data analysis technologies.

The generation of new profiling categorization models is only possible through the use of profiling techniques, which means that it is a key component of knowledge generation through predictive analytics and machine learning algorithms embedded in AI-powered software running on specific hardware. In this view, since humans are constantly and unconsciously profiled by automated systems that invisibly make decisions about their lives based on deducible knowledge, privacy protection must ensure that individuals have a role to play in codetermining how it is read and represented.

Kranzberg's [9] statement that "technology is neither good nor bad, it is also not neutral" soon led to a move away from both technological determinism and the instrumentalist view of the neutrality of technological artifacts. The conclusion remains that a sustainable and fair implementation of new technologies can only be achieved through specific regulations that clearly and objectively define the implementation methodologies, the restrictions on use, the level of risk in relation to the expected purposes, and, finally, accountability through fair and appropriate sanctions for the stakeholders.

In keeping with what was said earlier about profiling technologies, during the stages of profiling and adoption there is no limitation on action over individuals. There is a range of scope about grouping, including group profiling, which is an essential method of algorithmic classification present in automated profiling. This means that the computed profile, in relation to data mining and correlation patterns, is linked not only to individuals—identified or identifiable—but also to behavioral patterns or characteristics associated with groups (communities or categories).

As a result, technologies that use and apply profiling are able to handle data that is not fundamentally personal as it identifies groups or collectives. This is the case, for example, in applications that segment a group of consumers by certain consumer preferences to deliver targeted advertising, price discrimination by region, or explore, from group identity migration patterns, the future foci of infectious diseases.

The novelty that automatic profiling brings to the collective level is the algorithmic creation of special categories or groups. Unlike communities, groups pre-existing the operation of algorithms in the process of "knowledge discovery in databases," categories include dynamic groups that are the result of processing and extracting large volumes of data. The central characteristic of this type of group is that, from data processing, it is determined remotely by a computer, so that group members do not necessarily know they belong to the group.

Group profiles can be community-related or category-related. The former are pre-existing groups, where data mining is done to track correlations and patterns and thus identify common characteristics of the group members (ethnic group, ethnicity, employees of a company). In turn, categories are formed after correlations are established by data mining algorithms that identify common attributes.

As a result, the right to the protection of personal data is threatened with violation due to the invisibility and unawareness involved in personal data processing activities,

in addition to the usual opacity of algorithmic systems that in turn already change the way profiling is carried out. This deprives data subjects of the ability to control the processing of their information, losing in turn the ability to challenge the automated decisions that are made from their data, culminating in the injury of their rights and interests.

As for the prism of private life, the right to the protection of personal data can also be violated as the process of identity construction is interfered with by artificial agents that can operate from a human misrepresentation. Indeed, the assumption that human complexity and the indeterminacy of identity can be documented, "datafied," and represented by algorithmic systems is flawed.

Discrimination based on group identification is a possibility with very serious consequences. While the processed data and inferences resulting from the construction and application of profiling are considered anonymized, to say nothing of identified or identifiable individuals, it is possible that they will act, from knowledge extracted from databases, on algorithmically determined group identification.

It is notable, therefore, the need to implement mandatory impact assessment in order to prevent and mitigate the potential risks of indiscriminate use of automated profiling techniques powered by artificial intelligence systems. Risk assessment in the use of profiling techniques will be the key to identifying correlations and causalities between software powered by machine learning and its consequences for the daily lives of data subjects.

Implementing Impact Assessment. Given that the theoretical basis of the legal device that governs data protection in Brazil was inspired [3] by the European experience of preparation of the General Data Protection Regulation (GDPR), among the similar obligations and instruments between the two legislations, one of the adaptations brought by the Brazilian legislation was the Personal Data Protection Impact Assessment (RIPD), which in turn is equivalent to its homonym first created by the European authorities, the Data Protection Impact Assessment (DPIA).

The regulation of the RIPD still faces challenges because it appears as a tool still misunderstood, in which its scope and limitations are yet not known. About this, the main challenges for the regulation by the Personal Data Protection Impact Assessment (RIPD) suggest that the tool be identified in its real functions according to its role in the LGPD, supported by the notion of risk from its analysis and documentation, based on the hypotheses of mandatory preparation according to an adequately defined methodology and that, finally, such accountability to the ANPD be demonstrated from well-established parameters, not dismissing the possibility of eventual publicization.

Considering that the European Community guidelines offer a clear, objective, and specific parameter about the attribution of a civil liability system for risk management and prevention, it would be possible to adapt the Brazilian legislation to a model that could provide for an insurance system that would better guarantee the AI provider's compensation and solvency, giving rise to a better categorization of risks so that a solid implementation of impact assessments for the use of programs or devices based on automated decisions by AI would be possible.

The need to impose constant evaluations on the results of fully automated decisions is highlighted by the Guidelines on Automated Individual Decision Making and Profiling, regarding the relevance of measures and procedures to prevent errors, inaccuracies, and discrimination.

It is noticeable that, in the Brazilian scenario, the use of artificial intelligence for automation of decisions is not preceded by the preparation of impact assessments, especially when employed by the public initiative, since, according to the provision of the Brazilian General Law of Data Protection, there is the possibility of justifying the use of sensitive data—such as biometric data—when the shared processing of data is interpreted as necessary for the implementation of public policies set forth in laws or regulations by the public administration, as provided in Article 11, item II, paragraph (b).

However, despite the aforementioned provision, the LGPD does not have the prerogative to define the procedures for the preparation of the impact assessment for the use of AI, even though its article 20 contains the provision about the possibility of auditing decisions resulting from automated processing of personal data. It is necessary, therefore, to differentiate the impact assessment foreseen in the LGPD from the one that should be foreseen in eventual regulation of the use of AI. Whereas the Data Protection Impact Assessment (RIPD) provided for in the LGPD is intended to describe personal data processing processes that present potential risk to civil liberties and fundamental rights, the impact assessment that will eventually be implemented from specific regulation for the use of AI, in addition to the attention to data processing, should focus on the obligation of a detailed description of the output and the methodology used for the development of the system to mitigate decision bias, as well as the ways and means by which the training of systems using machine learning or deep learning techniques will be done.

Thus, it can be inferred, in line with current Brazilian legislation, that one of the demonstrative indicators of compliance with the law pointed out as a tool by the LGPD is the systematic analysis through the preparation of data protection impact assessments. However, the theoretical confusion between what would qualify as risk and what would be, in essence, a direct violation (non-compliance) causes the risk analysis to be postponed to a later stage than the impact assessment. This negligence is also a reason for the weakening of the mechanisms of prevention and mitigation of damages to data subjects.

The primary need and ultimate purpose of the impact assessment is to conceive, from the documentation and analysis of the data processing performed, an effective instrument of data governance that provides a fertile and secure soil for increasingly safe, predictable, and potentially less damaging decision-making, especially when it comes to automated decisions. Therefore, the culture of risk analysis and impact assessment preparation should be the perennial beacon of a healthy development of data processing in Brazil through the constant updating of impact assessments throughout the process of implementing artificial intelligence technologies that produce automated decisions in data processing in any and all sectors of society, whether private or public.

In this perspective, in order to guarantee the right of the data subject to understand the logic of the decision-making process and the meaning of the intended consequences, this new regulation on the use of AI will put the burden of proof on the controller to demonstrate the legitimacy of the fully automated processing by AI systems. The controller will have to demonstrate not only the sources and ways of collecting personal data, as already provided for in the LGPD, but also (a) the general lines of programming of the algorithms and their objectives; (b) explanations on the development of these algorithms; (c) the possibility of the algorithm modifying its own code without human intervention, as well as the predictability and verifiability of these modifications; (d) the relevant categories of profiles and their criteria; (e) the outputs of the decision-making process and their respective possibilities for assessing suitability and accuracy; (f) the feedback mechanisms; (g) the level of human intervention; (h) the main impacts on the data subjects and the respective risk mitigation measures.

4 Conclusion

Through specific legislation, such as the General Law of Data Protection (LGPD), regulations and ordinances, in addition to the recent transformation of the Brazilian National Authority for Data Protection (ANPD) into an autarchy, Brazil is on a slow but steady path that, if it continues at a gradual pace, will result in a solid and broad set of regulations to deal with issues such as privacy, data protection, metaverse, and artificial intelligence.

However, the proposal of norms in favor of broad and efficient regulation cannot be based solely on analogies and paraphrased copies of European texts. One cannot depend exclusively on the adoption of European terms, words, principles and values, because it is fundamental that each and every legal instrument must be contextualized and adapted to the specific circumstances and needs of each country, according to domestic precedents.

Legislators must learn from the pre-existing regulations of other countries, but they must go beyond mere paraphrasing. It is necessary to identify similar concepts and adapt them to the Brazilian reality, attending to the legal assumptions of responsibility, sanctioning typifications, and jurisdictional reach.

While ethics aims to extend individual rights in consonance and balance with collective rights, laws must be restrictive. To fulfill their restrictive role, however, laws must bring with them very well defined concepts and clear, possible, and efficient sanctioning parameters. However, this is not what Bill 21/20 has presented, given that its confusing and vague wording will make it impossible to impose efficient sanctions against offenders who permeate deviant behavior in relation to the beneficial, appropriate, and fair use of AI-powered technologies.

It takes time and caution to craft normative devices that aim to regulate the use of technologies with such potential for evolution and architectural modulation.

However, more important than creating laws with restrictions and severe sanctions, it is necessary to implement preventive action mechanisms, such as impact assessments.

Impact assessments will not only bring greater security for data subjects who have their information processed in an automated way, but will also enable entire databases to be filled with detailed analyses. These analyses will provide a solid framework about how various types of AI system architectures have been used in society for various purposes, assigned by private actors as well as by public policies and other state actions.

The remediation of disputes arising from violations of the fundamental rights of data subjects should only figure as the last alternative in such delicate issues as those involving personal data and automated decisions based on AI. It is necessary to pave the way for a perennial adoption of preventive systems so that the regulation of the use of AI can withstand wear and tear over time due to continuous technological innovation. To this end, in addition to figuring its pole of action in a preventive system, it should be broad and objective enough to be able to address the most varied problems that the creation of new AI system architectures—especially those powered by machine learning—may raise in the future.

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Tunneling and Replication in Hierarchical DFS

Ladislav Pešička and Luboš Matějka

Abstract Nowadays, distance learning, 5G mobile networks, and 4K cameras in mobile phones generate a large amount of data consumed on demand. The storage systems must fulfill these demands. This chapter presents a counting algorithm to optimize access in the hierarchical distributed file system. Different access strategies, such as tunneling, replication, and reconnection, are discussed and used to optimize file access.

Keywords Distributed file system · Replication · Hierarchical storage

1 Introduction

Today's world is highly connected with devices requesting data from servers. These servers rely on distributed file systems (DFS) for requested data. Traditional methods of DFS access are changing as data access patterns adapt to social network and mobile client needs. DFS is handling increased amounts of data requests, low access rates, and subsequent file archiving.

The hierarchical architecture of storage is the best way to enable data storage demands. A proper storage policy can store highly requested data at the fastest and highest layers of the storage node. Storage system scalability is achieved through increased DFS usage and storage nodes. Storage nodes replicate files, which improves the performance of DFS. When DFS is combined with a hierarchical file system, the resulting distributed hierarchical file system (hierarchical DFS) can fulfill data access needs.

Replication increases a system's performance, as well as its reliability. In turn, data is available if nodes fail. However, replication consumes storage space and affects

L. Pešička (✉) · L. Matějka
DCSE, University of West Bohemia, Plzeň, Czech Republic
e-mail: pesicka@kiv.zcu.cz

L. Matějka
e-mail: lmatejka@kiv.zcu.cz

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synchronization. Data tunneling and replication can increase the storage system's performance [1]. In addition, client-side data caching improves performance [2].

Hierarchical DFS must consider the following: (1) the location of stored data; (2) the number of replicas required for files; and (3) the suitable strategy for data access, including replication and data tunneling or client redirection to another server node. This chapter aims to design a proper algorithm to optimize data storage and access in a hierarchical DFS.

2 Replication

Replication is a DFS process in which the file, whether whole or its sections, is copied from the primary location to other servers in DFS. The algorithm determines the replicated data, the nodes, and the number of maintained replicas. Replication improves performance, availability, and fault tolerance. However, replication can lead to issues related to consistency.

Replication improves the reliability of the storage system. For performance issues, the system can create temporary dynamic replicas in the random access memory (RAM) disk to survive access peaks. These replicas do not increase reliability. Instead, they improve system performance. Replicas in nonvolatile memory (solid-state drives, rotating disks) increase storage performance and reliability. New replicas demand storage space and must be synchronized.

2.1 Replication in Different DFS

Different approaches are found to maintain data replicas. The first creates a permanent number of replicas, typically three at the time of file creation [3]. An example of this approach is Hadoop [4, 5]. The only other consideration is to create a replica at another storage rack, if applicable. The second approach dynamically creates replicas to increase the storage system's performance. The third approach does not ensure replication; it relies on independent software to make durable data. An example of this approach is Luster.

The replication of Gluster FS [6] is similar to RAID 1 mirroring. For example, there are four storages (S1, S2, S3, S4) and a replication factor of 2. Two subsets are formed by mirrored data storage (S1, S2) and (S3, S4). Gluster FS uses three volumes: (1) distributed, (2) replicated, and (3) stripped.

DFS Ceph provides three replication strategies: (1) primary copy, (2) chain, and (3) splay. Primary copy processes read and write on the first node. It updates replicas in parallel. In chain copy, writing is performed sequentially; reading is allowed after the last replication. Splay replication is like chain replication. However, half of the replicas are written sequentially and then in parallel.

Some systems, like iRODS, do not automatically replicate data [7]. It is possible to create rules running the replication after a specific operation. The users control the replica distribution policy.

3 Model of DFS Access Strategies

DFS consists of the set of file servers {FS1 … FSn}, and the clients connected to the servers. A high-speed network interconnects the server nodes. Each server node has a hierarchical structure of storage. Although the client can connect to different server nodes, the connection can have other characteristics. The default operation discussed in this chapter is the READ_FILE request.

The demonstration example uses a client connected to the FS1 server (see Fig. 1). The client needs to access data. Required data may be stored on FS1 or another file server. There are several approaches to how the DFS can react to this request. This chapter discusses both traditional (see Table 1) and new approaches (see Table 2).

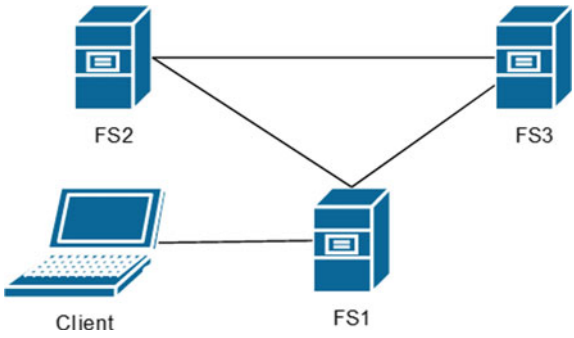

Fig. 1 Client connected to file server FS1

Table 1 Approaches related to how the client can access required file

Approach	Action	Description
Direct connection	– FS1 sends data to the client	Data served by FS1 node
Redirection	– FS1 sends a redirection message to the client – Client reconnects to another node	FS1 node redirects the client to another node
Replication	– Data are replicated at the FS1 node – FS1 sends data to the client	Replica created at FS1 node to increase performance for further requests of the file
Replication with redirection	– Data are replicated at a node different than the FS1 node, e.g., FS2 – FS1 → FS2 redirect message to client – Client reconnects to another node	Replica created at node more suitable than FS1 The client was redirected to the node to access the data

Table 2 Data tunneling access approaches

Approach	Action	Description
Data tunneling	– A tunnel from the FS1 server to the server containing data is established – Data provided to the client through FS1 node by created tunnel	Data tunneling may be better than redirection or replication. Data is accessed quickly The client accesses preserved link to DFS (client—FS1)
Data tunneling with optimization	– Data is stored at the connected FS1 node at the slow storage layer – Tunnel from another storage node with a quicker storage layer performs better	Data tunneling considered in this case Data directly stored at the connected node

3.1 Traditional Access Strategies

Direct connection is the simplest case. The FS1 node delivers data directly to the client. We can influence what kind of data will be stored on that node, including the data most accessed by the client.

If the server FS1 does not contain the requested data, it will locate a more suitable node for the client's data access. The client will receive a redirection message from node FS1 to reconnect to server FS2. This sequence is the expected behavior of the DFS. However, the new link between the client and server FS2 may not be faster than the link between the client and FS1.

Redirection and replication approaches improve DFS performance. Sometimes, it may be better to create a replica at different nodes rather than the node FSx in which the client is connected. Reasons include free storage space, node utilization, and link utilization.

3.2 Data Tunneling

The approaches previously mentioned, such as client reconnection, are used in current distributed systems. The new approach extends basic access mechanisms through data tunneling and data tunneling optimization [1, 8]. This tunneling mechanism outperforms local access to data.

As shown in Table 2, the client stays connected to the FS1 instead of reconnecting to another node. The file server FS1 mediates the data transfer from server FS2 through server FS1 to the client. Therefore, the data are tunneled from the file server to the client through the server FS1.

3.3 Data Tunneling in Hierarchical DFS

The concept of data tunneling can be subsequently extended through a hierarchical model. Tunneling from the remote node may outperform local storage access, even when the data are in local storage at the FS1 node. It can happen when the data are stored in lower (slower) layers of a hierarchical model at the local FS1 node. It can

also occur when they are stored in higher layers of a remote node. Storage layer speed can outperform the costs of data tunneling. Data tunneling provides better performance and lower access time—the client can access the best storage options for the required data. If the server connected to the client does not have the files' best replicas, it can provide high-quality replica access through data tunneling.

The client is rarely forced to reconnect to other file servers. Reconnections cause overhead, including establishment of new network connections and delays in data access. The entire system is more predictable and stable. Data tunneling also has some disadvantages—data tunneling places demands on system resources, including CPU decision-making times, bandwidth use related to the links between server nodes, and CPU tunneling times. It does not cause a significant load for an individual client. However, more overhead is required as more clients connect. In many DFS, server nodes are connected through robust, high-speed links to handle this load.

The decision parameters to determine the proper access strategy (i.e., reconnection, data tunneling, direct access) are shown in Table 3. The general decision algorithm on the storage node FSx is presented in Algorithm 1.

```
Target = null;
TargetCandidates = null;
(1)         Required data are stored on the connected
       node FS1?
       Yes:  TargetCandidates = FS1
(2)         Find all remote nodes where the required
        data are stored.
        Add them to the TargetCandidates.
(3)         Evaluate the cost of data transfer
        from TargetCandidates.
       Put the best node to the Target.
(4)         Decide whether it is better to reconnect
        the client to the node Target or use
        data tunneling from the remote node through
        FS1 or use local node FS1:
Reconnect:
- Send client reconnection message to the Target
- Send required data to the client from the node
  Target
Data Tunneling:
- Prepare data tunneling (Target -> FS1)
- Send required data to the client through
  the Target -> FS1 -> client
Direct Access:
- Access the data from the local storage FS1
  (Target = FS1)
```

Algorithm 1: General decision algorithm

Table 3 Decision parameters

Parameter	Description
Location of replicas of required file	Metadata server (databases) knows the location and storage speed of all replicas of the stored files. This information is easily obtained
Client access speeds to different servers	Clients can periodically measure access time to different server nodes. The network can be divided into regions. The client can only access servers from its own region

4 Counter-Based Algorithm

This chapter has discussed how to optimize file access through client redirection, data tunneling, and data tunneling with optimization. Decisions are based on data metrics such as access counters, our proposed algorithm.

It is crucial to decide which storage layer will hold the data. By adopting a simple rule, the data will be stored at the fastest layer with sufficient capacity. The data will move to slower layers if other files are more frequently accessed. Rather than moving the file to a slower layer, the new replica or a part of the file can be created at another node. Conversely, both approaches can be combined to move to a slower layer at a given node and make a replica at another node. Metrics to support this decision include measuring how often the file is accessed for reading and writing.

The counter can be a simple integer value that adds one each time the file is accessed. The value can also be regularly diminished to present access characteristics "in the last time." The reading counter can be global, regional, or local for the given storage node. The counters can be:

- Local for the given storage node
- Region-based (global for the set of storage nodes)
- Global for the whole system (value changes when the file is requested at any storage node).

Replica requires writing. Therefore, the writing counter should be global. A high amount of writing indicates that the file is often changed. In such a case, tunneling is a better option because each replica must be updated via writing requests.

4.1 Used Counters

Local counters are defined at each node. The counter increases when the local node provides access to the file f1 for reading or writing. The counters are:

- **Rcount(f1)**: Amount of reading access to the file f1 at the local node
- **Wcount(f1)**: Amount of write access to the file f1 at the local node (the write access is performed at each node with the replica of the f1 file)

– **RcountReq(f1)**: The client requested a file from this node (however, the file is not stored here)
– **RcountTun(f1)**: File is tunneled through this node.

High values of RcountReq or RcountTun mean that the file would be accessed from this node. Therefore, a replica at this node is considered. On the contrary, high values of Wcount mean that the file changes often. Therefore, replica changes must be maintained.

Local counters choose the proper layer of storage at the given node. When file f1 is in high demand, the file (or parts of the file) can move to higher layers. When the file is not accessed, the higher layer can be freed to another file.

An example of counter manipulation is shown in Fig. 2. The client requests the file f1, and the connected node FS1 modifies the RcountReq counter. The other nodes, FS2 and FS3, modify their RcountTun counters. The purpose of the counters is depicted in Table 4.

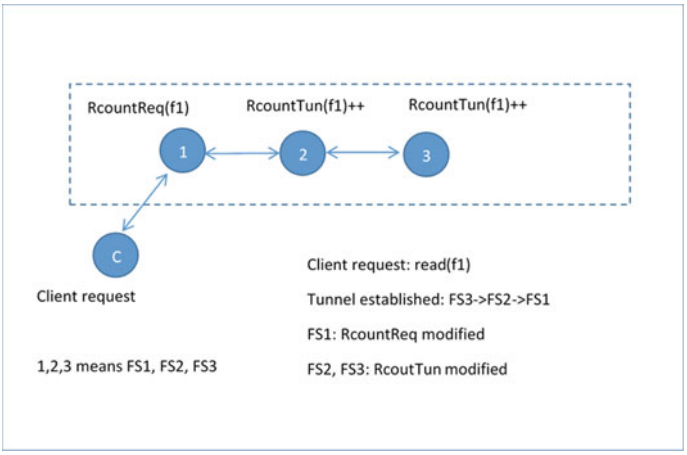

Fig. 2 Local counters and their role in replica decision

Table 4 Counters and their role in replica decision

Counter name	Usage	Meaning
Rcount	When the file f1 is requested from the local node and the file is stored at the local node	The importance of storing the file at the local node
RcountReq	The file f1 is requested from this node, but it is not stored there	The need for a replica at a given node
RcountTun	Another node requests the data to be tunneled through this node	Shortening the tunneling path

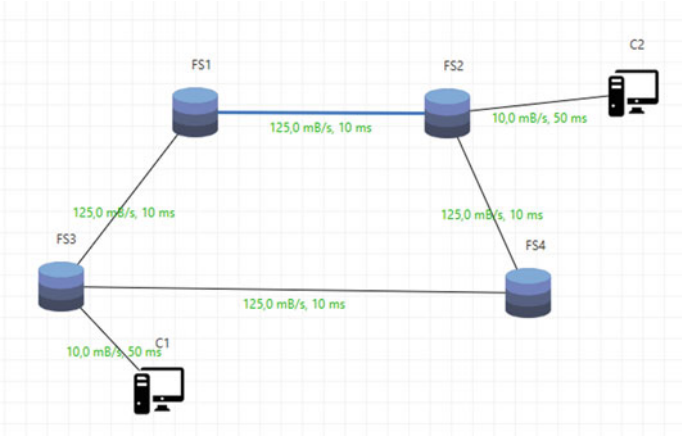

Fig. 3 Experimental topology

4.2 Decision Algorithm

The primary decision issue is based on counter values, as shown in the following chapter. In short, the algorithm provides the following steps:

1. Client requests file f1 from the connected server node
2. Server node decides how to fulfill the client's request
   (Direct access, Data tunneling, Replica creation, Client redirection)
3. Counters help to decide how to optimize storage for further requests.

5 Testing and Results

In the testing scenario, the network consists of file servers FS1 … FS4. Each server has three layers of storage with the following read access speeds: Layer 1–250 Mbps, Layer 2–90 Mbps, Layer 3–55 Mbps. Clients C1 and C2 are connected to servers (see Fig. 3) with the fastest links. Both C1 → FS3 and C2 → FS2 links have a speed 10 Mbps and latency of 50 ms. The clients regularly test the network connection speed against other file server nodes to be prepared for the reconnection request. The file f1 has 100 MB in size. It is located at FS2, Layer 1.

Request 1—C1 wants to access the file f1

1. C1 sends the request to the connected server FS3.
2. FS3 doesn't have the file f1, but the file is located at FS2. If FS3 is overloaded, it could send the reconnect_to(FS1) message to client C1.
3. FS3 established the tunnel FS3 → FS1 → FS2 to provide data to client C1. RcountReq(FS3) and RcountTun(FS1 and FS2) are increased.

Request 2—C1 wants to access the file f1
Similar steps occur as in previous requests. Both tunnels FS3 → FS1 → FS2 and FS3 → FS4 → FS2 are possible and equivalent. The tunnel, in this case FS3 → FS4 → FS2, is established. RcountReq(FS3) and RcountTun(FS4 and FS2) are increased.

Request 3—C2 wants to access the file f1
The server FS2 directly meets the request from client C2. The counter Rcount(FS2) is increased for file f1.

Request 4—C1 wants to access the file f1

1. The tunnel FS3 → FS1 → FS2 is established.
2. The threshold RcountReq(FS3) for file f1 is reached. The file f1 starts to replicate at FS3. When the replication is complete, the counters for the replicated file RcountReq are cleared where the replica is created (FS3).

Request 5—C1 wants to access the file f1
The server FS3 directly meets the request from client C1.

The counters select where the replica should be created, as well as if the replica will be used. The counters algorithm will help to optimize file access and replica creation decisions.

6 Conclusion

This research aimed to propose new approaches to how DFS can optimize performance. Today, client devices consume data provided via DFS. Mobile clients connect through changing network access speeds. In addition, client numbers and locations are changing. The power of server nodes has increased. Therefore, they can manage more processing overload. It enables us to store other attributes connected to the file, including counters in the algorithm. This chapter proposes an algorithm with counters. Counters assist in the selection of a proper replica location. Large DFS can be divided into regions, limiting the impact of the counters' overhead.

Replicated files consume storage space and increase maintenance overhead. Data tunneling and replication improve DFS performance with frequently written files. It also creates better access times after the first requests and prior to the creation of replicas. The proposed algorithm automatically chooses the optimal strategy, data access, storage location of the new dynamic replica, and optimal performance of the DFS.

DFS must cope with the changing, growing structure of the client and mobile devices. This approach, featuring data tunneling and counters algorithm, chooses the optimal access and storage strategy in the DFS.

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SAFeComNet: Safer Artisanal Fishing intEgrating a COMmunity NETwork

Fatoumata A. Y. Diouf, Madoune R. Seye, Moussa Diallo, and Bamba Gueye

Abstract In Senegal, artisanal fishing activities are increasingly carried out in white areas, in total absence of communication networks. This situation puts the fishermen at risk as they have no means of exchange with each other or with the mainland. Thus, we propose an architecture based on LoRa technology and enabling the transfer of important information such as location, messages and alerts. The works presented in this paper focus on a location update algorithm which enables each node to know the position of each of its neighbours. The proposed location update algorithm is evaluated respectively in an experimental and in a virtual test bench.

Keywords Ad hoc Network · Artisanal fishing · Communication · Localization update · LoRa

1 Introduction

Like many maritime countries, fishing plays a very important economic role in Senegal. This sector includes three branches of activity: inland fishing, marine fishing and aquaculture. However, most of the activities are related to maritime fishing (industrial and artisanal) which has an important impact on the national economy. Senegalese seas are among the most fish rich in the world. Indeed, with its 718 km of coastline, Senegal has a large continental shelf of 196,000 km^2 [1]. The regional program to

F. A. Y. Diouf · M. R. Seye · M. Diallo (✉)
Department of Computer Science, Polytechnic Institute (ESP), Cheikh Anta Diop University, Dakar, Senegal
e-mail: moussa.diallo@esp.sn

F. A. Y. Diouf
e-mail: fatoumataawayandediouf@esp.sn
URL: http://per-edmi.ucad.sn/~moussadiallo/

B. Gueye
Department of Mathematics and Computer Science, Faculty of Science and Technology (FST), Cheikh Anta Diop University, Dakar, Senegal

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strengthen the collection of fisheries statistical data in Member States and the creation of a UEMOA regional database, enabled Senegal to carry out the framework survey of artisanal marine fisheries in 2014. From this document [2], it appears that at the sub-regional level, Senegal, which has 72% of the fishing fleet of UEMOA countries, with a motorization rate of 85%, is the leader.

However, in the last two decades, the increase in the number of industrial fishing boats and climate change have completely unbalanced the artisanal fishing sector due to the scarcity of resources [3]. Today, artisanal fishing has become offshore ($\geq$ 10 km from the coast) and fishermen are forced to venture far from the coast in search of resources. Thus, artisanal fishing activities are carried out white areas. White areas are areas where no operator has deployed its mobile and/or Internet network. The fishermen of these pirogues have no means of communication, alerting or sharing information with other pirogues operating in the same area or with the mainland (national navy or fishing pier). This problem of safety at sea makes the social and human conditions difficult with more than a hundred deaths per year. These human losses have social and economic consequences for the country. However, it is important to note that industrial fishing, transport and recreational vessels are almost all connected to the AIS (Automatic Identification System) which is an electronic revolution for safety at sea [4]. But the very limited purchasing power of artisanal fishermen does not allow them to access this type of system.

The issue of safety and management of fishing activities in maritime areas which is not connected to a land cell phone network is pending. SAFeComNet wants to offer a dedicated geolocation and communication system. Our research is therefore oriented toward a low-cost solution for fishermen, taking advantage of free long-range frequency bands but also relying on new technologies of communication by electromagnetic waves and miniaturization of geolocation systems. The idea is to set up a very long-range ad hoc network for the transfer of information (position, heading, speed, weather, alerts …) by the implementation of the different connected devices. But also the collection of geolocation information for the creation of a database. This database will be of great importance for the management of the exploited areas/species, and will allow to improve the dynamic models of the fisher-fish-environment systems.

It is very important to note that in the SAFeComNet context, there is no central equipment to organize all the nodes (Embedded device in each pirogue). Therefore, the nodes do not have any knowledge about the position of their neighbours. In this paper, we focus on this problem. We propose a location update algorithm which enables each node to know the position of each of its neighbours.

The remainder of the paper is organized as follows. Section 2 describes SAFeComNet communication architecture as well the different SAFeComNet components. Section 3 analyses the SAFeComNet communication model and the algorithm used. Section 4 discusses the results of the experiments. Finally, Sect. 5 concludes our work.

2 SAFeComNet Communication Architecture

SAFECOMNET represents an ad hoc network allowing the exchange of location information and communication between fishermen within the sea and with the land.

The architecture of the solution is represented in Fig. 1. We will present, in detail, all the components of this architecture.

2.1 SAFeComNet Communication Components

- The device embarked in each pirogue

This embedded device is the heart of the system. It has two communication interfaces. The first interface is the IEEE 802.11. This interface, compatible with all types of smartphones, allows the crew's smartphones to be connected to the device. Thus, everything that comes from the smartphones (text, alerts, audio messages, geolocation, …) arrives in real time in the device. The second interface is a long-range LoRa interface. This interface allows to broadcast information from smartphones over very long distances.

Indeed, LoRa radio technology is more and more used in the deployment of ad hoc communication systems in disaster areas [5, 6], white areas [7–9] and agricultural environment [10] to have very large and robust coverage. Coverage tests carried out in rural white areas achieved a range of 16 Km [7, 9]. In the context of a maritime area, on the other hand, the tests carried out in Finland made it possible to reach a range of 35 Km [8].

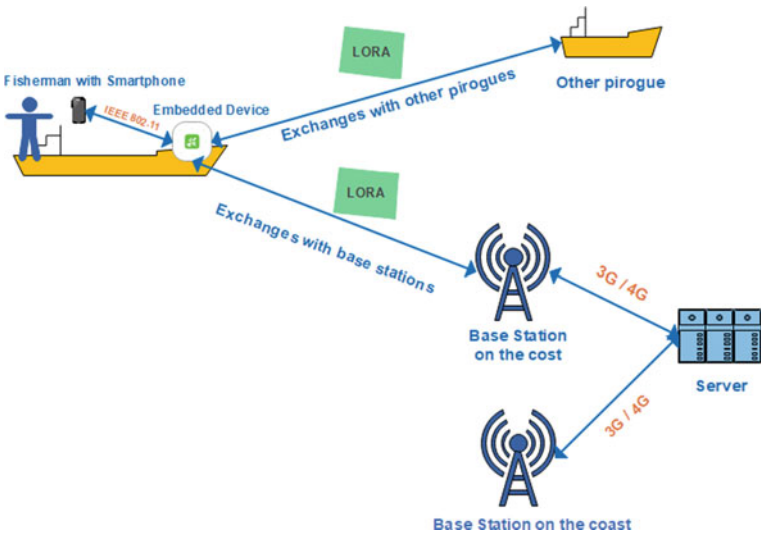

Fig. 1 SAFeComNet ARCHITECTURE

- Fishermen's Smartphone

The fishermen's smartphone is an important element of the network. It allows fishermen to send text or audio messages of up to 5 s (communication channel). In case of distress, fishermen can send or receive alerts. At each connection to a base station, the recorded GPS position is transmitted to the server (collection channel).

- Base station

The base stations are located along the coast and have two interfaces. A LoRa interface allowing the exchange with the devices embarked in the pirogues. A second 3G/4G interface allowing a connection with the server. It is important to note that this 3G/4G interface allows the base station to be permanently connected with the server. However, the LoRa interface is not always available for all the pirogues. Pirogues in a Yellow or Red security-level context are not connected to any base station. In this situation, all the information, such as geolocation, is stored in the onboard system (fishermen's mobiles in "back up"). This information will be transmitted to the server via the base station as soon as the security level becomes Green or Orange.

- Server

All the information coming from the pirogues (geolocation, alerts, …) is stored in a database on the server. An application running in this server allows to alert the national navy and the resource persons at the fishing docks in case of alert.

2.2 Different Levels of Security

The embedded device, depending on the number of connections with other pirogues or base stations, provides four levels of security:

- Green level:

The embarked device is both connected to at least one pirogue and a base station. In this situation, in case of an alert, the information will be received in the surrounding canoes and on land thanks to the base station. This is the best situation because the crews of the nearby canoes can intervene quickly. In addition, the server that received the alert via the base station will broadcast the information to the national navy but also to the nearest fishing docks.

- Yellow level

The onboard device is only connected to at least one pirogue. In this situation, in case of an alert, the crews of the nearby pirogues can intervene quickly despite the fact that the information is not known to the Navy and the fishing docks. However, if at least one of the surrounding pirogues is at a Green security level, the alert will be transmitted to the shore (Navy and fishing docks) via the base station.

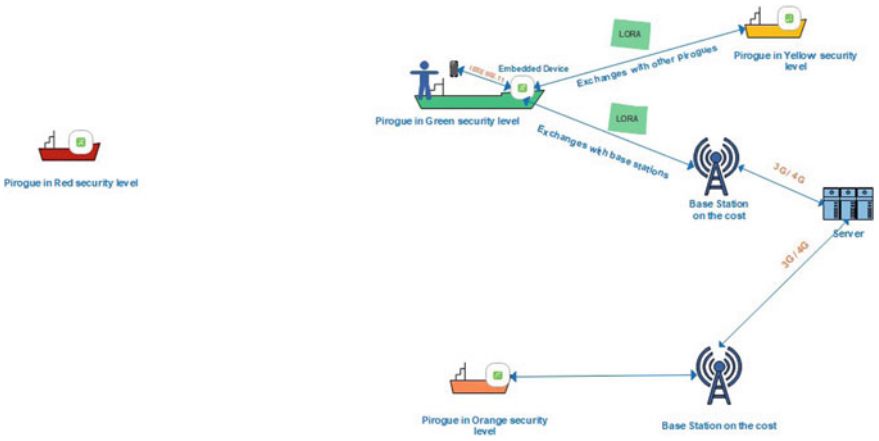

Fig. 2 Illustration of security levels

- Orange level

The onboard device is only connected to at least one base station. In this situation, there are no pirogues in the vicinity. Only the Navy and the pirogues on the fishing docks can intervene. This may take a little longer than the Yellow level. However, the alert is broadcast by the base station. All canoes connected to the base station will have the information. The crews wishing to do so can set a course towards the pirogue in distress.

- Red Level

The onboard device is unable to establish any connection. The crew is left to its own devices in case of a problem (Fig. 2).

It is very important to note that these safety levels are displayed on the device but also on the smartphones of the crew members. An intermittent beep will be added in case of a Red level to remind the crew that they are in danger, and that in case of a problem, they will have no help. It is also important to note that this device embarked in the dugout canoes must work in hostile conditions. The resistance of the materials constituting the box as well as the fixings must be studied. The aspects related to waterproofing must also be taken into account.

3 SAFeComNet Communication Model

In SAFeComNet, each embedded device broadcasts its location in the network at first then the message transmission can start.

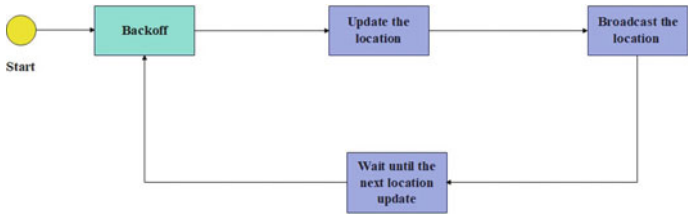

Fig. 3 Location update broadcast

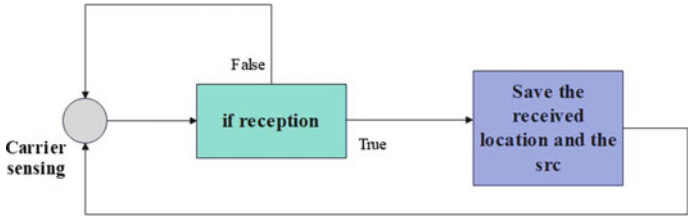

Fig. 4 Reception of the location update

3.1 Succession of Location Update and Transmission Phase

For the location update, each device must share its location at a given frequency. A period of 30, 60 or 120 s is then defined for sending the location, which allows each fisherman to know his neighbours. In order to avoid collisions during this period of location update, we decided to integrate a technique called backoff. The idea is to allow each box to choose a random time, added to the period of sending location (which is common to all boxes) and the whole constitutes the waiting time before sending each new location. This technique allows the boxes to send their location at different times and thus avoid collisions. This process is repeated for each location update. The devices are Transceivers; they can broadcast their location in the network and receive from their neighbours (Figs. 3 and 4). The src contains the source address. It is important to note that other parameters come into play such as the number of boxes in the network and the time on air. The time on air corresponds to the occupation time of the channel. Indeed, the larger these two parameters are, the more likely the number of collisions is. Hence, the importance of doing tests in order to determine the most suitable time on air for a certain number of boxes (thus pirogues) in the network, and consequently to choose the appropriate localization update period. Boxes can send beacons to their neighbours. Therefore, even if the fisherman does not use his smartphone or if it is down, the location of his neighbours will be saved.

After this phase of localization, the transmission of messages can start allowing the sending of alerts, important messages in the network.

3.2 Location Update Algorithm

The location update algorithm is shown in Algorithm 1. Each box chooses a backoff randomly and sends its location update. Before each new sending, a new backoff is chosen.

Algorithm 1 Location broadcast

```
time ← current time − the last location update time ;
loctime ← the time set for a location update ;
backoff ← (1, loctime) ;
if time >(backoff + loctime) then
    Send localization ;
else
    time is too short ;
end if
```

4 Evaluation of the Proposed Location Update Algorithm

We first performed a test with a limited number of real devices. After that, in order to evaluate the proposed location update algorithm in a context with a large number of nodes, we implement a virtual test.

4.1 Evaluation in an Experimental Test Bench

We realize a test bench with dragino nodes to evaluate the update of the localization. The draginos $LG01$ have a WiFi interface, a wireless LORA module, an ATMega328P microcontroller, a linux system and USB connectors.

Since the boxes are LORA gateways, we tested three modes (Mode 4, 5 and 9). Each mode is a combination of a spreading factor (SF), a time on air and a bandwidth. We created in each box, a database that records the balises sent by the dragino and a second database of reception of the neighbours' balises. This allows us later to make a comparison and determine the success rates of the transmission.

We used three location update times : 30, 60 and 120 s. The tests are carried out in an experimental test bench consisting of a base station and two access points (Fig. 5) in three transmission contexts: The mode 4 with time on air = 1102 milliseconds, spreading factor = 12, bandwidth = 500 KHz.

The mode 5 with time on air = 732 milliseconds, spreading factor = 10, bandwidth = 250 KHz.

The mode 9 with time on air = 315 milliseconds, spreading factor = 8, bandwidth = 500 KHz.

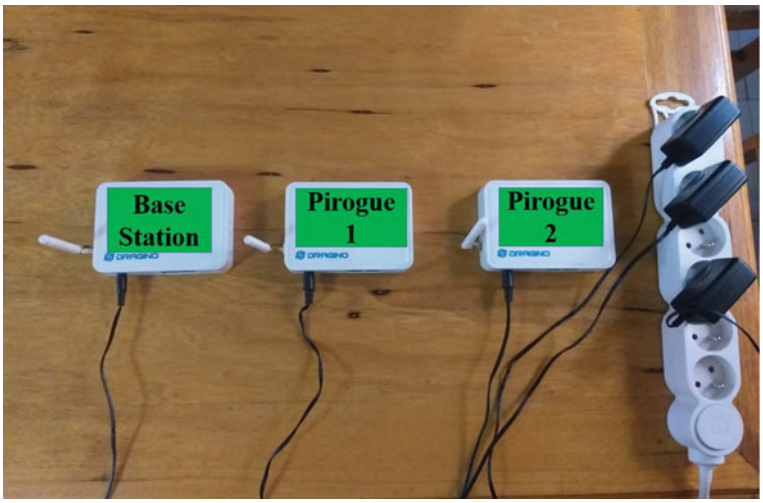

Fig. 5 Test bench with draginos

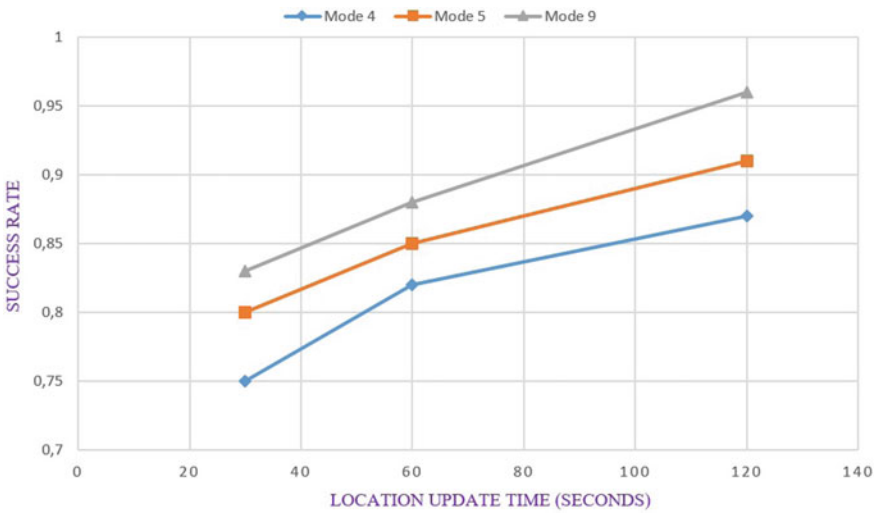

Fig. 6 Location update success rate for three Modes

The location update success rate is presented in Fig. 6. This success rate is determined by the ratio between the number of received location update and the number of sent one. This success rate can therefore be used to quantify the risk of collision. Following the tests, we can note that:

- For all modes, the results obtained for 120 s are better than those for 30 and 60 s. Indeed, the higher the location update time, the less collisions there are.

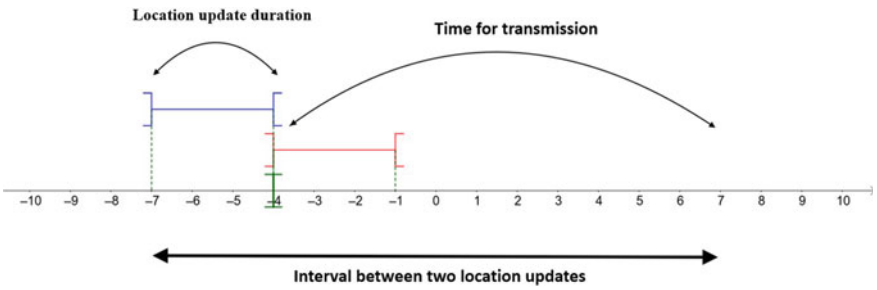

Fig. 7 Interval between two location updates

- The results obtained for mode 9 are better than those for modes 4 and 5. This is explained by the time on air which is shorter for mode 9.

Being limited by the number of devices, we continued the tests in a virtual way with more than three devices.

4.2 Evaluation in a Virtual Test Bench

A test scenario based on the results obtained in Sect. 4.1 subsection is set up. We have defined a time interval between two location updates (in our model this interval is 15 min). In this interval, one time is used for data transmission and another for location update. The latter depends on variables such as the number of nodes in the simulation or the transmission probability [11]. The objective is to make it as short as possible while keeping a high probability of success in transmissions. Thus, it can be reused for data transmission while keeping the same backoff for each node.

Figure 7 shows an example of an interval between two localization updates.

In this diagram, location update time represents $\frac{3}{14}$ of the total time. But this is only as an example. Our work in this part consists in determining this time according to the number of nodes, the probability of success and the configuration of the transmitter in the channel. Indeed, we have seen that with LoRa, the transmission metrics (the spreading factor, the width of the channel) play a role on the channel occupation time(time on air).

In our simulation environment, there is a population that increases over time. The population has been incremented up to 100 nodes to push the tests compared to results in real environment.

The instant of transmission was taken as the only element to determine a transmission collision. Indeed, the instant of transmission is not in reality the only sufficient element to determine a collision because the choice of a channel and of a different spreading factor can avoid a collision when the instant of transmission of two nodes is the same [12].

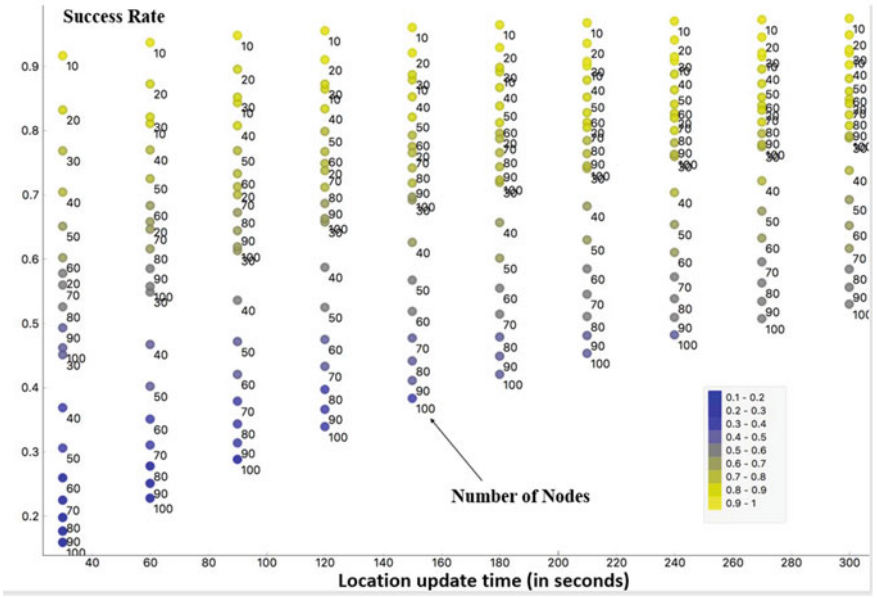

Fig. 8 Transmission success rate for fishermen as a function of the location update time (time on air: 700 ms)

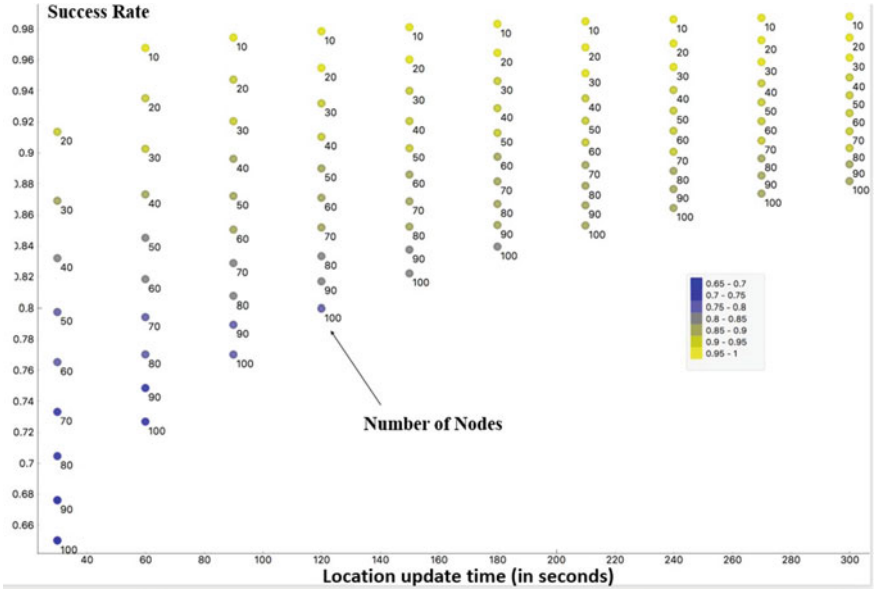

Fig. 9 Transmission success rate for fishermen as a function of the location update time (time on air: 300 ms)

Channel occupation times per node as a function of spreading factor and channel width were considered using the calculator on [13]. Three cases have been chosen: compromises between channel occupation time and transmission range.

Each node draws a backoff, and its occupation time is added to it. If two nodes pull the same backoff, a collision occurs. If two nodes pull backoff close enough that their channel occupations overlap, a collision also occurs.

This scenario is repeated 500 times for each simulation. Indeed, beyond 500 iterations, the results no longer vary. For each simulation, the percentage of successful transmissions over a given time interval is output. For each population, this test is performed over intervals of 30s up to 300s, in steps of 30s.

Figures 8 and 9 show the per cent success in transmission for fishermen as a function of the location update time.

These results show a few things:

- As the population increases, the percentage of success decreases for a fixed location update time.
- As the location update time increases, the success percentage increases for a fixed population.
- For the same population with a fixed location update time, the more the channel occupation time increases, the more the percentage of success decreases.
- The remarks above allow us to say that in a situation of high density, using a low spreading factor is the best solution. Indeed, this induces a smaller channel occupation time and allows better results.
- In a situation of very low density, using a high spreading factor allows a better use of our resources, because with this metric, we have results that allow us to have more than 75% success probability.

5 Conclusion

We propose a long-range ad hoc communication network named SAFeComNet and adapted to the artisanal fishing in Senegal. In Senegal, artisanal fishing activities are increasingly carried out in white areas. This situation puts the fishermen at risk as they have no means of exchange with each other or with the mainland. In that context, there is no central equipment to organize all the nodes (Embedded device in each pirogue). Therefore, the nodes do not have any knowledge about the position of their neighbours. In this paper, a location update algorithm which enables each node to know the position of each of its neighbours is proposed and evaluated respectively in an experimental and in an virtual test bench.

In our next work, we plan to integrate a mobile application to manage the transmission of data and various services.

Acknowledgements This work is supported by the Fond d'Impulsion à La Recherche project of Polytechnic Institute (ESP) of Dakar, Sénégal.

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Reviewing Non-intrusive Load Monitoring Using a Pilot Study of an IoT Device to Disaggregate Energy Usage

Matthew McCrory, Adele H. Marshall, Aleksandar Novakovic, and Geoffrey Collins

Abstract Non-intrusive load monitoring (NILM) disaggregates energy consumption data collected from a single measurement point into appliance-level data. This process facilitates energy savings. Most studies treat NILM as a residential task with few considering its application in industry. By chronologically reviewing existing literature, this paper presents a review of the latest research in NILM, focusing on its potential employment within a utility company, Northern Ireland Water. A practical example of NILM is also provided using data collected by a pilot IoT device where the benefits of NILM are exhibited via a cost analysis. Results from the literature review show deep learning models to be the most recent preferred disaggregation approach. Furthermore, the standardization of evaluation metrics is deemed essential to facilitate the comparison of different disaggregation models. Finally, the NILM tool kit is outlined as a useful platform for Northern Ireland Water to practically implement NILM.

Keywords Non-intrusive load monitoring · Energy consumption · IoT · Pilot study

M. McCrory · A. H. Marshall (✉) · A. Novakovic
School of Mathematics and Physics, Queen's University Belfast, Belfast, UK
e-mail: a.h.marshall@qub.ac.uk

M. McCrory
e-mail: mmccrory12@qub.ac.uk

A. Novakovic
e-mail: a.novakovic@qub.ac.uk

A. H. Marshall · A. Novakovic
Joint Research Centre in AI for Health and Wellness, Ontario Tech University, Oshawa, Canada

G. Collins
Northern Ireland Water, Belfast, Northern Ireland, UK
e-mail: Geoffrey.Collins@niwater.com

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1 Introduction

Northern Ireland Water (NIW) has the largest electricity bill in Northern Ireland, totaling around £30 m per year in 2021. This expense is due to the energy-intensive procedures implemented to clean and pump water. Astonishingly NIW spends the same amount on electricity as a combined average of almost 40,000 UK homes. Consequently, this is driving innovative approaches to save energy through new technologies. This paper investigates the method of non-intrusive load monitoring (NILM) [1], an energy load disaggregation system, by exploring its suitability, development, and application using a piloted IoT device.

Using only the aggregated data from a single measurement point, NILM can both identify the operational state and predict the power consumption of individual appliances. An effective NILM system could potentially identify the most energy-intensive appliances in NIW operations without the cost of installing individual smart meters. NIW could subsequently evaluate each element of the water treatment process and make informed decisions on the appliances value relative to its energy consumption.

Figure 1 exhibits a household NILM system. Fluctuations in power arise following the change in operational state of each appliance.

The unique power consumption of each appliance is referred to as the 'load signature' which is used to group appliances into one of four types (Table 1).

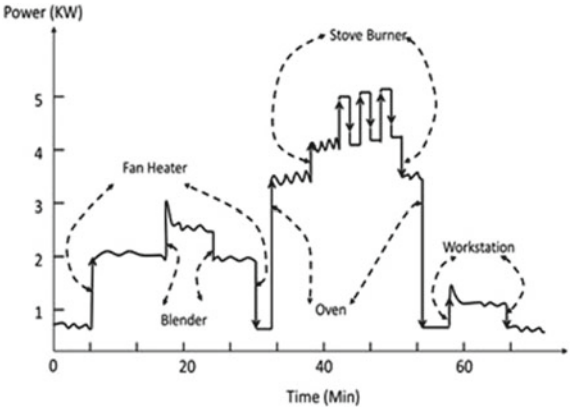

Fig. 1 Residential application of NILM (taken from [2])

Table 1 Appliance types

Type	Description	Examples
Type I	Two states	Toaster
Type II	Multiple number of states	Washing machine
Type III	No fixed number of states as consumption varies constantly	Dimmer lights
Type IV	Constant state	Smoke alarm

The goal of this paper is explore the literature to identity the cutting edge research in NILM with the aim of making recommendations for its potential implementation by NIW. A practical example using a piloted IoT device provides data that is utilized in cost analysis to assist the quantification of the practical benefits of NILM.

The remainder of this paper is arranged as follows. Section 2 provides a literature review of the data, learning approaches, and evaluation metrics involved in addressing the research questions. Section 3 gives a brief description of the pilot IoT device, the results of which are presented in Sect. 4. Section 5 discusses the potential for the NILM implementation in the NIW setting, and Sect. 6 concludes the paper.

2 Literature Review

NILM was introduced by George Hart in 1992 [1]. Since then, advancements in deep learning, metering equipment, costs, and Internet of things (IoT) devices have caused a surge in recent research. Given the availability of data, early NILM studies utilized low-frequency residential datasets [3, 4]. These datasets continue to dominate modern literature; however, the creation of industrial datasets [5–7] has seen more studies consider NILM within industry [6, 7]. The increased sophistication of deep learning models has also influenced NILM literature with recent studies moving away from machine learning approaches in favor of deep neural networks, namely, convolutional and recurrent neural networks (CNN and RNN).

Among existing literature, Angelis et al. [8] are one of the few authors to provide an extensive evaluation of the current state of the art for NILM. Their paper utilizes findings from over 200 studies to emphasize the evolution of NILM datasets, learning approaches, and evaluation metrics. Results showed the prevalence of residential studies as well as the clear gap in performance between deep learning and machine learning models, with the former providing state-of-the-art disaggregation results. Similarly, Pereira and Nunes [9] provide a thorough review of the main datasets, metrics, and tools for evaluating the performance of NILM systems and technologies. Results indicated several barriers that make performance evaluation challenging including missing data and limited labeling. This paper also acknowledges a lack of energy estimation studies and how research breakthroughs are only viable if the NILM research community integrate contributions in a common framework.

Aside from these evaluation-type papers, most NILM studies focus on the implementation of a NILM system, often including a variety of machine and deep learning disaggregation models in a bid to find the most effective model.

2.1 NILM Data

NILM Datasets. Rapid advances in IoT device capabilities and metering equipment have led to a recent spike in the number of publicly available NILM datasets. Despite

this, most datasets primarily use residential data with only three using industrial data (Table 2). Datasets typically include electrical features at both an aggregate and appliance level with the latter considered 'ground-truth' data, used for NILM evaluation.

Data Collection. IoT devices and electric meters collect data at either a high (1 kHz and above) or low (below 1 kHz) frequency [6]. While higher frequencies allow for more easily distinguishable load signatures, existing studies gave good results for low-frequency datasets also [10]. Shin et al. [11] however claim it is possible for a sampling rate to be too low suggesting a rate of at least 1–3 Hz to avoid load signatures being 'destroyed.' Data for NILM tasks is not always available and is often time consuming to collect. Atypical for a time series problem, the creation of synthetic data is an unlikely solution [12, 13]. Most recently, Quy et al. [13] used four different interpolation techniques to augment high frequency NILM data from low-frequency datasets.

Feature Extraction. The goal of the feature extraction process is to derive a signature (feature vector) that can be used to uniquely identify each appliance. The features included are classified as either steady state or transient (Fig. 2). Steady-state features exist when an appliance is operating with a steady state (usually when a low sampling rate is used). Active power is conclusively the most popular steady feature; however, Bonfigli et al. [14] insist reactive power is equally as important with its inclusion found to improve the NILM algorithms predictive accuracy. Transient features are extracted when the signal evolves in an unpredictable way, typically when a high sampling rate is used for example in transient power and transient voltage noise.

Studies have achieved good results using both feature types. Reddy et al. [16] recommend that a hybrid approach of both feature types will lead to an improved appliance signature. Results from this study saw the 'feature fusion' algorithm outperform the steady-state and transient feature algorithms by 9% and 15%, respectively.

There is no 'optimal' number of features proposed. Both [17, 18] used three features while two of the three industrial studies used active power as a solitary feature.

Table 2 Breakdown of the three industrial datasets

Name	Year	Number of appliances	Features	Time period (days)	Aggregate sampling (Hz)	Appliance sampling (Hz)
ASF	2015	4	P	68	1	1
IMD	2018	8	P, Q, S, V, I	111	1	1
HIPE	2018	10	P, Q, S, V, I	92	1/5	1/5

Features include, power (P), reactive power (Q), apparent power (S), voltage (V), current (I)

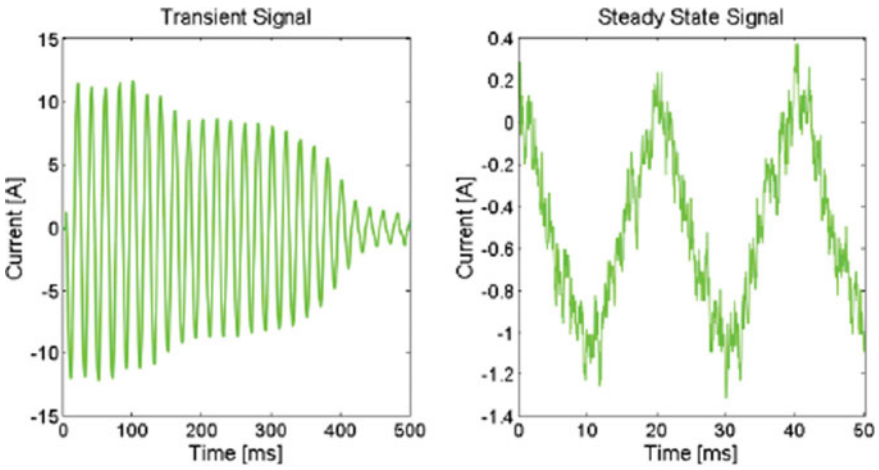

Fig. 2 Transient and steady-state signals (taken from [15])

2.2 Machine Learning Approaches

NILM is formulated as a supervised learning task with a goal of predicting the power consumption or state (ON/OFF) of each appliance. Similarly, NILM is considered a classification or regression problem with each study using a machine or deep learning approach as the foundation of their model. Machine learning was the most popular approach for early studies, with the hidden Markov model (HMM) featuring prominently [3, 4]. More recently, deep learning has moved to the forefront of NILM literature with CNNs and RNNs regarded as the state-of-the-art learning approaches.

NILMTK. Developed by Batra et al. [19] NILMTK is an open-source tool kit that includes a range of datasets, pre-processing algorithms, benchmark disaggregation algorithms, and accuracy metrics. The purpose of NILMTK is to enable the comparison of different learning approaches; it was also the first platform to enable the comparison of multiple approaches across multiple datasets. Since its development, the NILMTK has been used to facilitate state-of-the-art results in various studies [9, 20].

HMM. Studies using HMMs define several consumption states for each appliance, with each state receiving an individual probabilistic distribution. Despite its presence diminishing among studies, Hosseini et al. [21] found the recognition accuracy of the Factorial-Semi-HMM model (a variation of the HMM) to surpass that of RNNs, showcasing the model's competitiveness against a deep learning approach.

Deep Learning. Deep learning was first introduced to NILM by Kelly and Knottenbelt [22] who employed sequence-to-sequence learning (s2s). This approach trains a deep neural network to map between an input and an output sequence while removing the power consumption contribution of all but the target appliance. Note, the input

sequence represents a window of aggregate power that applies to the target appliance and the output sequence is a prediction of the target appliances power consumption. Zhang et al. [23] evolved this approach, employing a unique sequence-to-point (s2p) model to predict the midpoint of the output signal as opposed to the entire sequence. Since then, s2s and s2p learning have become staple output approaches for NILM, most often utilizing a CNN. The popularity of CNNs emanates from the model's resistance to noise in the input data as well as its ability to extract complex features that are independent from time via its convolutional layers. Studies have achieved high performance using both 1D and 2D convolutional layers. Notably, Barber et al. [24] applied four pruning algorithms on the s2p CNN seen in [23], reducing the number of weights by 87% while maintaining a state-of-the-art performance. Yang et al. [25] utilized 2D convolutional layers to conduct a current-to-image conversion, representing the characteristics of each appliance as the CNN's input.

RNNs are best known for their ability to handle time-series data. Additionally, variants LSTM and GRU's capacity to deal with the vanishing gradient problem make it an attractive approach for NILM tasks. Kim et al. [26] were first to explore state detection with a RNN, since then, the model has been adapted. Krystalakos et al. [27] take a GRU approach with a goal of improving disaggregation accuracy and reducing computational complexity. Similarly, Quek et al. [28] designed two LSTM networks for appliance classification. Alongside their results both the CNN and RNN's compatibility with the NILMTK has cemented their presence among NILM literature.

Industrial Studies. Martins et al. [6] and Kalinke et al. [7] use a combination of machine and deep learning approaches. Their goal to disaggregate the total load by each appliance using the HIPE, IMDELD and REDD datasets [7] found the deep learning models to record the lowest error rate in 11 out of 12 instances. Similarly, [6] disaggregate the total load by each appliance and found the Wave-NILM model overcame the Factorial-HMM model in most evaluation metrics for every appliance. Holmegaard and Kjaergaard [29] instead compare three machine learning approaches, Combinatorial Optimization, FHMM and FHMM with day specific training, the latter providing the best outcome. Ultimately, while certain learning approaches appear more attractive than others, their performance is judged by the evaluation metrics.

2.3 Evaluation Metrics

In NILM studies, there is no standardized evaluation metric. The most popular metrics are those used within regression and classification problems. This includes f-score, recall, accuracy, precision, true positives, true negatives, false positives, false negatives, root mean squared error (RMSE) and mean absolute error (MAE). Studies have

also employed specific load disaggregation metrics that include the energy-based f-score [30], the total energy correctly assigned (TECA) [3] and the energy accuracy [8].

An important separation is offered by Mayhorn et al. [30] where metrics are categorized as either event detection (ED) or energy estimation (EE). The former regards NILM as a classification problem, assessing how the model performs in identifying an appliance's operational state. The latter treats NILM as a regression problem, approximating the amount of energy each appliance consumes at each timestamp. The authors insist ED and EE are equally significant. Furthermore, the inclusion of both metrics is considered essential to any NILM study as it allows for the most comprehensive assessment of a model's performance.

When considering the most appropriate evaluation metric Angelis et al. [8] insist studies should acknowledge both the operational power level and the frequency of usage for each appliance. This is because of the impact the operational power has on certain EE metrics like the RMSE and MAE. Attention is drawn to how a MAE comparison between two appliances operating at different wattage levels will not provide any significant conclusions given that the appliance operating on a higher level will ordinarily have a greater MAE. Consequently, RMSE and MAE are regarded as inappropriate evaluation metrics, despite their popularity among NILM literature. Despite comprehensively reviewing the theory, a full understanding of NILM is not complete without considering its practical implementation.

3 Methods

The proposed IoT device (Fig. 3) was built to record the frequency of electric meter pulses per minute. The resistor is responsible for regulating the flow of electrical current while the photoresistor registers each pulse from the electric meter. This resistor was connected to the photodiode using the appropriate pins. The antenna provided an internet connection, and the battery powered the device ready for piloting.

Before implementation of the device, the ambient light level in the garage (location of the electric meter) was identified. Knowledge of this allowed for the device to be coded to recognize a change in the light level as the electric meter pulsed. The device was positioned accordingly and the pulse counting started. The number of pulses observed each minute were posted to Ubidots [31], an IoT platform used to store and visualize data. Periodically, different appliances in the house were switched on, causing a change in the number of pulses observed by the device. Using Ubidots, the different events (appliances changing state) were visualized.

The intention was then to establish the load signatures of a sample of appliances as well as the consumption patterns of different appliance types and a cost analysis for a sample of appliances.

An experiment was conducted to identify each respective load signature of each appliance by periodically switched them on and off again over a period of 21 h. The

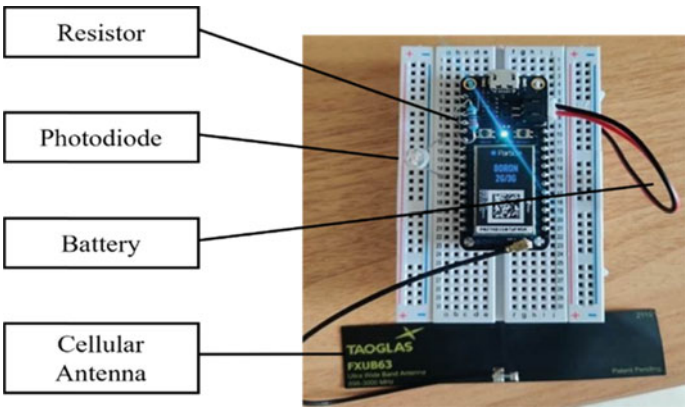

Fig. 3 Wiring diagram of IoT device

study did record for 24 h with three of having no additional appliances used allowing the baseline ambient pulse to be established.

Using Eq. (1) a prediction was made as to how many times the electric meter would pulse. The ambient pulse level relates to the low power consuming appliances operating in the background at baseline.

$$\text{Pulses per min} = 60/(3600/\text{Appliance Wattage}) + \text{Ambient Level}. \quad (1)$$

Equation (2) was then used to convert the number of pulses to kWh, which is a measure of how much energy is being used per hour.

$$\text{kWh} = (\text{number of pulses})/1000. \quad (2)$$

The cost for each appliance can then be calculated by multiplying the cost per unit of energy per kWh by the number of KWh energy consumed from Eq. (2).

4 Results

Pulse Experiment. The results of the pulse experiment (Table 3) were recorded over a one minute period. Pulses ranged from 1 to 5 per second with the expectation that if there is 1 pulse per second, then there should be 60 pulses recorded per minute, 2 pulses per second should yield 120 pulses recorded per minute and so on, hence formulating the 'pulses expected' column in Table 3. The 'pulses recorded' are those observed in the experiment with the final column in the table representing the difference between the expected and observed. The results show the device performed well up to 4 pulses per second with the performance dropping off at 5 pulses per second; thus, the device's performance is satisfactory.

Table 3 Experiment results

Pulses per second	Pulses expected	Pulses recorded	Difference
1	60	60	0
2	120	118	2
3	180	176	4
4	240	234	6
5	300	284	16

Table 4 Pulses prediction versus actual

Appliance	Wattage (W)	Predicted	Actual
Toaster	1500	29	28
Kettle	2500–3000	42–52	49
Hairdryer	2000	38	37

Identifying Appliance Load Signatures. Given the known Wattage of the various appliances, it was possible to determine an expected number of pulses per appliance using Eq. (1). The results (Table 4) showed a high level of accuracy where the predictions were close to the actual. A visualization of the actual load signature for each appliance is illustrated in Fig. 4.

Observing Appliance Behavior. Figure 5 depicts how the consumption pattern (kWh) varies across different appliance types over the observation time. For example, the shower (type I) has two states, which is either OFF or consuming 0.082 kWh. Conversely, the dishwasher is a type II appliance. Across its 30 min cycle it consumes

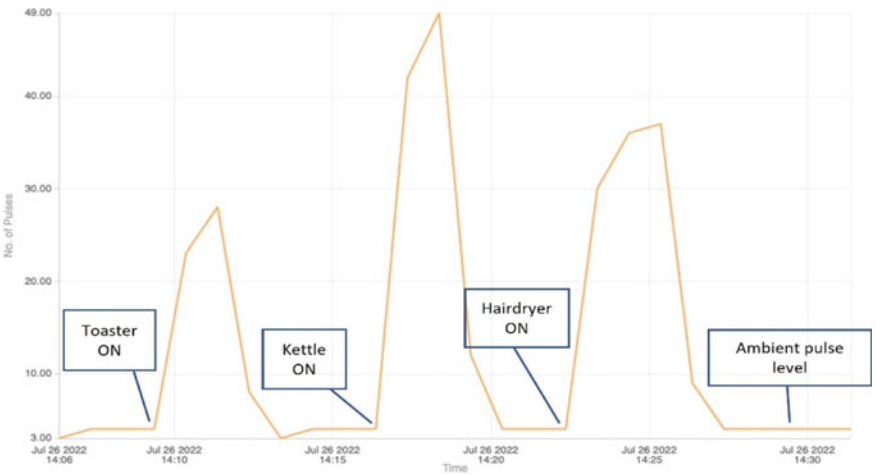

Fig. 4 Load signatures for toaster, kettle, and hairdryer

between 0.003 and 0.084 kWh. Despite appearing to behave sporadically, the dishwasher has a fixed number of states making it easier for the disaggregation algorithm to learn its load signature in training and disaggregate it effectively. An example of a type III appliance could not be included as they are uncommon within a household setting. The main takeaway however is that the energy consumption will be different each time the appliance is used, making disaggregation difficult.

Cost Analysis. The cost of running each appliance is a product of the appliance's total energy consumption over its runtime and the tariff [32] imposed by the electricity provider. Examples using the data in Fig. 5 are illustrated in Table 5. While the dishwasher appears the most expensive, it is worth noting that costs are heavily influenced by each appliance's runtime.

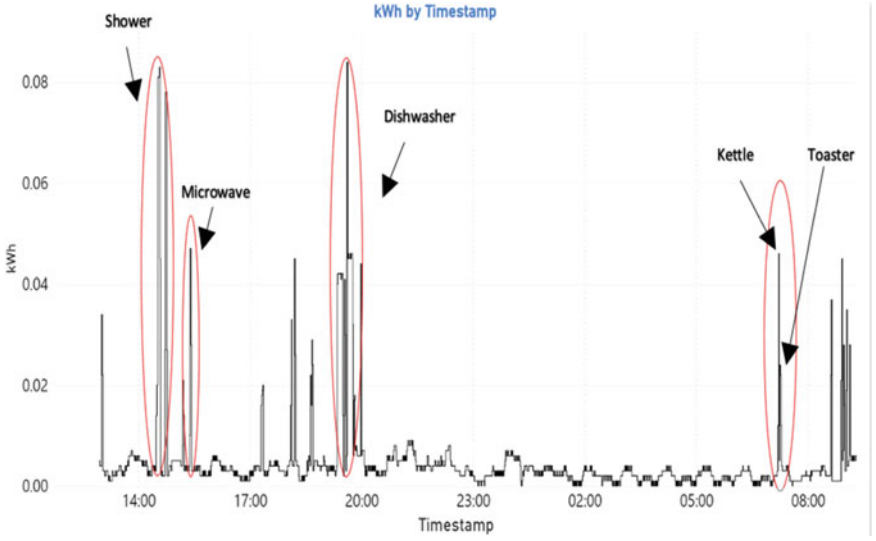

Fig. 5 Aggregate kWh over 21-h period

Table 5 Cost analysis

Appliance (type)	kWh	Tariff (£ per kWh)	Cost (£)
Shower (I)	0.328	0.2952	0.097
Dishwasher (II)	1.013		0.299
Microwave (I)	0.073		0.022
Kettle (I)	0.075		0.022
Toaster (I)	0.058		0.017

5 Discussion

5.1 Data

To date there are only three recognized industrial NILM datasets. This poses a problem for NIW as a lack of available data has intrinsically led to a lack of research in NILM within industry. Until industrial NILM studies become more abundant, our understanding of both the benefits and challenges will be limited. However, it is still possible to gather valuable insights from residential datasets but with the caveat that there are characteristics of industrial datasets that are not transferrable. For example, within the HIPE dataset, Kalinke et al. [7] acknowledge a dependency between different industrial appliances like the screen printer and the soldering oven, these dependencies are less common in residential data. Additionally, unlike household appliances, industrial machinery tends to be of Type III classification given the continuous nature of its energy demand. Type III is also regarded as the most difficult appliance type to disaggregate and likely holds a strong presence among NIW's machinery.

Existing literature indicates NIW can achieve optimal results collecting data at a high or low frequency. With a low sampling rate NIW must be aware of the difficulty in detecting low energy consuming devices considering that switching events are not prominent. Despite this, steady-state features arising from a low sampling rate, namely active power, continue to deliver state-of-the-art results, particularly within industrial studies. Conversely, a high sampling rate brings the benefits of transient features which are useful for distinguishing appliances operating simultaneously. However, this requires using more expensive hardware to collect the data. The data is also complex and requires a high computation time for pre-processing. The best approach may be to sample at a rate that captures both steady and transient features as seen in [16].

Just as there is no recommended sampling rate, NIW can choose any number and combination of features for their dataset. In line with other industrial studies [6, 7] it may be wise to begin with active power as the solitary feature and then follow with a combination of steady-state and statistical features given the effectiveness of statistical features in disaggregating Type I and II appliances [17].

5.2 Machine Learning Approaches

Machine learning approaches continue to feature among studies most likely due to their simpler implementation and lower computational complexity. While the results in Hosseini et al. [21] indicate the HMM is a competitive disaggregation model, HMMs are known to be inefficient should the number of disaggregated appliances increase [33]. This has led to HMMs only being included as one of several benchmark models.

Zhang et al. [23] had one of the most impactful contributions to NILM literature highlighting the flexibility of a neural network architecture, a characteristic that is less prevalent within machine and statistical learning approaches. In this study, five convolutional layers were included, allowing the model to extract the most meaningful features to perform disaggregation. Additionally, the CNNs ability to include both 1D and 2D convolutions make it an attractive approach for NILM.

The RNN's functionality within NILM derives from its ability to capture the sequential information of the input data while retaining a memory of what it has processed in previous steps, two features that are non-existent among machine learning models, yet extremely effective for NILM. Given the efficiency of the convolutional layer as a feature extractor and the LSTM/GRUs applicability for sequential data it is unsurprising that authors have designed their models to include each of these components, it is advisable for NIW to do the same.

Both the RNN and CNN are two of eight different algorithms compatible with NILMTK. Like Kalinke et al. [7] NIW can train each algorithm using the implementation at NILMTK and then evaluate the performance of each of these algorithms using their own appliance-level data. Ultimately, NILMTK gives NIW a guided introduction to the NILM process alongside the tools to implement it practically. NIW must however be aware of the time and resources necessary to train each model given the extensive number of parameters and their complexity for understanding.

From NIW's perspective, the HMM can provide adequate disaggregation results with a simpler implementation and at a lower cost. However, modern literature dictates that deep learning models provide promising results. Ultimately, NIW must decide whether less computationally intensive models like the HMM are worth pursuing at the expense of higher accuracy results. Equally NIW must have the resources and understanding to employ complex deep learning models like the CNN and RNN.

5.3 Practical Discussion

Results from Sect. 4 provided both the load signatures and a cost analysis for a sample of household appliances as well as drawing attention to how the consumption pattern varies among different appliance types.

From NIW's perspective, identifying the load signatures (Fig. 4) will be less straightforward. This is due to industrial machinery operating simultaneously, creating more overlap among the aggregate data. Another consideration for NIW is the sampling rate used. Data in Fig. 5 is collected every minute, this is a low sampling rate however it provides enough data for a signature to notably develop. Too low of a sampling rate such as aggregate data collected every 30 min, would make appliance disaggregation difficult as it may fail to capture an appliance's runtime. Conversely, a higher rate such as every second, would make disaggregation much easier.

Providing a cost analysis for individual appliances is one of the key advantages of NILM. However, the cost of an appliance can be calculated using Eqs. (1) and (2) so it is important to highlight the refinements that NILM has to offer. NILM identifies the state, runtime, and consumption for each machine. This facilitates a detailed cost breakdown that would not be possible using just these two equations. Secondly, NILM acknowledges type III machinery which features prominently in industry. The amount of energy consumed by a type III machine is purely circumstantial, limiting the ability to predict its cost. For NIW this may relate to a water pump that's runtime is fluctuating in response to a change in rainfall. An effective NILM algorithm can detect this fluctuation, providing an accurate breakdown of the cost.

6 Conclusion and Recommendations

Rising energy tariffs have made NILM imperative for NIW. This paper considers NILM from a theoretical and practical perspective, with a particular focus on the use case for NIW and the 'state of the art' for each element of the NILM process. Despite a lack of industrial studies, results showed that deep learning models are dominating the literature and providing state-of-the-art results. Furthermore, the practicality of NILM was demonstrated via a cost analysis using data collected with an IoT device.

It is apparent that more industrial studies are required to fully understand the behavior of type III appliances. Future studies should also consider NILM as both a classification and regression task as well as adopting the energy f-score for load disaggregation and TPs/TNs/FPs/FNs for event detection. This will help standardize the evaluation process while facilitating the comparison of different NILM models. Furthermore, to overcome the extensive training time of deep neural networks future studies should consider lightweight disaggregation models.

For NIW the next step should be to explore the data collection process at both an aggregate and appliance level. This will require deploying high frequency energy meters on sites where NIW have already existing sub-metering installed. The frequency of data collection may require alteration for the most optimal level. Meanwhile the readings from the sub-meters can be used to characterize equipment and provide ground-truth data. In the first instance, the NILMTK will be used to gain a practical understanding of NILM using pre-existing industrial datasets, with the view to incorporating NIW data once it is available. The NILM techniques may then be applied to the aggregated data from NIW's high frequency meters and the results compared with the known data from sub-metering. This will prove particularly valuable to the business when considering application to sites where there is a concentration of energy-intensive assets such as the water treatment works and wastewater treatment works.

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Airflow Analysis in a Double-Skin Façade Building Under Tropical Climates Using Evolutionary Algorithms

Gisele Goulart Tavares, Sabrina Barbosa, Leonardo Goliatt, and Priscila Capriles

Abstract Buildings may use 20% more energy by 2050 as a result of climate change, and energy efficiency is a key component of sustainable development in the construction industry. In this context, the double-skin façade has gained recognition as a design solution with the potential to enhance the energy efficiency of buildings in both hot and cold climates. The purpose of this research is to look at the usage of PSO and GA optimization algorithms in conjunction with EnergyPlus in the evaluation of design parameters of buildings with double façades using computational models. The optimization algorithms operate in the generation of scenarios, considering two climatic zones in Brazil. The tool can potentially assist civil construction designers in productive computing resources, enabling faster, and more assertive decision-making.

Keywords Double-skin façades · Optimization · Design parameters

1 Introduction

Civil engineering represents one of the human activities that consume the greatest energy and natural resources, resulting in serious environmental consequences by altering the natural ecosystem to accommodate the built one. In addition, it plays an active role in sustainable development, reducing social disparities and conserving the environment. To achieve sustainability, the construction sector must adopt an innovative stance, introducing new concepts and procedures for planning and constructing sustainable buildings.

Double-skin façades (DSF) have gained popularity as a passive technical method for moderating thermal conditions while also offering office buildings a modern

G. G. Tavares (✉) · L. Goliatt · P. Capriles
Federal University of Juiz de Fora, Juiz de Fora, MG, Brazil
e-mail: giselegoulart@ice.ufjf.br

S. Barbosa
Rio de Janeiro State University, Rio de Janeiro, RJ, Brazil

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and transparent appearance and minimizing energy demands. A DSF is made up of an outer layer that is typically glazed and is placed over the traditional façade of the building, providing a cavity that allows air to circulate between the layers. Harkouss et al. [8] performed computer simulations of different scenarios from the exchange of materials and geometric characteristics of one residence, considering, for example, different types of glass, window dimensions and thickness of walls and roofing system. The authors used an evolutionary multi-objective methodology to minimize the thermal and electrical demands of the residence, automating the decision-making process of materials and architectural configurations to be used in the project.

The literature contains a wide range of research that involved the modeling and simulation of numerous scenarios with various architectural typologies [7, 11]. However, alternatives are frequently conducted individually, and the results apply to comparisons of generated outputs. This technique necessitates numerous tests and a lengthy execution time, making simultaneous analysis of multiple variables impossible. The modification of the geometry and material properties of the building structure has been presented in the literature as studies of isolated configurations [12, 13], without taking into account the impact of such modifications on the overall performance of the building, which necessitates the development of a computational model capable of performing more complex analyses. Thus, the combination of energy modeling software and optimization algorithms has demonstrated a promising option [2, 8]. In addition, most of the studies mainly focus on the modeling of residential buildings and other typologies are often neglected.

The present work aims to apply evolutionary algorithms in conjunction with the EnergyPlus [6] thermo-energy modeling software to optimize design parameters in buildings with DSF in Brazil climate zones. Also, it is suggested that the optimized results be compared to data from the literature for the naturally ventilated structure with DSF.

2 Material and Methods

2.1 Double-Skin Façade Model

The model used to test the optimization method in this study was developed by Barbosa [3]. The base case model is a 11-story open plan office skyscraper with 12 m x 15.5 m proportions and 3.5 m floor-to-floor height. The longest sides face north/south, with horizontal windows at mid-floor height and a window-to-wall ratio of 50%. On the north face, a clear single-glazing outer layer was applied, creating a 100 cm air cavity. The occupancy hours are set from 8 a.m. to 6 p.m. throughout the year. The occupancy density was set at medium capacity, or 14 people per 100 m^2. As a result, each thermal zone was assigned a population of 26 persons. The multi-story façade construction chosen for the basic case model has a cavity that is open vertically and horizontally, covering the whole face of the building from the first floor.

The ground level was designed without a second skin to allow air to enter through the cavity's bottom. Readers can find information about the thermal properties of the envelope composition, other geometric parameters, and the internal heat gains in the reference work [3].

2.2 Bioclimatic Zones

Brazil, located between the parallels of 5°16'19"north and 33°45'09" south, has a diverse climate that ranges from the mildly cooler southern region to tropical climes in the center and north coastal districts. Brazil's territory is divided into eight bioclimatic zones. These areas are related to the climatological characteristics of the country's various regions [1].

The tests in this study were carried out using climate files from the cities of Rio de Janeiro and Brasilia. The weather data adopted are from the US Department of Energy's website [6] and are based on weather test reference year databases. The analysis of these two exemplary towns aims to compare the use of design choices under various climatic conditions.

Zone 4—Brasilia City The zone is primarily concentrated in the center west. It includes the national capital despite covering only 2% of the country's land area. Brasilia has a tropical high-altitude climate typical of plateaus and mountains. The average temperature is around 22 °C, with the annual peak happening in the spring months. The rainy season starts in October and takes at least March. The average annual rainfall is around 1700 mm. Wind speeds are less than 6 m/s for 95% of the year and primarily from the east. During the summer, the wind direction is mostly from north to east. Calm conditions account for 35% of the time [4].

Zone 8—Rio de Janeiro City The zone comprises the largest of the country, with 58% of the territory, and contains most of the coastal districts, as well as key capital cities such as Rio de Janeiro (RJ), Belem (PR), Natal (RN), and Vitória (ES). Rio de Janeiro has a tropical climate, with an average temperature of 24 °C and annual rainfall ranging between 1000 and 1500 mm. The average temperature in the highest elevations can plummet to sixteen degrees, and precipitation can reach 2500 mm. The seasons of spring and summer are hot and rainy, while autumn and winter are cold and dry. Winds are fairly dispersed in the city, with a mild dominance to the west and speeds less than 6 m/s over 99% of the year [4].

2.3 Design Parameters

In order to maximize the airflow in DSF model, a set of design alternative parameters were defined. Table 1 shows the variables and values tested, which generated different scenarios. Those cases were then simulated by using the particle swarm optimization

Table 1 Design parameters used to generate different scenarios simulations

Position	Parameters	Sets [a]
x_0	Cavity width	[0.55:0.5:0.00]
x_1	Cavity top opening	[0.1:0.1:1.0]
x_2	Cavity bottom opening	[0.1:0.1:1.0]
x_3	Rotation	[0:45:270]
x_4	Increase in back windows	[0.0:0.1:0.4]
x_5	Increase in front windows	[0.0:0.1:0.4]
x_6	Vertical movement of back windows	[− 0.8:0.1: + 0.8]
x_7	Vertical movement of front windows	[− 0.8:0.1: + 0.8]
x_8	Opening ratio of back windows	[0.1:0.1:1.0]
x_9	Opening ratio front windows	[0.1:0.1:1.0]

[a] Sets are given by [minimum value:incremental value:maximum value]

and the genetic algorithm. The cavity width parameter, which has twelve possibilities, refers to the value added to the distance between the north façade and the double skin layer; starting from 0.4 m. Another design alternative is the opening of the top and the bottom of the cavity. They were set with ten percentage possibilities each, with 0.1 being the minimum value allowed by the EnergyPlus thermo-energetic modeling software. The rotation parameter refers to the azimuth of the building, which modifies the face of the building north façade; they were set with seven values (0°, 45°, 90°, 135°, 170°, 215°, 270°). Another optimized parameter is related to the front and back windows, allowing the algorithm to explore the positioning and opening area of the windows.

2.4 Evolutionary Settings of Parameters

Particle Swarm Optimization PSO [10] is an algorithm composed of a population (swarm) and formed by individuals (particles) that move in a defined space. Each particle i in this space represents a possible solution to an optimization problem by its position x_i and velocity v_i. Furthermore, each particle has two types of knowledge: social and cognitive.

Social knowledge indicates that a particle can obtain "knowledge" by observing other particles that belong to its group. And cognitive expertise is about the ability to gain your own experience over time and knowing when to qualify it as good or bad. Therefore, two possible variables for the solution are updated during execution: the best global position among all particles in the swarm and the best position of the ith particle. The velocity and position vectors of particle i are stored at time t during algorithm processing and used for swarm update at time t + 1. The PSO algorithm is good at finding sub-optimal solutions in a reasonable amount of time. It is also easy to use and takes up is easy to implement and has a small number of parameters, these being c1 and c2, which control the influence of the cognitive and social information, respectively.

Genetic Algorithm Simple genetic algorithm (GA ou SGA) can be defined as genetic-inspired search procedures and natural selection of species. They embrace the concept of survival through classification tests in an artificial system. Holland [9] adopted the semantics of biology in his algorithm and thus listed three crucial pieces of information in constructing a GA: the chromosome, the individual, and the population. The author [9] was looking for a way to code every possible solution to an optimization problem on a chromosome representing an individual.

The set formed by individuals defines a population, and these individuals are encoded by their chromosomes that will be submitted to evaluations that measure their performance. With some criteria based on their performances, individuals will be classified and, after they reproduce to form a new generation, part of the evolution mechanism of solutions in the algorithm.

The recombination and mutation operators work on the child individuals. Imagining that individuals parents are among those with the best aptitudes, it is expected that their children will be good solutions in the next generation. Imagining that individuals parents are good and are among those with the best aptitudes, it is expected that their children are too, representing good solutions in the next generation.

In this paper, each particle in PSO and individual in GA encodes a candidate solution. With these optimization algorithms, the goal is to find one scenario that maximizes airflow in the front window of the fifth floor of the building.

2.5 Computational Method

The PSO and GA algorithms were used with EnergyPlus open-source software to search for scenarios that maximize the airflow in the front window on the fifth floor. We used the proximity of the fifth floor to the mid-height of the building to determine the window for airflow analysis. Using the difference between the airflow that enters and leaves the fifth-floor window as an objective function $\mathrm{OF} = \mathrm{flow_{out}} - \mathrm{flow_{in}}$, where $flow_{out}$ is the airflow that leaves the front window of the building on the fifth floor, and $\mathrm{flow_{in}}$ is the airflow that enters this same window. The objective was to maximize the airflow from the front window toward the double skin façade. This air current promotes natural ventilation, improving the thermal sensation. The flow obtained hourly during the day was filtered so that the objective function used only flows in the 8 AM to 6 PM range. This period comprises business hours where the maximization of airflow aims to improve users' thermal comfort.

Initially, the geometric model IDF extension file was parameterized, allowing certain file sections to be modified using a script without compromising the syntax recognized by EnergyPlus. After changing the IDF file, the script uses EnergyPlus to run the energy model simulation and parses the output files to extract airflow values. Thus, PSO and GA could be used to optimize the model parameters described in Table 1, acting on generating scenarios and analyzing the objective function. Figure 1 presents the data flow in the algorithm that evaluates and simulates the design parameter combinations.

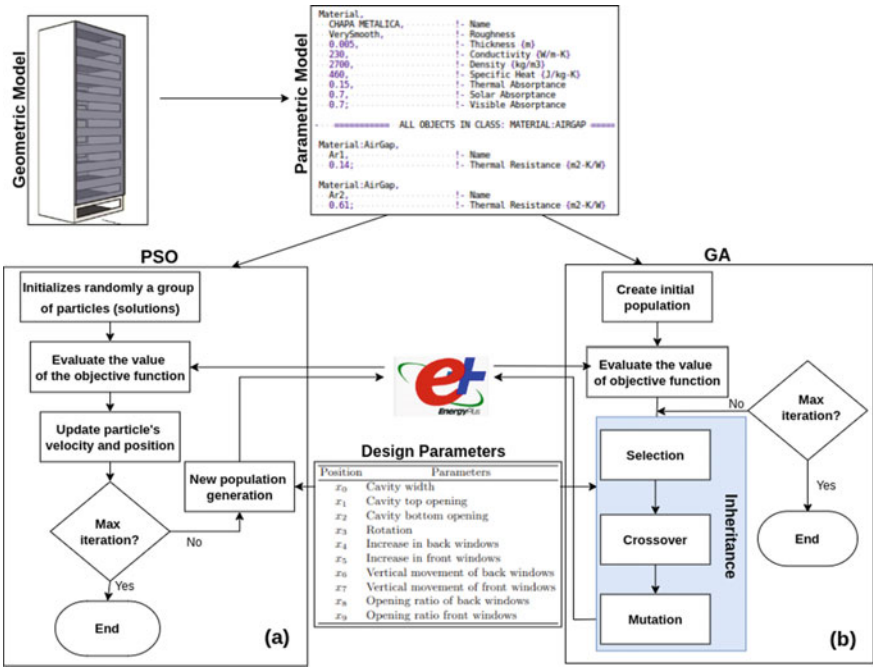


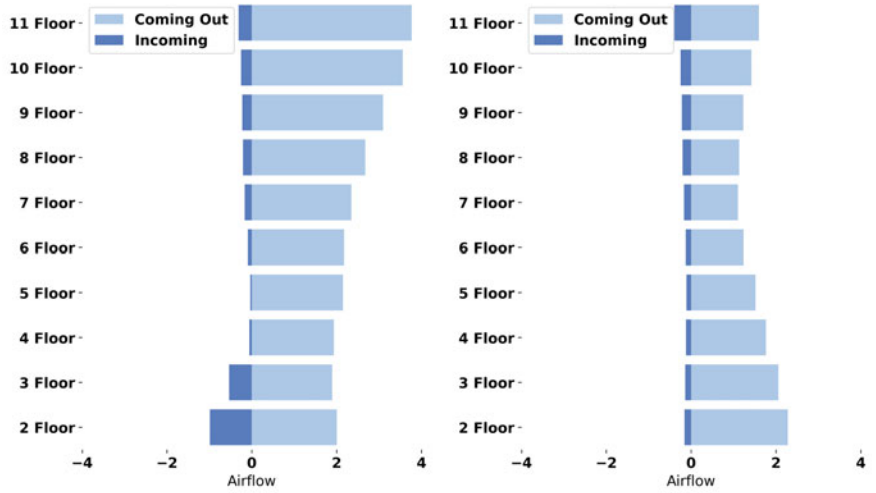
Fig. 1 Data flow from model IDF to optimization algorithms PSO (**a**) and GA (**b**)

3 Results and Discussion

The airflow maximization in the double skin façade model was calculated using EnergyPlus simulations. The objective function (to be maximized) is the difference between the airflow that enters and leaves the fifth-floor front window. PC specifications include a CPU Intel Core i5-9400F, RAM 32GB, and Linux Ubuntu 14.04.4 LTS operating system. The range of parameters to be optimized is shown in Table 1. The computational tests were carried out using the PyGgmo framework [5].

We executed each computational experiment 20 times to obtain statistical data to evaluate the model's performance. PSO, presented in Fig. 1a, was configured with the following parameters during the model selection process: 20 people in a population evolving over 50 generations; c_1 and c_2 were set to 2.05, respectively; omega = 0.7298 for all generations. The GA (Fig. 1b) parameters were set as follows: 20 people in a group evolving over 50 generations; 0.95 in crossover factor; 0.02 in mutation probability; 1 in elitism; roulette selection strategy; exponential crossover strategy; and Gaussian mutation type. The parameters described are the default values of the Python Pygmo library [5].

Figure 2a, b presents the airflow graphs for the best scenario found by the optimization algorithms tested in the cities of Brasília and Rio de Janeiro, respectively. Analyzing the 20 independent runs of the algorithms, the maximum value for the



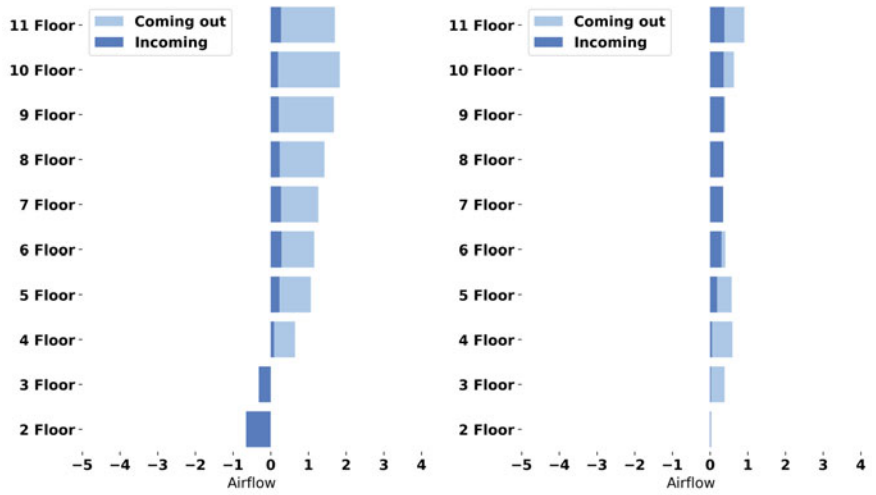
(a) Brasília (b) Rio de Janeiro

Fig. 2 Airflow leaving and entering the front window of the building floors with double skin façade in the optimized scenario for the cities studied

objective function value was reached by the two methods tested in at least one run. In the case of Rio de Janeiro, the optimal value was found in five independent runs of the GA, while PSO reached this optimal value in two runs. For Brasília, the optimization obtained the maximum airflow in the front window in seven runs of the GA and one of the PSO. It is important to note that the vertical axes of the graphs start on the second floor because the focus of the analysis is the double façade, which begins on the second floor.

For Rio de Janeiro, the optimized scenario presented the following solution vector: [0.55, 1.0, 0.1, 45°, 0.4, 0, − 0.7, 0.7, 0.9, 0.5]. Comparing with the best case for airflow found by [3], used as the base model in this work and with solution vector [0.55, 1.0, 0.1, 0°, 0, 0, − 0.8, 0.8, 1.0, 1.0], the optimized model kept: the façade cavity with 100 cm, the top of the cavity completely open, the front windows without vertical increase, and the base of the façade closed. The changes found by the algorithm were related to the rotation of the building, with the azimuth of 45° in the best scenario, an increase of 40 cm vertically in the back windows, an alteration in the position of the back and front windows by 10 cm each, and opening percentages for the front and back windows of 50% and 90%, respectively.

In the city of Brasília, the algorithms returned the solution vector [0.55, 1.0, 0.1, 45°, 0.4, 0, − 0.8, − 0.2, 0.9, 0.5]. Compared to the [3] model, the cavity width, opening of the top of the façade, size of the front windows, positioning of the rear windows, and closing the base of the façade were maintained, as well as in the results for the city of Rio de Janeiro. For better performance of the building in relation to airflow, the algorithm proposed rotating the building by 45°, increasing the front



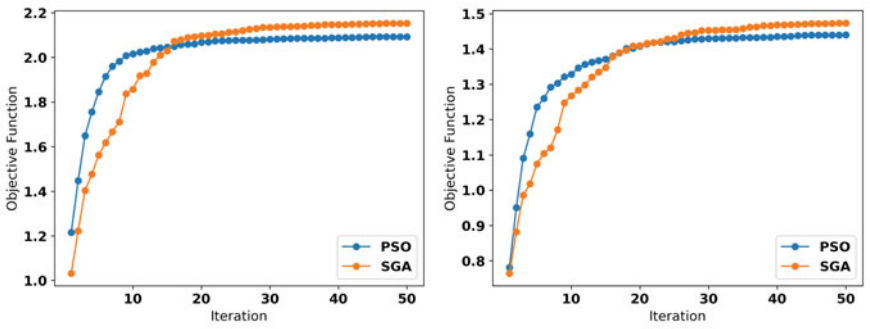
(a) Brasília (b) Rio de Janeiro

Fig. 3 Differences between the airflows found in the best scenario of the optimizations and the simulations of the base case in the cities studied.

windows by 40 cm and modifying the positioning of the front windows so that in the base configuration, the windows are positioned closer together to the floor. In the optimized scenario, they are shifted 100cm downwards. The opening percentages of the front and rear windows were 50% and 90%, respectively.

Figure 3a, b presents the differences between the flows found in the best scenario of the optimizations and the simulations of the base case. In Brasília, the optimization showed an improvement in the flow leaving the window and going toward the double façade and in the flow entering the building from the fourth to the eleventh floor. In Rio de Janeiro, this improvement in airflow occurred from the third to the eleventh floor for the coming out airflow and from the fifth to the eleventh floor for the incoming flow.

Figure 4 shows the average convergence of the objective function. Initially, tests were carried out with 100 iterations of the algorithm. Still, the difference in the objective function values from iteration 50 onwards was not very significant, so for the other executions, the limit of 50 iterations was defined without harming the final result of the optimization. In PSO and GA, the best values for objective function are found, which are 2.1543 and 1.4760 m^3/s for Brasília and Rio de Janeiro, respectively. From the convergence graphs, it is possible to notice that the GA always remains above the PSO from iteration 30 onwards, despite the two reaching the best objective function values in some independent runs. This happens because the GA approaches the optimized scenario more often during the 20 runs and faster during the 50 iterations. This behavior of the algorithms indicates a better performance of the GA. Regarding the execution time, each run of the PSO lasted around 34 h, and the



(a) Brasília (b) Rio de Janeiro

Fig. 4 Average convergence of the objective function over the 50 iterations of the evolutionary algorithms for the fifth-floor airflow

GA was approximately 33 h. Testing the models manually and individually would require considerably more time than that presented by the algorithms, sometimes requiring more than one specialist to carry out the simulations and demanding extra time to compare the individual simulated models.

The proposed method proved effective in semiautomating the process of optimizing buildings with DSF, aiming to support the planning of more efficient, sustainable, and comfortable constructions for their users. In addition, the developed method has the potential to contribute to civil construction designers in making faster and better decisions in buildings still in the design phase. The approach can be applied to any building as long as a construction model is available. The computational procedure makes it possible to quickly find energy-efficient solutions, including specific knowledge and the generation of multiple solutions, where they may be unusual or even counterintuitive.

4 Conclusions

This work evaluated the airflow optimization in a double façade building model in two Brazilian bioclimatic zones to improve users' thermal comfort. For this, the evolutionary algorithms PSO and GA, together with the EnergyPlus software, were used to optimize the constructive parameters of the computational models. After the analyses, it is possible to conclude that the two methods tested presented satisfactory results in the search for scenarios with better airflow distributions compared to the results achieved by [3]. However, the GA has shown relatively better performance because of the execution time and faster convergence.

Considering the different configurations for the final DSF model in the two climatic zones tested, the performance of numerous manual tests and considerable execution process can make the analysis of many variables simultaneously unfeasible.

On the other hand, the use of optimization algorithms made it possible to consider the influence of parameter changes on the project in its entirety, allowing for more complex analyses. In the future work, it is proposed to carry out more executions of the algorithms and tests of other optimization methods as well as multi-objective techniques. It is also planned to test the computational approach in different buildings with a double façade. Accessing other models with this type of architecture was one of the difficulties encountered during the project execution.

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Digital Reading Fluency Training for Primary School Students—Concept and First Results

Sara Durski, Ute Massler, and Wolfgang Müller

Abstract Good reading fluency is of tremendous importance for private and professional life, and it is important to acquire this skill at school. Primary school in particular builds the foundation for this ability. A typical approach to training reading fluency is reading aloud methods. The Readers' Theatre is considered an effective method in this context. For intensive reading fluency training, students should practise reading also outside the classroom. This paper presents a digital learning tool based on the Readers' Theatre for individual and personalised reading fluency training to be applied in school and especially out of school at home. Aspects of interactive storytelling that increase learning motivation and engagement in a game-based context and aspects of adaptive learning for (partially) automated, individualised, and personalised training are integrated in the concept. The concept was implemented as a prototype and tested with 15 students of a third grade. Usability tests and ethnographic interviews were conducted to assess acceptance of the approach. This paper reports on the conception, development, and evaluation of the prototype reported in the context of corresponding evaluations. Based on the findings, the paper discusses readiness of the approach for future use in schools linked to learning activities at home.

Keywords Media-based learning · Seamless learning · Reading fluency · Readers' Theatre · Adaptive learning · Interactive storytelling

S. Durski (✉) · U. Massler · W. Müller
University of Education Weingarten, Kirchplatz 2, 88250 Weingarten, Germany
e-mail: durski@md-phw.de

U. Massler
e-mail: massler@ph-weingarten.de

W. Müller
e-mail: mueller@md-phw.de

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1 Introduction

Digital media such as computers, tablets, and smartphones have become an indispensable part of our lives. Children come into contact with them from an early age. In Germany, 99% of households with children have a computer or laptop and 99% have Internet access. Despite these developments, media-based learning and computer learning are only used to a limited extent in schools [1], although the use of new technologies in the school context offers great potential due to the individualisation and personalisation possibilities.

Studies have confirmed that primary school students have significant deficits in school-language reading competence [2], and the number of students with reading difficulties is rising. Results from the progress in an international Reading Literacy study revealed that the proportion of students with reading difficulties in the fourth grade increased from 16.9 to 18.9% in Germany between 2001 and 2016 [3]. Another study between 2016 and 2021 reported a continuing decline of reading competence, possibly linked to school closings and distance learning in the context of the COVID-19 pandemic [4]. The heterogeneity of the student community is also increasing [3] and is also present in the area of reading competence. Deficits in reading competence are problematic because they can impair learning in various school subjects and can be the reason for underperformance in school. An essential component of reading competence is reading fluency [5]. To be able to read fluently, students require basic reading skills that enable them to assign word meanings quickly and reliably at the level of letters, words, sentences, and text passages. In addition, texts must be read (aloud) at an appropriate reading speed and with the right intonation. Repeated reading aloud has positive effects on accuracy, fluency, and comprehension of reading [6]. There are a number of repeated reading aloud methods, such as the Readers' Theatre [7].

For intensive training of reading fluency, self-learning phases are also highly relevant. However, while many reading aloud training activities require a reading partner, such a reading partner is not always present for all students outside the classroom.

The contributions of this paper are as follows: First, we provide the design of a one-to-one digital training program that aiming to improve the reading fluency of primary school pupils. Secondly, it discusses individualisation and personalisation possibilities for the students by using aspects of adaptive learning and interactive storytelling.

The remainder of this paper is as follows: First, an overview of the state of the art is given, including the method Readers' Theatre to train reading fluency, digital tools for reading fluency training, as well as gamification and adaptive learning is provided. Next, the taken approach in this project based on a design-based research methodology is explained and the developed concept is presented. Scenario depicting the application of the conceptualised and developed learning technologies highlighting the effects of interactive storytelling elements and adaptive learning approaches exemplify the developed solution of this work. First approaches to the evaluation

of the developed solution and the investigation results are presented in the following. This work concludes with a summary and an outlook.

2 State of the Art

2.1 Reading Fluency Training

This work focuses on the development and first testing of a digital learning tool for training reading fluency. Since research has shown that reading accuracy and reading comprehension can be improved through repetitive reading methods such as, e.g. repeated reading or paired reading [6], the reading fluency method Readers' Theatre has students cooperatively practise reading dialogical texts divided into different roles [7]. The Multilingual Readers' Theatre (MELT) extends Readers' Theatre to include a bilingual or multilingual approach that integrates school languages, foreign languages, and migration languages [8]. MELT is valued by learners and teachers as very motivating and instructive [9]. Both MELT and the Readers' Theatre serve as the basis for the work presented here.

2.2 Digital Tool for Reading Fluency Training

The use of digital media, especially mobile devices in the class, realises context-free learning in the sense of seamless learning [10]. This means that students can learn independently in terms of time and place, whether in the classroom, at home or in other contexts. There have been several approaches to support reading fluency training with digital technologies. For instance, the digital application MyTurn-ToRead based on an e-book is designed as a virtual reading partner for practising fluent reading [11]. The traditional Readers' Theatre has been extended by Vasinda and McLeod [12] through the use of podcasts, which can later be published for parents or other students. Durski et al. developed an extension to the voice assistant Alexa to take the role of a reading partner [13].

GameLet is another digital learning environment for reading fluency training and is based on MELT. The aim of GameLet is to record a podcast in a digital recording studio together with classmates. For this goal, reading must be practised repeatedly by using different training methods. The narration of a story guides the student through the tool. The student trains his reading both in self-directed, individual settings, where the computer takes over the reading roles of the classmates and serves as a speech model, and in collaborative group settings. In addition, the student receives peer and teacher feedback [14]. Thus, GameLet's training scenarios with gamified, self-guided, and collaborative learning make it possible to intensify and extend learning activities to outside school environments.

2.3 Gamification and Interactive Storytelling

As some students find repeated reading aloud activities monotonous, it is important to increase motivation and engagement to practise [15]. This can be achieved through gamification. The idea of gamification is "the use of game design elements in non-game contexts" [16]. Individual game elements are taken and placed in a completely different context [16]. Game design elements can include goals, rules, competitions, reward systems and levels. A gamification design process is not necessarily about designing a proper game, but more about increasing motivation and engagement through some sort of play. Especially in digital learning tools, gamification can have additional value in fostering motivated and engaged learning with the joy of play [17].

There are various approaches for the realisation of game-based learning. In this work, the game design element of interactive storytelling is used to increase student motivation and engagement. In addition, through storytelling, it is possible to teach and learn successfully because stories transmit information and serve as a central element for human thinking and communication [18]. When telling a normal story, there is usually a strict sequence of events and action. This aspect differentiates typical stories from interactive stories, because in interactive storytelling there is "an entire dramatic universe of potential stories: a storyworld" [19]. The interactive process creates a dynamic narrative and "enables storytellers as well as story listeners to make their own decisions actively to determine the later course of the storyline" [20]. Thus, a digital learning tool can be individualised and personalised through interactive storytelling. Furthermore, research has shown that interactive storytelling inspires learners and can promote the acquisition of a language [21]. Branching paths can be used to visualise the different possible ways the student can take through his or her choices. However, these "branching paths are generally too linear to suffice for highly interactive storytelling" [22].

2.4 Adaptive Learning

The use of computers for learning has been investigated for several decades. Much early research has focused on developing training programs that allow students to learn better and faster. Regarding the development of reading competence, learning with a computer has proven beneficial in developing the ability to decode [23].

But computer-based training programs also have the unique ability to provide individualised and personalised training. Since so far, no digital design exists enabling students to practice their reading fluency in an individualised and personalised way, this study aims at designing one. One way to develop a digital learning tool with individualisation and personalisation possibilities is to use adaptive learning. In this case, digital monitoring of learning progress can take place by using technologies. Learning content can be dynamically and individually adapted based on the learner's

performance, that is his skills and abilities [24]. Consequently, students can work through already known topics or learning content more quickly and thus gain more time for learning content that is still unknown or problematic for them. A survey of students at the Colorado Technical University using an adaptive learning platform reveals that they have more control over their learning content, they are more engaged, and they feel that classes are more fun with the platform. In addition, student performance improved [25].

3 Methodology

The aim of this project is to develop and test a digital learning tool for primary school students to train reading fluency in a personalised and individualised way. Therefore, the research question is: How should a digital learning tool for personalised and individualised reading fluency training be designed to be accepted by students?

To answer this research question, this project pursued a design-based research (DBR) approach [26]. Actions and decisions that affect learning experiences are incorporated in the DBR approach and integrated into the research. It uses design processes for research and practice that are linked to scientific thinking and action [27]. In this way, the DBR approach unites theory with practice [28], whereby practice becomes the centre of theory development [27]. The following aspects distinguish the DBR approach from other design processes [29]: (1) there is a clear reference to scientific goals, theories, and results; (2) the documentation of the design process is careful and systematic; (3) through formative evaluation, critical monitoring takes place; and (4) context-independent theories are developed.

In this way, in the DBR approach, the development is accompanied by regular evaluations and continuously refined with the aim of developing sustainable innovations [30]. There is a combination of knowledge- and application-oriented research in a continuous cycle of design, implementation, evaluation, and re-design [26]. At an early stage, users are integrated into the product development process. Later, they regularly test the development during implementation using acceptance and usability tests. Thus, real-life requirements can be identified and needs understood [31]. In the present study, the aim is to gain new understanding and knowledge about the use of a digital learning tool for individualised and personalised reading fluency training for primary school students.

4 Concept

The target group of the digital learning tool for training reading fluency consists of third and fourth graders with deficits in school-language reading fluency. This tool allows students to train their reading fluency in single training sessions in individualised and personalised ways. The concept of this work is based on Readers' Theatre

and GameLet, but unlike GameLet, the concept does not include a multilingual approach. This is due to the fact that this tool is addressed to younger students.

For effective training of reading fluency, the tool is based on the proven reading aloud method Readers' Theatre. With the digital learning tool, students are enabled to practise reading aloud on their own since the system takes over the reading parts of the other reading roles in the Readers' Theatre script, thus providing virtual reading partners. Beneficial too is that by listening to the parts read aloud by the system, the student hears the correct pronunciation, emphasis, and reading speed. To intensify the reading fluency training, various reading fluency activities such as audio book reading, reading at a favourite place or reading with a partner are used. Since good text comprehension is a key requirement to be able to read a text with adequate reading fluency, comprehension tasks such as quizzes (see Fig. 1) or cloze are also integrated into the learning tool. To ensure student immersion into the story world and connect the different learning tasks, short videos guide the student through the learning tool. Provided videos continuously tell a narrative of a story and introduce the student to the language and content of the story.

In the tool, there are two different stories. The first story is from the Readers' Theatre script, this story takes place under water and is about a little mermaid. The second story is the story told in the videos, which guides the student through the tool and can be influenced by the student. This second story takes place in an old theatre and the main character of this story is an elderly man who once worked in the theatre. However, there is a fusion of these two stories, so the mermaid from the theatre script also appears in the second story.

While learning with the learning tool, the student can make decisions that affect the plot of the story. Hence, each student can influence the development of the story. For example, the student can influence to change the location or decide to meet the mermaid. Thus, for example, one student leaves the location of the old theatre and enters the mermaid's world, while another student interacts with the mermaid via

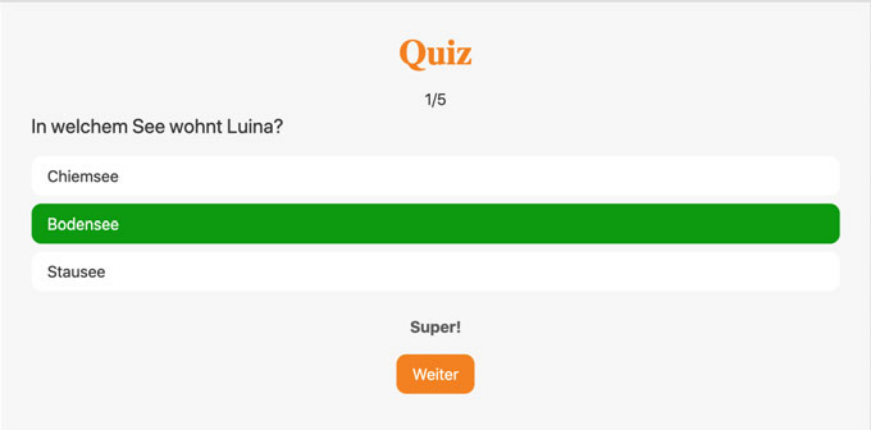

Fig. 1 Question from the quiz

video call, staying in the theatre. Thus, elements of interactive storytelling are used to increase and maintain the motivation and engagement of students.

In an interactive story, there can quickly be extensive branching paths through the many different possible paths that learners take. Hence, in the context of this work, reduced branching paths were chosen for feasibility. Figure 2 shows an example of the branching path for the interactive story of this work.

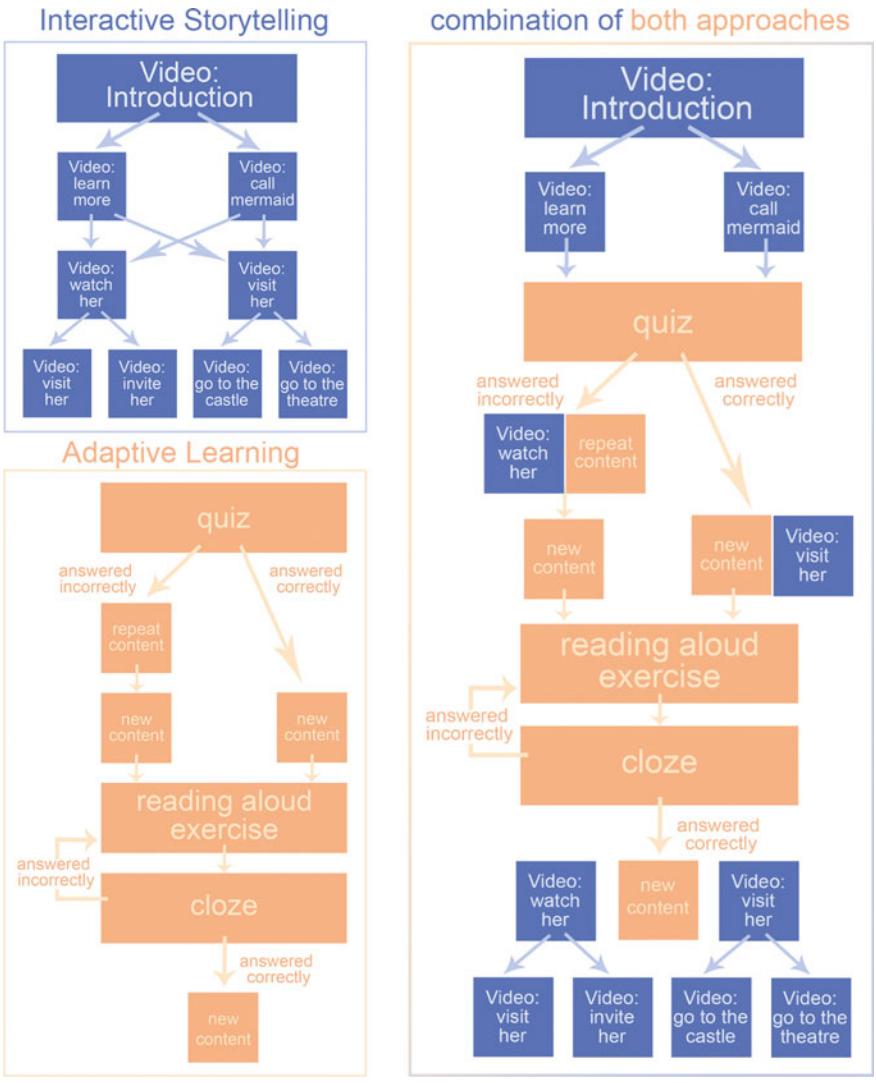

Fig. 2 Different branching paths (interactive storytelling, adaptive learning, and both combined)

The focus of this work is to find out whether a combination of interactive storytelling and adaptive learning is possible and accepted by students. Aspects of adaptive learning are integrated into this concept for (partially) automated, individual, and personalised learning. Thereby, future learning content is dynamically adapted according to the learner's performance providing him with direct feedback. For example, a student who has finished a task well gets a different task from the system than a student who has finished the task not so well. Figure 2 also shows a branching path to aspects of adaptive learning incorporated in the concept and a branching path illustrating the combination of both approaches.

For the development of the digital learning tool, personas and scenarios were created. The following scenario illustrates the intended use. Louis' class teacher wants Louis to train his reading fluency through repeated reading aloud. Since he does not have a reading partner at home, his teacher tells him to train with the digital learning tool. Louis is excited about learning on the computer. To begin with, he watches a short video in which an avatar greets him and tells him about a mermaid. Now Louis is interested and wants to learn more about the mermaid. But before he can find out more, he has to decide which way he wants to go. He decides against calling the mermaid and first wants to learn more about the mermaid. Louis does not get the chance to call her again, but he can decide to visit her or invite her later. But there are not only videos and exciting story decisions but also reading tasks, quizzes, and cloze. Louis also completes these tasks. However, Louis does not know that his next learning content will be personalised based on his performance in the quiz or cloze.

The concept was implemented as a prototype. This prototype focused on the combination of aspects of the two approaches adaptive learning and interactive storytelling as well as the use of the videos (see Fig. 3). Videos supporting the interactive story were adapted to the age of the target group. Child-friendly, colourful images were used and for the spoken content different computer voices were used, generated by text-to-speech technology. When the student has the opportunity to make a decision regarding the story, there are two buttons with a brief explanation of the two different story ways. By clicking on a button, the student chooses one of the two ways and a new video starts. However, as the prototype is not yet fully functional, it cannot implement the adaptive learning path of the learner. A person has to navigate to the next learning material according to the student's performance and decision.

5 Evaluation

Using the digital learning tool, students can practice their reading fluency in an individualised and personalised way. By integrating the two concepts of adaptive learning and interactive storytelling, the learning content can be dynamically adapted to the student's performance and motivation can be maintained or even increased through the different story choice options. In spite of these advantages, it is not clear whether students will accept the combination of aspects of the two approaches

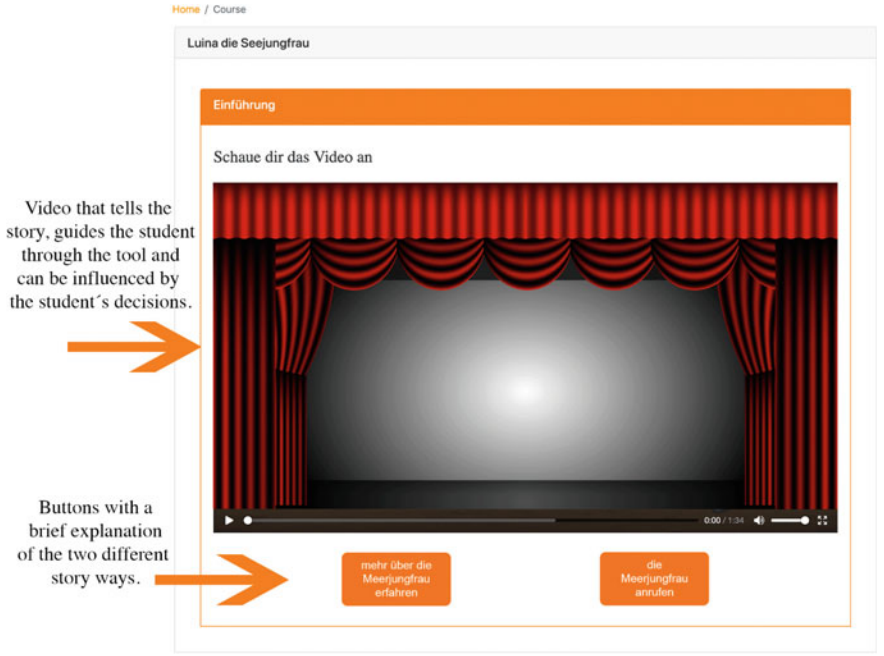

Fig. 3 Video and two buttons for the two different story ways

adaptive learning and interactive storytelling and whether it has a good usability. To investigate this issue, the design and use of the prototype of the learning tool were evaluated.

In accordance with the DBR approach, the development of the digital learning tool is tested through regular evaluations and is then continuously developed further. The prototype based on the concept described before was tested. Individually, 15 primary school students from a third grade class took part in these tests. The focus of this test was to investigate the combination of the two different aspects (adaptive learning and interactive storytelling). During the evaluation, usability tests and ethnographic interviews were conducted. The benefit of a qualitative study is that the experience and actions of the students can be investigated and follow-up questions can be asked; thus, backgrounds, causes, and unclear aspects can be uncovered.

To use the learning tool, students need a web-enabled device. For the tests, they were provided with a laptop. After a short introduction to the content and technical aspects, the student was asked to practise with the prototype on their own and to share their thoughts aloud. When the student indicated problems or pointed out misunderstandings and ambiguities, he was asked to elaborate. In addition, after the training with the prototype, the student was asked questions aiming at assessing his acceptance of the learning tool. On average, each student needed about 20 min to complete the whole test. A content analysis was used to analyse the qualitative data collected. The results of this first evaluation show that a combination of aspects of

adaptive learning and elements of interactive storytelling is possible and accepted by the students. Both the adaptive learning and interactive storytelling features are perceived positively. The students find the tool good, funny and they enjoy practising with it. They can imagine using it in the future. For example, the interaction possibilities for the story were described by the students as "really good and exciting choices", which motivated them. Important too, the evaluation results brought to light the high heterogeneity of the student community. As a consequence, the target group for this project was reduced to third and fourth graders with deficits in school-language reading fluency and age-appropriate German language skills.

The results of this research also contributed to improve and further develop the concept. Most students found it easy to understand the videos; however, a few students wished that the speaker made longer pauses between sentences and paragraphs. Consequently, in order to avoid overloading the students, the content of the videos was improved and speech pauses were incorporated. The videos for the prototype used computer voices, which some learners found unnatural. Hence, we plan to replace corresponding voices by audio recording from human model readers.

6 Summary and Outlook

This paper pursues the design of a digital learning tool for individualised and personalised reading fluency training that could be accepted by primary school students. To address this aim, a concept combining aspects of interactive storytelling and adaptive learning is developed. A game-based learning environment is created through the interactive storytelling aspects, which increase student motivation and engagement to practice reading fluency. The adaptive learning aspects allow the students to work faster on learning content that they are already good at and to work more intensively on content that they are not yet so good at. For this purpose, the system adapts the next learning content according to the student's performance. For effective training of reading fluency, the tool is based on the reading aloud method Readers' Theatre.

The concept was implemented in a prototype and evaluated by 15 primary school students. The aim of this evaluation was to test the acceptance of the two combined approaches of interactive storytelling and adaptive learning. Qualitative data were collected through usability tests and ethnographic interviews, which were analysed with content analysis. The evaluation results show that the combination of the two approaches is feasible and accepted by the students. The interactive storytelling aspects motivated the students to learn and they enjoyed it very much. Moreover, students disclosed their willingness to use the digital learning tools for individual and personalised reading fluency training in the future.

In spite of these positive reactions, the prototype needs to be improved and further developed. The videos will be improved based on the evaluation results, and the prototype will be technically further implemented. Since the focus of this evaluation was on the acceptance of the combination of the two approaches, only a part of the complete learning tool was tested. In addition, a critical aspect of this study is that

the sample consisted of 15 students, and it is important that more data be collected through further studies. Thus, the prototype needs to be developed further, and in next evaluations, the further development and the extensive learning tool should be evaluated with a larger sample. Furthermore, the acceptance of teachers and experts should be investigated.

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Application of Data Mining Clustering for Patterns Analysis of Cyberbullying Surveys

Marcos Orellana, Pablo Arévalo, Alexandra Bermeo, Juan-Fernando Lima, Priscila Cedillo, and Maria-Ines Acosta-Uriguen

Abstract In latest years, harassment or abuse through mobile devices and the Internet has been on the rise. This issue, better known as cyberbullying, is crueler and more dangerous than the traditional ways of bullying, largely due to the anonymity on social media or the Internet possibly generating consequences across the person's lifetime. Therefore, different approaches have been developed in the search of alerting, informing, and preventing about cyberbullying situations such as the creation of regulations, issuing laws, or promoting technological approaches. This paper aims to find relevant patterns by applying clustering techniques, and to accomplish this goal, the survey titled the scale of victimization among adolescents through mobile phones and Internet (CYBVIC) has been used allowing to measure behaviors of harassment, aggression and social exclusion. The results obtained by the clustering can be used to combat this social problem due to this analysis highlights the seven most important questions and the hidden patterns among the filled responses.

Keywords Cyberbullying · Harassment · Data mining · Clustering algorithm · CYBVIC

M. Orellana (✉) · P. Arévalo · A. Bermeo · J.-F. Lima · M.-I. Acosta-Uriguen
Universidad Del Azuay, Cuenca, Ecuador
e-mail: macosta@uazuay.edu.ec

P. Arévalo
e-mail: pablo.loja@uazuay.edu.ec

A. Bermeo
e-mail: alexbermeo@uazuay.edu.ec

J.-F. Lima
e-mail: flima@uazuay.edu.ec

M.-I. Acosta-Uriguen
e-mail: marore@uazuay.edu.ec

P. Cedillo
Universidad de Cuenca, Cuenca, Ecuador
e-mail: priscila.cedillo@ucuenca.edu.ec

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1 Introduction

Social media platforms have gained popularity among people of different ages [29] since they provide users not only with a good platform for communication and information exchange, but also with quick access to recent news [32]. Then, these sites are usual stops for billions of people today, hence attracting various illegal activities and promoting wrongdoing in some instances [28].

Abuse in a cybercontext has a tendency to be crueler and more dangerous than forms of bullying in the real world, due to its unique characteristics: (1) has a relationship with the degree of technological experience; (2) occurs indirectly, therefore it can be done anonymously; (3) the abuser does not usually see the reaction of the victim; (4) the different roles of the bystander in cyberbullying are more complex than in traditional bullying, since they can deal with the abuse by different means; (5) a motive for traditional bullying is thought to be status gained by displaying power over others, in front of witnesses, but the abuser will often lack this in cyberbullying; (6) the breadth of the potential audience is increased; (7) it is difficult to escape from cyberbullying as it can take place through various technology platforms such as emails, dating social networks, cell phones, online games, and voicemail [15, 26]. The consequences of cyberbullying can include anxiety, depression, and even suicide, and they are detrimental both individually and societally [24]. This is why having policies, regulations or tools to prevent this problem is a constant challenge for society.

There are several studies that suggest different approaches to use in cases of cyberbullying [18, 23]. They can be categorized into: laws and regulations seeking to regulate the use of the Internet; study plans focused on safe use of the Internet; and finally, technological approaches to combat cyberabuse [23]. Data mining techniques have an important role in this third approach since they are used to resolve issues related to cyberbullying, allowing the development of better solutions with a better understanding of this problem [2]. Therefore, this work, through the use of data mining techniques, aims to find relevant patterns, as well as determine the most important questions from the data collected. For this, the K-means algorithm was used, an unsupervised grouping method, which can be adapted to new examples and its use extends to various areas. This document is structured as follows: Sect. 2 presents the related works, Sect. 3 describes each of the steps involved in constructing the process, Sect. 4 shows the obtained results , and Sect. 5 presents the conclusions and future work.

2 Related Work

According to the analyzed studies, cyberbullying can be defined as the use of the Internet and various technologies to send or publish embarrassing or harassing content, either to a person or to a group of them [15, 17]. In other words, cyberbullying is the abuse that is done repeatedly through information and communication tech-

nologies (ICT) presenting serious negative consequences for life, both for the victim and for the perpetrator [26]. In general, information is fundamental in the face of this threat since, based on it, the pertinent prevention measures are determined [6]. This is why the process of analyzing the great amount of data, generated by different sources, and the possibility of identifying patterns or vocabularies of cyberbullying has been studied from different approaches [6].

For starters, Bozyigit et al. [3] proposed a study in which several artificial neural networks models have been designed with different approaches to detect cyberbullying in social network contents. The developed model had an F-value of 91% which combines the measures of accuracy and completeness to return a more general measure of the quality of the model. Moreover, the authors of [23] used unsupervised tools, for example, implementing K-means models to create partitions by iterative relocating entire data sets into groups, which are then used for word extraction and pattern grouping, improving a Naïve Bayes classification model focused on cyberbullying based on accuracy and calculation time. In other cases, the practices of school educators were evaluated, through their perceptions of cyberbullying. Using clustering techniques, various groups of educators were identified according to their way of acting in the face of this problem [8].

Moreover, surveys have been used as a method of collecting information to detect signs of violence, behaviors or actions that define cyberbullying. Such is the case of Udris [27] that through a self-report questionnaire on technology use habits, cyberbullying, and experiences of cybervictimization through linear regression presented that 22% of the participants had experienced cybervictimization, while 7.8% admitted have cyberbullied others. In other cases, through a peer relations questionnaire related to the frequency of bullying in a school environment, the results obtained showed that the prevalence of abuse was 55%, many of the students did not share information about if they suffered or not abuse and in others cases did not listen to abusive situations [10].

3 Methodology

The methodology for conducting this study was ruled by four steps: (i) data collection, (ii) data preprocessing, (iii) application of clustering techniques, and (iv) evaluation of the model. A detailed graph of each of the steps can be found in the following link: https://bit.ly/3Us53t2 The initial activity focuses on data collection through the application of a cyberbullying questionnaire. Then, in the data preprocessing stage, data cleaning techniques were applied with the aim of improving results. The next two stages related to the application of clustering techniques and the evaluation of the model were performed by a data scientist who executed the necessary grouping algorithm and the subsequent evaluation of results, identifying behavioral patterns.

3.1 Data Collection

The data collection stage was developed through the application of a questionnaire composed of two parts: the first one, where sociodemographic information of the participants was collected such as geographic location, family and student information, and level of psychological well-being; while, in the second part, the scale of victimization among adolescents through the mobile phone and of Internet, CYBVIC [4] was included. This scale is made up of 18 items that measure abusive behaviors through a response range of 1–4 (Never, Sometimes, Many times, Always). Victimization through a mobile device is measured through 8 items, which evaluate behaviors that involve aggression, violation of privacy, denigration, and social exclusion [9]. Similarly, victimization through the Internet considers the previous eight items, adding two more items in relation to identity theft. This scale was built and validated in Spain and Mexico [9]. It has an appropriate internal consistency in addition to having adequate psychometric properties, demonstrating that it is a valid and reliable measure in research that seeks to expand knowledge about this social problem [4, 9]. The sample was made up of university students in Ecuador.

3.2 Data Preprocessing

In the first place, empty surveys that do not have any type of response were discarded, in order to obtain optimal results. Subsequently, it was necessary to determine the attributes to be considered in the following activities, so for this particular study, the items corresponding to victimization using a mobile device from the CYBVIC scale were selected [4]. The importance of these items arises because mobile technologies access the Internet and communication systems, such as social networks, more quickly, providing additional mechanisms for aggressors to reach victims more easily [30]. In addition to them, a scale of mental well-being with a range of 1– 10 (being 1 excellent and 10 terrible) present into the sociodemographic part of the questionnaire was included because cyberbullying negatively impacts the mental health of young people. The psychological manifestations of cybervictims are: decreased self-esteem and motivation, low performance in daily activities, sadness, fear of rejection, and need for approval [11]. This is why having this scale will allow knowing the level of perception of psychological well-being of the respondents and if it is influenced by previous abuses perpetrated against them.

Since the cyberbullying survey is of the ordinal type, there are ways to handle them. In certain cases, these values are considered as clearly categorical data, completely omitting the order, this causes a substantial loss of information that can cause erroneous results [13]. On the other hand, ordinality can be considered in continuous data methods if they are used scores for each of the categories citing as an example the Likert scale that has values from 1 to 5 for their respective categories [14, 16]. That is why, in this study, in order to obtain correct results, only the numerical values

from 1 to 4 on the CYBVIC scale, and from 1 to 10 on the psychological well-being scale were considered, since they represent an ideal way for each of its categories [16]. Finally, prior to the application of the grouping algorithm, it is mandatory to have standardized data to avoid bias in the results. Normalization is applied to scale values to fit a particular range. When manipulating attributes belonging to different units and scales, adjusting the range of values is essential [7]. In order to have uniformity in all the selected data, in this particular case, the values obtained in the psychological well-being scale were normalized to a scale ranging from 1 to 4.

3.3 Application of Clustering Techniques

Clustering is a useful technique in data science, and it is widely used as one of the most important steps in exploratory data analysis [12, 23]. Clustering can be defined as the unsupervised classification of data elements or observations; in other words, the data sets have not been classified into any group and therefore do not have any class attributes associated with them [14]. Clustering algorithms are used to find useful and unidentified pattern classes by dividing data into groups of similar objects. An example related to this technique is the search for purchasing patterns considering a retail database that contains information about the purchased items [22].

***K*-Means** It is one of the most used and known clustering algorithms [23, 25]. The K-means algorithm has been widely studied and implemented in several domains [22]. This method partitions a set of N samples X into K disjoint clusters C, each group handled by a centroid [20]. The main objective is to choose centroids that minimize the inertia, or the sum of squares criteria within the group.

$$\sum_{i=0}^{n} \min_{\mu_j \in C} (||x_i - \mu_j||^2) \tag{1}$$

K-means is composed of three stages. Initially, it selects the initial centroids by choosing samples from the data set. Then, it assigns each of the elements of the data set to its closest centroid [20]. Subsequently, it creates new centroids based on the mean value of all the samples destined for each previous centroid. Finally, the difference between the new centroids and the old ones is calculated, these steps are repeated until the centroids do not move significantly [20].

3.4 Evaluation of Model

Since K-Means requires an input K value, there is no precise value in terms of the number of groups that should be laid out. Consequently, the selection of this value influences the results obtained [14]. Therefore, in this study, the elbow method is

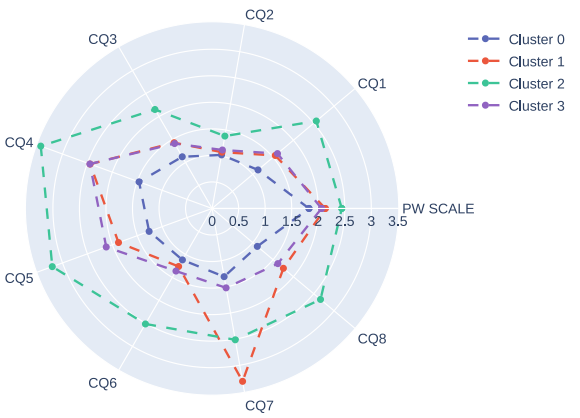

Fig. 1 Radar plot: Highest and lowest centroids per question.

applied, with the aim of determining the optimal number of clusters. The elbow method model performs K-means clustering on the data set for a range of k values, and for each of these values, the sum of the squared errors (SSE) is calculated [19, 31]. Subsequently, the objective is to select a low value of k that provides a low SSE, usually established by the elbow [19, 31].

4 Results

The results of the applied method are showing: As a first point, it is obligatory to identify the optimal number of clusters for the study. The figure of the elbow graph (https://bit.ly/3fRCG8Q) shows that $K = 4$ is the optimal number. As it is a graphic method, it facilitates its use in several areas with large-scale data, making it more recommendable than other methods, because they may have computational overhead and longer processing times [31]. As a next step, after the K-Means algorithm was applied, the centroids for each resulting group were obtained. They represent the behavior of the resulting clusters, with their categorized groups. Figure 1 demonstrates that the values of cluster 0 are the lowest ones compared to the other groups. The centroids in each one of the questions are answered below a value of 2, which equals to "sometimes," in the cyberbullying scale. This occurs in a similar way, with the value of the centroid related to psychological well-being. On the other hand, both clusters 1 and 3 can be observed as an increase in the value of the centroids, which it also occurs in the scale of psychological well-being. It can be seen that the centroid of cluster 1 stands out in RQ7, and its value on the well-being scale is increased compared to clusters 0 and 3. The most visible case can be observed in cluster 2, whose centroids are corresponding to the CYBVIC questions, exceed the threshold of 2 and 3 for the most part (Sometimes, Many times), causing the centroid of the psychological well-being scale to have the highest value.

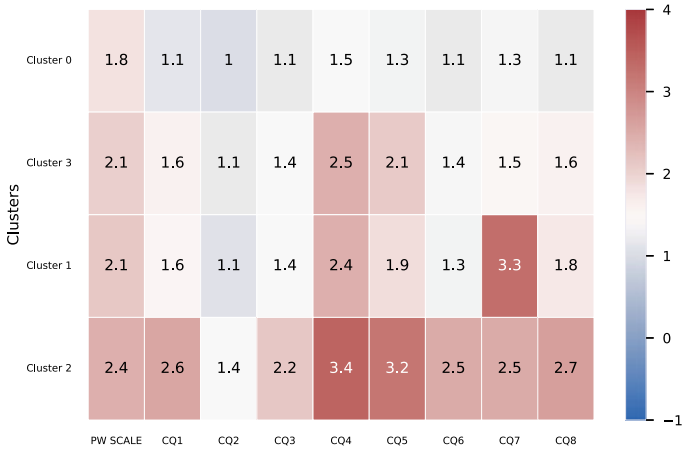

Fig. 2 Heat map: clusters, questions, and centroids' scales

To analyze the behavior presented in the centroids, a heat map was used for a clearer and more precise distinction (see Fig. 2). It can be seen that, if the values of the centroids corresponding to the cyberbullying scale increase, the centroid of psychological well-being does the same. This can be explained because people consider that their psychological state is not excellent due to the fact that at some point in their lives they suffered from these types of abuses, which can leave scars that are difficult to forget. While these abuses occur, the victim suffers from low self-esteem, as well as a low perception of his or her abilities, insecurities, isolation, and in certain cases can lead to situations as unfortunate as suicide [1, 5, 21, 24]. This proves that the most frequent these abuses are, the worse daily mood of the victim is.

Similarly, there are questions with a greater impact on psychological well-being. Figure 3 shows the frequency of responses to each of the questions in each of the clusters. Question 7 stands out, related to receiving calls in a row but with no one to answer in cluster 1, which is mostly made up of values of three and four (often, always) with values that are already a little high on the well-being psychological scale. Similarly, in cluster 2, the impact of question 4 related to telling lies or false rumors and question 5 related to sharing secrets or private information with other people can be noted, causing the values on the psychological well-being worryingly higher. This corroborates what was previously stated, since the values in cyberbullying questions increase, especially the aforementioned questions, the values in the psychological well-being scale do in the same way.

Finally, the original values of the centroids corresponding to psychological well-being were obtained and can be seen in the link: https://bit.ly/3A5BrJK, in which it can be seen that if their values exceed four, they begin to show signs of abuse. The centroid corresponding to cluster 2 has a value of 5.3 and the values corresponding to questions 4 and 5 are the highest, classifying this group as dangerous due to the clear

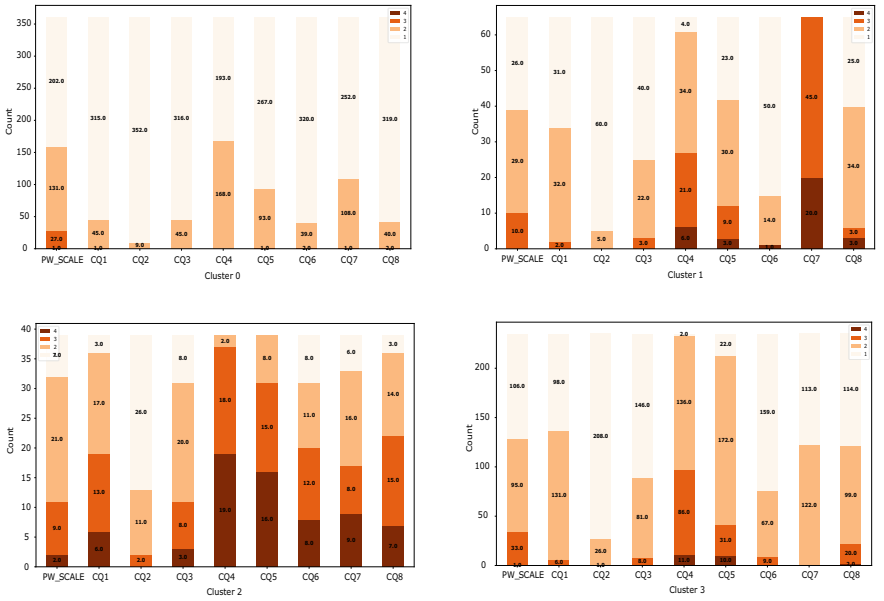

Fig. 3 Stacked bar chart: response frequency per question in each cluster

signs of cyberabuse it presents, as well as a very negative perception of its mental stability. This facilities to implement intervention plans and help these groups to prevent worsening of much more serious situations.

5 Conclusions

In this study, the data mining clustering technique was applied in order to find significant patterns in the applied questionnaires. Thus, for the development of the study, sociodemographic questions and the CYBVIC scale for mobile devices were used in a sample made up of university students from the city of Cuenca. Similarly, it is important to emphasize the importance of having normalized data prior to applying the algorithm in order to avoid erroneous results. Therefore, normalizing the data to a general scale was satisfactory. The K-Means application was ideal since the results obtained allowed to locate behavior patterns in which it is observed that perceived psychological well-being worsens while the frequency of cyberabuse on mobile devices increases. This corroborates what has been previously presented in the literature, where it is mentioned that the serious consequences of cyberbullying start from isolation and decreased self-esteem, escalating progressively until reaching limit situations such as suicide. This process can be applied in future projects

focused on cyberbullying where, in addition, it has been planned to expand the study sample, as well as work with more variables in order to contribute to the decrease of this social problem.

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Radio Coverage Prediction in Wireless Networks: A Bibliometric Study

Marianne Alfredine Omonlola Balogoun, Vinasétan Ratheil Houndji, Michel Dossou, and Anne-Carole Honfoga

Abstract The problem of predicting radio coverage is a fundamental step in the wireless networks design process and is nowadays very helpful in reducing drive tests for monitoring. Among the continuous flow of research in this area, a scientific contributions map becomes relevant to guide future researches correctly. This paper provides a bibliometric analysis and future research avenues to predict radio coverage. A structural insight is obtained on conceptual clarification, collaborations, top sources, authors, affiliations, most cited documents, and most cited countries. A total of 3134 documents have been analyzed: 49% are journal papers and 51% are proceedings papers. 60% of them are published during the last seven years. The majority of recent relevant works on the topic are focused on wireless communication systems, specifically 5G. The USA, China, and India are leading the way in research in this field. IEEE access, IEEE transactions on antennas, and propagation are the leading journals.

Keywords Wireless networks · Radio coverage prediction · Bibliometric study

M. A. O. Balogoun (✉)
Africa Center of Excellence in Mathematics and Computer Sciences, Dangbo, Benin
e-mail: marianne.balogoun@imsp-uac.org

V. R. Houndji
Institut de Formation et de Recherche en Informatique (IFRI), Abomey-Calavi, Benin
e-mail: ratheil.houndji@uac.bj

M. Dossou · A.-C. Honfoga
Research Unit in Photonics and Digital Broadcasting (URPHORAN), Abomey-Calavi, Benin
e-mail: michel.dossou@uac.bj

A.-C. Honfoga
e-mail: Annecarole.honfoga@uac.bj

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1 Introduction

Electromagnetic wave propagation is at the heart of several wireless networks used in our daily lives. Among the primary objectives of wireless network operators, coverage and capacity occupy a choice place. To provide optimized coverage and a higher capacity, the network coverage is usually evaluated [1]. During the network design, channel modeling provides sound theoretical guidance for communication systems design. This technique defines the process of characterizing the law of radio waves propagation in realistic environments [2]. Path loss or path attenuation is the most important parameter in channel modeling, especially in designing and analyzing the link budget of a telecommunication system. It represents the reduction in power density as the electromagnetic wave propagates in free space. In wireless communication and signal propagation, the signal may be attenuated due to propagation effects (reflection, refraction, diffraction, free space loss, aperture medium coupling loss, absorption) or terrain contours (environment, antennas height and location, distance between transmitter and receiver, propagation medium) [3]. Indeed, seven major path loss categories have been identified in the literature: Theoretical/Foundational Models, Basic Models, Terrain Models, Supplementary Models, Stochastic Fading Models, Many-Ray Models, and Active Measurement Models. For an accurate mapping of the extent of radio coverage existing and planned networks, researchers have developed various methods and approaches whose effectiveness is determined by the predictive power of the path loss model in many diverse environments and at distinct frequencies [4]. The introduction of machine learning (ML) approaches also provided competitive results with state of the art [1, 2, 5–8].

With the voluminous, fragmented, and controversial streams of research on this topic produced by the emphasis at this time on empirical contributions, bibliometric analysis is suitable for scientific mapping [9]. It gives many exciting overviews of the most relevant works, sources, countries, words, expressions, affiliations, authors, etc. To the best of our knowledge, there is no bibliometric study on this topic in the literature. This paper aims to deliver a bibliometric study to obtain a structural insight into different methods and several parameters involved in predicting radio coverage.

The rest of the paper is structured as follows: after Sect. 2 which presents the research methodology, Sect. 3 presents the highlights of this work. Sections 4 and 5 address respectively our results and discussions and the conclusion with some research directions.

2 Methodology

This paper presents the bibliometric study based on data extracted from Web of Science (WoS) [10] database. On July 31, 2022, bibliometrics data were picked from the WoS using this search string: (“radio coverage” OR “received signal strength” OR “radio wave propagation” OR “path loss”) AND (prediction OR prevision OR calculation OR computation OR forecasting OR evaluation OR estimation).

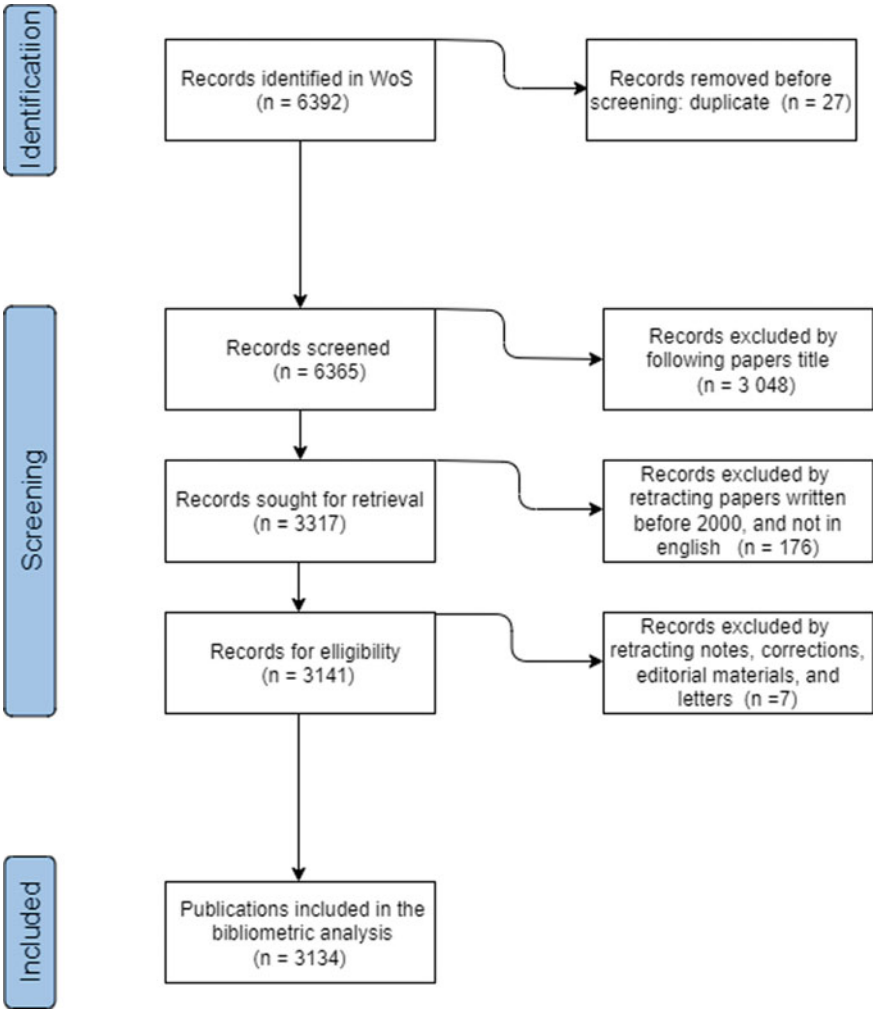

Fig. 1 PRISMA flow of selection process

Figure 1 shows the selection process using the Preferred Systematic Reviews and Meta-Analyses (PRISMA). In short, for further analysis, 6392 publications between 1984 and 2022 have been identified in WoS related to *radio coverage prediction*. A significant number of publications per year have been noticed between 2000 and 2022. A total of 3134 relevant publications have been identified from these publications including articles, article book chapters, article data papers, article early accesses, article proceedings papers, proceedings papers, and reviews. Furthermore, previously selected records were exported to plain text format files from WoS including authors, publication year, title, abstract, subject categories, and source journal.

Then, the relevant documents acquired could be effectively used to perform bibliometric analysis using biblioshiny. The last one is the shiny interface of the Bibliometrix library programmed in R for comprehensive science mapping analysis of scientific literature [9]. In addition, it facilitates integration with other statistical and graphical packages.

3 Highlights

This bibliometric analysis based on *radio coverage prediction* could help researchers to have a bibliometric overview of papers relative to this area of research. Our study shows the dynamics of research on *radio coverage prediction* between 2000 and 2022. The research works from 2015 to 2022 represent 60% of the considered documents. The recent interest in this theme is proven. It is explained by other prediction techniques and the apparition of 5G networks. Actually, most of the most cited documents in the field are about 5G and IEEE 801.1 is the standard widely used.

It also highlighted that prediction models vary according to different environments, transmitters frequencies, etc. In addition, Nigeria is the African country that contributes the most to scientific's production on this topic and has collaborated with China, Spain, etc. Nevertheless, research in this area remains poor in Africa on the need for empirical work. The USA is also very open to collaborating with other countries.

Grunwald et al. [4] worked on an overview of research on existing approaches (traditional and ML model-based) spanning more than 60 years till 2012. In the last decade, works in the same direction have not yet been done.

The topic is quite open to African researchers and scholars. Therefore, studying the possibilities in the African context to predict radio coverage will be helpful for wireless network design and supervision.

Today, it is shown that ML or deep learning gives competitive results with state-of-the-art [11]. So, machine learning approaches will help to predict radio coverage based on actual measurements of path loss (urban and rural areas, especially in forest-covered high hills or mountains [12]).

The deployment of Digital Terrestrial Television in Benin can be used to get true measurements to provide efficient machine learning algorithms to predict radio coverage as in [8].

Supplementary efforts such as [1] on predicting radio coverage for wireless networks to reduce long and costly drive tests can be made with other deep learning and machine learning models.

All path loss prediction models are based on works in the physical layer. Few works show advances in the application of machine learning in wireless communication with other layers such as the MAC layer, network layer, and application layer [13, 14] for other purposes like power control. Thus, to supervise the network, accurate predictions can be made by exploring additional pieces of information on others network layers.

4 Results and Discussion

This section presents and discusses the key findings from our bibliometric study.

4.1 Main Documents on Radio Coverage Prediction

Table 1 presents primary data collection information from the WoS database containing publications related to *radio coverage prediction*. After screening the data, 3134 documents were included in this study. Of these documents, 49% are articles and 51% are proceedings papers. They were written by 7971 authors, with 132 of them writing 151 documents alone. On average, these documents have been published for less than 8 years till 2022, indicating that there is recent activity in this research field.

Table 1 Main information about documents on *radio coverage prediction* in WoS

Description	Results
Main information about data	
Time span	2000:2022
Sources (journals, books, etc.)	1516
Documents	3134
Annual growth rate %	5.12
Document average age	7.32
Average citations per doc	10.43
References	49,995
Document contents	
Keywords plus (ID)	1812
Author's keywords (DE)	7294
Authors	
Authors	7971
Authors of single-authored documents	132
Authors collaboration	
Single-authored documents	151
Co-authors per documents	3.7
International co-authorship %	20.07
Document types	
Article	1476
Article; book chapter	7
Article; data paper	3
Article; early access	6
Article; proceedings paper	49
Proceedings paper	1577
Review	16

4.2 Annual Scientific Production

The total number of documents published each year in the period from 2000 to 2022 is shown in Fig. 2. After 2014, the annual production is at least 200, except in 2022. The 2022 papers number is justified by the fact that the year is still in progress. The highest production occurred in 2018 with 305 papers, followed by a small decrease in the number of papers published in the years 2019–2021, possibly due to the COVID-19 pandemic. Nevertheless, 60% of related works on *radio coverage prediction* have been published in the last seven years.

Annual scientific production of *radio coverage prediction* can be identified by considering key sources. The top 20 most relevant sources are shown in Table 2, with IEEE access being the most relevant source, having published 99 documents. This is followed by IEEE transactions on antennas and propagation with 87 documents, IEEE transactions on vehicular technology with 72, Wireless personal communications with 58, and IEEE transactions on wireless communications with 56. The growth dynamics of these first five sources is depicted in Fig. 3.

4.3 Source Growth Dynamics

Figure 3 shows that activity for "IEEE access" was minimal prior to 2015, but has since become the leading publication source. This is likely due to its creation in 2013 and its openness to various areas covered by "IEEE," giving it more chances to publish than other sources. Meanwhile, "IEEE transactions on antennas and propagation" has seen exponential growth and is the most suitable journal to publish research related to *radio coverage prediction*.

4.4 Top 20 Relevant Authors Based on the Number of Papers

The ranking of the 20 relevant authors who have the highest number of publications is shown in Fig. 4. Most of these authors are academics, but M. V. S. N. Prasad from the Radio and Atmospheric Sciences of Division National Physical Laboratory, which is a non-academic laboratory, is also included. The two first authors Bo Ai and Zhong, Zhangdui from the same Beijing Jiaotong University published 20 papers each on the topic. The fact that they have written so many documents on the subject until 2022 (see Fig. 5) shows that this field is interesting and still relevant. In addition, the authors in this shortlist are mostly from Asia, followed by Europa and Africa (especially Nigeria). The interest of these continents in the topic is highlighted. A look at Fig. 5 shows that Zhong, Zhangdui worked in the highest time span and Faruk Nasir from the University of Ilorin in Nigeria worked in the lowest time span. Further research can be performed to provide more empirical work.

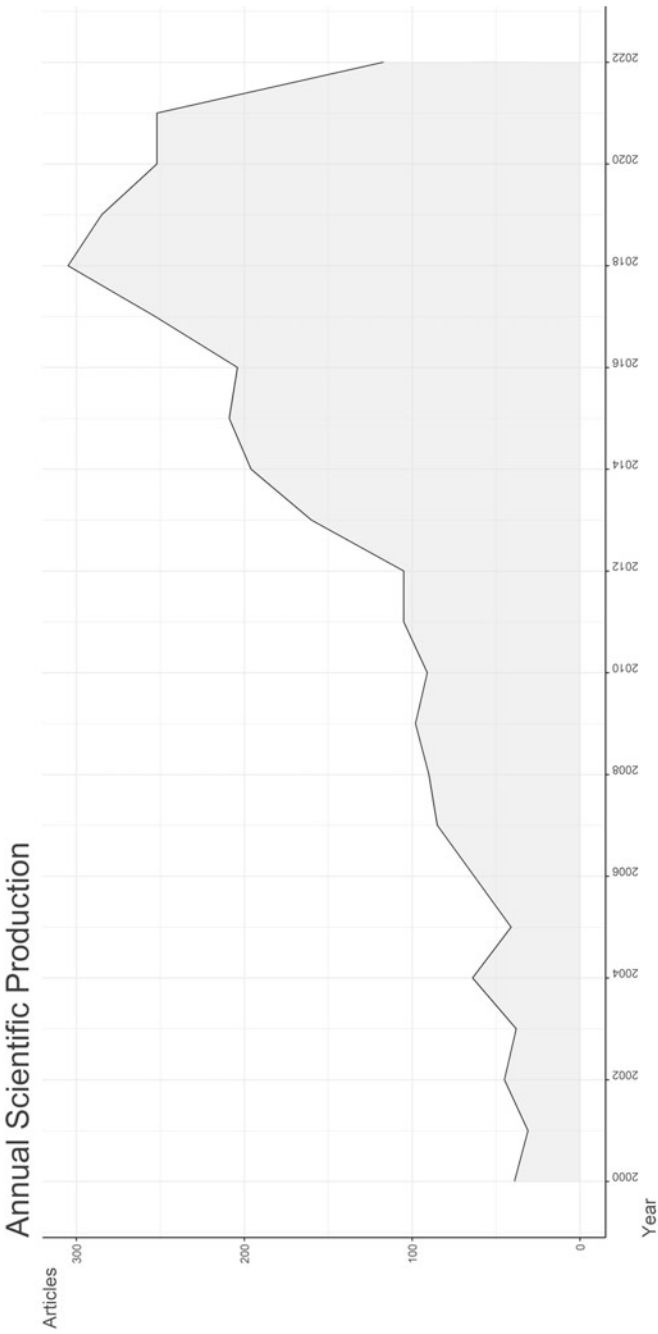

Fig. 2 Annual scientific production

Table 2 Top 20 most relevant sources

Sources	Articles
IEEE access	99
IEEE transactions on antennas and propagation	87
IEEE transactions on vehicular technology	72
Wireless personal communications	58
IEEE transactions on wireless communications	56
Sensors	50
IEEE antennas and wireless propagation letters	43
Radio science	27
IEEE journal on selected areas in communications	23
IEICE transactions on communications	23
IET microwaves antennas and propagation	22
IEEE antennas and propagation magazine	20
IEEE transactions on communications	20
IEEE internet of things journal	19
International journal of antennas and propagation	19
IET communications	18
Wireless communications and mobile computing	17
Microwave and optical technology letters	16
Wireless networks	16
EURASIP journal on wireless communications and networking	15

4.5 Top 20 Most Relevant Affiliations

Figure 6 displays the 20 most relevant affiliations. The Beijing Jiaotong University (China) leads the ranking with 66 publications, followed by the Beijing University of Posts and Telecommunications (China) with 62, etc. All of these affiliations are universities, and the four first are China's universities. The University of Michigan, the University of British, and the University of Toronto are the American universities on the shortlist. The University of Ilorin and Covenant University from Nigeria are the two African universities on this shortlist. The other affiliations are Asian and European, respectively.

4.6 Top 20 Most Cited Documents

Most globally cited documents are presented in Fig. 7. The two first most cited documents ([15] cited 1370 times and [16] cited 840 times) are both about radio coverage prediction in the microwave and millimeter-wave radio spectrum which corresponds

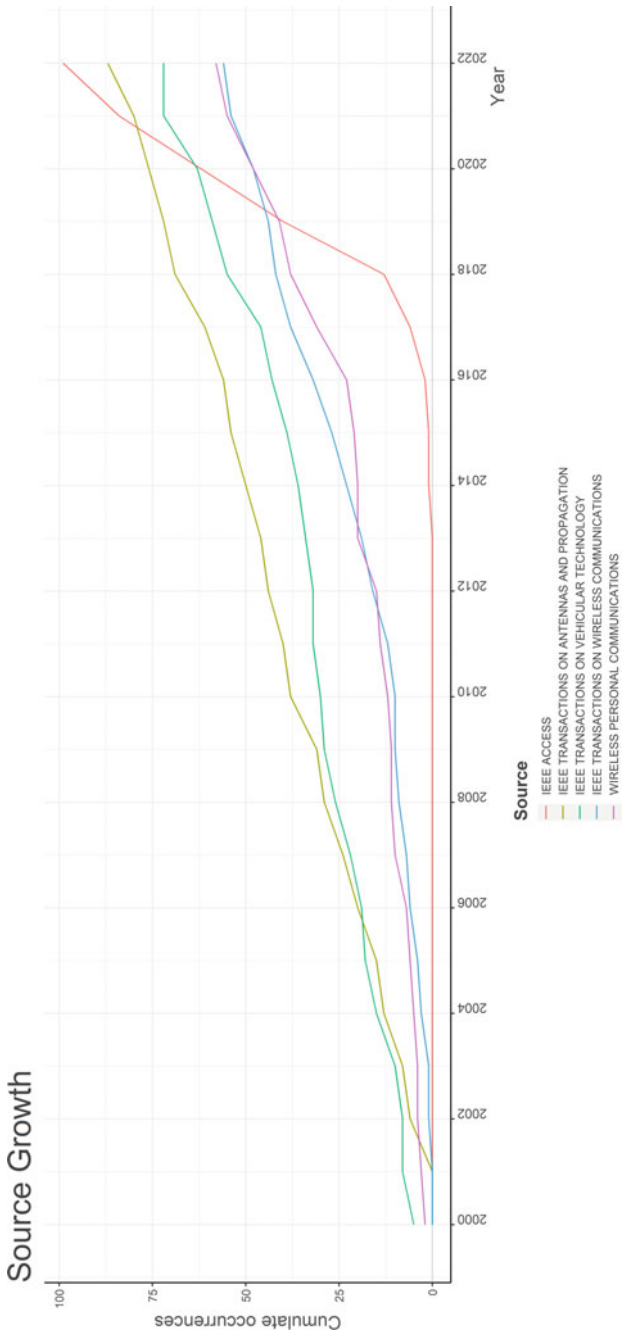

Fig. 3 Source growth dynamics

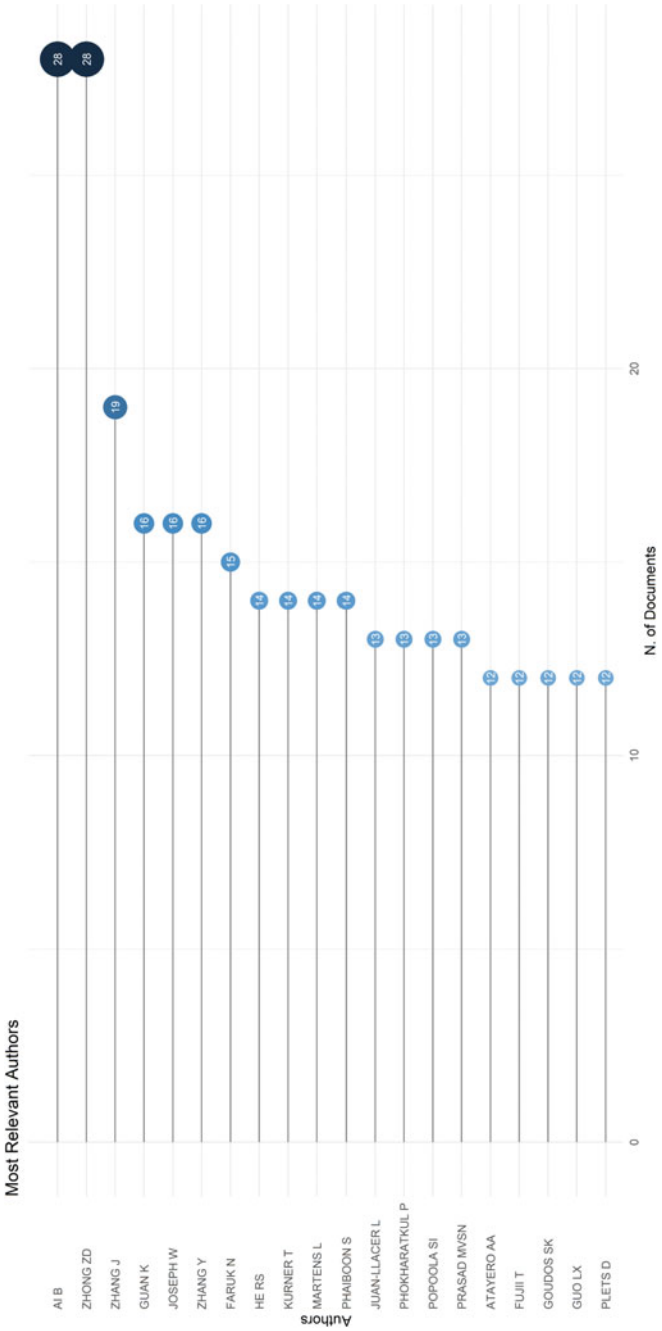

Fig. 4 Top 20 relevant authors

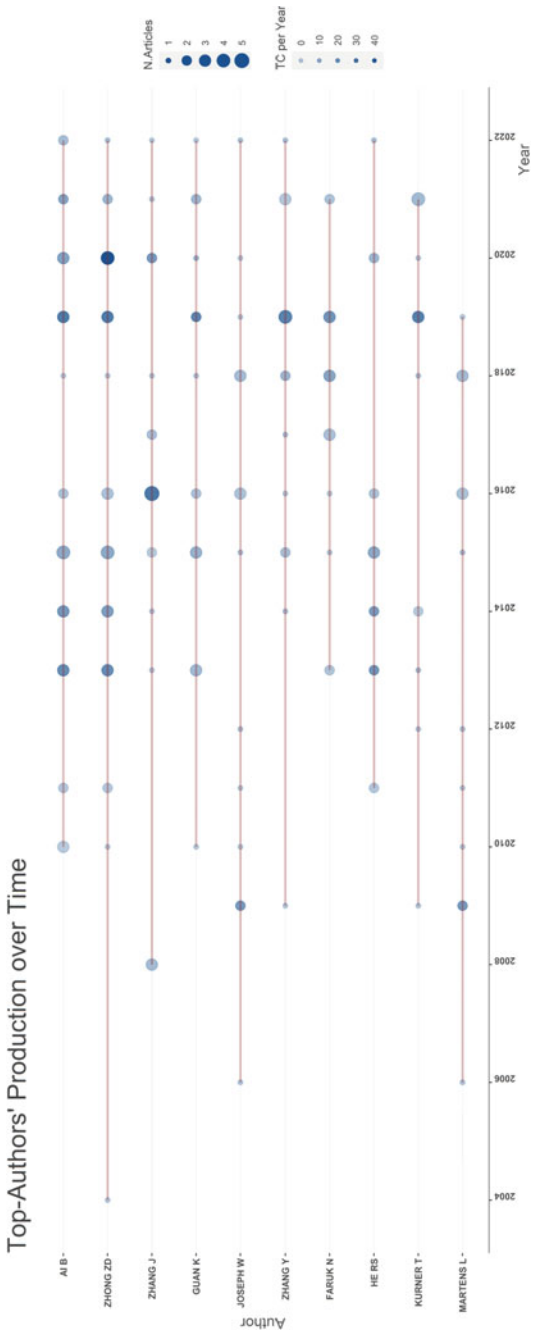

Fig. 5 Top 10 authors' production over time

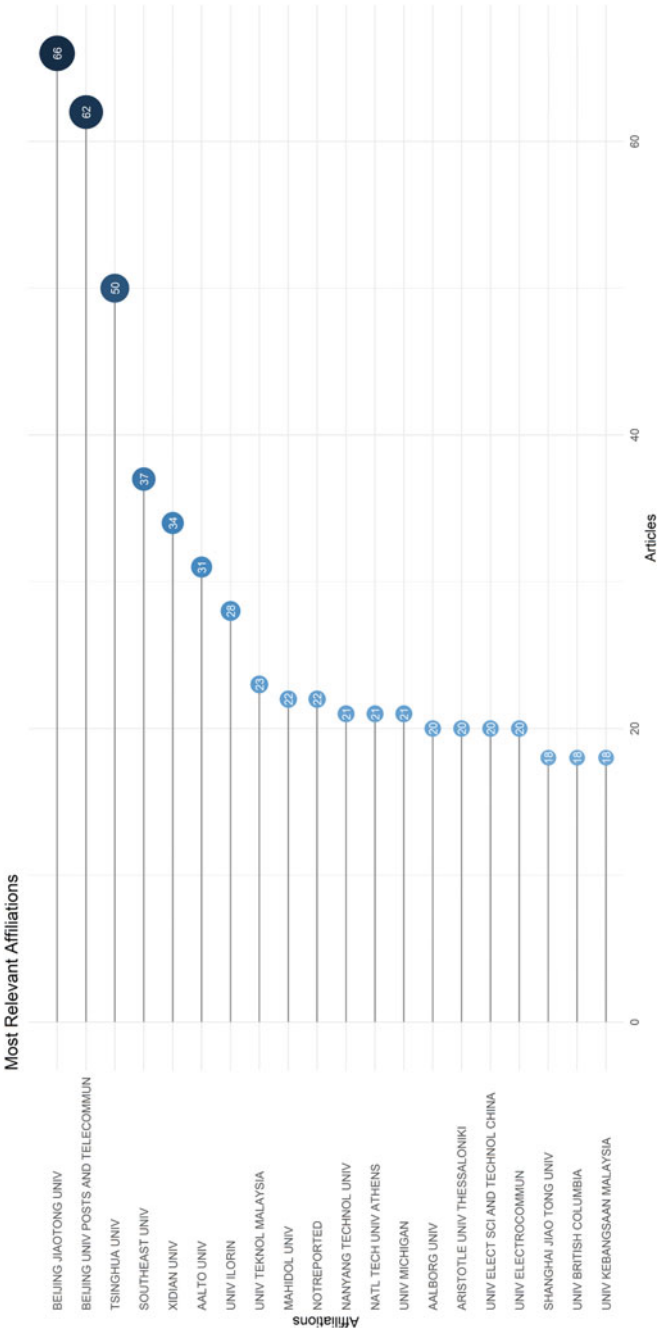

Fig. 6 Top 20 most relevant affiliations

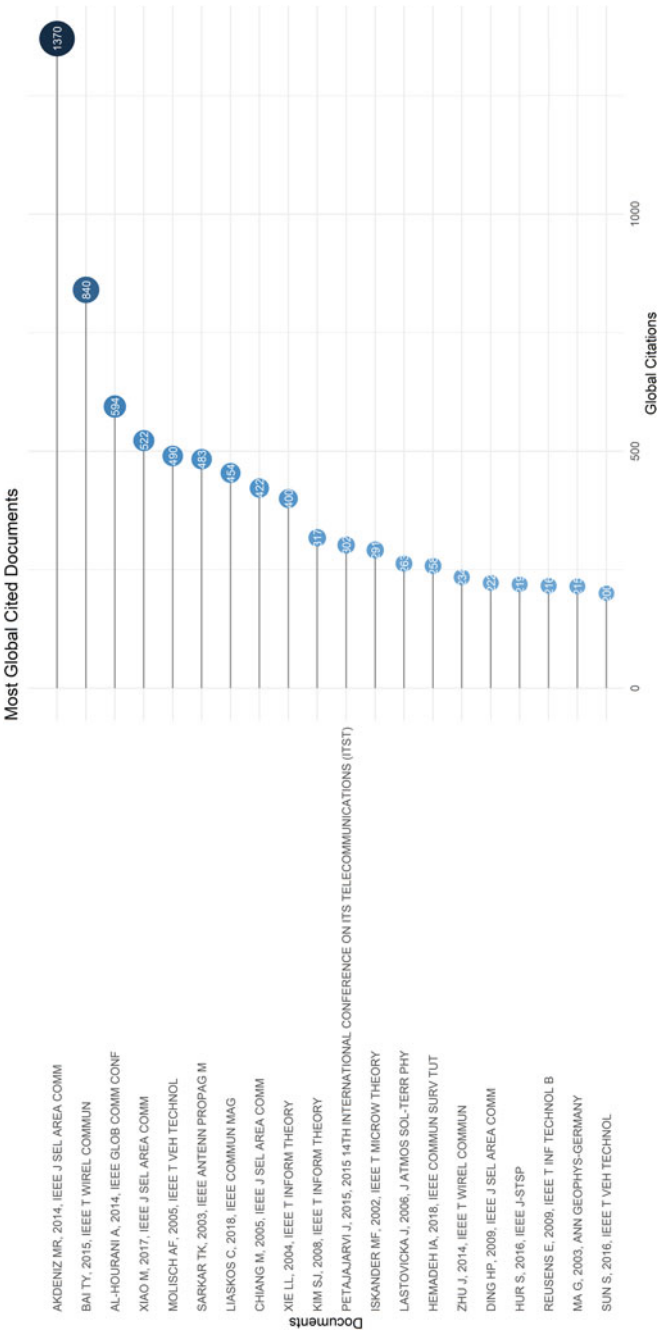

Fig. 7 Top 20 most cited documents

with 5G spectrum. In this shortlist, five documents are determined as not really relevant. The remaining papers have been ranged into six categories which are: mobile systems (1), all wireless communication systems (2), airborne wireless communication systems (3), terrestrial wireless communications systems (4), microwave and millimeter-wave radio spectrum (5), IoT (WBAN, LPWAN, UWB) (6).

Recent works are focused on all wireless communication systems in general. Especially microwave and millimeter-wave radio spectrum have been more studied. Table 3 presents the key objective per category of fifteen relevant papers of these twenty most cited qualitative method documents.

4.7 Top 20 Scientific Production on Radio Coverage Prediction

Table 4 shows the country's scientific production on *radio coverage prediction*. It is noticed that China is at the top of the list with 1119 documents. The second position is occupied by the USA with 811 documents. The third and fourth in rank are respectively India with 361 documents and Japan with 340. Other countries on this shortlist produced less than 300 documents. Asia and Europa countries are dominant and globally developed countries produce more than others.

4.8 Words Cloud Relative to Radio Coverage Prediction

Figure 8 presents the words cloud relative to *radio coverage prediction*. Table 5 is obtained by merging singular and plural words or expressions, and words with multiple scriptures. It shows the twenty words or expressions most used by authors in their documents. Understanding these keywords and the links between them will help to better understand the subject. Within these expressions, *model* appears 231 times. So the most important for radio coverage prediction are different prediction models. These models are designed using different approaches like purely theoretical modeling, empirically fitting often traditional statistical modeling or machine learning *algorithms*, etc. Indeed, during *wireless communication systems* design, the knowledge of *propagation channel estimation* is necessary. It includes *path loss* prediction which ensures good networks *performance* and a *capacity optimization*.

During *transmission* from antennas, the electric field is converted and transmitted as radio waves subject to phenomena like *diffraction* due to the *environment diversity*. In addition, the prediction through the *scattering* channel can be done for outdoor or indoor localization and at different frequencies. So, propagation models that estimate path loss based on the range are valid only for the modeling environment and its resemblers and usually do not provide accurate temporal and spatial information. However, ray-tracing models are specific to the 3D environment and

Table 3 Key objectives of most cited documents

Category	Author/date	Objective
1	Sarkar (2003)	To design a suitable receiver that will receive the transmitted signal, distorted due to the channel multipath and dispersion effects, and will decode the transmitted signal. An understanding of the various propagation models can actually address both problems
2	Phillips (2013) Liaskos et al. (2018) Kim et al. (2008)	To provide a literature survey and make an analysis of the works performed on this topic since 60 years. To make a fairly continuous research on path loss prediction methods and give future directions for research in this area. To propose a radical new approach, enabling deterministic programmable control over the behavior of wireless environments. To derive performance bounds and achievable rates and compare the relative for exchanging messages between two nodes over a shared half-duplex channel with the help of a relay for three protocols including the Gaussian case with path loss
3	Al-Hourani (2014)	To propose a statistical propagation model dependent on the elevation angle between the terminal and the platform for predicting the air-to-ground path loss between a low altitude platform and a terrestrial terminal on the urban environment properties
4	Iskander and Yun (2002)	To describe ray-tracing application, classical empirical models and statistical models, new challenges about propagation prediction and some new approaches for meeting these challenges
5	Sun et al. (2016) Hur et al. (2016) Hemadeh et al. (2018) Xiao et al. (2017) Akdeniz et al. (2014) Bai and Heath (2015)	To compare three candidates large-scale propagation models and provide one more suitable for the entire microwave and millimeter-wave radio spectrum use case. To present 28 GHz wideband propagation channel characteristics for millimeter-wave urban cellular communication systems and compare measurement data with ray-tracing data. To understand the millimeter-wave band's properties and present associated channel models while reporting on the main measurement and modeling campaigns. To present a comprehensive survey of millimeter-wave communications for future mobile networks by summarizing the recent channel measurement campaigns, modeling results, and discussing recent signs of progress. To derive detailed spatial statistical channels models to provide a realistic assessment of Mmwave micro-and picocellular networks in a dense urban deployment using recent real-world measurements at 28 and 73 GHz in New York. To propose a general framework to evaluate the coverage and rate performance in mmWave cellular networks
6	Reusens et al. (2009) Petajajarvi et al. (2015) Molisch (2005)	To discuss propagation channel and propose path loss models to evaluate energy efficiency of single-hop and multihop network topologies in wireless body area networks for remote health monitoring. To present an overview of ultrawideband propagation channels and to identify the key parameters for channel models and describe deterministic and stochastic models

appropriate to urban environment scenarios. Nowadays, machine learning or deep learning *algorithms* also are used.

Table 4 Top 20 scientific production countries

Rank	Region	Freq
1	China	1119
2	USA	811
3	India	361
4	Japan	340
5	UK	246
6	South Korea	211
7	Germany	197
8	Canada	191
9	Spain	160
10	Italy	155
11	France	146
12	Malaysia	133
13	Russia	122
14	Brazil	120
15	Turkey	119
16	Nigeria	113
17	Greece	109
18	Finland	85
19	Australia	70
20	Iran	70

Fig. 8 Words cloud

Table 5 Most cited words

Words	Occurrences
Model	231
Propagation	200
Prediction	150
Systems	133
Networks	121
Path loss	100
Communication	87
Channel	83
Performance	78
Design	73
Capacity	64
Algorithms	57
Diffraction	55
Environments	52
Wireless	47
Channel estimation	41
Scattering	33
Optimization	31
Transmission	31
Diversity	29

4.9 Co-citation Network

The study of co-citation is explained as follows: When two authors are cited simultaneously, then the latter has a co-citation relationship. It is an important measure to assess the intellectual flow and development of research activities in a particular discipline. Figure 9 shows a co-citation relationship between 50 authors. These strong links in the co-citation network translate that authors keep an overview of most documents from 1968 to 2017. So, the authors highly assess the intellectual flow and development of research activities on *radio coverage prediction*. Two clusters are observed around Hata (1980) and Rappaport (2013). Their works are respectively about propagation loss in radio mobile services [17] and millimeter-wave mobile communications for 5G cellular [18]. These papers are references, and suitable results have been gotten.

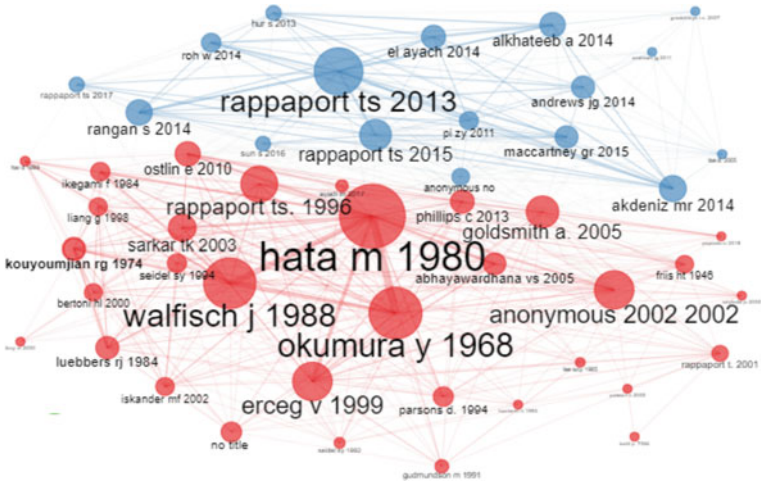

Fig. 9 Co-citation network

4.10 Conceptual Structure Map

Figure 10 displays the conceptual structure map. Two clusters are identified. This co-words analysis shows that most of the words displayed are nearby the concepts of *radio* and *power* and form the first cluster. The second cluster is around *urban* environment. This structure map also demonstrates that path loss prediction is part of both clusters.

4.11 Co-occurrence Network

Co-occurrence is the relation between two words or expressions when they appear simultaneously in the same area. This relation is shown in Fig. 11 with edges between keywords in documents related to *radio coverage prediction*. Two clusters have been identified. The first cluster is about propagation prediction models. The second cluster is about communication network system design.

4.12 Country Collaboration

Figure 12 shows the collaboration between countries. USA scholars and researchers strongly collaborated a lot with China ones in particular and collaboration is strong between America and Asia. Collaboration between African countries and others remains poor. Little collaboration is observed with Nigeria.

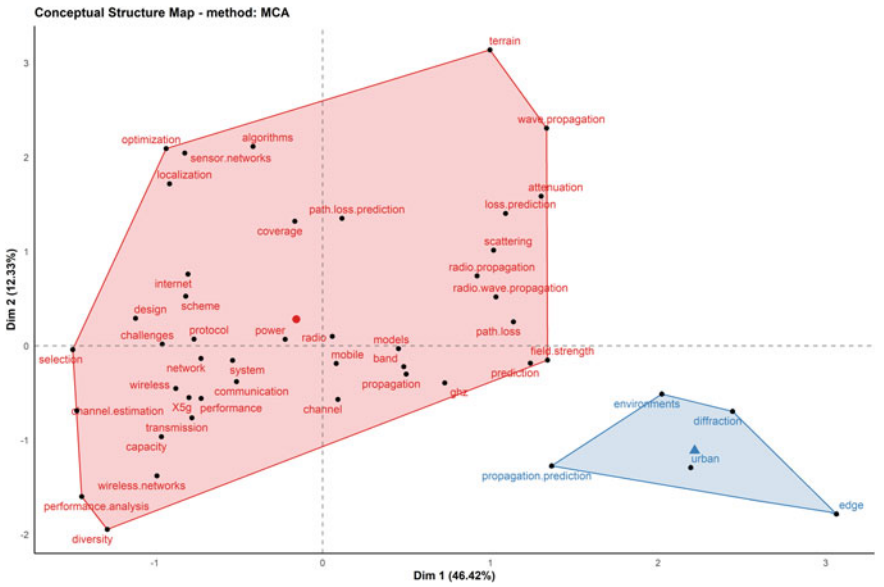

Fig. 10 Conceptual structure map

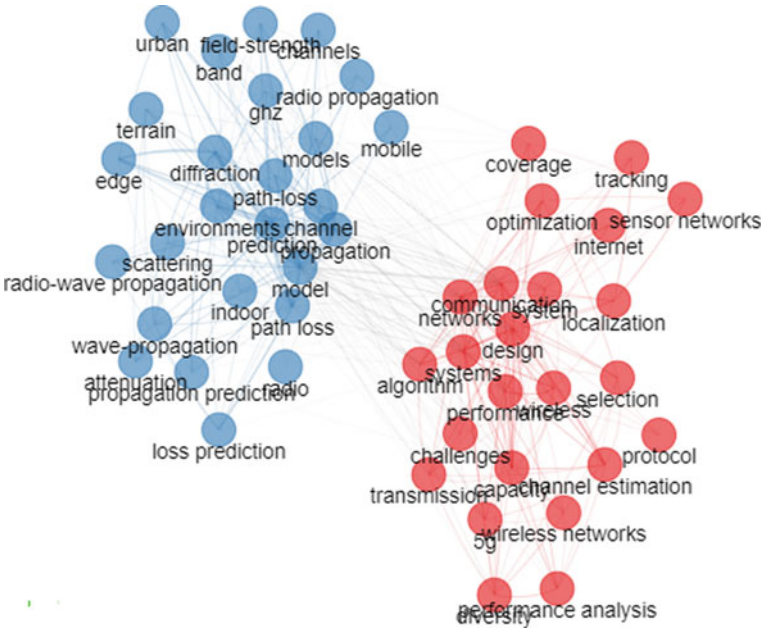

Fig. 11 Co-occurrence network

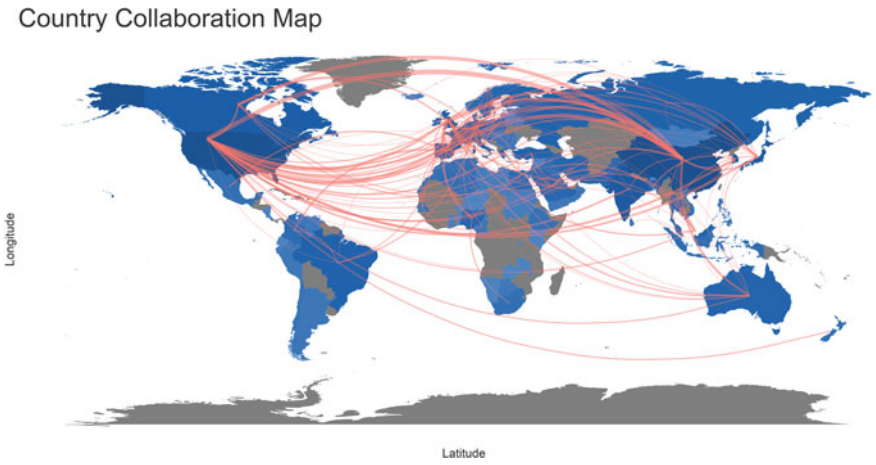

Fig. 12 Country collaboration map

5 Conclusion and Future Research Avenues

In this paper, bibliometric analysis of data extracted from WoS on radio coverage prediction has been presented. This analysis was conducted on 3134 documents identified from 2000 to 2022. Out of these publications, over 51% were proceedings papers and 49% were articles. The relevant parameters taken into account were the relevant publication sources, countries, words, expressions, documents, the main authors, and their affiliations. The results prove that interest in this topic has increased during the past seven years (2015–2022), as shown by the 60% of publications recorded. Additionally, it has been established that wireless communication systems, especially 5G, are the main field of research related to recent works on the subject. Within the top 20 relevant sources, five of them stand out: "IEEE access," "IEEE transactions on antennas and propagation," "IEEE transactions on vehicular technology," "Wireless personal communications," and "IEEE transactions on wireless communications." This study highlights that developed countries such as China and the USA are the most productive. As the research interest in African countries is not very noticeable, Nigeria is the only one among the top twenty productive nations. This bibliometric analysis constitutes a starting point for researchers working on this topic and is beneficial for conducting a thorough literature review on radio coverage prediction. African researchers should primarily concentrate on investigating topics related to radio coverage prediction and field measurements, in order to solve environmental issues such as broadcast network coverage and mobile network coverage. Future research can focus on measurement model-based path loss prediction in African environments. Accurate studies are needed in urban and mountainous contexts, and ray tracing models can be explored to provide spatial and temporal information to enrich machine learning models. Lastly, more work is necessary with a focus on monitoring, to reduce long and costly drive tests.

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Survey of Intent-Based Networks and a Methodology Based on Machine Learning and Natural Language Processing

Remigio Hurtado, Cristian Picón, Arantxa Muñoz, and Juan Hurtado

Abstract Intention-based networks (IBN) have been developed in order to solve the problems of traditional networks such as: inefficient performance management, security and applications, the company spends too many resources on troubleshooting, instead of investing in new business services. These problems are solved with IBN because this technology combines artificial intelligence and machine learning, in order to transform the commercial intention of users into strategies for configuration, operation and maintenance of the network. IBN is an architecture in which Cisco has invested in recent years; however, it is a broad architecture to be explored and adopted by organizations. Because of this, in this research, a survey is developed using a methodology and algorithms in order to examines the elements for implementation, applications in different environments, tools, protocols, algorithms and trends of intent-based networks. For the development of the survey, two processes have been used: the first one consists of a general method which is used for text extraction, natural language processing of scientific articles and exploratory analysis. This method allows us to obtain the most relevant topics within the data set. The second process starts from the processed data set and then applies two filtering methods. The first method which we have named "Calculation of Importance-Based Approach" and the second method which we have named "Bag of Words Extraction by Cosine Similarity-Based Approach." These methods help us to obtain the items most related to the topics obtained in the general method to develop the survey of intention-based networks. These processes may be useful in other fields of interest.

Keywords Intelligent networks · Intent-based networks · Research methodologies · Survey · Software-defined networks · Artificial intelligence ·

R. Hurtado (✉) · C. Picón · A. Muñoz
Universidad Politécnica Salesiana, Calle Vieja 12-30 y Elia Liut, Cuenca, Ecuador
e-mail: rhurtadoo@ups.edu.ec

C. Picón
e-mail: cpiconv@est.ups.edu.ec

J. Hurtado
Instituto Superior Tecnológico Particular Sudamericano, Simón Bolívar 1-62, Cuenca, Ecuador
e-mail: jphurtado2@sudamericano.edu.ec

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Machine learning · Quality of service · User quality · Natural language processing · Algorithms

1 Introduction

Intention-based networks (IBN) are a paradigm shift in telecommunications processes. An intent refers to the interaction that operators and enterprises have with network technology to express their expectations about the services, behavior and efficiency provided by the overall system. IBNs, unlike programmable networks such as software-defined networks (SDNs) that rely on action-condition policies and the manual form of an ever-growing set of applicable programming interfaces (APIS) and exposed capabilities, IBNs offer network users to set their end goals with the network, rather than offering a list of instructions to execute without being able to determine why those instructions were dictated [1]. The network itself must determine when and what actions or configurations to execute, in which technology domains, for which end users and end devices [2]. Thus, behind an intent-based network surface, there is automation and increasing autonomy in the processes to be executed. While automation refers to the ordering of previously scheduled workflows, albeit enriched with conditions, policies and some degree of adaptability through scripting, autonomy refers to a whole new level of network responsibility. It is about giving the network an orchestrator, service management, real-time parameter configuration and complete management of massive resources in the different domains, in the face of a dynamic flow of demands and users to be served. The full deployment of the intent paradigm should eventually transform programmable networks into self-programmable networks [3].

The **main idea** of using IBN is to change the network infrastructure paradigm. This implies that it does not have to be the user who adapts to the capabilities of the network, but rather that the network adjusts to the needs of each user. Going forward, the IT developed by IBN will automate the management of domains including: campus, branches, WAN, IoT and big data, providing a significantly new level of automation, in order to improve service, innovation and network infrastructure. Given some requirements of different modern network environments, it is necessary to use different methods to improve the quality of service and traffic engineering to optimize the traffic flow of a large number of applications, such as voice and/or video traffic. The definitions of intent in each working group are slightly different and specific to their respective core technology. However, intent is understood as a high-level statement of the objectives, service level or business objectives that the network should be able to achieve or the desired behavior that the network is expected to comply with. The intent does not entail concrete actions or configuration steps that the network should take to achieve the described objectives. It is also recognized that for intentions to be a feasible communication abstraction between people and networks, the network must be able to implement certain automation and intelligence

mechanisms, potentially through the use of artificial intelligence (AI) and machine learning (ML) methods.

The **objective of this research** is to advance the discussion around IBN by publishing concrete ideas and proposals. We will analyze what is the challenge in managing networks that are currently more defined and programmed by software, but far from being based on intentions. The **main contribution** is to indicate the key points to be able to manage, analyze and contribute with clear and concise ideas in order to be able to implement an IBN, with a hierarchical architecture built on the foundations of self-learning, with automation extended to the orchestrator and artificial intelligence. The current advances in IBN development, protocols, algorithms, tools and phases for implementing an IBN will also be discussed. To achieve this objective, in this research, a survey is developed using a methodology and algorithms. For the development of the survey, two processes have been used: the first one consists of a general method which is used for text extraction, natural language processing of scientific articles and exploratory analysis. This method allows us to obtain the most relevant topics within the data set. The second process starts from the processed data set and then applies two filtering methods. These methods help us to obtain the articles most related to the topics obtained in the general method to develop the survey of intention-based networks.

The rest of the article is organized as follows. Section 2 presents the related works that have been currently developed. Section 3 begins with the methodology used to conduct the research by means of a text filtering algorithm to obtain some keywords to address the themes and topics to be described in the article. Section 4 presents the results of applying the methodology. Section 5 presents the survey of IBN that has been developed from the results obtained after applying the filtering algorithm. It also presents the objectives of IBN, IBN fundamentals, architecture, phases, challenges and problems that occur when implementing this type of architecture, the trends toward which it is focused and where it is intended to go with intent-based networks. Finally, the main contributions of this survey and conclusions are presented.

2 Related Work

This section presents the most relevant work related to the development of the survey in IBN networks. In [4], it is determined the advances that have been given in the networks based on intention, it is related about the evolution that has been given in terms of development frameworks, platforms and tools, it also mentions the natural language processing that is driven by IT, and it also mentions the operation of the networks based on the intention, its architecture and the adaptations that are to the world of the telecommunications. Mainly, it concentrates on a comprehensive analysis of existing frameworks and platforms providing the latest standardization activities. Finally, it gives a perspective on the challenges and where the construction of an intent-based network system is headed. It states that intent-based networks focused on 6G technology can effectively solve the problems of traditional networks

in terms of efficiency, flexibility and security. It also gives a clear point on some configuration and maintenance strategies that are prominent for the development of 6G technology. In [5], a clear idea is given of the quality of service (QoS) that networks should have based on customer-centric intent. In addition, a new metric is generated that allows taking into account the business value of e-services for end users. To achieve this quality management method, an algorithm is implemented that is responsible for routing the data packets in the network, taking into account the current load and the route through which it is routed. Finally, it is determined that the proposed method generates an average gain between 2 and 5 times higher than what users are used to. In [6], it is stated with respect to 5G network automation that to improve network provisioning, there are many orchestrators that are focused on network management but not all the features needed for complete network management can be obtained. Therefore, automated platforms are an absolute necessity. A generic IBN-based system is used to manage and automate the network lifecycle; this system includes machine learning for resource state prediction for proactive decision making to manage the lifecycle of the automated segments.

3 Methodology

In order to carry out the survey, a methodology that encompasses two processes was followed; first, a **general method** that serves to **text extraction**, **natural language processing** of scientific articles that results in a transformed data set for the **exploratory analysis**; in addition, this method allows the **calculation of the most relevant topics** in the data set. Fifty-eight journal articles and/or books were selected; the articles were mostly extracted from IEEE Xplore and Science Direct libraries. Second, from the processed data set, **two article filtering methods** are followed. These methods allow from a set of terms or topics to filter the most related articles with respect to those terms or topics. The first method called **term importance calculation (CIT)-based approach** and the second method called **bag of words extraction by cosine similarity (BACOS)-based approach**. Finally, the method (CORE filtering) is presented to develop the survey from the information resulting from the general method and the CIT and BACOS approaches. Table 1 presents the parameters and their description for understanding the methodology.

3.1 General Method for Document Collection, Articles Preparation and Exploratory Analysis

The diagram of the general method is presented in Fig. 1 and Algorithm 1 for document collection, articles preparation and exploratory analysis.

Table 1 Parameters and description

Name	Description
x	It is every scientific article
Originalbody	Original body of the article
Originaltittle	Original title of the article
Originalabstract	Original abstract of the article
Numcitas	The number of citations contained in the article
StopWords	Words that are not relevant in the articles
idArticle	Identification of each item
abstract1	It is the processed abstract
TR	Most relevant topics generated by the general method
fw	Importance
n-grams	Subsequence of *n* elements of a given sequence

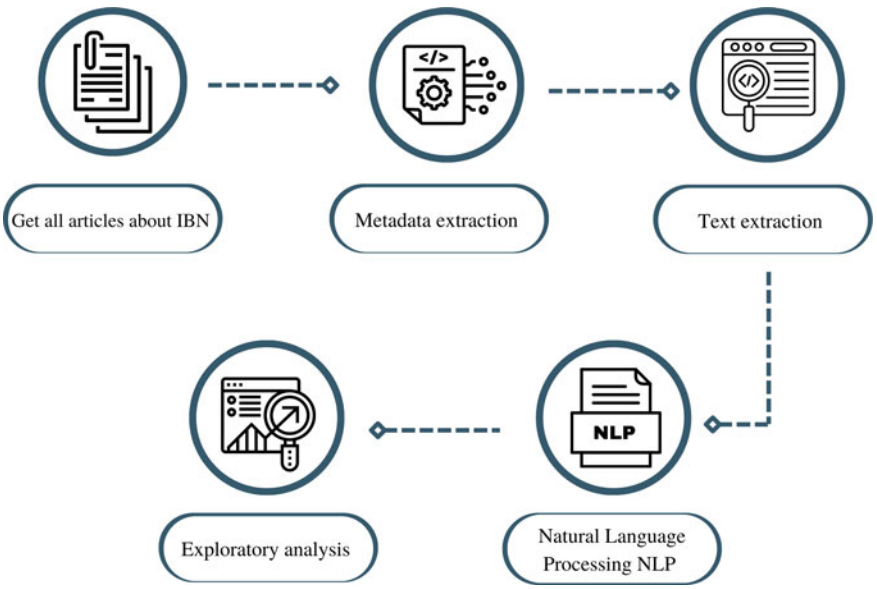

Fig. 1 General method

Algorithm 1 General method for collection and preparation of articles

Input: scientific articles on IBN
Process:

Articles preparation

For each article x:

1: Metadata extraction: originaltitle, originalabstract, keywords
2: Text extraction: originalbody (text of the document without the references)
3: Form each article with the following variables: idArticulo, originaltitle originalbody, numcitas, keywords, reference, originalabstract, tipo
4: Data processing: natural language processing (NLP) for the variables originaltitle, originalbody and originalabstract:
   1: Transformation to lowercase
   2: Elimination of Stop words
   3: With regular expressions extract the words with alphabetic characters (a–z)
   4: For each word perform lemmatization. Each word (plural, feminine, conjugated, etc.) converts to its lemma. The lemma is the form that by convention is accepted as representing all the inflected forms of the same word
   5: Form each article with the structure: idArticulo, originaltitle, title, keywords, originalabstract, abstract1 originalbody, body, tipo, reference.

Exploratory analysis

1: In the body variable of each article, the frequency of words is calculated, and the common and uncommon words are identified.
2: In the variable abstract1 of each article, the frequency of words is calculated, and common and uncommon words are identified.
3: Visualization:
   1: Word clouds with the n most common words in body and abstract1
   2: The most relevant topics (or terms) are obtained. Uni-grams, bi-grams and tri-grams (sequence of words that occur most frequently) are generated with the body words, for which purpose word vectorization, keyword calculation, bag of words and frequency calculation are performed.

Output: most relevant topics

3.2 Approach Based on Term Importance Calculation (CIT)

This method is based on the method of identifying topic importance of recommender systems by Bobadilla et al. [7]. We have extended the process and equations according to the item set and the field of intent-based networks. The phases of the CIT method are presented in Fig. 2 and Algorithm 2.

$$\mathrm{fw} = \frac{1}{4\left(\frac{N_w^k}{N^k} + \frac{N_w^t}{N^t \log N^a/N^t} + \frac{N_w^a}{N^a \frac{N^a}{N^t}} + \frac{N_w^b}{N^b}\right)} \tag{1}$$

where N^k, N^t, N^a, N^b represent the number of words in the abstract (abstract1), keywords, title and body of the articles (body), respectively. N_w^k, N_w^t, N_w^a, N_w^b represent the number of times the topic appears in keywords, Abstract, Title and body, respectively.

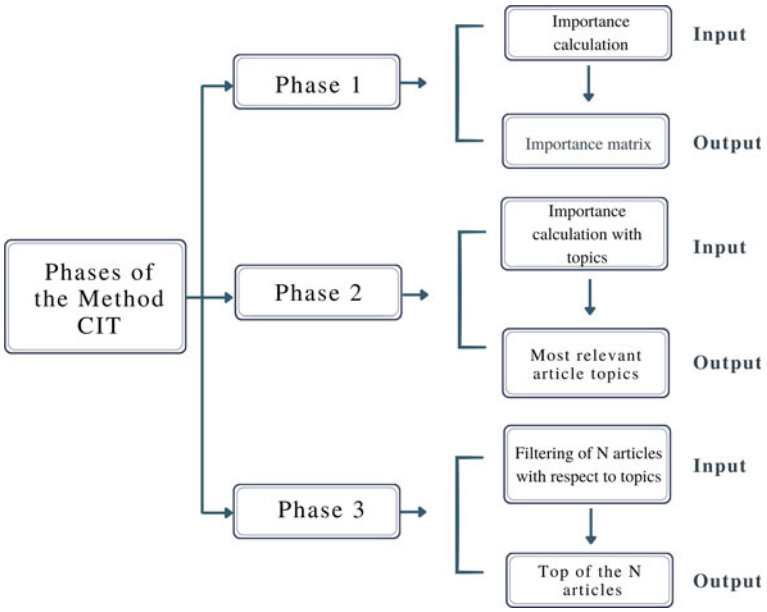

Fig. 2 Phases of the term importance calculation approach (CIT)

Algorithm 2 Approach based on term importance calculation (CIT)

Input: most relevant topics (TR) recognized with the general method (the topics to be searched). Example: SDN and intelligence and intent-based networks.

Process:

Phase 1: calculation of importance (learning) of TR topics in all articles

For each topic (or term) w of TR:

For each article x:

Importance calculation fw (Eq. 1)

Phase 2: calculation of the importance of the articles with respect to the topics to be searched

For each article x:

1: fwTotal := 0 #total importance of x with respect to the topics to be searched

2: For each topic (or term) w to be searched:

if topic w is in more relevant topics TR

– Obtain fw from the importance matrix. The importance of topic w in article x.

– FwTotal := fwTotal + fw

For each word in topic (term):

– if word w is in more relevant topics TR

– Obtain fw from the importance matrix. The importance of the word w in item x (with Eq. 1)

– FwTotal := fwTotal + fw

Phase 3: filtering

Filter the N items with higher FwTotal value (higher importance) with respect to the search topics. In this case, $N = 3$.

Output: importance matrix, importance of the search topics in each article, N articles with the highest importance

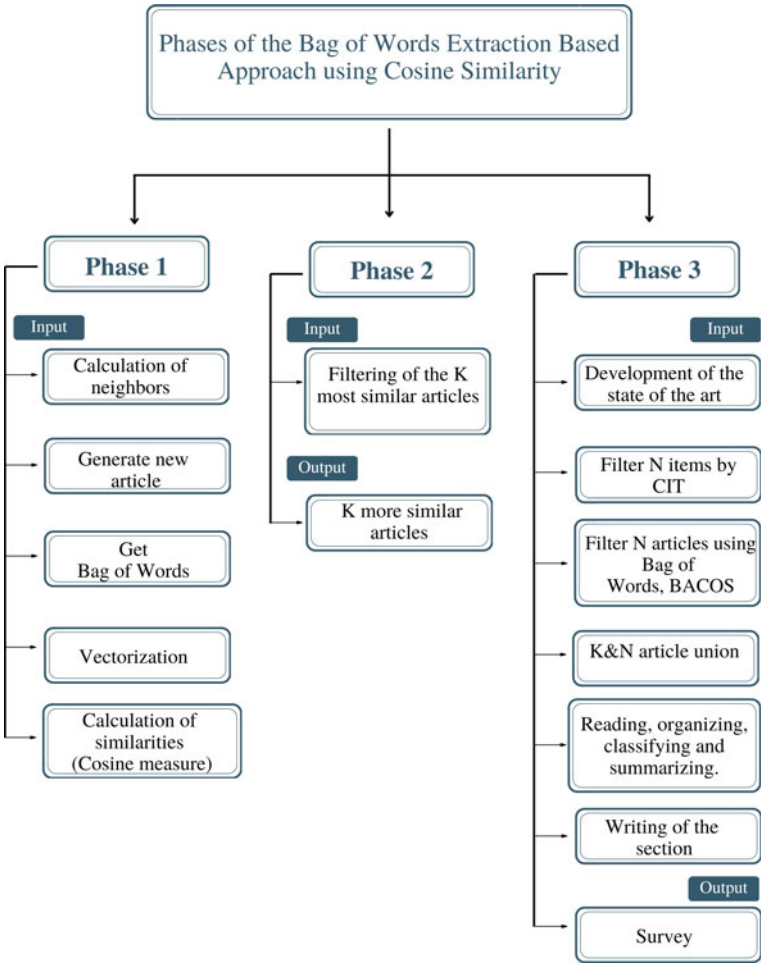

Fig. 3 Phases of the bag of words extraction approach based on cosine similarity (BACOS)

Algorithm 3 Approach based on bag of words extraction through cosine similarity (BACOS)

Input: terms or topics (new article, i.e., the words to be searched)
Process:

Phase 1: calculation of neighbors

For each article x:

1: Keyword generation in title, abstract1 and body
2: Get Bag of words with keywords of title, abstract1 and body
3: Vectorization
4: Calculation of similarity (cosine measure) between x article and the new article

Phase 2: filtering

Filter the K items most similar (neighbors) to the search topics (new item). In this case, $K = 3$.

Output: K most similar items

3.3 Approach Based on Bag of Words Extraction by Cosine Similarity (BACOS)

In general terms, the similarity of all articles with respect to the new article represented by the terms or topics to be searched is calculated. The process is presented in Fig. 3 and the Algorithm 3 of the article filtering method.

3.4 Survey Development Method

Finally, following the Algorithm 4 (CORE filtering), the survey is developed.

Algorithm 4 CORE filtering: survey development method

Input: topics of TR

Process:

For each Tr topic develop the section on the survey:

1: Filter *N* articles using the method of filtering based on importance (CIT)
2: Filter *K* articles using Bag of Words filtering method and cosine similarity (BACOS)
3: Union of the subsets of items *N* and *K*
4: Reading, organizing, classifying and summarizing
5: Writing of the section

Output: survey sections

4 Results

Once the general method for the collection and preparation of articles is applied and the exploratory analysis is performed, several results are obtained. Table 2 shows the result (title and body) of applying the metadata extraction process to all the articles. After the metadata extraction, we proceed to process the metadata, which consists in the first instance in transforming all the extracted information into lowercase. After obtaining all the information, we continue with the natural language processing, which consists of eliminating StopWords, handling regular expressions and lemmatization. All this process is followed in the general method. The result of this process is presented in Table 3.

Table 2 Metadata extraction

idArticle	Originaltitle	Originalbody
1	A learning automaton-based controller placement	A learning automaton-based controller placement
2	A software-defined networking-oriented security	Received June 24, 2019, accepted July 6, 2019, …
3	A survey of networking applications applying	Received June 24, 2019, accepted July 6, 2019, …

Table 3 Result of the application of the general method

Id	Title	Keywords	Abstract1
4	Design iot device configuration translator iot …	[‘iot’, ‘ translator’, ‘iot-cloud’, ‘netconf …	Rapid growth iot internet thing make life burd …
5	Learning automaton controller algorithm softwa …	[‘learning automaton-based controller placem …	Software-defined networking SDN move control p …

4.1 Exploratory Analysis

Once the whole process of the general method is completed, we proceed to interpret the results and identify the information needed to write the survey. In the first instance, a frequency analysis of the words within the body and abstract1 fields is performed. After the analysis of the most frequent words “topics,” we proceed to generate the n-grams with the words in body. The **n-grams** indicate the top of the most frequently occurring words. These n-grams allow to determine the main topics for survey development. The top of the 20 tri-grams (combination of 3 words) is presented in Fig. 4.

4.2 Approach Based on Calculation of Importance (CIT)

Once all the processed information is obtained, the topics to build the survey are obtained. Next, Table 4 shows a representation of the topics and connections that have been determined with the CIT method. Example: if you have $N^k = 5$, which are the keywords, $t = 11$ words in the title, $a = 52$ words in the abstract, and if the word “controller” appears once in the title, 3 times in the abstract, 1 time in abstract and 7 times in the body, then the importance of this word is:

$$\text{fw} = 1/5 + 1/7.42 + 3/245.81 + 7/1000 = 0.349$$

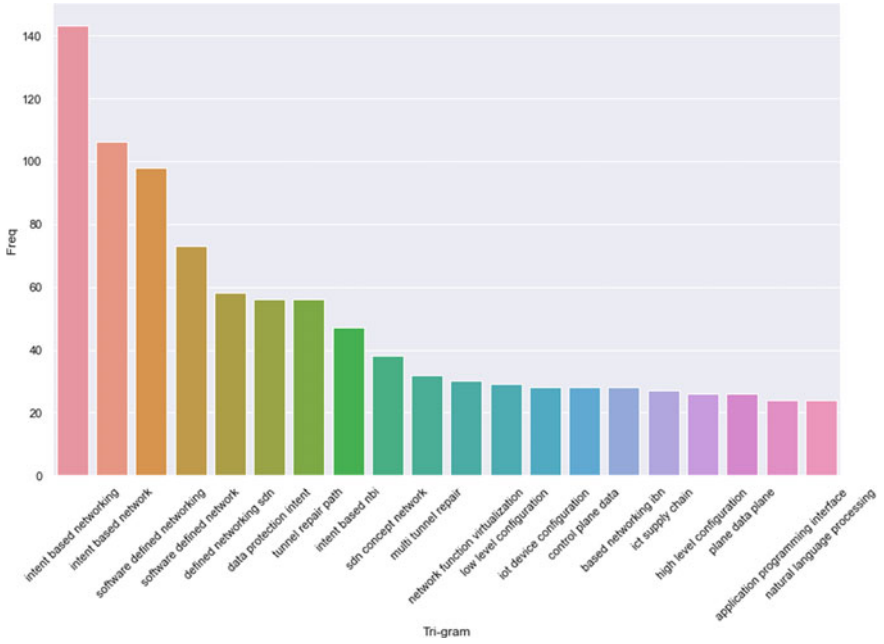

Fig. 4 Tri-grams, in frequency scale

4.3 Bag of Words Extraction-Based Approach (BACOS)

After obtaining all the articles, we proceed to the extraction of bag of words by calculating the similarity between the articles and this generates a list of similar articles. An example of results is presented in Table 5. After obtaining all the necessary information for the writing of the survey with all the topics, we proceed to represent all the topics within a Neo4j software; in this way, we add the nodes that in this case become the words with more weight within our research. At the same time, Neo4j allows to add attributes in each node; in this way, an attribute is the weight that has been obtained by means of the CIT method. After the definition of each node, the relationships are assembled, and the graph shown in Fig. 5 is obtained as a result. The most relevant topics of the article data set are obtained by means of the CIT, BACOS and general method filtering algorithms. As can be seen in figure, intention-based networks (IBN) are the container of all the topics to be addressed within the survey. Once all the information has been represented, the **topics** to be developed have been defined, which are: fundamentals of intent-based networking: (a) architecture, phases, challenges and phases of IBN, (b) functions of IBN: policies, systems, tiers, services, orchestrators, controllers and applications and (c) IBN trends. In order to go deeper into each of the topics/themes determined, the development method (CORE filtering) explained in the methodology is followed. The following section presents the survey developed with the methodology of this research. Each section has been

determined following the most relevant topics determined by the general method of our methodology, each section has been developed following the most relevant articles in each topic, and the most relevant articles in each topic are determined by the CIT and BACOS filtering methods.

5 Survey of Intent-Based Networks

Firstly, among the fundamentals of IBN, we can highlight: (a) An **intention** refers to an order or an objective given by one person to another, in order to realize an objective or state to be achieved without providing the means to be able to fulfill that order or objective. It is assimilated that the person must derive in an autonomous way the necessary tools to be used and the steps to be taken in order to be able to fulfill the indicated objective. Intention works for humans because of several factors: (1) Humans are intelligent in both the formulation of intention and the understanding of the goal. (2) Humans tolerate incomplete information sets and thus can perform a specific task. (3) Dialogue is an invaluable capability that humans use in order to resolve ambiguity as they proceed with the execution of the intention [8]. (b) **Software-defined networks** are a network technology of the modern era which allows an efficient management of heterogeneous networks. SDN provides a solution to some of the problems faced by traditional networks, since they allow for a customized configuration of the network and the services they offer, through an application that can be developed by network administrators [9]. Traditional networks support specific policies implemented when the devices are built and therefore have a limitation on the dynamic configuration of network parameters [10]. The SDN architecture is divided into the data plane, the control plane and the application plane. These features make the network functions hardware-independent. They also consist of two important components: controllers and switches. The controllers are responsible for generating the flow rules, which are the instructions for packet processing, and the switches are responsible for forwarding traffic according to the flow rules [11]. (c) **Intent-based networks** are a paradigm that aims to reformulate the management of networks, domains and services, based on the functioning of human intent. Current networks are programmable, but in turn need programmers, they also allow the management of policies, which are essentially actions for the execution of predefined tasks [12]. Therefore, engineers and all network operational staff must define how, when and what network functions should do, and this in turn has to be meticulously detailed in multiple layers of large-scale resources and technologies. No single entity in the network, including the management layer, has a complete representation of the overall objectives toward which individual policies represent particular and incomplete programs. Thus, intent-based networks should be able to enable the definition of much higher level, and in turn, more persistent, sometimes invariant and abstract objectives without requiring instructions on how to achieve them. Therefore, this in turn will require additional capabilities within the IBN, i.e., it requires artificial intelligence [13], but as with humans, no intelligence in itself is sufficient to carry out

Table 4 Importance results with the CIT method

SDN	Service	Data	Controller	Application	Policy	System	Traffic	Switch	Level
0.0000	0.0137	0.0107	0.0000	0.0002	0.0014	0.0005	0.0000	0.0000	0.0099
0.0034	0.0000	0.0005	0.0273	0.0003	0.0000	0.0000	0.0000	0.0046	0.0000
0.0026	0.0033	0.0028	0.0051	0.0023	0.0000	0.0044	0.0044	0.0046	0.0022
0.0060	0.0009	0.0043	0.0007	0.0037	0.0004	0.0007	0.0017	0.0002	0.0009

Table 5 Result of the BACOS method

idArticulo	bag_of_words
1	Learning automaton controller algorithm software
2	Software-defined networking-oriented security
3	Networking application applying software

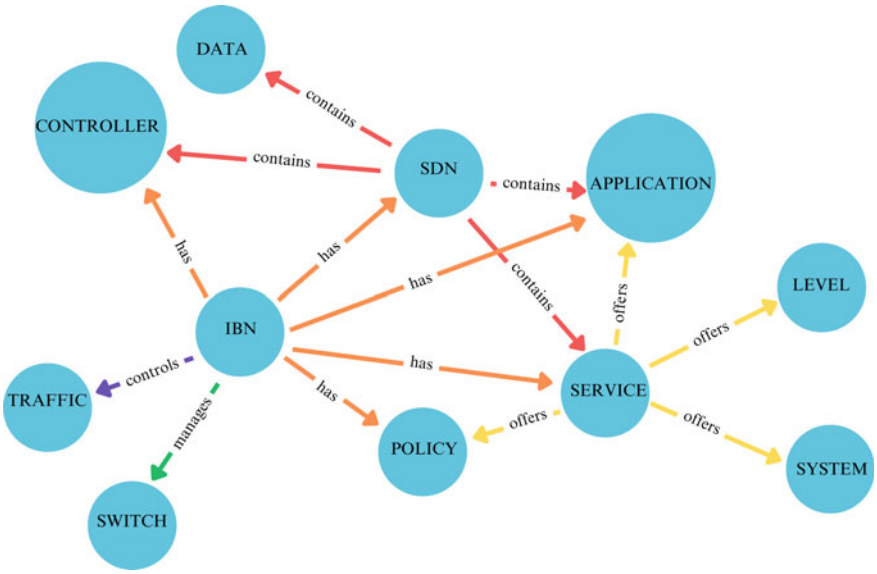

Fig. 5 Graph of words represented in the research field of intent-based networks

an intent, without the ability to understand the context or intent. In networks, context awareness is a fully detailed, real-time measurement and monitoring of resources, the technological domain, network functions and the level of service [14]. To bridge the abstraction and automation gap between intentions and interfaces, machine learning is used.

5.1 Operation of an Intent-Based Network

IBN is based on software-defined networking through the use of a network controller that acts as a central control point for network activity. Such controllers are crucial to the abstraction of the network that allows IT to treat the network as an integrated whole [16]. Controller-driven networks across all domains (including access, WAN, data center and cloud) collaborate and extend their benefits across the enterprise

and help make digital transformation a reality [15]. IBN are geared in digital transformation and in turn utilize the three on-demand changes that these generate such as: scalability, agility and security. This tells us that the network configuration is currently configured element by element to be replaced by automated programming that links directly to all network elements, using consistent policies based on intent (what you want to do) [17]. Therefore, we can say that IBN are based on policies which encompass the expressions of the desired user experience; the prioritization of applications; the network functions that chain to services; rules that are managed internally and that these in turn are applied to some applications or services which are managed within the network or even the rules of the SLAs.

5.2 Challenges of Intent-Based Networks

Among challenges of IBN, the following have been identified:

- Improve your performance, security and application management
- Manage and monitor data, users and highly distributed applications
- Get to work in a Centralized way and with a global vision
- Eliminate errors associated with manual entries
- Ensure operational efficiency
- Representation of human intent in terms of machine language [4].

5.3 Functions of the Intent-Based Network

Intent-based networks need to fulfill a number of essential functions such as: (a) translation and validation, (b) automated deployment, (c) assurance, (d) upgrades and (e) optimization. **Translation and Validation**: In this phase through a graphical interface, the system allows users to enter commands in natural language which is different from machine language; the translation of these different languages is the first phase [18]. Humans are prone to make mistakes, and the user can enter a wrong intention; in this phase, a validation of the entered policy will be performed and in turn it can be executed. **Automated Deployment**: Once the intention to be achieved has been defined, the system is in charge of performing the following processes on the fly; without the need of any user intervention or manual follow-up, the system ensures that all the established policies are met and that the final objective is achieved. **Assurance**: IBN take care of protecting the whole network and makes sure that the network is always protected against any attack or some malicious activities that may cause serious problems in the network. In case of finding any fault this will be notified to the administrator to take appropriate actions [19]. **Upgrades**: IBN will be in constant execution of programs which help us to verify the status of the network

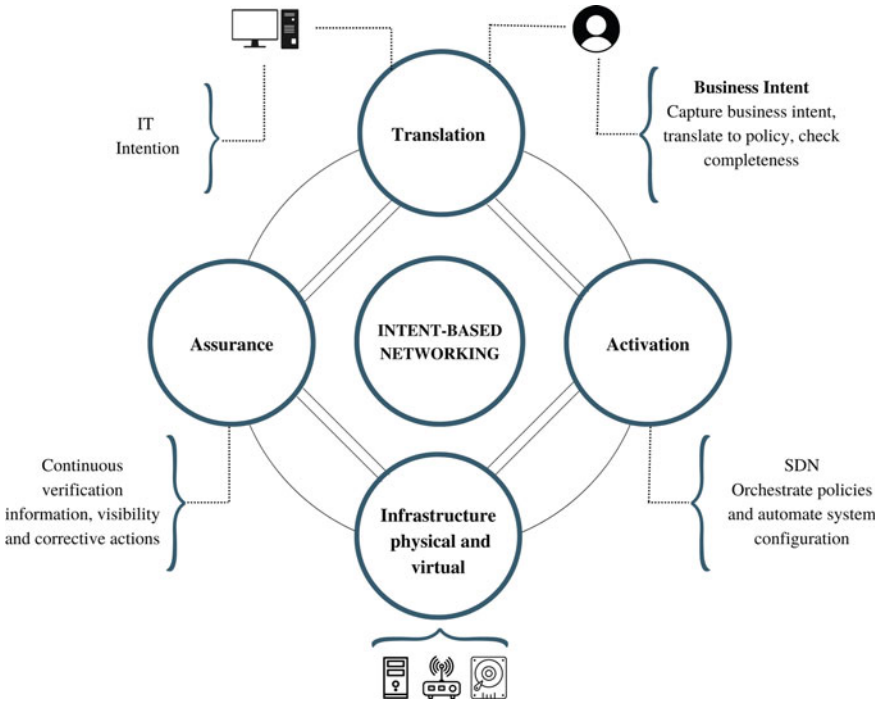

Fig. 6 IBN architecture of [15]

and in case of having any pending update it will perform it autonomously; in case of having any failure, this will be notified to the administrators of the problems and in turn of the actions that must be carried out to correct the error. **Optimization**: IBN uses machine learning algorithms to perform corrective and optimization actions dynamically to keep the network performing properly [20]. According to [15], the architecture of an IBN is distributed as shown in Fig. 6.

5.4 Quality of Service of Intent-Based Networks (QoS)

Intent-based networks, while taking care of device management, also take care of QoS levels to meet global standards. An IBN to achieve QoS uses the Quality of Experience (QoE) management method that is customer-oriented, which allows customers to request end-to-end service for any service at a specific time [5]. The quality of user experience QoE has great validity by having an IBN that fully controls the infrastructure. Figure 7 presents the process of an IBN from a user quality of experience QoE point of view.

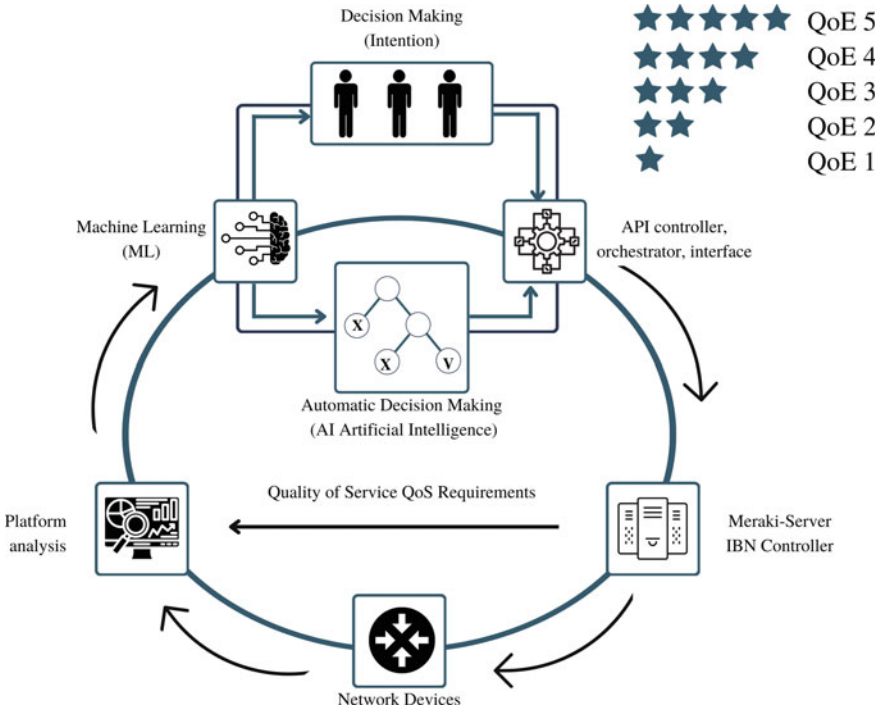

Fig. 7 Quality of service of intent-based networks

5.5 Trends of IBN

IBN are focused on taking SDN to a whole new level by encompassing various SDN capabilities. IBN are in development with better and better capabilities that are encompassing the trend of network management. Among the trends are:

- Multi-cloud networking: IT teams are facing increased complexity as 60% of enterprises expect the majority of their applications to be hosted in the cloud in order to provide better connectivity and security to applications [21].
- Secure offices: Through artificial intelligence AI, it is expected to obtain secure offices through voice assistants based on artificial intelligence; this requirement is generated due to the stages of COVID-19 that has been occurring during these years.
- Automation: Due to the demand for greater agility and the lack of ICT staff, intent-based networks will facilitate policy-based management in an automated manner from data centers to public or private clouds.
- Remote access: IBN will be responsible for extending policies and ensuring the security of remote access.

– Quality of service: IBN must correct errors so that the user is fully abstracted and achieves a high level of QoS [5].

5.6 Highlights and Most Important Contributions of This Research

This paper proposed a methodology for the identification of the key knowledge of the articles. This methodology can be used in any area of research. In the survey, we have presented the classifications that networks have based on IBN intent. We have identified several key factors that are necessary for the implementation of this type of networks, such as activation and translation phases, automated implementation, assurance, updates and optimization. We were able to identify that these networks do not simply use QoS. QoS and QoE are key points for user satisfaction, all controlled by a service category rating metric. The survey and the applied methods are the main contribution of this research: first, a survey on intention-based networks, to facilitate the understanding of this type of networks that in the future will be the ones that will cover the entire telecommunications system. The applied methods, both the general method and the CIT and BACOS methods, facilitate the research to the users. Emphasis is made on the filtering of key topics in order to develop a shorter term research than we are used to, since the results of the algorithm present us with a clear vision and the filtered articles that will be necessary to develop any type of research.

6 Conclusions

In this survey, we provide recent advances in networking based on intent-based networks. We first provide an information analysis using a natural language processing algorithm, based on existing architecture, platforms and algorithms, and then focus on the challenges and future directions toward building an Intent-based network. Through the integration of new technologies will gradually bring networks in line with intent and therefore, in future years, intent-based networks will make an exceptional paradigm shift in the control and management of telecommunication networks. A brief history of intention was also analyzed, how it has been adapting from human capabilities and how to transform them into execution policies focused on telecommunication areas. Then the operation of a network based on the intention was analyzed obtaining a clear and concise knowledge about the management of these networks, also a clear point of the challenges that IBN face to get to work in a centralized way and with a global vision in order to ensure a very high operational efficiency so that administrators can monitor the entire network in a much simpler way to the current one. This will be achieved because the IBN must have a very

high QoS policy, since they are in charge of controlling an end-to-end service for any service or query that the user is requesting and this can be done in a simple and effective way. All this is possible thanks to the introduction of artificial intelligence and machine learning, which intention-based networks adopt in order to have total control of the entire infrastructure implemented.

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Study on the Collective Behaviors of Topologically Interacting Neighbors Using Network Theory

Richard Kyung and Hyunseo Lee

Abstract In recent years, consensus dynamics and artificial intelligence have attracted attention in studying modern social units such as intelligent grid communities. Research in consensus dynamics involves investigating the diverse behaviors of entities, such as the communication between communities and the geometries of social units. When designing optimized social networks, it is essential to consider all situations a social unit may encounter and identify potential issues in advance. Using consensus dynamics in graph theory, this paper investigates the impact of the geometry of social networks on time scales and the consensus of communities composed of multiple decision-making agents The present study explored the adjacency matrix of a structured network with random groups to examine their interactions in this diffusively multi-coupled agent system and elicit a time-scale separation. Computer simulation and calculations utilizing MATLAB and Python programming showed that increased communication and contact might help achieve consensus, but this is dependent on the geometrical dependencies of social structures.

Keywords Consensus dynamics · Network theory · Multi-agent system

1 Introduction

1.1 Network Theory with Multi-agent System

When each dynamic system is connected to a network and exchanges state variables with each other, it becomes possible for them to handle new tasks that individual systems cannot. Here, we examine how the consensus study can solve a distributed

R. Kyung (✉)
CRG-NJ, Cresskill, NJ 07627, USA
e-mail: nycrick@gmail.com

H. Lee
Seoul International School, Seoul, Korea

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optimization problem with multi-agent systems. The object in Fig. 1 is called a graph, where the small circle dot is expressed as a vertex or node, and the arrow is expressed as an edge. Each edge has a weight, and the number indicated next to the arrow in Fig. 1 is the weight of each edge [1]. In instances with many nodes or edges, expressing a graph as a formula rather than a figure may be clearer. To express the graph as a formula rather than a figure, the graph G is often expressed as [2]

$$G = (V, E, A), \tag{1}$$

where

$V = \{1, 2, 3, 4\}$ is a set of vertices and $E = \{(2, 1), (3, 1), (1, 3), (4, 3)\}$ is a set of edges. Let's take a look at how the direction of the arrow is indicated by comparing it with Fig. 1.

However, a matrix that is more frequently used than the adjacency matrix is a matrix called (graph) Laplacian, which is defined as

$$L := D - A, \tag{2}$$

where D is a diagonal matrix and the ith diagonal element is defined as $\sum_{j=1}^{N} a_{ij}$. That is, it is the sum of all elements of the ith row of the adjacent matrix. The (i, j) th element l_{ij} of L is $l_{ij} = -a_{ij}$, $l_{ij} = \sum_{j=1}^{N} a_{ij}$ when $i \neq j$. Therefore, for a certain graph, the information provided by the adjacency matrix and the Laplacian matrix is the same, and if the graph is given, the Laplacian matrix can be obtained. Since the Laplacian matrix will play an important role in the future, let's look at some properties. First, by definition, a Laplacian matrix always has an eigenvalue 0, and one of the eigenvectors corresponding to this eigenvalue 0 has at least $1_N := [1, 1, 1, \ldots, 1]^T \in R^N$.. (The symbol 1_N denotes a column vector of size N in which all elements are 1.) This is because $L1_N = 0 \cdot 1_N$ holds because the sum of each row of L always becomes 0. On the other hand, it is known that all nonzero eigenvalues of a Laplacian matrix have a positive real part. The reason for this can be demonstrated using the Gershgorin Theorem [4–6].

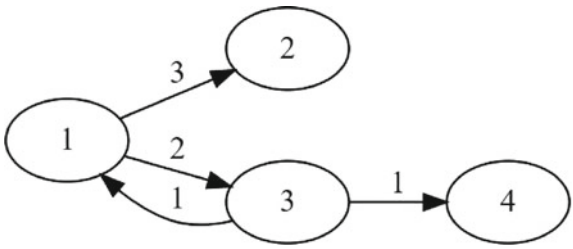

Fig. 1 Since arrows mean edges and have directions, such graphs are called directed graphs, or di-graphs for short [3]

1.2 Gershgorin Circle Theorem

Consider a given random matrix $A \in R^{n\times n}$. If, on the complex plane, the ith diagonal element a_{ii} of the matrix A is centered and a disk of the radius $\sum_{j=1,j\neq i}^{n} |a_{ij}|$ is defined as D_i, all eigenvalues λ of the matrix A belong to the union of the disk D_i. Thus

$$\lambda(A) \in \cup_{i\in\{1,\cdots,n\}} D_i \tag{3}$$

is satisfied. [7] If the Gershgorin theorem is applied to the Laplacian matrix L, from the definition of the diagonal elements of L, all the disks D_i for L pass through the origin and are located on the right half-plane of the complex plane, so all eigenvalues except the origin must have positive real parts. On the other hand, if all sides in Fig. 1 are in both directions and all weights are 1, it is displayed more simply (see Fig. 2) instead of a double-headed arrow.

A straight line in this graph denotes a double-headed arrow, and it is called an undirected graph because the edges do not have directionality. The weights are the same in both directions, and if omitted (as shown in this figure), all weights can be considered as 1. As both the adjacency matrix and the Laplacian matrix representing the undirected graph are symmetric matrices, the eigenvalues of the Laplacian matrix L are all real numbers and are greater than or equal to 0. There are many differences between (a) and (b) in Fig. 2. Firstly, all nodes in (a) are connected, whereas the graph of (b) is not. Then, to know whether a given graph is connected or not, should we always draw a picture like this?

Since all eigenvalues of a symmetric Laplacian matrix are real numbers, one can arrange them in order and promise $\lambda_1 \leq \lambda_2 \leq \cdots \leq \lambda_N$. Since the Laplacian matrix always has 0 as an eigenvalue in the previous discussion, λ_1 must always be 0. That is, the following expression holds [9]:

$$0 = \lambda_1 \leq \lambda_2 \leq \cdots \leq \lambda_N. \tag{4}$$

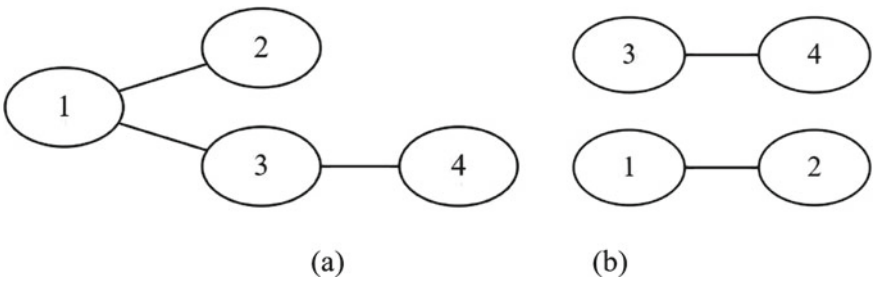

Fig. 2 Undirected graph [8]

At this time, it will be clear whether the graph is connected or not by determining whether the second smallest eigenvalue λ_2 of the Laplacian matrix is 0 or not.

2 Materials and Methods

Graph theory and networks have maintained close relations. As shown by Euler's development and the famous story of the seven bridges of Konigsberg, networks have shown dyadic relationships between units. With this abstraction in place, standardized tools can then be applied to rather separate systems. These have become a central toolbox to various disciplines such as social systems, the web, and neurosciences with relevant studies in graph theory and networks. Within the framework of Network Science, a system consists of a set of nodes representing individual units of the system and a set of links. The spectral properties of a matrix characterizing the network demonstrate a broad range of its dynamic and structural features. We often utilize the adjacency matrix (A) and the Laplacian matrix (L), dependent on the problem at hand. The spectral features of networks have been thoroughly examined, and numerous constraints have been established. However, this study focuses mainly on the basic spectral properties of undirected networks.

3 Results

3.1 Connected Small Communities (MATLAB Simulations)

As customary, the eigenvectors in the adjacency matrix have been ordered from the largest λ_1 to the smallest λ_N, while eigenvalues in Laplacian matrices were ordered from smallest to largest.

Figure 3 shows eigenvalues λ_1 and λ_6 are more equally distributed along the line. The distribution pattern of these eigenvalues in Laplacian matrices shows the nodes' distribution and also decides the speed of convergence.

Figure 4 shows a few of the eigenvalues λ_1 and λ_6 are overlapped along the line. The distribution pattern of these eigenvalues in Laplacian matrices shows that the nodes' distribution of the original system is more concentrated. The speed of convergence has been improved compared to the case in Fig. 3.

Figure 5 shows a few of the eigenvalues λ_1 and λ_6 are overlapped with 4 roots along the line spreading regularly. The distribution pattern of these eigenvalues in Laplacian matrices shows that the nodes' distribution of the original system is concentrated. The speed of convergence has been improved compared to the case in Fig. 3.

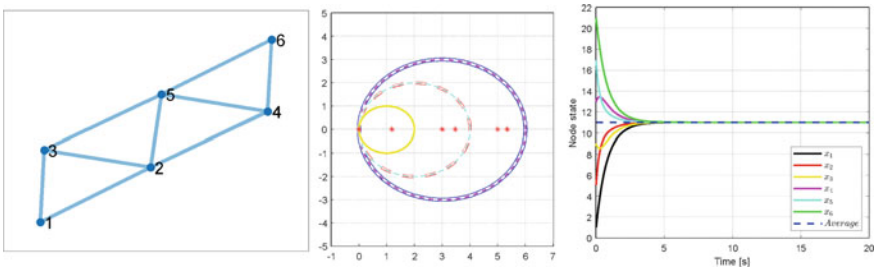

Fig. 3 Six nodes system 1

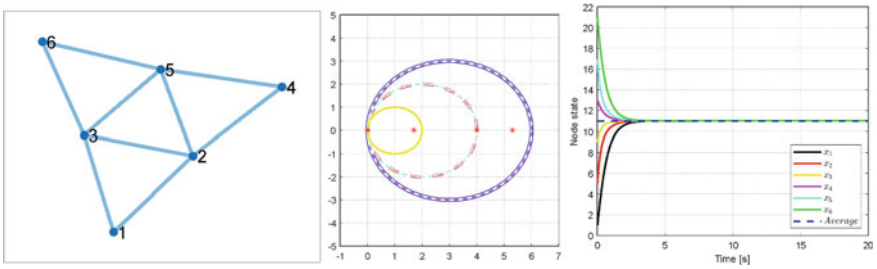

Fig. 4 Six nodes system 2

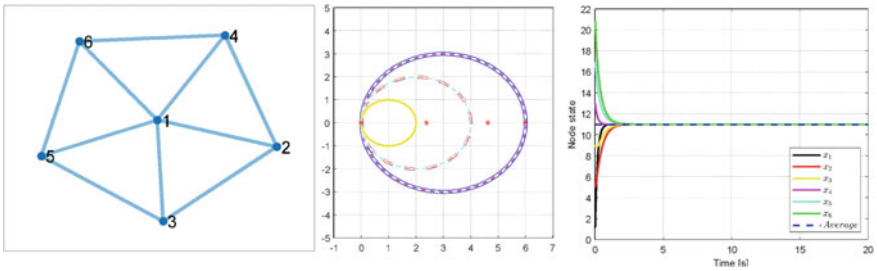

Fig. 5 Six nodes system 3

3.2 Community Analysis: Simulations via Python

A social network of bottlenose dolphins (Fig. 6). Four communities detected by the Louvain algorithm implemented on gephi (http://www.gephi.org) are shown in different colors. Schematic of overlapping communities. Adjacency matrix (unweighted) with 3 groups having consensus dynamics on this network displays a time-scale separation until around $t = 0.1$ s, and the approximate consensus is reached within each group (groups indicated by color); then a consensus is reached between the groups in about 1 s. Figure 7 with the parameters [(100, 0.25), (100, **0.4**),

Fig. 6 Communities: simplified network (right)

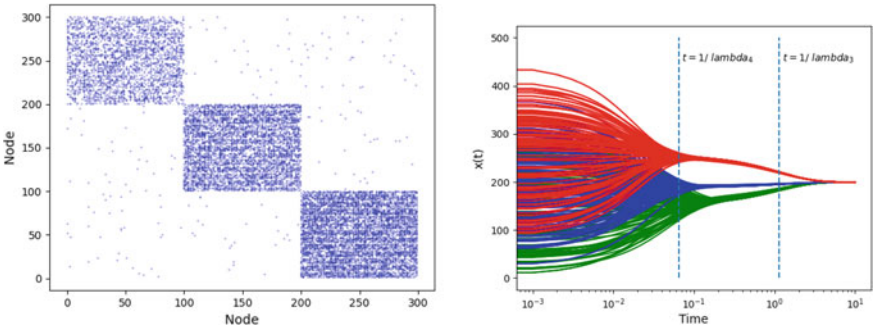

Fig. 7 [(100, 0.25), (100, 0.4), (100, 0.5)] = [(#nodes along each axis, probability)]

(100, **0.5**)] = [(#nodes along each axis, probability)] shows denser in the second and third blocks since the probability has increased by 10%.

These observations are not limited to the case where the structure of the network is block-diagonal but can be extended to the general case where the network consists of a random and noise component that has a stochastic block model so the network can be very sparse.

4 Discussion and Conclusion

As previously shown by sample figures, the present study shows a significantly greater time-scale separation due to fewer edges connecting the communities as presented by the study, which inherently means they have less effect on each other or take more time to incur. As the number of random edges between the communities increases (such as the magnitude of the perturbation to the adjacency matrix of the three separate communities), the time-scale separation is reduced in turn, communities reach the same consensus value by a $t = 1/\lambda$. It is important to note that this parameter can be controlled by adjusting random edges added to the communities. Since these communities were arbitrarily connected graphs, the conclusion is maintained.

Using this property, it is possible to "distributedly" find the average value of a certain value of each node in a graph composed of very many nodes and complex

edges without a centralized computation unit. In order to obtain the average centrally, information from all nodes must be gathered and processed, whereas the distributed algorithm presented above shows that an individual node can obtain the average of the entire network through local communication only with nodes placed around itself. This property can be used for the formation flight of many drones. When a certain optimization problem needs to be solved in a network of multiple nodes, each node interacts with neighboring nodes while solving a problem given only to itself. It can be used in the case of solving the entire optimization problem (distributed optimization) by itself. To analyze the dynamics, time scales, and communities, Python and MATLAB codes are written. Simulations of consensus dynamics on a network show that the dynamics converge asymptotically toward the state $x = 1^{\mathrm{T}} x_0/n$.

By performing stochastic simulations, this study can be used to find the epidemic threshold for the susceptible-infected-susceptible dynamics in networks, diffusion of temperature or pressure problems in engineering, and communication issues in social fields.

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Study on Simulation-Based Autonomous Ship Test and Evaluation

Kwangil Lee and Seungwook Hwang

Abstract As the digitalization and artificial intelligence (AI) technology has been spotlighted on the maritime industry, most researches are focused on the autonomous ship. Major obstacle of the autonomous ship is the test and evaluation of the autonomous ship. This paper covers the study on the simulation-based autonomous ship test and evaluation technology. Since the real time and mass scale for the realization of the real world. We focused on the scalability. We also propose the simulation scenarios for the evaluation of the autonomous ship technology.

Keywords Autonomous ship · Simulation · Collision avoidance · Safety · Test and evaluation

1 Introduction

Recently, the digitalization and artificial intelligence (AI) technology has been spotlighted on the maritime industry. These technologies bring a lot of changes in the process in the maritime industry. These brings an automation in the process of the shipping. One of the biggest challenges in the shipping industry is autonomous ship [1].

Many researches are focused on the autonomous ship design. Some of the researches are focused on the autonomous ship frameworks based on the simulation [2]. Some works are related with system design related with navigation system [3, 4]. This works focused on the development of autonomous navigation system itself. However, the feasibility of the autonomous ship needs to be tested fully before it is used commercially since the safety of the vessel is an important issues in the maritime.

K. Lee (✉) · S. Hwang
Korea Maritime and Ocean University, Busan 49112, South Korea
e-mail: leeki@kmou.ac.kr

S. Hwang
e-mail: hsw@kmou.ac.kr

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Test and evaluation of autonomous commercial merchant ships are real challenges. When it fails, a commercial merchant ships cause a significant disaster in terms of the environment, safety, and economic perspective. So, even before it starts its test trail in the sea, it needs to be tested and evaluated fully its function and its safety.

This paper covers the study on the simulation-based autonomous ship test and evaluation technology. Since the real time and mass scale test for the realization of the real world, our simulation frameworks provide the connectivity with European Maritime Simulation Networks (EMSN) [5]. We also propose the simulation scenarios for the evaluation of the autonomous ship technology.

2 Simulation Frameworks

2.1 Structure

The overall structure of the autonomous ship simulation is illustrated in Fig. 1. As shown in Fig. 1, our simulation platform is connected with a local ship handling simulator and other simulators via VPN which provides a connection with EMSN. The proposed simulation framework consists of autonomous navigation system, monitoring tool, remote control system, analysis tool, and DIS adaptor.

The objective of our frameworks is to provide a system that enables autonomous system to be tested and evaluated, not develop the autonomous system itself. When a system developer or manufacturer develops its own autonomous navigation system, their system is placed on the autonomous navigation systems in our frameworks. Then, our simulation frameworks test and evaluate their system. The detailed functions of each module is explained in the following sub-clauses.

2.2 Functions

The functions of each modules in our simulation frameworks are as follows:

ANS is the controller of the autonomous ship. When each manufacturer develops its own autonomous ship control system. This system is placed on the ANS module and connected to other simulation modules in our platform. This is the main module which are tested and evaluated in our simulation platform.

DIS adaptor is used when the target module cannot provide DIS functionality. With the DIS adaptor, the manufacturer enables to be tested and to be evaluated in our platform with minimum adjustment. The major function of the DIS adaptor is to convert the information provided by either NMEA sentences or 450-sentences into DIS packet.

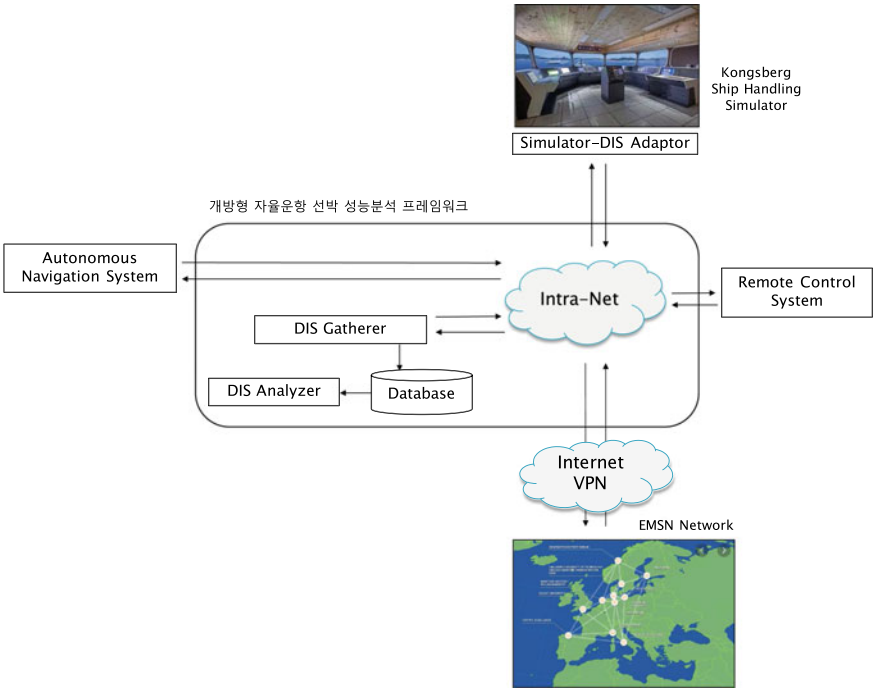

Fig. 1 System architecture

Remote control system is the module which can be controlled by the human directly. It also provides the voice communication with the participant in the simulation networks.

Monitoring tool is to collect the DIS packets in the simulation networks and to store in the database for the future evaluation. This module stores all packets in the simulation networks and evaluate of the ANS system.

Analysis tool is to provide the evaluation results based on the information on the database after the simulation. Analysis tool provides the information of the ship which is controlled by the ANS, position, speed, and direction of the other ships. Based on these information, it provides the evaluation on various metrics.

2.3 Autonomous System Adaptor

Autonomous system adaptor is a path between autonomous navigation system and ship handling simulator. The information used in the ship simulator is based on the IEC 61162-450 [6]. However, the information used in our simulation framework is based on the OpenDIS packet [7]. So, the information conversion between 450

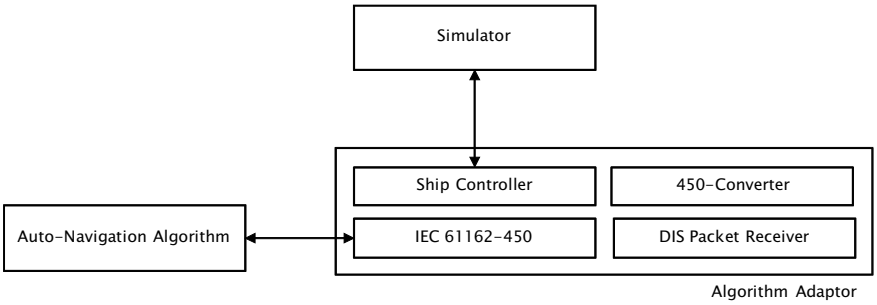

Fig. 2 Autonomous system adaptor

and DIS packet shall be performed. For tis, our adaptation module consists of IEC 61162-450, DIS packet receiver, Ship Controller, 450-Convewrter as shown in Fig. 2.

DIS packet receiver receives all DIS packet in the network and deliver to IEC 61162-450 converter. When it receives with DISPacket class and delivers to 450-Converter for the communication with the ship handling simulator/ the other directions performs in the similar way. IEC 61,162–450 generates and processes the packets which comply with IEC 61162-450. 450-Converter receives the information from DIS packet such as target ship type, size, location, and speed. These information needs to be converted into NMEA 450 so as to exchange with ship handling simulator.

3 Autonomous Ship Analysis

3.1 Simulator Process

For the autonomous ship simulation, it is important to control the ship. Since the ship simulation performs in the ship handling simulator, we exchange the control command and its status information with ship handling simulator. Our simulation process is illustrated in Fig. 3. As shown in Fig. 3, we provide the interface with the steering wheel controller and telegraph controller in the simulator which are used to control the ship course and speed accordingly.

When autonomous ship control module decides to change the ship movement, it generates the heading information and speed information. This information is converted to MODUBUS which will be delivered to steering wheel controller and telegraph. These information is delivered into the DIS adaptor. Then, it delivers to the proper simulation module.

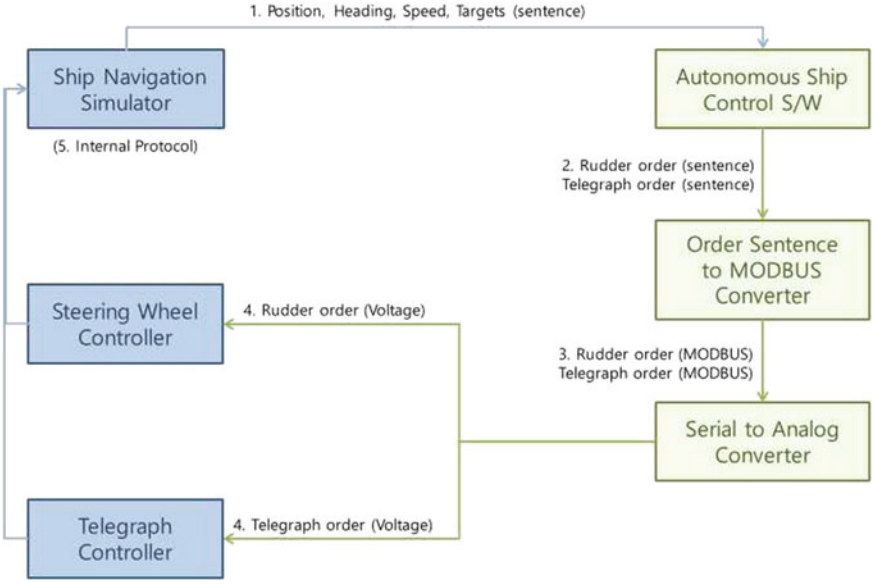

Fig. 3 System structure

3.2 Autonomous Ship Analysis

Based on our simulation frameworks, autonomous ship analysis module evaluates each autonomous ship algorithm/systems. These functionalities include the evaluation on both the navigation functionalities along with the waypoint and collision avoidance.

Autonomous Function Analysis. The analysis is based on the analysis which are stored in the database during the simulation. So, analysis module needs to upload, parse, analysis of the data, and display its results.

- Navigation area recognition: the recognition capability to identify the navigation area currently such as near port, deep sea, and costal area.
- Weather recognition: recognition of navigational weather such as wind, wave, and current in the navigational area
- Navigational law: apply of the navigational law based on the collision risk

Collision Avoidance Evaluation. It is important to evaluate of the collision avoidance capability of the autonomous ship. We first develop the evaluation model for the situational awareness of the autonomous ship which will be considered in the collision avoidance decisions.

- Collision distance/time: the relative shortest distance from the other ship or TCPA (the time when arrives at the nearest distance)
- Distance: the shortest distance that the objects or ships are passing by

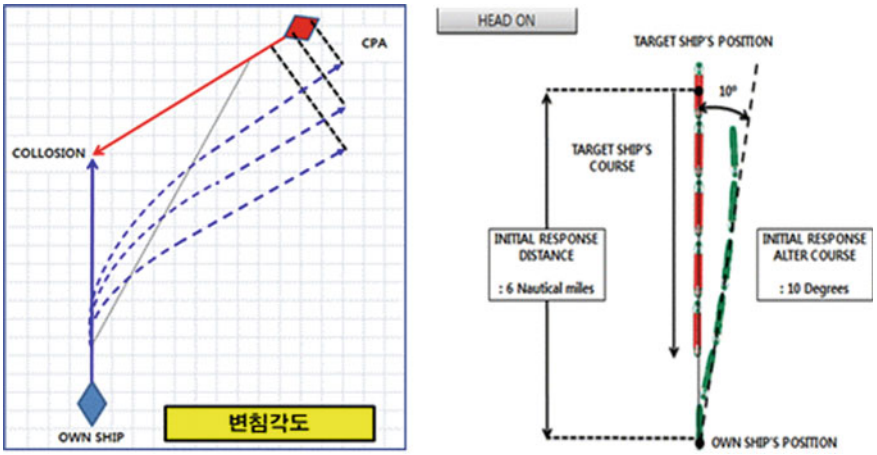

Fig. 4 Measurement of collision avoidance performance

Table 1 Table captions should be placed above the tables

Items	Unit	Description
Route compliance	−2	Xmin * (−2) =
Course change time	−5	12 point, bold
Collision avoidance-target 1	−10	Left side passing
Collision avoidance-fishing vessel	−5	Passing CPA is ess than 0.5 mile
Collision avoidance-target 2	−5	Left side passing

– Alter course angle and speed: The speed and course during the collision avoidance behavior is shown in Fig. 4.

Evaluation model. Our evaluation model is based on the performance metrics. This evaluation model is also used for the navigation performance of the navigator. The major evaluation metrics are collision, route compliance, time to course changes, and the operations of the collision avoidance. The evaluation sheet is illustrated in Table 1.

4 Evaluation and Analysis

Our simulation frameworks are implemented and installed. Our simulation frameworks are connected to the EMSN as shown in Fig. 5. Using the EMSN, we connect 11 simulation centers and connect with 30 ship handling simulator. With 30 ships,

Fig. 5 Simulation test-bed and its results

we are able to simulate the various autonomous ship scenarios. For the simulation, we develop ten navigation scenarios and evaluated in our frameworks as shown in Fig. 4. Our simulation frameworks is able to provide the real-world simulation with the combination of autonomous ships and human-navigated ships.

In the experiment, an autonomous navigation system which are developed by the third party are used for the simulation analysis. The ANS system is plugged in our simulation frameworks and evaluated as shown in Fig. 6. As shown in Fig. 6, ① displays the simulation results performed the simulation. ② shows the final results in terms of collision, route, and result are displayed. The results are computed with the value with 'collision' and 'route.' ③ shows the event log for the each performance category in ②. The details of the evaluation are listed in the display. Finally, ④ shows the final score.

In the experiment, an autonomous navigation system which are developed by the third party are used for the simulation analysis [2]. The ANS system is plugged in our simulation frameworks and evaluated. The evaluation system is based on the analysis on the navigation capability and collision avoidance. Based on our evaluation system, the test results are displayed in our system. Also, our system provides all events and log information to check or to review the system that occurs during the simulation. After the simulation with scenarios, the some results of the evaluation is illustrated in Fig. 7.

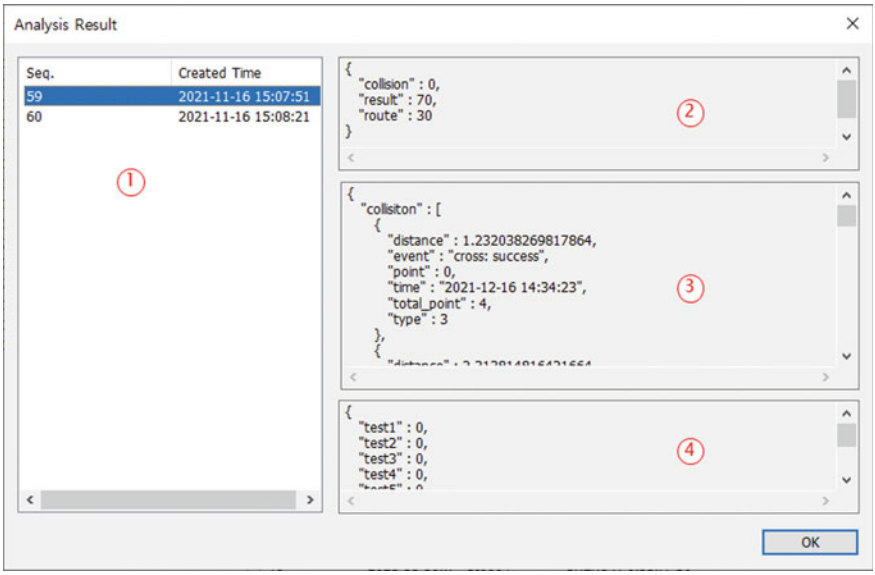

Fig. 6 Autonomous evaluation system

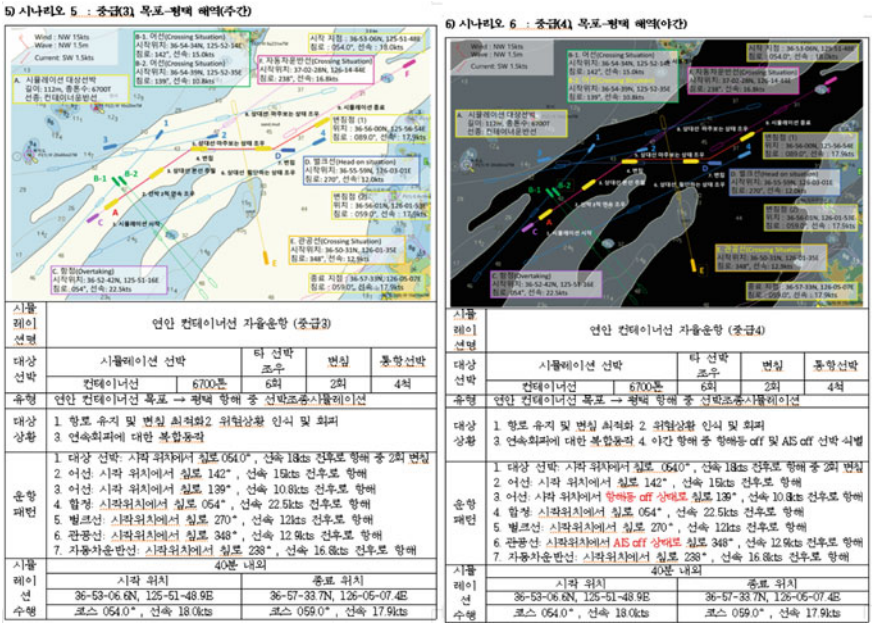

Fig. 7 Autonomous ship evaluation results

5 Conclusion

Autonomous ship has a great importance on the maritime digitalization. For the success of the autonomous ship, it is important to be tested and evaluated fully as well as to develop autonomous ship technologies. In this paper, we study and implement on the simulation-based autonomous ship. The proposed simulation frameworks provide an interface with the real test environment for the ship navigation, and the manufacturer and system developer develop its own system and easily test its system. Even though we develop to test autonomous navigations and some scenarios for the autonomous ship performance, it needs to be developed to test other autonomous system, such as various sensors and engine systems, and more various navigation scenarios to realize real-world navigation circumstances. These will be left for the future study.

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Optimisation of Healthcare Supply Chain Models to Enable Decision Making During a Pandemic

George Maramba, Hanlie Smuts, Funmi Adebesin, Marie Hattingh, and Tendani Mawela

Abstract The world is slowly recovering from the worst pandemic after the 1918–1920 influenza pandemic. The Corona Virus Disease 2019 (COVID-19) is a highly infectious virus that spread across the entire world in just under three months. All economic activities and healthcare supply chains were disrupted, resulting in poor decision making and inadequate knowledge to fight the pandemic. The healthcare supply chain models and systems failed to handle the impact and shock caused by the pandemic. Healthcare institutions were overwhelmed by a high number of sick and dying patients, governments struggled to source adequate personal protective equipment, clothing and medical drugs that were required to contain the deadly virus. This study was conducted to investigate the possibility of optimising the healthcare supply chain models to support management decision making during a pandemic. The study applied a systematic literature review and a case study to simulate an optimised supply chain model and determine its capability to enable decision making during a pandemic.

Keywords Healthcare supply chain optimisation · Management decision making · Healthcare management systems

G. Maramba (✉) · H. Smuts · F. Adebesin · M. Hattingh · T. Mawela
University of Pretoria, Pretoria, South Africa
e-mail: u19083051@tuks.co.za

H. Smuts
e-mail: hanlie.smuts@up.ac.za

F. Adebesin
e-mail: funmi.adebesin@up.ac.za

M. Hattingh
e-mail: marie.hattingh@up.ac.za

T. Mawela
e-mail: tendani.mawela@up.ac.za

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1 Introduction

The fast-spreading Corona Virus Disease 2019 (COVID-19) forced governments to take drastic measures such as lockdowns and curfews to slow down its rapid spread [1]. While this appeared to be the most ideal solution to contain the spread of the virus, it created a new set of unforeseen challenges [2, 3]. The lockdowns and curfews caused a disruption in the supply chain, which created speculative shortages of much-needed healthcare essentials [4, 5]. During the early days of COVID-19, the distribution of personal protective equipment, clothing and drugs was delayed by disrupted supply chains due to lockdowns and curfews [6, 7]. Furthermore, these challenges were exacerbated by the worldwide disruption of global supply chains [8]. A well-refined healthcare supply chain is key during a pandemic [7, 9]. There are many variables that need to be considered and managed [10], which require a holistic approach, and coordinated activities to fight a pandemic [11]. As supply chain models play a significant role, particularly during a pandemic [12], it is prudent to optimise them to enable decision making.

This paper is structured as follows: Sect. 2 describes the background to the study, followed by Sect. 3, which presents the research approach. Section 4 contains a discussion of the findings, while Sect. 5 presents the recommendations and conclusion, as well as opportunities for future research.

2 Background

The world's reactionary approach to the COVID-19 pandemic indicated that it had underestimated the pandemic's catastrophic repercussions and economic disruptions [1, 10]. Maintaining the healthcare supply chain, essential services and lockdowns or curfews proved challenging, particularly during the first three months of the pandemic [13], in the initial phase of the pandemic, there was a high mortality rate, as there was not much knowledge about the virus [14]. This scenario created panic, confusion and a scramble for personal protective equipment, clothing and drugs [5], resulting in speculative shortages.

The disruption of the healthcare supply chain resulted in most governments making uninformed decisions and distributing personal protective equipment, clothing and vaccines haphazardly [5]. This haphazard distribution resulted in shortages, hoarding and unnecessary price increases [6, 15]. There was a demand shock during the early months of the pandemic that required supply chain systems to manage and ensure fair distribution [5]. In addition, some countries were importing all their personal protective equipment, clothing, medical drugs and vaccines as they did not have production facilities [16]. While some countries had not budgeted for this expense and did not have the resources to purchase the required consumables [17], the demand shock was exacerbated by the disruption of the global supply chain and travel restrictions [18].

Healthcare institutions were overwhelmed as they had to administer a huge influx of patients [19], lacked robust supply chain models [5], did not have the capacity to deal with increased volumes [9] and encountered shortages of healthcare workers to administer COVID-19 infected patients [14]. The pandemic revealed and amplified the shortcomings in the existing healthcare supply chain system [5]. The shortage of face masks and respirators in the USA demonstrated a failed supply chain system [10, 19]. Federal government structures, policies and current supply chain systems were found to be too rigid and to lack the flexibility required during a pandemic such as COVID-19 [12, 19]. The procurement of healthcare supplies cannot follow red-tape processes during a pandemic. The researchers started by conducting a literature review to identify and determine the challenges experienced in the healthcare supply chain models and systems during the COVID-19 pandemic. The second part of the study was a case study conducted using real data for the KwaZulu-Natal province in South Africa to simulate an optimised healthcare supply chain and determine if it can aid real-world decision-making capabilities.

3 Methodology

The aim of this study was to investigate the possibility of optimising healthcare supply chain models to support management decision making during a pandemic. To achieve this outcome, the researchers approached the study in two phases. Firstly, they conducted a systematic literature review (SLR) to gain a scientific perspective and in-depth understanding of healthcare supply chain models and challenges encountered during the COVID-19 pandemic. They used a higher education institution (HEI) journal search engine to locate relevant studies. The studies identified through the SLR process must have been executed, published and peer-reviewed during the pandemic, with the aim of exploring healthcare supply chains.

The keywords "*optimise supply chain models*" and "*decision making during a pandemic*" were applied to execute the search, together with the publication period parameter of 2020–2022. The search returned 189 papers, 32 of which did not directly explore the healthcare supply chain and COVID-19 pandemic. Therefore, they were excluded. The researchers screened the remaining 157 papers considering completeness and contributions towards healthcare supply chain models and supply chain during a pandemic. Twenty-seven studies were selected and analysed for this paper. Table 1 presents the studies selected by journal source and the number of selected papers per journal.

The 27 selected studies were uploaded into the Leximancer software to identify common themes. Leximancer is an automated content analysis software tool used to analyse textual content in documents (https://www.leximancer.com).

The second phase of the investigation entailed conducting a case study in KwaZulu-Natal. The South African healthcare supply chain data required for the case study was purchased from two of the biggest healthcare suppliers in South Africa. The first data set purchased from a healthcare consumables' wholesaler contained

Table 1 Reviewed studies

Journal source	Number of papers per journal
European Journal of Operational Research	1
The International Journal of Logistics Management	7
Journal of Enterprise Information Management	1
International Journal of Physical Distribution and Logistics Management	1
IEEE Transactions on Engineering Management	5
Industrial Management and Data Systems	2
Benchmarking: An International Journal	1
International Journal of Operations and Production Management	1
Business Process Management Journal	1
International Journal of Environmental Research and Public Health	1
Journal of Organizational Change Management	1
Supply Chain Management: An International Journal	1
IEEE Transactions on Automation Science and Engineering	1
South African Medical Journal	1
Annals of Operations Research	2
Total articles	27

prices, quantities, date of purchase and other transactional details of personal protective equipment, clothing, drugs and vaccine products. In addition, the data included information on manufacturers, customers, distribution centres and warehouses. The data contained the geographical positioning system (GPS) coordinates for all the role players. The supplied data did not include personal information or information that could identify the institution. The second data set contained statistical data on the number of deaths and COVID-19 infections. It was downloaded from the official South African pandemic site: https://sacoronavirus.co.za/. The third data set was downloaded from the website of Statistics South Africa: https://www.statssa.gov.za/ . This data set contained data on population distribution for South Africa. Only data for KwaZulu-Natal was required.

Using Python programming language, the researchers were able to produce a comprehensive simulated supply chain model. The supply chain model was designed with the ability to load data extracts such as procurement data, network partners such as suppliers, manufacturers, warehouses and healthcare institutions, population statistics for the country and provinces, healthcare data such as diseases, and the number of infections and deaths.

The next section discusses the findings of the SLR, as well as the KwaZulu-Natal case study.

4 Discussion of the Findings

The findings are discussed in two parts. The first part addresses the findings derived from the SLR, while the second part presents the case study conducted in KwaZulu-Natal.

4.1 Systematic Literature Review Outcome

The textual content analysis executed identified the core aspects that needed to be smoothened during the pandemic (presented in Fig. 1). The early studies conducted in 2020, which was also the initial phase of the COVID-19 pandemic, identified shortcomings in healthcare supply chain models [4, 5, 19, 20]. During a pandemic, timely decision making is key as it can mean either life or death for citizens [5]. The early stages of COVID-19 experienced a higher rate of infection and high death rate [8, 12]. The early 2020 studies identified supply chain disruptions as a major contributing factor. The healthcare supply chain models lacked resilience, robustness, a consistent network of suppliers and innovation and had never been tested, particularly under high demand and pressure [4, 19, 21].

Studies by Olan, Arakpogun [22] and Zhu, Chou [23] discovered that healthcare supply chain models were not sustainable as they failed to handle the supply shock caused by a shortage of raw materials due to unstable and disrupted supply chain networks. This was worsened by the demand shock triggered by the stockpiling and hoarding of the essential commodities that were required to produce the healthcare consumables [23]. This triggered unjustifiably increased prices of personal protective equipment such as medical ventilators [12] and an extreme shortage of face masks in the USA [5, 8].

The disruption of the healthcare supply chain resulted in some federal governments sourcing COVID-19 vaccines directly from dodgy suppliers as some transactions got manipulated [12]. This also contributed to a lack of transparency and lack of good governance [18, 24]. The poor handling of COVID-19 vaccines and personal protective equipment resulted in the panic-buying of commodities such as face masks and citizens rejecting some of the vaccines [6, 10]. In some developing countries, the distribution and transportation of vaccines were unnecessarily costly and chaotic [17].

The 27 reviewed studies sampled for this study concurred that a supply chain plays an important role during a pandemic. However, they could not aid decision making [9, 19, 25–28]. The reviewed studies showed that existing supply chain models lacked the ability to adapt, upscale and downscale during the pandemic [20, 29, 30]. Furthermore, the pre-COVID-19 healthcare supply chain models did not provide the capacity to perform data analysis to gain knowledge [4, 11, 28, 31, 32]. A study by Devarajan, Manimuthu [28] called for the adoption of predictive analytics and optimisation as part of the supply chain model to identify trends and patterns.

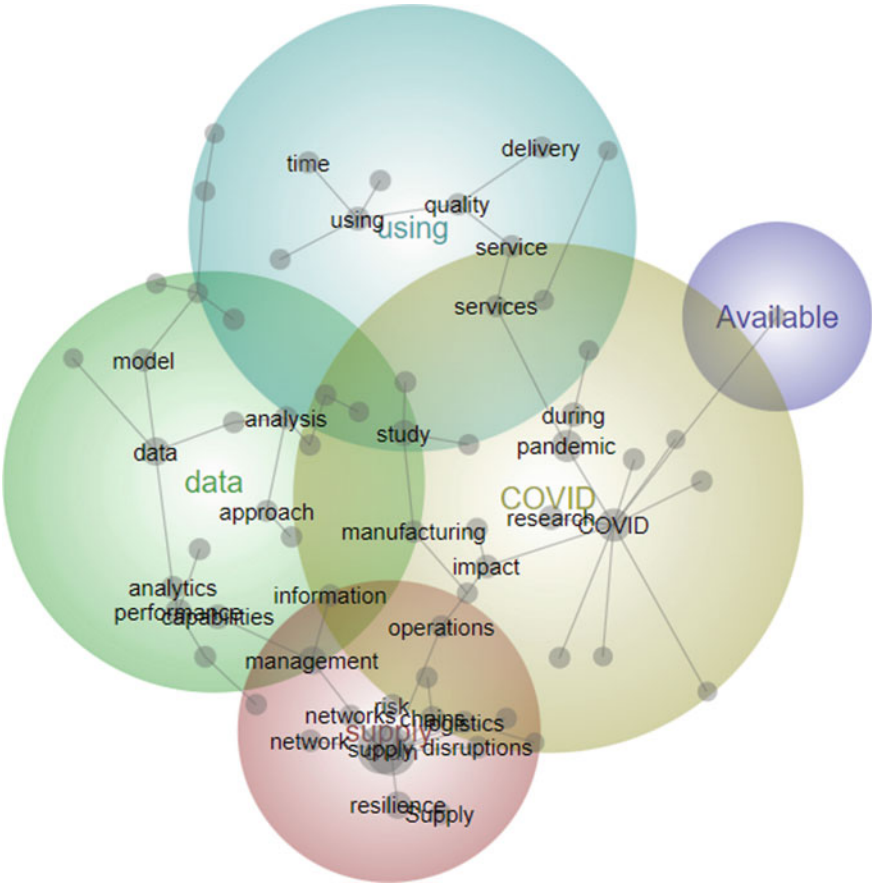

Fig. 1 Main concepts and themes identified in the systematic literature

This study goes further to embed the predictive aspect of supply chain models to enable informed decision making.

In addition, the reviewed studies identified challenges in current supply chain models that need to be resolved and optimised. They are summarised in Table 2, which depicts the supply chain challenge, with a reference to the research conducted.

The studies identified a lack of collaborative risk management, real-time monitoring, information sharing, supply network management, scenario planning, advanced data analytics and predictive aspects [33, 39]. While there are many challenges in the current healthcare supply chain models, key decision making, predictive analytics and integration are the core aspects required in a modern supply chain model to circumvent a pandemic such as COVID-19 [33, 34]. The next section discusses the case study conducted in KwaZulu-Natal.

Table 2 Existing supply chain model challenges

Supply chain model challenge	Authors
Unable to manage sourcing components from multiple locations to make a single product	[31]
Import and export logistics were easily disrupted, affecting the supply chain models	[31]
Lack of smart and modern decision-making capabilities	[20, 31, 33, 34]
Manual work in warehouses slow down distribution and responsiveness to a pandemic	[31]
The absence of artificial intelligence, analytics and predictive models using supply chain transactions is regressive	[20, 22, 31, 35]
The manufacture of most essential goods by a few countries such as China proved to be a threat during the early days of COVID-19	[31]
Most supply chain models lacked dynamic capabilities and flexibility	[20, 31, 36]
Some supply chain models did not include the logistics aspect	[36, 37]
No knowledge learning can be derived from most of the existing supply chain models	[29, 33]
The disruption of the supply chain models results in shortages	[38]
Lack of agility, quick recovery after disruption	[38]
Lack of integration with partners, customers and suppliers	[33, 39]

4.2 Case Study—KwaZulu-Natal

The COVID-19 pandemic revealed many shortcomings in the existing supply chain models around the world, including those in the most developed nations [28]. Many decisions were made without adequate consultation, knowledge and understanding of the pandemic [40]. Some governments and healthcare institutions abandoned the use of supply chain models, thereby making disastrous decisions [9]. Therefore, this case study was conducted to determine if a supply chain model can be optimised to provide the capability to enable decision making during a pandemic.

In order to perform a real-world simulation, population statistical data for KwaZulu-Natal was loaded to provide a population distribution of the province. The results are shown in Fig. 2, Block A. Secondly, the healthcare data set was loaded in the model. To avoid a cluttered visual, only the purchased and distribution data of the Johnson & Johnson vaccine was loaded, with all its relevant values, such as cost, purchased quantities, date of purchase, receiving customers and their GPS coordinates. Thirdly, the COVID-19 infection data for KwaZulu-Natal was loaded. The simulated results are presented in Fig. 2, which depicts four blocks. Block A shows the COVID-19 infections heat map. Block B shows the provincial warehouses and vaccination sites. Block C indicates the road network to vaccination sites. Block D shows warehouses, gazetted vaccination sites and proposed vaccination sites.

The design was aimed at using all this information to manage the supply chain effectively and to enable detailed analytics and predictive scenarios to make informed

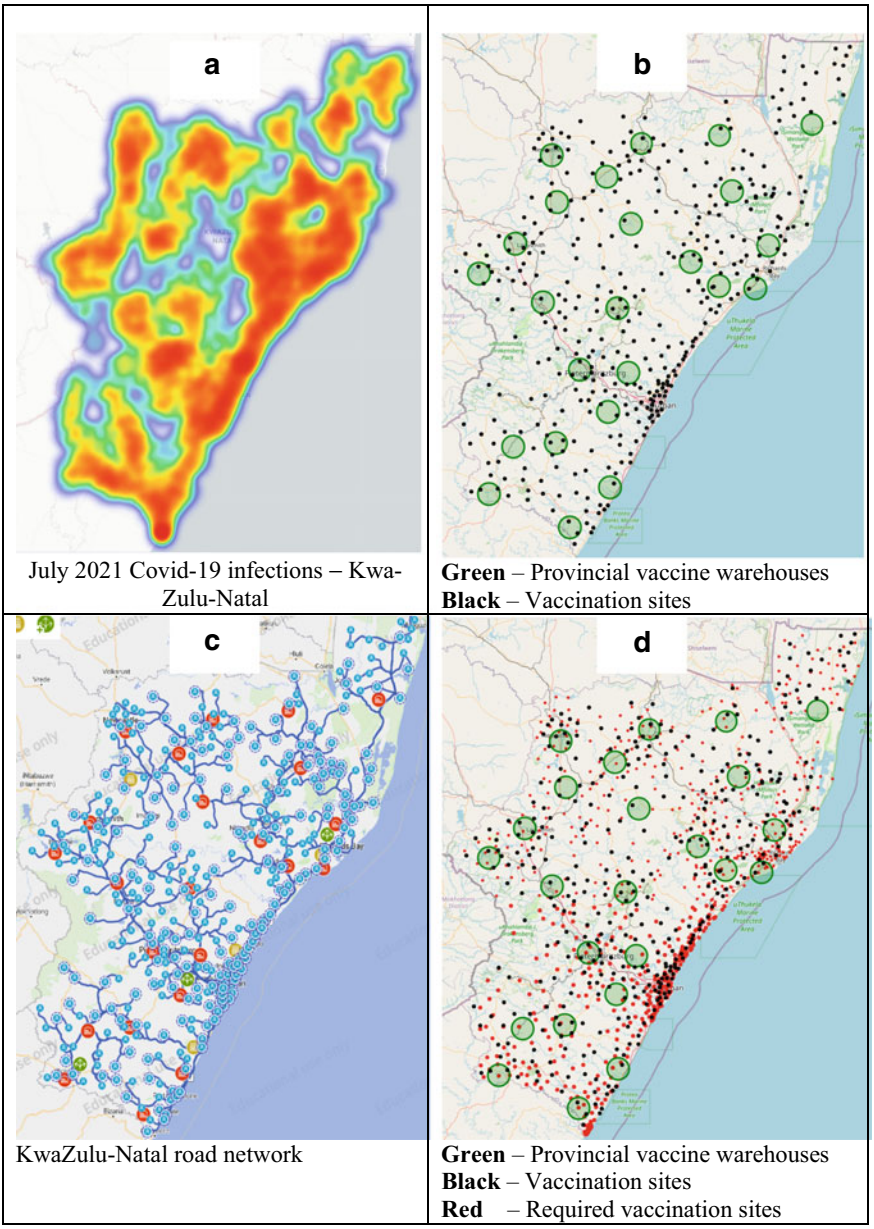

Fig. 2 Results of the predictive supply chain model

Table 3 Supply chain model decision making

Integrating data into the supply chain	Supply chain model solution
COVID-19 infections	The model provided a heat map, which includes a visual. Decisions can be made, and predictions can be tested
Population statistics	The model used a designed algorithm to calculate the required number of vaccination sites based on infection numbers and population distribution
	The model was able to calculate the number of medical practitioners required in the province
	The model calculated the possible number of vaccinations per site per day
Healthcare procurement data	The model used population data, the number of infections and procurement data to determine if the vaccines ordered were adequate. If not, it flagged the anomaly, providing the correct values
	The model was integrated into the Google API for GPS coordinates. This provided the capability to simulate the road network
	The model was able to predict the number of vehicles required to transport the vaccines

decisions during a pandemic. The results of the proposed supply chain model are summarised in Table 3.

The first version of the proposed supply chain model proved to be very effective, as it provided accurate calculations, "if case" scenarios and predictions, which are fundamental when making decisions. A supply chain that harmonises pandemic data, population and healthcare data gives a holistic view, which provides a platform for all-inclusive decision making.

5 Recommendations and Conclusion

The objective of this study was to investigate the possibility of optimising healthcare supply chain models to support management decision making during a pandemic. The investigation was executed in two steps. Firstly, an SLR was performed to understand healthcare supply chain models and challenges encountered during the COVID-19 pandemic. Secondly, three data sets, comprising population data, infection data and healthcare supply chain data, were integrated and simulated as a case study to understand how it may support and enable management decision making during a pandemic (shown in Table 3).

It was established that the supply chain model should not just be used for procurement and the sourcing of the required healthcare consumables. It should rather be enriched to utilise the transactional data to provide detailed analyses and predictive statistics to guide the making of informed decisions. In order to save lives during a pandemic, the application of optimised supply chain models that can perform data

analytics, predictions and "if case" scenarios, as well as integration with network partners, will aid decision making and circumvent most of the avoidable challenges. The envisioned supply chain model provides guidance and enabled KwaZulu-Natal's leadership to make informed decisions timeously. Such decisions not only include the distribution of vaccines, and personal protective equipment but may also inform decisions such as the number of medical practitioners required, the optimised road network assignment and the number of distribution vehicles required to meet the demand.

The simulation was limited to a single province of South Africa. Therefore, there is a need to conduct a broader investigation. In addition, further research on enriching and optimising existing supply chain models may be conducted. The experience the world gained from the COVID-19 pandemic is a wake-up call and a starting point for in-depth research and solution design to combat the next pandemic.

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Information Security Policy Compliance: Usefulness and Ease of Use

Sussy Bayona-Oré and Norman Fong Ochoa

Abstract Various information security (IS) standards and frameworks have been proposed with the objective of safeguarding an organization's information assets. The Information Security Policy (ISP) is one of the tools for managing the IS. ISP compliance continues to be a topic of interest in the IS area. This paper presents a quantitative, descriptive and cross-sectional research of the critical factors in ISP compliance. Data were collected from 103 security professionals. The relationships between the factors perceived ease of use (PEU), perceived usefulness (PU), security knowledge (SK) and security culture (SC) and ISP Compliance Intention (INT) were analysed. The results show that PU and PEU factors are strongly related to INT, while the SK and SC factors are significant related to INT.

Keywords Information Security Policy · Perceived ease of use · Perceived usefulness · ISO 27001

1 Introduction

There is recognition that the incorporation of Information and Communication Technologies (ICT) in organizations increases productivity, improves the products and services [1] they offer and has given rise to a new paradigm called digital transformation (DT). Just as ICT has brought benefits, organizations are more exposed to incidents and malicious attacks.

Faced with this situation, information security arises as a need to protect the main assets of organizations. This situation has led different specialized organizations to propose standards and frameworks, such as the ISO/IEC 27000 family [2], COBIT

S. Bayona-Oré (✉)
Universidad Autónoma del Perú, Panamericana Sur Km. 16.3, Villa El Salvador, Lima, Perú
e-mail: sbayonao@hotmail.com

N. F. Ochoa
Universidad Nacional Mayor de San Marcos, Av. German Amézaga S/N, Ciudad Universitaria, Lima, Perú

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and NIST; with the purpose of ensuring that organizations, when implementing them, safeguard information in terms of integrity, reliability and timeliness.

ISO/IEC 27001 establishes the best practices for the Information Security Management System (ISMS) and ISO/IEC 27002 defines the best practices for the implementation of the ISMS, structured in controls, domains and objectives. The Information Security Policy (ISP) is a common security, and it is mandatory for employees [3]. However, despite efforts made by organizations, non-compliance with ISP by employees is a problem that affects organizations.

Various authors have made and will continue to make combinations of various theories/techniques to analyse information systems security policy violations which originate from human behaviour [4]. Similarly, various factors influencing ISP compliance have been mentioned in the literature, such as attitude, perceived severity, self-efficacy, subjective norms, ISP awareness, security culture, severity of sanctions, perceived vulnerability of security threats and training, among others [5, 6].

Several authors maintain that in the design and development of the ISP, a simple and easy to understand language should be used [7] so that they can be put into practice [8], as well as paying attention to the wording of the ISP [9].

In this study, we seek to understand the behaviour of people in relation to ISP. For this purpose, we propose to analyse two additional factors in the intention to comply with ISP, namely perceived usefulness (PU), perceived ease of use (PEU) together with the factors security culture (SC) and security knowledge (SK).

The purpose of this article is to present the results of a study of the relationship of the factors related to the intention to comply with ISP, according to the professionals responsible for information security.

2 Theoretical Framework

2.1 Theories/Models Used to Explain ISP Compliance

Several authors [1, 7] have combined different theories/techniques to analyse how human behaviour causes the violation of information systems security policies. On the other hand, we cannot fail to consider that new knowledge is generated through research; thus, new theories/techniques could be established through which new combinations of theories/techniques would be obtained.

Among the theories used to explain compliance with ISP are the Theory of Planned Behaviour (TPB), Protection Motivation Theory (PMT), General Deterrence Theory (GDT), Social Bond Theory (SBT) and the Theory of Reasoned Action (TRA), a predecessor of TPB [4].

2.2 ISP Compliance: Factors

There are also several factors that influence the compliance of ISP. These include attitude, perceived severity, subjective norms, awareness, security culture, severity of sanctions, perceived vulnerability, education, training, certainty of sanctions, personal norms, organizational commitment and knowledge of ISP, among others [5, 6].

A practice is using simple language when drafting the ISP. The ISP should be clear and easy to understand so that they can be practised [7, 8].

In this paper, the factors PU, PEU, SK and SC are reviewed. In the case of the first two factors, the definitions have been adapted from the definitions established in the technology acceptance model (TAM) [10].

The factors PU and PEU were proposed by Johnson [11] to determine the relationship to undergraduate students' behavioural intentions to adopt information security policies.

Perceived Usefulness (PU)

For ISP to be useful, it is necessary to disseminate and educate users so that they understand the benefits of IT security, so ISP must be seen by the organization's employees as a useful tool that helps them in their daily practices.

PU of ISP is related to the level at which the employee believes that ISP benefits the organization and its compliance to other employees. Taking into account the importance of PU in ISP compliance, the following hypothesis was proposed.

H1. There is a relationship between PU and INT.

Perceived Ease of Use (PEU)

PEU of ISP is the level at which people think they will have to make an effort to be able to use ISP appropriately. The development of ISP should be done taking into consideration that they should be easy to understand for all individuals in the organization and easy to put into practice [7].

Also, simple language should be used when drafting ISP so that employees feel confident in following the security guidelines [7, 8], so attention should be paid to the wording of ISP [9]. Taking into account the importance of PEU in INT, the following hypothesis was proposed.

H2. There is a relationship between PEU and INT.

Security Culture (SC)

SC is related to the establishment of standards, policies and training [12]. Building security culture starts with generating awareness of security issues [12]. In an organization that has an organizational security culture, employees are aware of the policies and the penalties for no-compliance [13].

It is important to promote information security culture, since organizations require more knowledge on information security than other aspects, such as ISP or monitoring, to establish an information security culture from the highest level [14]. Likewise, a positive security culture can increase compliance with ISPs [14]. Taking into account the importance of SC towards INT the hypothesis was proposed.

H3. There is a positive relationship between SC and INT.

Security Knowledge (SK)

According to ISO/IEC 27002, the ISP must be published in different media and communicated to all the organization's employees and interested parties. Several studies claim that there is a significant relationship between knowledge and attitude [15].

It has been reported that differences in the behaviour of individuals are influenced by their prior knowledge levels [15]. If an employee has a prior security knowledge feel familiar with their company's IS compliance activities. To determine how SK relates to INT, the hypothesis was proposed.

H4. There is a positive relationship between SK and INT.

Factors Relationship

Figure 1 shows the relationship between the factors.

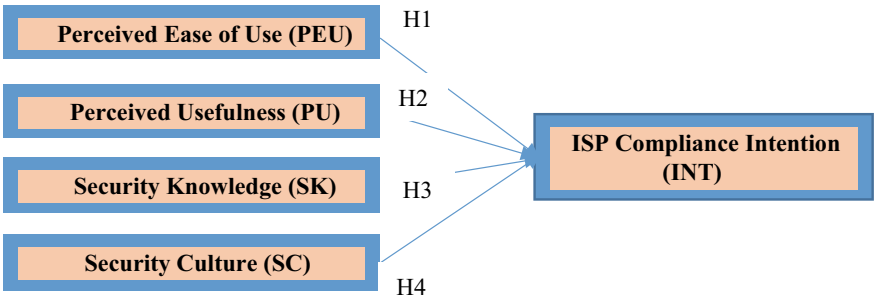

Fig. 1 Relationships between the factors

3 Methodology

The research is quantitative with a descriptive and cross-sectional approach. The sample is non-probabilistic.

Table 1 Cronbach's alpha

Factor	Items	Cronbach's alpha
PU	3	0.763
PEU	4	0.933
SK	3	0.856
SC	4	0.957
INT	4	0.963

Table 2 Characteristics of the participants ($n = 103$)

Aspects	Percentage (%)
23–30	23.3
31–40	33.0
41–50	34.0
More than 50	9.7
Male	68.5
Female	31.5
University students	53.4
Master	46.6
Ph.D.	2.9

A total of 103 professionals participated in the survey. The questionnaire items were adapted from studies [14, 16] and divided into three modules. The first module of the questionnaire contains the questions related to the sociodemographic aspects of the participants, and the second module contains the questions related to the factors PEU, PU, SK and SC. The third module contains the questions related to the INT. The questionnaire items considered a 5-point Likert scale. SPSS statistical software was used for data analysis. Table 1 shows the Cronbach's alpha as a measure of reliability of the instrument. The Cronbach's alpha of the 18 items was 0.954. Table 2 presents the characteristics of the participants. The percentage of survey participants is distributed among men with 69.9% and women with 30.1%.

The ages of most of the respondents are between 41 and 50 with 34% and in the 31–40 range with 33%.

4 Results

The results show that the standard most mentioned by the participants is ISO/IEC 27001 with 78.6%, ISO/IEC 27002 with 29.2%, and COBIT with 24.3%.

Four factors are reviewed in this study. Table 3 presents the mean and standard deviation of the items PU and PEU factors. From the results, the mean values for each item were greater than 4.

Table 3 Mean and standard deviation of the items PU and PEU factors

Item	Mean	Standard deviation
PU		
ISP compliance benefits the organization	4.515	0.7392
Not violating ISP safeguards the dignity and well-being of the individual	4.456	0.9978
ISP compliance optimizes resources	4.505	0.7524
PEU		
Have skills and knowledge to comply with ISP	4.311	0.8405
Follow ISP on your own	4.388	0.7826
Self-compliance with ISP	4.476	0.7119
Follow the ISP without assistance	4.476	0.7119

Table 4 Results of the hypothesis test

Hypothesis	*P*-valour	Spearman's rho	Result
H1: PEU → INT	0.000	0.696	Intense
H2: PU → INT	0.000	0.644	Intense
H3: SK → INT	0.000	0.521	Significant
H4: SC → INT	0.000	0.488	Significant

Spearman's correlation technique was used to test the hypothesis. Table 4 presents the results of the hypothesis test.

According to the results of the *P*-values, there is a correlation between the factors PEU, PU, SK and SC with INT. PEU and PU factors are strongly related to INT, while the SK and SC factors are significant related to INT. The identification of these factors allows practitioners to improve IS.

Although there is a correlation, it is important to continue with training and awareness programs to improve the level of ISP compliance.

5 Conclusions

Information security is key in organizations. One of the IS tools is the Information Security Policy (ISP). The ISP must be known by all the organization's collaborators and compliance with it is mandatory. Non-compliance with the ISP is a topic of interest to the scientific community. This article presents the results of a quantitative, descriptive and cross-sectional research. According to the results, the mean values of the items of the instrument are greater than 4.0. The results of this research show that there is a relationship between the factors PEU, PU, SK, SC and INT. Given the results, it is important to consider these factors when designing and implementing

ISP in organizations. The limitation of this work is the type of non-probabilistic sampling and the sample size, which does not allow generalising the results. Future work may consist of developing qualitative studies to examine each of these factors in depth, as well as proposing a model for evaluating the influence of additional factors such as training and awareness on ISP compliance.

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Sentiment Analysis of IMDB Movie Reviews Using Deep Learning Techniques

Beatriz Alejandra Bosques Palomo, Flor Helena Valencia Velarde, Francisco J. Cantu-Ortiz, and Hector G. Ceballos Cancino

Abstract Movie reviews help users to evaluate and decide if a certain movie is of their particular interest. Nowadays, there is a lot of data about movies like IMDB which is an extensive database containing thousands of movie reviews. However, analyzing each of these reviews can be time consuming and tedious, so machine learning models could be implemented for automation and analysis of these reviews. Sentiment analysis is a process that uses artificial intelligence and machine learning to find a point of view, a keyword, or a feeling in order to highlight the information of interest in the process. In this sense, an opinion can be interpreted as a dimension in the data regarding a particular topic and can be very useful in various fields of application such as data mining, web mining, and social media analytics. This paper aims to use an IMDB database that contains 50,000 reviews, and we intend to apply transformer-based language models like Bidirectional Encoder Representations from Transformers (BERT), RoBERTa, and XLNet for sentiment analysis. Moreover, we implement a TF-IDF and cluster analysis to gain insights about the topics related to both positive and negative reviews (Yasser in IMDB movie ratings sentiment analysis, 2022 [1]; Kumar et al. in Int J Interact Multimed Artif Intell 5(5), 2019 [2]; Chakraborty et al. in Soc Netw Anal Comput Res Methods Tech 7:127–147, 2018 [3]; Gadekallu et al. in Sentiment analysis and knowledge discovery in contemporary business. IGI Global, pp 77–90, 2019 [4]).

Keywords Sentiment analysis · NLP · Movie reviews · BERT · Cluster analysis · TF-IDF

B. A. B. Palomo (✉) · F. H. V. Velarde · F. J. Cantu-Ortiz · H. G. Ceballos Cancino
Instituto Tecnológico y de Estudios Superiores de Monterrey, 64849 Monterrey, NL, Mexico
e-mail: A01039875@tec.mx

F. H. V. Velarde
e-mail: A00823131@tec.mx

F. J. Cantu-Ortiz
e-mail: fcantu@itesm.mx

H. G. Ceballos Cancino
e-mail: ceballos@tec.mx

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1 Introduction

We currently live in a world where technology plays a crucial role in many aspects of our lives. People share their knowledge, experiences, and thoughts through social media, blogs, forums, review sites, tweets, etc. This has boosted human collaboration and the sharing of opinions which integrate positive or negative sentiments, and many companies, politicians, and service providers analyze this data to implement strategic decision choices [5]. Short texts specially have gained a great importance over traditional blogging because of its simplicity and effectiveness in influencing crowds. Sentiment analysis provides a method to understand these short texts and to derive meaningful insights from them [2].

Sentiment analysis as a research area is gaining popularity, and it can be considered as a classification process that can be divided into five steps. First, we have data collection which can come from content contained in blogs, forums, social networks, etc. This data is commonly unstructured, expressed in different ways, and with different vocabularies, slangs, and context. The manual analysis of all this data would be almost impossible. The next step is text preparation which consists in cleaning the extracted data before analyzing it. In this step, irrelevant information and non-textual contents are removed. Then, step three involves the sentiment detection by the examination of the extracted sentences of the reviews and opinions. Step four involves the classification of the sentiment or emotions. Subjective sentences can be classified into positive and negative classes and even good, bad, like, dislike, etc. The final step is the presentation of the output where the text results can be displayed graphically for proper interpretation [5].

Natural language processing (NLP) relies on machine and deep learning algorithms to automatically learn syntactic and semantic rules using a set of examples for tasks like sentiment analysis. Recently, transformers have been introduced as new methods to perform NLP tasks with better results. A transformer is a deep learning model that is self-sufficient and that evaluates its input and output data representations. By using transfer learning with transformer language models, the pretrained models can be shared and then be fine-tuned depending on the specific task it will be assigned. This eliminates the need of training a new neural network from scratch so you can focus on fine-tuning for your application [6]. There are currently a variety of transformer-based language models available. Some of the most famous ones include Megatron, GPT-2, XLNet, BERT, Turing-NLG, CTRL, and T5. Some of these models will be described below.

BERT, Bidirectional Encoder Representations from Transformers, was developed by Google for NLP tasks. BERT takes the whole input text sequences altogether unlike other directional models that do this task from one direction. In order to pretrain BERT, two strategies are used. The first one is mask language model (MLM) which works by replacing some words from the input with masked tokens. The second one is next sentence prediction (NSP) which helps BERT understand the longer-term dependencies across sentences by predicting if one sentence comes after the other. Available BERT models can be fine-tuned with all of its parameters and thus result in

faster training times by simply adding a classification layer to the core BERT model [7].

The BERT model consists of a series of bidirectional multilayer encoder-based transformers. BERT used 12 transformer encoders, and nowadays, there are several pretrained BERT models that are variations of the original BERT model like BERT-Small and BERT-Large.

There is another model that builds on BERT and modifies key hyperparameters, removing the next-sentence pretraining objective and training with much larger mini-batches and learning rates. This model called RoBERTa was first proposed by Liu et al. [8], and in their paper, they presented a replication study of BERT pretraining with modifications in the pretraining steps. For instance, RoBERTa uses large mini-batch sizes to train the model for a longer time over more data. RoBERTa also removes the NSP loss present in BERT and it trains on longer sequences. Additionally, RoBERTa is trained with dynamic masking meaning that the masking pattern will be generated every time a sequence is fed to the model. Overall, RoBERTa can achieve substantially better performance than BERT for some tasks [9].

Finally, there is XLNet which combines the strengths of autoregressive language modeling and autoencoding in order to deal with their individual limitations. XLNet has the capacity to learn contextual information by maximizing the expected log-likelihood of a sequence of words considering all permutations. It is considered that XLNet can produce better performance against other models, especially for long texts. It has been implemented in IMDB datasets, and it achieves the lowest error rates outperforming BERT in various tasks including sentiment analysis [9].

Another relevant task in NLP consists in identifying common topics presented in a collection of documents, reviews, and other text structures that can have potential value. One such analysis is TF-IDF which is a combination of two different words: Term frequency and inverse document frequency. Term frequency allows us to quantify the amount of times a term was present in the document of interest. However, it is known that documents can be of varying lengths, and they can either be very small or very large. So in order to account for this variability, the occurrence of the term of interest is divided by the total number of terms in that document. On the other hand, inverse document frequency takes it a step further by also considering a level of importance for the keywords. IDF will assign a lower weight to words that appear more frequently and a greater weight to those that are infrequent since they will provide greater value to the analysis [10]. Equations 1 and 2 below show the formula for finding IDF [11]. So in conjunction, it can be said that the greater the occurrence of a word in a document, the higher the term frequency, and the smaller the occurrence of a word, the higher the importance of the word in a particular document.

$$\mathrm{tf} = \begin{cases} 1 + \log_{10}(f_{t,d}), & f_{t,d} > 0 \\ 0, & f_{t,d} = 0 \end{cases} \tag{1}$$

$$\begin{aligned} \mathrm{idf}_j &= \log\left(\frac{D}{\mathrm{df}_j}\right) \\ w_{ij} &= \mathrm{tf}_{ij} + \mathrm{idf}_{ij} \end{aligned} \tag{2}$$

Other methods considered in this work include K-means clustering which is an unsupervised learning algorithm that classifies data into K number of clusters. Each of these clusters is defined by K centroids in which each centroid is a point that represents the center of a cluster. The algorithm uses an interactive approach in which each centroid is first placed randomly in the vector space and moves to the center of the points closer to them. For each iteration, the distance between the centroid and the points is recalculated so the centroids move to the center of the closest points. The algorithm stops when the groups' positions do not change anymore. Given the results of the different groupings, the best number of K can be chosen. Some of the methods to measure the performance of the algorithm include the elbow method or the silhouette score which provide some insight for group definition. Both of these methods will be used in this work to evaluate the performance of k-means.

In this paper, we will implement three different transformer models for sentiment analysis on a labeled IMDB dataset that contains 50,000 movie reviews. The dataset contains a balanced amount of positive and negative reviews. Additionally, we will implement TF-IDF and an unsupervised learning approach using k-means clustering in order to gain some insight regarding the main topics that are discussed in both positive and negative movie reviews.

2 Methods and Data

2.1 Exploratory Data Analysis

Before fine-tuning and implementing the BERT, RoBERTA, and XLNet models, we performed the corresponding data preprocessing and exploratory analysis of our dataset.

The dataset was originally organized with the reviews in one column and the sentiment in another column (positive or negative). It was also found that the dataset contained 418 duplicate reviews in the dataset so after removing them, we were left with 49,582 reviews. Then, we proceeded to clean the data by removing stopwords and converting the target variable to a binary classification.

For the exploratory data analysis, we first explored the ratio between positive and negative reviews, and it was found that the dataset is balanced, making it adequate for training and testing. The number of positive reviews was 24,698, while the number of negative reviews was 24,884.

Then we created two word clouds of both positive and negative reviews (Figs. 1 and 2) in order to have a visual overview of the most frequently used words in each type of review. Here, we can see that individual words do not give much information about the sentiment since it will depend on the whole context in which the words are used. The most common words in the reviews included 'film,' 'movie,' 'one,' 'story,' etc.

Fig. 1 Common words positive reviews

Fig. 2 Common words negative reviews

2.2 TF-IDF and K-Means Clustering

As previously established, the most common words in both positive and negative movie reviews include ‘movie,’ ‘film,’ and ‘one’ among others. Thus, we decided to eliminate them. Additionally, we are performing k-means clustering analysis in order to identify the main topics that are discussed in positive and negative reviews separately. In order to do this, we decided to eliminate other words like ‘people,’ ‘watch,’ ‘worse,’ ‘bad,’ ‘horrible,’ ‘terrible,’ ‘awful,’ ‘good,’ and ‘great’ because they are either not relevant or are directly related to the sentiment and do not provide

useful information for the clustering analysis which is performed separately for positive and negative reviews. The elimination of these words allowed us to have more representative clusters that give some insight regarding the specific topics discussed in the reviews.

2.3 Transformer-Based Models

The second task that was performed in this work regarded the classification of the reviews into either positive or negative. In order to do this, a balanced sample of 10,000 movie reviews was chosen. Three transformer-based models were tested including BERT, RoBERTa, and XLNet in order to test and compare their classification performance. Some of the training parameters that were chosen include a maximum sequence length of 64, a learning rate of 0.00001, a train batch size of 4, and finally, the number of training epochs was set to 3. The training of each of the models took around an hour and a half. In the next section, the performance results of each of the models will be shown.

3 Results

3.1 TF-IDF and K-Means Clustering

We applied TF-IDF and K-means to perform text clustering to a sample of our data. We selected a random sample of 5000 reviews for each positive and negative groups. As mentioned above, we decided to eliminate the most common words for all reviews since the purpose of the clustering is to identify relevant topics discussed on the reviews. Therefore, we noticed that by keeping these words, the clusters obtained did not provide significant results.

To determine the optimal number of clusters for our dataset, we decided to use both the elbow method and silhouette scores. For the first method, we plot the value of the cost function produced by different values of k from 4 to 12. As it can be seen in Fig. 3, the value of k at which improvement in distortion declines was achieved with $k = 8$ with the positive reviews. In Fig. 4, we can see that similar results were obtained with the same value of k for the negative reviews.

Finally, to verify that our number of clusters was the optimal, we decided to run several experiments changing the value of k (from 6 to 9) and comparing its silhouette coefficient. This is a metric to calculate the goodness of a clustering technique. The silhouette coefficient value ranges from -1 to 1, where 1 means the clusters are clearly distinguished and well apart from each other. In the same manner, a value of 0 means clusters are indifferent, and -1 means clusters are assigned in the wrong way. Tables 1 and 2 show the results obtained from the different experiment for positive

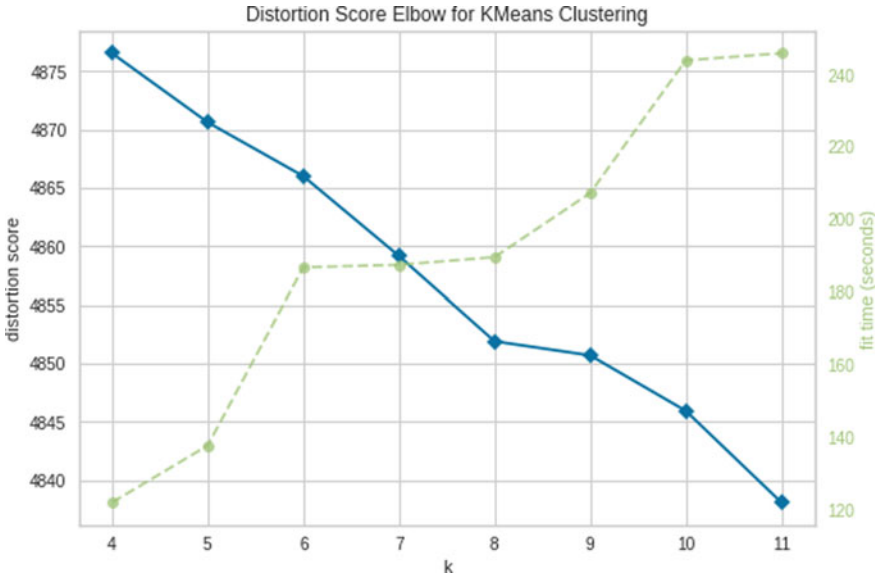

Fig. 3 Elbow plot for positive reviews

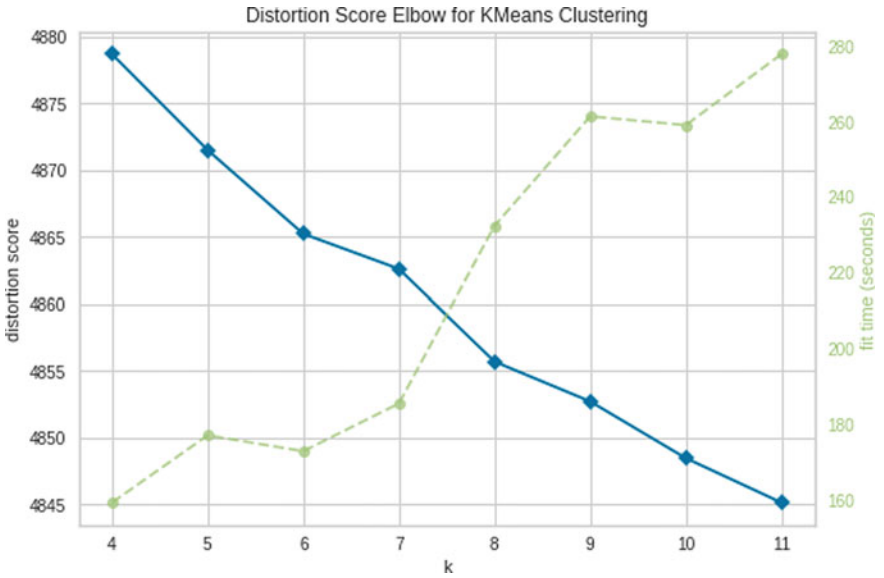

Fig. 4 Elbow plot for negative reviews

Table 1 Silhouette scores for positive reviews

Experiment	Silhouette
$k = 6$	0.00135458
$k = 7$	0.00134394
$k = \mathbf{8}$	**0.00144818**
$k = 9$	0.00079878

Table 2 Silhouette scores for negative reviews

Experiment	Silhouette
$k = 6$	0.00105030
$k = 7$	0.00124287
$k = \mathbf{8}$	**0.00169**
$k = 9$	0.00163

and negative reviews, respectively. After analyzing the results, we can confirm that the optimal k is 8 for both positive and negative reviews since the highest silhouette coefficient was obtained with $k = 8$ in both cases.

In order to get insights from the clusters obtained, we analyze the most common words for each cluster as shown in Table 3 (for positive reviews) and Table 4 (for negative reviews) (Figs. 5 and 6).

3.2 Transformer-Based Models

In this section, we present the performance results for the BERT, RoBERTa, and XLNet models. As previously established, a sample of 10,000 movie reviews was used to train each of the models. Additionally, a testing set of 500 samples was used to evaluate the performance of the models in new data. Due to the characteristics of the models, it is expected that XLNet will have a better performance than the

Table 3 Most common words in each cluster (C) for positive reviews

C	Words
0	**Music**, **dance**, **song**, love, **band**, **rock**, **sing**, number, enjoy, perform
1	**Character**, **play**, life, **perform**, **actor**, end, story, **role**, time, **act**
2	**Show**, **episode**, **season**, **series**, love, character, funny, **family**, **television**, end
3	**Game**, mario, **play**, **graphic**, **level**, bond, character, **fight**, existence, world
4	**Horror**, **gore**, **slasher**, **budget**, fulci, low, **effect**, story, **atmosphere**, **creepy**
5	**Funny**, **comedy**, **laugh**, **enjoy**, **fun**, star, time, action, play, **entertain**
6	Story, war, character, animated, interest, world, end, scene, work, serie
7	Love, story, feel, beautiful, life, character, family, girl, scene, act

Table 4 Most common words in each cluster (C) for negative reviews

C	Words
0	**Horror**, **kill**, **killer**, **monster**, scene, **slasher**, thing, **gore**, **scary**, character
1	**Book**, **read**, **story**, character, **version**, love, end, **change**, act, **adapt**
2	**Show**, **episode**, **series**, character, **season**, kid, funny, stupid, interest, act
3	**Funny**, **laugh**, **comedy**, **joke**, **stupid**, character, kid, **humor**, plot, act
4	Character, story, play, love, man, work, interest, year, thing, plot
5	Guy, **action**, **fight**, plot, **seagal**, act, character, **car**, end, girl
6	**Zombie**, **dead**, **gore**, fulci, **horror**, **budget**, **vampire**, director, plot, **blood**
7	Act, waste, actor, **plot**, **script**, character, **story**, **money**, end, **poor**

Fig. 5 Word cloud for cluster 0 in positive reviews

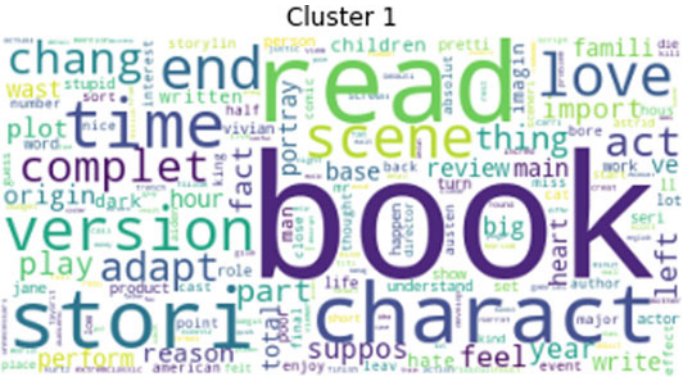

Fig. 6 Word cloud for cluster 1 in negative reviews

	precision	recall	f1-score	support
0.0	0.92	0.83	0.87	246
1.0	0.85	0.93	0.89	254
accuracy			0.88	500
macro avg	0.88	0.88	0.88	500
weighted avg	0.88	0.88	0.88	500

Fig. 7 BERT performance results

	precision	recall	f1-score	support
0.0	0.94	0.84	0.89	246
1.0	0.86	0.95	0.90	254
accuracy			0.90	500
macro avg	0.90	0.90	0.90	500
weighted avg	0.90	0.90	0.90	500

Fig. 8 RoBERTa performance results

	precision	recall	f1-score	support
0.0	0.95	0.84	0.89	246
1.0	0.86	0.96	0.91	254
accuracy			0.90	500
macro avg	0.91	0.90	0.90	500
weighted avg	0.91	0.90	0.90	500

Fig. 9 XLNet performance results

BERT-based models since it has been proven that XLNet can outperform them for sentiment analysis tasks.

In Figs. 7, 8 and 9, the evaluation metrics for each model are presented. In Figs. 10, 11 and 12, the corresponding confusion matrices are shown. It was observed that the overall training loss for the BERT model was 1.471. On the other hand, the RoBERTa model showed a loss of 1.019 and the XLNet model of 0.00143.

4 Discussion

One of the objectives of this work was to analyze the main topics that were present in positive and negative reviews separately to provide more insight regarding the dataset. With the results presented above, we will now discuss some of the main findings obtained after applying TF-IDF and clustering analysis. As previously shown, we

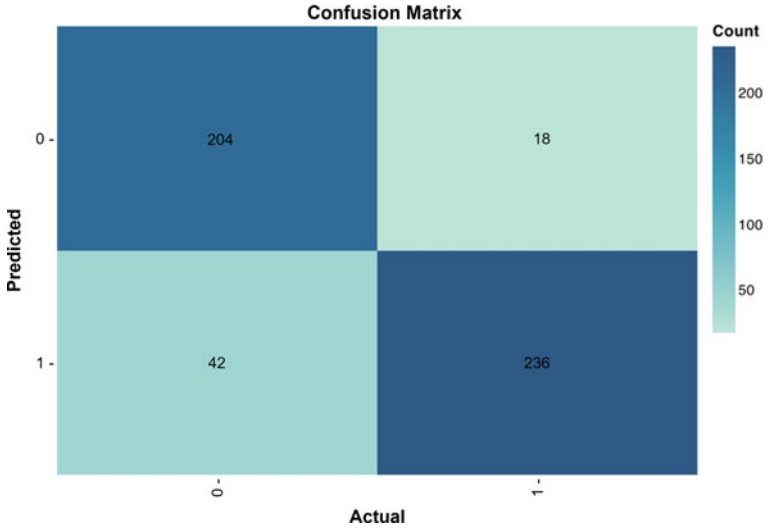

Fig. 10 BERT confusion matrix

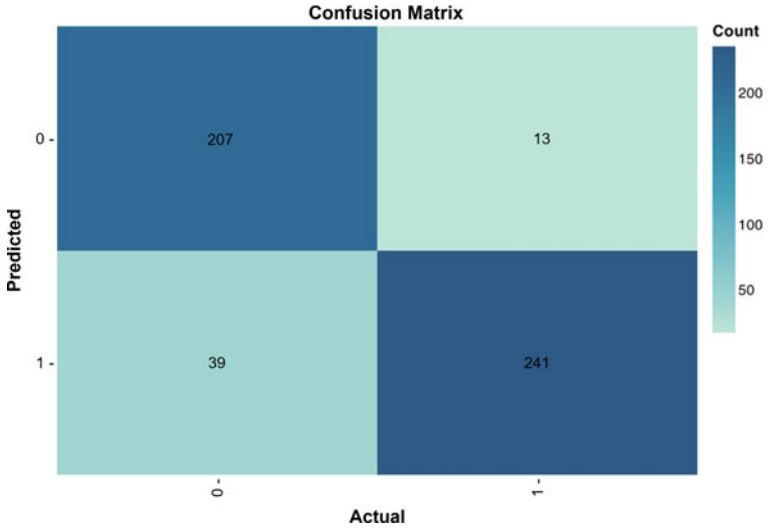

Fig. 11 RoBERTa confusion matrix

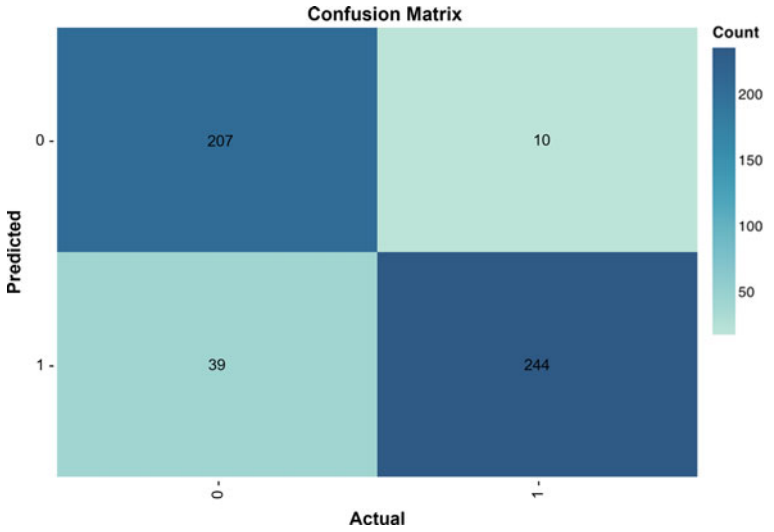

Fig. 12 XLNet confusion matrix

first decided to eliminate some words that provided no relevant information toward the clustering which included words that were directly associated toward the sentiment and not the topics discussed.

Tables 3 and 4 show the results of applying k-means clustering. As for positive reviews, it can be seen that some main topics were identified given the words that appear with more frequency in the cluster. For example in the case of Cluster 0 (Fig. 5), we can see words like 'music,' 'dance,' 'song,' and 'band' which implies that the topics in this cluster relate with movies that could be related to the genre of musicals or movies involving dancing and singing. Cluster 1 included words like 'character,' 'play,' 'perform,' 'actor,' 'role,' and 'act' which could imply that another topic in positive reviews was focused on the acting performance of the characters. The other clusters were analyzed in a similar manner. Cluster 2 focused on topics related to series and family related content, Cluster 3 was related to games and action, Cluster 4 focused on horror movies and effects, and Cluster 5 on movies in the genre of comedy. We could see that Clusters 6 and 7 were less defined and were also very similar between them. They included words like 'character,' 'story,' 'time,' 'life,' and 'world.' Perhaps, the topics are related more to the plot line of the movies.

Now for negative reviews, we can see a rather different topic focus. For example, in Cluster 0, we can find words like 'horror,' 'kill,' 'killer,' 'monster,' 'slasher,' and 'scary' which could indicate that this cluster includes topics related to negative views of some horror movies focused on slashers, gore, and monsters. Cluster 1 (Fig. 6) was interesting since it included words like 'book,' 'read,' 'version,' 'change,' and 'adapt' which can imply that another common topic in negative reviews was related to movies based on book adaptations. It is common for movies based on books to be criticized by the audience so this cluster highlights it. As for the other clusters, we

can see that Cluster 2 was related to series, Cluster 3 was related to comedies and humor, Cluster 5 was related to action movies, Cluster 6 again was related to horror movies but with a main focus on zombies and vampires. Cluster 7 included criticism of the plot and the acting performance. As in the case of positive reviews, here we also identified a rather vague cluster which was Cluster 4.

After analyzing both clusters for positive and negative reviews, we can say that many of the positive reviews were related to movies in the musical genre, comedies, and even horror. People tend to show a positive attitude toward the music and the performance of the actors in the movies. On the other hand, negative reviews focused on topics related to horror movies but mainly for movies related to zombies and vampires which might imply that this type of horror movies was not that well received by the public. Additionally, there was also plenty of criticism related to the plot, acting performance, and movies that were adaptations from books. This analysis provides a deeper insight from movie reviews other than just the sentiment classification into positive and negative reviews.

One of the main objectives of this research paper was to apply transformer-based language models and compare their performance when classifying movie reviews. After analyzing the results, we can observe that XLNet and RoBERTa achieved same overall accuracy (0.90) and f1-score for negative reviews (0.89). However, XLNet performed slightly better at predicting positive reviews than RoBERTa (XLNet, 0.91; RoBERTa, 0.90). As we expected, BERT obtained 2% lower values for both accuracy and f1-score when compared with XLNet. The reason why XLNet and RoBERTa obtained the best results is due to the fact that both addresses some limitations of BERT. For example, in XLNet all tokens are predicted in random order (permutation language modeling); on the other hand, in BERT, only the masked (15%) tokens are predicted. RoBERTA uses others strategies that make the algorithm more robust; it removes the next sentence prediction (NSP) task from BERT's pretraining and uses dynamic masking.

5 Conclusion

After performing text analysis, we can conclude that TF-IDF is a tool that, in contrast to other methods like bag of words (BOW), provides information on the more important words in the document by generating a weighted representation. In addition, K-means clustering provided useful insights regarding the main topics talked about in both positive and negative movie reviews. After analyzing the results of the movie reviews classification models, XLNet was confirmed to outperform BERT for this particular sentiment analysis task. Finally, for future work, we propose to test the models with a larger number of reviews in order to have a more reliable evaluation. Additionally, we will like to test the models in other tasks related to NLP.

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Holistic Tweet-Based Sentiment Analysis on the China-Taiwan Conflict

Sergio Eduardo Vega Guzmán, Gustavo De Los Ríos Alatorre, Francisco J. Cantu-Ortiz, and Hector G. Ceballos Cancino

Abstract The following work dissects the popular opinion on the China-Taiwan conflict via a holistic sentiment and emotion analysis on data obtained from the Twitter API, aiming to go beyond a polar interpretation of information with the objective of expanding the current understanding of said subject through the acquisition of a structured numerical representation of the data in order to classify the opinions using a softmax function to evaluate the presence of emotions conveyed in the sample. 5809 tweets related to the recent international tensions were obtained, pursuing keywords like "Taiwan", "China" and "war". First, raw data was analysed by observing the most frequent hashtags and by performing Latent Dirichlet Allocation (LDA) to find possible topics. After that, the dataset was subjected to a sentiment analysis process done with the Twitter-RoBERTa-base model complementing the results with the text2emotion library.

Keywords Sentiment analysis · Natural language processing · Twitter API · BERT · RoBERTa · LDA clustering

1 Introduction

In recent years, social networks have served as a window towards global events. People around the world use these platforms to express their thoughts, emotions and concerns. These same platforms are also used by government officials and institutions

S. E. V. Guzmán (✉) · G. D. L. R. Alatorre · F. J. Cantu-Ortiz · H. G. Ceballos Cancino
Instituto Tecnológico y de Estudios Superiores de Monterrey, 64849 Monterrey, NL, Mexico
e-mail: A01194108@tec.mx

G. D. L. R. Alatorre
e-mail: A01410922@tec.mx

F. J. Cantu-Ortiz
e-mail: fcantu@itesm.mx

H. G. Ceballos Cancino
e-mail: ceballos@tec.mx

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of different countries to communicate official messages and views about a variety of subjects. Analysing these varied expressions can prove to be vital in not only understanding current global situations but also in analysing how different people throughout the world react to such events [1].

An international situation that has seen a rise in online presence in the middle of 2022 is the increasing tension between China and Taiwan regarding the sovereignty of the latter. News reports and postures concerning both parties have been expressed by local and international political figures, in turn giving way to online discussions and debates among social network users around the world. Analysing these user-generated opinions may provide helpful insight towards understanding how conflicts like these are perceived around the world.

A holistic sentiment analysis done on tweets on this topic might expand the current understanding of the conflict in relation to public opinion. Understanding not only the general sentiment but the particular emotions that news convey on the spectators will shed light upon commonly overlooked nuances in general tendencies. Granting the capacity of looking further into the perspectives and emotions that govern the collective experience of very distinct groups of people. The inclusion of LDA clustering was also considered. As it is an important generative probabilistic model that the team considered relevant for the research due to its capability to perform topic modelling, Understanding that many words may have repeated occurrences among different topics. Thus, preventing the hindrance of making specific words exclusive to a certain region in the clustering space, and in turn allowing for a broader understanding of how these words were present among the obtained topics regarding the conflict.

1.1 Historical Context

Taiwan is an island located in the First Island Chain that has been independent from mainland China since 1949. The PRC views Taiwan as a renegade province and wants to unify it under the "One China Policy". Tensions between the two have risen, with Beijing taking aggressive actions [2]. Some fear this could spark a conflict with the USA, which has shown a pro-Taiwan posture through the Taiwan Policy Act. This act provided Taiwan with almost 4.5 billion dollars in security assistance.

2 Method and Data

The data used throughout this work corresponds to different tweets available via the Twitter API with their respective metadata. The tweets were gathered using specific hashtags related to events that took place between September and August of 2022 with regards to the growing crisis between China and Taiwan. Some of the expected insights provided by the tweets include postures about the conflict expressed by each

user, information provided by news-outlet accounts and information related to certain political figures that have had a role during the recent crisis, such as President Joe Biden, President Xi Jin Ping and Taiwanese President Tsai Ing-wen.

The text on the tweets will be subjected to a preprocessing treatment through which the features relevant for the sentiment analysis process will be kept. Each tweet in the dataset will be subjected to the following process:

1. Lowercase casting
   This was done in order to standardize the data that was going to be processed. In order to make sure the results were reliable, the data had to be in a standardized format.
2. Stop word removal
   Words that are found commonly throughout the English language. Stop words are processed out of the dataset since these words do not provide a valuable insight into the meaning of the sentences that will be analysed and categorized. Some common examples of this type of words consist in articles or prepositions, which in it of themselves do not carry a significant semantic meaning. Stop word removal also aids in reducing the dimensions of the dataset bettering processing times [3].
3. Lemmatization
   Lemmatization refers to removing inflectional endings from words and returning the words as they appear in the dictionary; this form of the word is called a lemma. The process allows the words that go through it to retain its intended part of speech and meaning.

After processing the data, it was then examined using non-supervised artificial intelligence in order to distribute it into topics using Latent Dirichlet Allocation (LDA). LDA consists of a generative probabilistic model of a text corpus. In it, documents are represented as random mixtures over latent topics (meaning that while the topics are already there, they are yet to be discovered), where each topic is characterized by a word distribution. LDA assumes the following generative process for each document w inside a corpus D [4]:

1. Choose N Poisson(ξ).
2. Choose θ Dir(α).
3. For each of the N words w_n:
   (a) Choose a topic z_n Multinomial(θ).
   (b) Choose a word w_n from $p(w_n|z_n, \beta)$ a multinomial probability conditioned on the topic z_n.

Similarly to principal component analysis (PCA) which is used with numeric data to decompose a larger value into a series of smaller values to make a dimensional reduction [5]. LDA is applied to text data and works by decomposing the word matrix of the corpus into two smaller matrices, the Document-Topic matrix, which contains the possible topics in the document and the Topic-Word matrix which contains the words that the defined topics can contain.

After the topics and their keywords were obtained, the research team interpreted the results to give further context on the what findings represented. The interpretation was not arbitrary by any means, since it was based on historical context and supported by words that convey specific emotional tendencies.

Finally, a holistic sentiment analysis was performed. An emotion detection process that considered five categories in the emotional spectrum (happiness, sadness, surprise, anger and fear) was performed using the library text2emotion on the tweet corpus. The results of the described analysis would then complement the results of the polar analysis (negative, positive, neutral) performed with a classic sentiment analysis approach utilizing the Twitter-RoBERTa-base model from the hugging-face library of models. The results of both analyses were then interpreted in a compound fashion that made use of the synergy to provide a deeper understanding on the general consensus about the sentiment and emotions present among the texts. The use of a transformer-based model was considered for the project since the capability of these models for processing data in a parallel manner [6] has made them the go-to option in many natural language processing (NLP) applications, with sentiment analysis being among those most benefited. On top of that, since the model operates with a RoBERTa-based functionality, it was expected to have a good performance, based on the GLUE benchmark scores achieved by the original RoBERTa [7] and the results obtained by the TweetEval team [8].

2.1 Obtention and Analysis of the Dataset

By means of the Twitter API, we were able to obtain 5809 raw tweets about the China-Taiwan conflict. We gathered tweets that contained keywords such as: “Taiwan”, “China”, “War”, “Taiwan Policy Act”, “One China Policy”. All of the mentioned keywords are related to the conflict and the diplomatic postures of the countries involved with the Taiwan Policy Act referring to a US Initiative that seeks to bolster Taiwanese defences by providing 4.5 billion American dollars over the next four years starting in 2022. The policy act was passed in September 14, 2022. On the other hand, the One China Policy refers to the political doctrine in mainland China that seeks to unify China as a whole. The One China Policy considers Taiwan as a part of China and does not see it as an independent country. Different countries have to recognize the policy in order to have diplomatic relations with China, even the USA which currently recognizes that it has ties with China and a “robust unofficial relationship” with Taiwan. The intention of looking for these keywords among the different tweets was to find patterns and postures about the conflict and the diplomatic measures by the countries involved in it.

The prepossessing of the raw data included: removal of the stop words, removal of symbols that did not provide anything of value, lowercase casting and lemmatization. We discovered that many of the tweet data contained a large portion of unnecessary information such as hyper-link tags, hashtags and Twitter-specific user tags that were also removed in the preprocessing section of the analysis.

After that, visual analysis of the most frequent words in the dataset was performed. A word cloud containing the most frequent words in the dataset was developed. The most common hashtags present in the dataset were also extracted and presented in a graph. Lastly, LDA analysis was performed in order to attempt to extract and interpret topics present in the dataset.

2.2 Sentiment Analysis

After being preprocessed, the tweets were then passed to the Twitter-RoBERTa-base for sentiment analysis modelling, which categorized the polarity in the texts as positive, negative or neutral. This particular RoBERTa model is specialized for inference in tweets [8]. The model has been trained on around 58 M tweets. Finding the polarity in the text was helpful in detecting the immediate tone of the text, yet offered limited information.

2.3 Emotion Detection

Regarding the specifics of the multi-label emotion detection, the Text2Emotion Python library was used. The division obtained after the implementation of said algorithm produced five different categories in which human emotion was abstracted. The five categories did a gross generalization on the components of feeling, proposing a penta-dimensional output that included happiness, anger, surprise, sadness and fear. Considering the emotions behind the text offers valuable insight about what the person who wrote said text felt and was concerned with at the moment of writing, going beyond just a positive, negative or neutral sentiment.

3 Results

3.1 Results of the Analysis Done in Raw Data

Considering how word size equals word frequency in the word cloud, a superficial idea can be derived from the terms are associated with this general topic in the tweets. We can see the names of the parties involved in China and Taiwan. We can also see the word “War”; we can address this to it being related to the keywords in the search, but the interesting part comes from analysing other words that also pop up frequently. The names of the leaders of the world powers involved in the conflict appear as “Xi” and “Biden”. Invasion seems to also be a pretty frequent word among the tweet corpus. Some phrases such as “communist party”, “democracy” and “invade Taiwan” are also

Fig. 1 In the generated word cloud the words the larger the word the more frequently it appears in the post-processed tweets

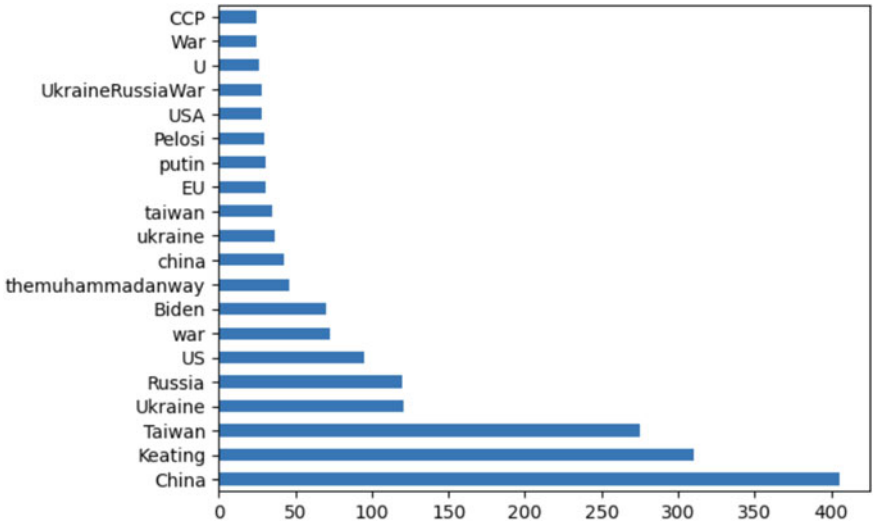

Fig. 2 Displays the more common hashtags found throughout the dataset

pretty notorious. Some of the frequent words also reflect concerns regarding other international conflicts happening at the same time with the appearance of Russia and Ukraine (Fig. 1).

In order to get a preliminary analysis of the topics present throughout the tweets, the more common hashtags in the dataset were extracted. Throughout these hashtags, again, it is possible to observe words related to other international conflicts such as with Russia and Ukraine. Words related to the names of political figures such as Biden or Pelosi are also present. Political parties appear as well in the form of the Chinese Communist Party (CCP). The results seem to reflect a war-oriented perspective from the users that wrote them (Fig. 2).

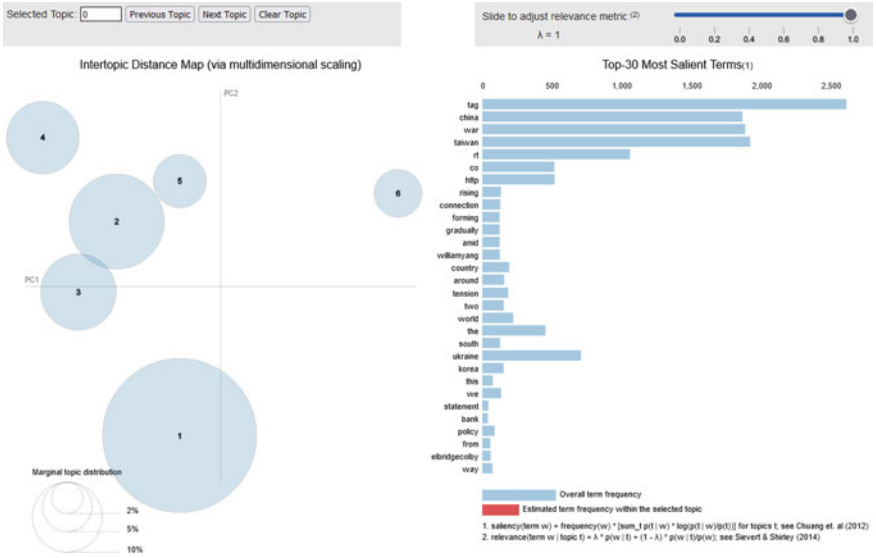

Fig. 3 For the LDA analysis, the data was divided into six clusters in order to observe and compare the words that defined said clusters by appearing most frequently

After the text cleaning was considered sufficient for analytic purposes, the research team took on the endeavour of applying an Latent Dirichlet Allocation (LDA) clustering algorithm with the purpose of extracting the relevant topics discussed by the people involved in the conversations that were taking place in Twitter in relation to the China-Taiwan conflict. In practice, LDA analyses the frequency of the words appearing in the dataset of tweets, considering words that could transmit a particular topic when together. The purpose of the clustering had to with the necessity of extracting the relevant data so that we could further explore into the dynamics and sentiments embedded in these different topics (Fig. 3).

After analysing the clusters, we obtained the following observations regarding the underlying topics.

– Topic 1: Expectative/Doubtful thoughts regarding an invasion of Taiwan by China.
– Topic 2: Relates the situation to major international actors (Russia, Ukraine).
– Topic 3: Regards local tensions on a possible civil war.
– Topic 4: Related to military concern, since words like NATO and military are involved.
– Topic 5: Focuses mostly in the relationship between Taiwan and neighbouring countries.
– Topic 6: Seems to have keywords related to the One China Policy.

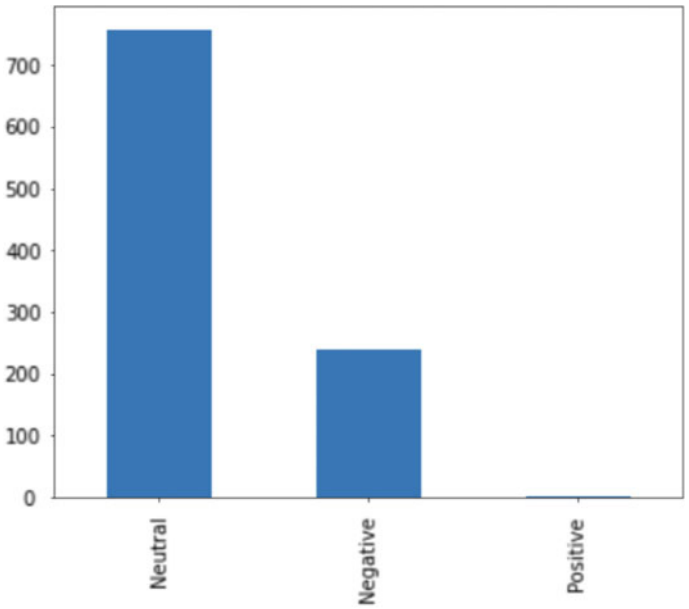

Fig. 4 Sentiment analysis results

3.2 Sentiment Analysis and Emotion Detection Results

The binary sentiment analysis showed that the most prevalent result was a neutral take on the subject, having a presence that was twice as high as the second most common classification (negative interpretation) (Fig. 4).

The findings also showed coherence with the expected emotional alignment with the conflict since there were almost no positive takes on the subject (Fig. 5).

The results of the emotion sentiment analysis indicated that the top three most prevalent emotions were anger, sadness and happiness. Although the latter can appear contradictory due to its incoherence with the topic at hand, the research team considered that the "high" prevalence of happiness had to do with the models incapacity to discern between nervous anxiety and fearsome elation. This is further supported by the findings of the traditional sentiment analysis exploration that showed almost non-existent positive feelings on the tweet corpus. However, since this still remains a valid critique to the research, the future work section goes into more detail about what will be done to clarify this "abnormal" prevalence.

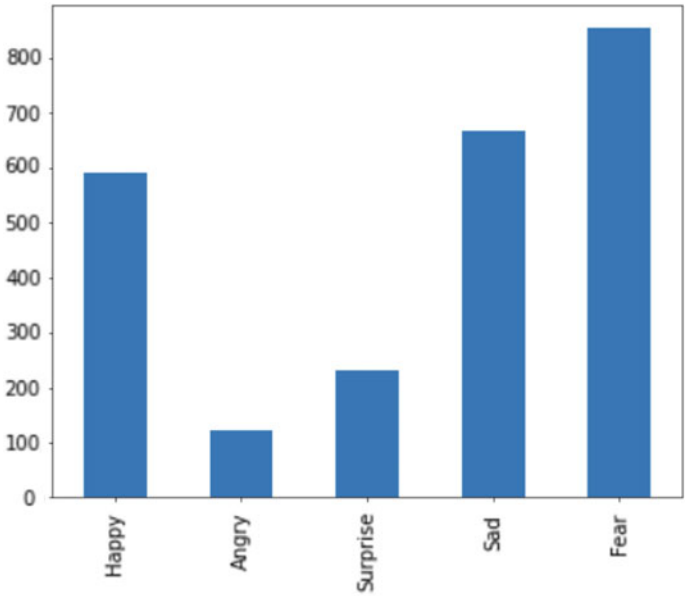

Fig. 5 Text2Emotion results

4 Discussion

Based on the findings presented in the results section, it can be observed that emotion detection does complement the findings in the text. Considering the emotions present throughout the different tweets is rather helpful at determining the public perception that the topic has in a social network. Meanwhile, the sentiment analysis results are helpful in understanding the tone that the gathered texts have. Among some of the more interesting findings, was the fact that a neutral tone was prevalent throughout the majority of the tweets, it can be inferred that this phenomenon was caused partly by the news coverage of events regarding the China-Taiwan tensions, since news outlets need to maintain a neutral demeanour in their writing.

As for the emotion detection findings, the abundance of fear seems pretty relevant due to the high international concern for the conflict and the possible scenarios associated with it. A result that took the research team by surprise was the high amount of happiness reflected by the text2emotion results. This may have to do with feelings of nervousness present throughout the tweets which may not have necessarily been written with obvious sad connotations leading to text2emotion detecting happiness in them. It must be said that the tweet format heavily hinders the capacity of the model to identify emotions on this particular humourist opinions due to the data scarcity in a tweet's content. Hence, the necessity of a broader and more extensive text format would be better when interpreting emotions while the state-of-the-art models improve humour identification [9].

Regarding the implications derived from the work and findings presented, the research team believes that the proposed method offers valuable insights towards understanding postures and emotions in texts related to a certain topic and the topics that stem from it in public discussion. While the interpretations of the topics are subjective, the keywords related to each of them seem to paint a really complete picture of what the public associates with the topic at large. The findings suggest that combined use of sentiment analysis, emotion detection and topic modelling can aid researchers in understanding textual social media posts based on trends, political postures or global events. This enhanced perspective could also potentially benefit from the use of other complementary data such as the location from which the tweet originated. If the dataset gathered using the API were to include the locations of origin of the different tweets, the sentiments, emotions and topics could also be associated with certain zones, leading to an even more detailed understanding of the public posture towards a topic throughout different populations.

Concerning possible drawbacks from the work detailed throughout this experiment, it can be said that while Twitter offers valuable insights from a global perspective, the same cannot necessarily be said from a local point of view. Twitter is not among the most popular social networks in Taiwan and is in fact banned from Mainland China. If the study was to be replicated focusing on opinions of the local populations involved, other social networks such as Weibo should be considered.

The main limitations present on the research have to do with the inability of the model to discern between nervous humour and genuine happiness, due to the fact that the words involved in the building of a humorist panic sentence and a genuine happy sentence are virtually the same. This particular phenomenon at first seemed to contradict our findings and overall interpretation of the data; however, since the study was based on both emotion sentiment analysis and polar sentiment analysis, the latter showed that there was nearly no presence of positive views on the topic, meaning that in fact those phrases interpreted by the emotions model were misunderstood as elatedness. The aim of the project is limited to the reach of the tools that were available when the analysis was performed; however, we have proposed the construction of a model that is able to interpret modern fatalist humour to create a more accurate analysis with non-conflicting results.

5 Conclusion

Based on the obtained findings that sentiment analysis models can be expanded into more ambitious proposals capable of categorizing human emotions into representative abstractions that might shed light upon unexplored tendencies that usually go unobserved by simplistic approaches like polar based research. However, although there are several models trained to perform multi-label classification on text prompts, they still struggle to go beyond simplistic analyses that can be easily misled by modern human humour at the time of classifying between fearsome nervousness and earnest happiness. Nevertheless, this still remains a hypothesis supported by the evidence of

the polar analysis that showed almost non-existent positive sentiments towards the China-Taiwan conflict and needs to be investigated in detail. Other aspects related to the findings of the sentiment analysis model should also be considered, such as the fact that news headlines could have also contributed to the high number of neutral results that were found. This also brings to light how helpful it can be to bring emotion detection to complement the sentiment analysis results, shedding some more light towards some deeper aspects also present in the text.

5.1 Future Work

The biggest assumption of the paper is that the large presence of happiness softly classified tweets was due to the models incapacity to discern between fearsome nervousness and earnest happiness, since phrases such as "LOL, we are all going to die" can be easily misinterpreted by the model that we used due to its context free nature. Thus, the necessity of a tool that actually takes into account contextual cues about modern humour becomes an imperative for future analyses on topics of similar nature. Hence, the successive work proposed by the team is a model that specifically interprets human humour and its underlying emotional intention. A more ambitious goal would be to fuse the findings with common NLP sentiment analysis to increase the accuracy reflected by either, changing the current evaluation of the classifier or by expanding the emotion spectrum that is currently used by tools such as text2emotion.

The experiment we propose for a future paper will evaluate the variation in the emotion detection with regards to the text size. That way the research team can test the hypothesis that states that a bigger text will yield better and less ambiguous results by giving the model more information to compute. Furthermore, an optimal text size threshold to analyse a given input can also be determined by calculating the loss versus the text size. This information can be very useful when comparing NLP deep learning models and when analysing their progress over time.

Lastly, we would like to acknowledge Tec de Monterrey and CONACYT for sponsoring the research.

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Security Assessment on a USB Debugging-Enabled Virtualized Android TV

Eric Blancaflor, Din Marvin Anave, Hans Christian Deniega, Archie Brendan Mangubat, and Ireland John San Pedro

Abstract The Internet of things has developed new advances in technology, and having the connection of devices is now slowly becoming a standard. One of the home staple devices is TVs, which have evolved from cabled TVs to smart capabilities. The researchers surveyed Android TV owners/users and assessed their knowledge regarding the drawbacks of their devices. According to the survey results, the respondents are not aware of the vulnerabilities of their systems, making them prone to attacks. The researchers assessed the vulnerability of the Android TV by utilizing Nmap for listening and connecting Kali Linux to the USB Debugging-Enabled virtualized Android Oreo TV and scrcpy for controlling the TV via Kali. After the assessment, the researchers were able to identify that the security of the device was lacking due to the absence of a defense system. Therefore, they recommend a firewall implementation in Android TVs.

Keywords Android TV · Internet of things (IoT) · Smart devices · Security threats · Authentication · Biometrics · Encryption · Keystore · Verified boot · Vulnerability assessment

1 Introduction

1.1 Background of the Study

In these current times, Smart TVs are the industry standard form of television. Users are increasingly transitioning from conventional TVs to Smart TVs [1]. Among the different types of Smart TVs in the industry, Android TV, with a number of advantages derived from the Android ecosystem, has undoubtedly emerged in becoming the most popular one [2]. A Smart TV, specifically an Android TV, enables the

E. Blancaflor (✉) · D. M. Anave · H. C. Deniega · A. B. Mangubat · I. J. S. Pedro
School of Information Technology, Mapúa University, Manila, Philippines
e-mail: ebblancaflor@mapua.edu.ph

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capabilities of processing and Internet connectivity with the integration of a better viewing experience with complete support for Web 2.0 features, online clips, movies, games, and browsing. However, the connectivity of an Android TV with a public network (Internet) brings further challenges, which set drawbacks due to its issues affecting the Android TV itself. Security is one of the many fundamental features of an Android TV these days; they are growing more complex devices and more capable of receiving, storing, processing, and transmitting large quantities of personal data. With these capabilities, it provides a variety of attack vectors, which might make these systems extremely susceptible to security threats. Modern Android TVs have security features that are beneficial in protecting and ensuring that the information and data are kept secure from disclosure to unauthorized users [3]. These security features include the following: authentication, biometrics, encryption, keystore, trusty trusted execution environment (TEE), and verified boot. Authentication is the most widely used security feature in an Android TV [4]. It employs the paradigm of user-authentication-gated cryptographic keys, which necessitates and involves the storage of cryptographic keys as well as service providers and user authenticators. Biometrics is also one of the security features in an Android TV, which offers a BiometricPrompt API that developers can utilize to integrate biometric authentication into their applications [5]. Encryption is also a common security feature in an Android TV which ensures that if an unauthorized user attempts to access the information, they will be unable to read it. Another security feature is the keystore which supports key creation, importing and exporting cryptographic keys, importation of raw symmetric key encryption, asymmetric key encryption, and decryption with suitable padding modes, and more.

In this study, the researchers will assess, test, and perform a vulnerability assessment and evaluation on a virtualized Android TV, to identify the potential key vulnerabilities and recommend possible solutions. In addition, as presented in Fig. 1, the researchers utilized the National Institute of Standards and Technology (NIST) Cybersecurity Framework as their conceptual framework, due to its reputation as being part of one of the top cybersecurity frameworks [6] and to its purpose, which is to provide a more flexible and cost-effective approach in helping the organizations when it comes to protecting and safeguarding their assets from cybersecurity attacks and also to increase their overall security to prevent the loss of data and give an adequate knowledge about what cybersecurity is [7], which is in line with the study's objectives. In the *identify function*, the researchers will first identify the important information relevant to conducting the study and the assets that must be protected. In the *protect function*, the researchers will focus on providing the essential techniques to secure the aspects of the defined function, such as by examining existing methods that may be used to protect the Android TV's security. When it comes to the *respond function*, the appropriate approaches will take place following the vulnerabilities identified in the detect function. In the *recover function*, the necessary approaches are outlined if the company is affected by a cyberattack.

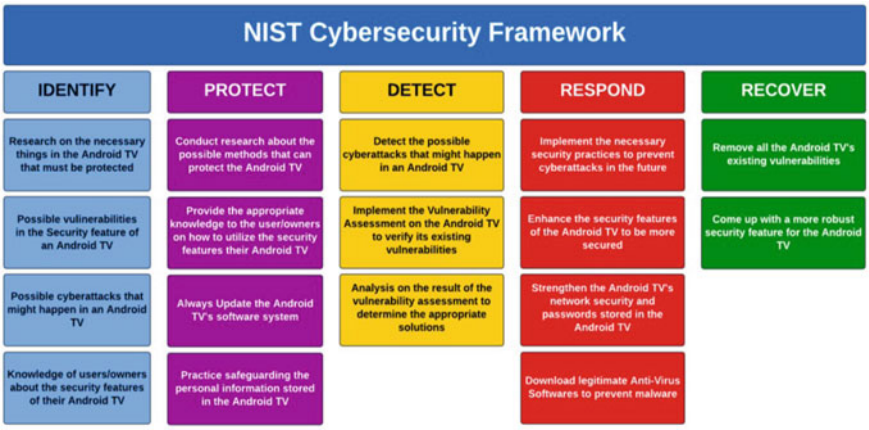


Fig. 1 NIST conceptual framework [6]

1.2 Objectives of the Study

In this study, the general objective is to evaluate the possible user-harming vulnerabilities of an Android TV in a virtualized environment. The awareness of the vulnerabilities of the device can be raised to mitigate the harm it can bring to its users, and solutions to the vulnerabilities can be made. The research questions below are the questions that the researchers would like to answer: (a) Are Android TV users aware of the possible security issues of their devices? (b) What vulnerabilities of the Android TV can be compromised by an attacker?

1.3 Research Objectives

In this case study, the researchers aim to conduct a vulnerability assessment on a virtualized Android TV to determine the possible vulnerabilities and their corresponding solutions. With that said, the researchers listed the following specific objectives of the study are (a) to conduct vulnerability assessment on the security features of a virtualized Android TV, (b) to determine and understand the possible vulnerabilities of a virtualized Android TV.

1.4 Scope of the Study

The researchers will perform the simulation test using a virtualized Android TV Oreo device (Android 8.1.0) in Oracle VM VirtualBox. In line with this, Kali Linux is the

operating system from which the vulnerability assessment and penetration testing tools will come, such as Nmap, which acts as the listener. Furthermore, executing commands from the attacker's device to the victim can be done by using ADB shell commands. Moreover, controlling the TV is also possible through the use of scrcpy. In addition, the researchers will conduct a survey questionnaire to assess the knowledge and awareness of its target respondents about the security features of an Android TV, the survey's target are Android TV owners and users, and their ages will range from 18 to 60 years old, where according to a 2022 study of Leichtman Research Group [8].

2 Review of Related Literature

2.1 Tackling Security Issues of a Smart TV

A Smart TV connects to the home network to deliver services such as video streaming. It utilizes Ethernet and Wi-Fi to stay connected. After connecting the TV to the network, the next process is to input login information and access the menu displaying the applications, or new apps could be installed from the app library. Although when it comes to connected TVs in the network, privacy threats, botnet concerns, and Wi-Fi network compromise are all significant concerns [9]. Other security risks with Smart TVs include the opportunity for hackers to corrupt them in order to access residential Wi-Fi installations and breach other network devices [10]. Some of the most significant downsides of utilizing Smart TVs include the danger of cyberattacks, the possibility of crashes, malware, and spy cameras [4]. Not only are computer systems vulnerable to attacks, but Smart TVs are also considered a potential target device by attackers. Some attacks gain access inside of a Smart TV because of the user's actions, especially if the user is not well informed about signs of viruses or attacks [11]. The most frequent ways that device misconfiguration leads to a cyberattack include leaving ports open, employing insecure protocols, enabling debugging tools, relying on weak or default passwords (or using no passwords at all), using unused services, and so on. These examples increase the success of an attack [12].

2.2 A Security and Privacy Analysis of the Android TV Ecosystem

Within the past few years, throughout the modern era of technologies, Internet-based TV has become more and more popular, to the detriment of the old broadcast TV model [13]. TV providers and analytics/advertising firms may have access to users' Personal Identifiable Information (PII), such as unique identifiers, hardware addresses, or watching patterns [14]. In this study, the researchers discovered that

the majority of TV applications exhibit potentially hazardous and privacy-invading behaviors and that tracking and advertising libraries are mostly to blame in these situations.

2.3 Smart TV Attack Through Hijacking

The study discusses how a Smart TV can also be attacked through multi-channel remote control [15]. This attack is through mimicry, where the attacker uses commands and exploits the Smart TV to gain control. Zhang et al. [15] propose that the attack, which is an Evil Screen attack that targets the remote controller, is made to access the victim's data inside the Smart TV. The attacker combines the three types of wireless communication: Infrared, Bluetooth, and the Wi-Fi of the remote control. The procedure of this attack is to exploit the wireless channels. First, the attack will force Wi-Fi provisioning, a standard process for Smart TVs to enable Wi-Fi, using less secure wireless channels (i.e., IR and BLE) and obtaining the password for a secured WLAN (i.e., SSID and password). The exploit takes advantage of this weakness to actively tie a fake remote control to the TV within the same WLAN because most Smart TVs do not examine the remote control pairing requests [15]. This study gives us the discovery that multiple Smart TVs are possible through a remote control.

2.4 Android Smart TV Box Vulnerability Discovery via Log-Guided Fuzzing

Android TV boxes are different from a regular Android TV; its type is known as a type of over-the-top (OTT) television streaming device that is capable of streaming channels by connecting it using an HDMI cable. This type of Android TV has devices which are licensed and pirated [16]. One study has developed a new vulnerability discovery using their own developed dynamic log-guided fuzzing. After conducting their test, they discovered 37 vulnerabilities in 11 Android Smart TV boxes. Threats such as memory corruptions, gaining access to sensitive data, corruption of vital boot environment settings, visual and auditory disturbances [17].

3 Methodology

3.1 Research Design

The research design that the researchers utilized in developing the study is descriptive. In addition, the researchers of this study utilized a survey questionnaire to gather relevant information that would benefit the overall process of the study. The researchers used purposive sampling as their method to gather the responses of the eligible target participants. An online survey questionnaire was conducted and disseminated by the researchers to the eligible respondents to gather information about the overall knowledgeability of the users when it comes to the security features of the Android TV, their awareness when it comes to the existing vulnerabilities, and its possibility of being prone to be hacked. In addition, Google Forms was used to create and disseminate the online survey. The results of the survey questionnaire of this study will be illustrated in a graphical pie chart figure. In line with this, all figures that would be presented will contain a comprehensive explanation about what the figure presented is all about to give a detailed discussion to the readers. Furthermore, any unrelated and inconsistent responses will be rejected and will not be included in the overall presentation of the results to ensure the integrity of the result.

3.2 Vulnerability Assessment Process

The researchers tested the accessible tools for vulnerability testing. For testing purposes, the USB debugging option was enabled on the settings of the virtualized Android TV. Nmap is the first tool utilized in the study; after scanning the ports, the researchers have decided which open port they will test. The port 5555 was chosen to be suitable for testing its vulnerability. The other tools used in the study are adb and scrcpy.

4 Results and Discussions

4.1 Survey Questionnaire Results

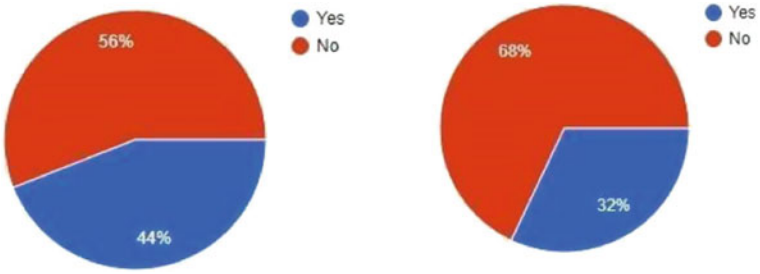
As shown in Fig. 2, the Asus brand obtained the highest percentage by having 26%, which means that most of the users who answered the survey are currently using Asus as their Android TV brand. On the other hand, the brand LG Uplus obtained the second highest by having 16%. TCL/Thomson brand also obtained 10%, which gained the third highest percentage. The Devant Android TV brand obtained a percentage of 8, while Philips and Hisense brands both got 6%. In addition, the

Android TV brands of Sharp, Panasonic, Epson, Asus, and Xiaomi have obtained an equal percentage of 4, while Skyworth, LG HelloVision, Airtel, and Toshiba all got a 2% response from the survey.

Figure 3 shows that most of the respondents who answered the survey are not downloading any third-party applications on their Android TV, which shows that 56% responded. In comparison, 44% answered that they are downloading third-party applications from the application store. Moreover, it shows that from 50 respondents who answered the survey, most of them are not aware of any security issues with their Android TV, by having a 68% for the "No" choice. In contrast, 32% of the respondents knew about the existing security issues of their Android TV.

As presented in Fig. 4, from the 58% who answered the choice "No," it shows that the majority of the users are not entirely aware that there are existing attacks that can be conducted and done by hackers on their Android TV, while there are 42% of respondents that are knowledgeable and aware about the current attacks that might

Fig. 2 What brand is your Android TV?



Do you download any third-party applications from the application store?

Are you aware of any security issues involving your Android TV?

Fig. 3 Question about awareness

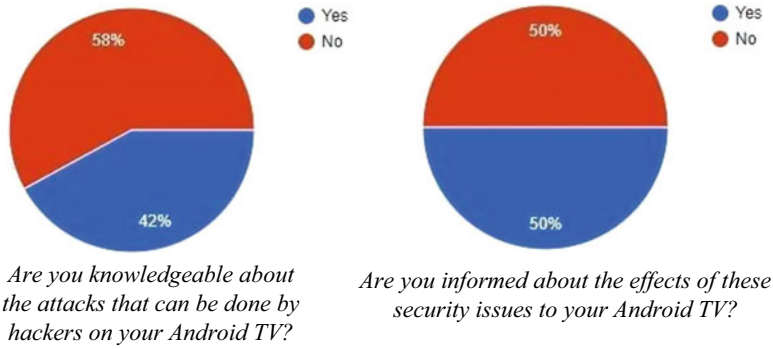


Fig. 4 Question on know-how in securing Android TV

be executed. Likewise, both choices of "Yes" and "No" obtained a percentage of 50, which means that from 50 respondents who answered the survey, there is an equal number of respondents that are informed and not informed about existing security issues that might affect their Android TV.

Figure 5 presents that from the security practices to prevent breaches from the Android TV, 34% of the respondents answered that the practice they are using is not installing non-reputable applications on their Android TV, which is the highest. While updating the software and updating to the latest software and implementing strong passwords to secure the network, both obtained a 22%. On the other hand, 20% of the respondents who answered the survey are using a strong password as their practice to prevent security breaches on their Android TV, while there is one respondent who answered that it is only relying on the VLAN's security to prevent cyberattacks from their Android TV.

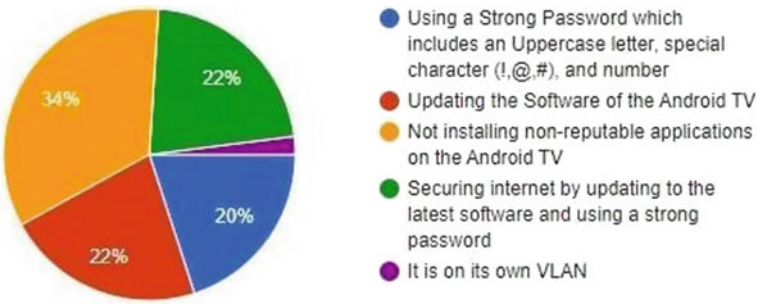


Fig. 5 What security practices do you utilize to avoid security breaches on your Android TV?

4.2 Vulnerability Assessment Result

Android Debug Bridge is used to run a Unix shell to execute commands in Android devices. It can be exploited by scrcpy and other mirroring softwares like it, which provides a display and control over the USB debugging-enabled device [18]. As depicted in Fig. 6, Kali pinged the Android TV to validate their connection. Utilizing Nmap, open port scanning was performed as well. After a check for open ports, it was determined that port 5555, utilized by numerous services. Scrcpy was then installed so the ADB command could connect Kali Linux to the Android TV.

As shown in Fig. 7, following the connection of Kali to the Android TV through its IP address, the shell was then initialized, which gives full access to the attacker. By executing commands, the attacker can do malicious acts such as creating a malicious bat file or monitoring the display of the Android TV itself. As mentioned before, the attacker can monitor the target device's display. Besides monitoring, the attacker can also control the device connected through scrcpy. This is done by connecting the IP address with the port number based on the list of ADB devices.

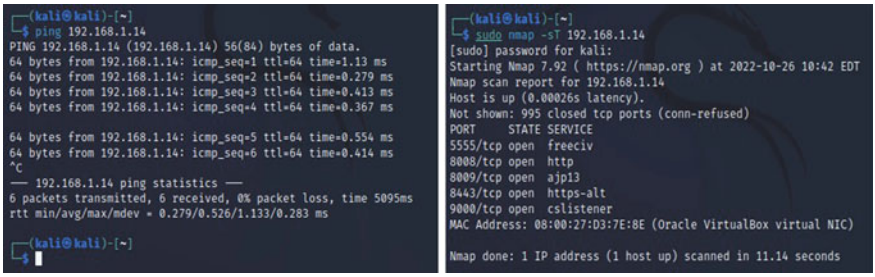


Fig. 6 Ping and scan results

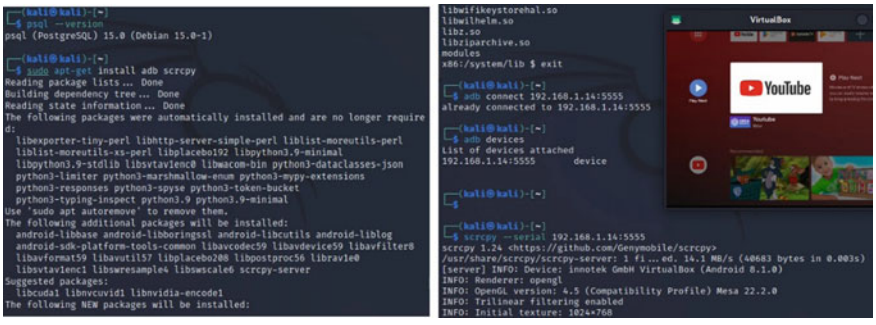


Fig. 7 Installing adb scrcpy, displaying and controlling the Android TV using scrcpy

5 Conclusion and Recommendation

In conclusion, based on the survey results, users are not that knowledgeable about the current dangers of their Android televisions. The survey also reveals their confidence in Android TV's lack of security safeguards. The researchers discovered that the device's security is inadequate, as many of its Nmap-discovered open ports can be exploited by attackers. Android TVs also lack a firewall, allowing a three-way handshake without repercussions. In addition, the study demonstrates the dangers of having the USB debugging option activated in Developer Settings. ADB commands are often used for installation and debugging; however, in the hands of an attacker, they can be used to compromise the device. The vulnerabilities of Android TV can be further analyzed by utilizing physical Android TVs. The platform's vulnerabilities can be tested to assess if the study's results would be similar. Besides that, there is also a limited availability of virtual Android TV versions on the Internet. The researchers recommend to future researchers that the implementation of an integrated firewall in Android TVs has the capability to allow or block certain applications, thus improving its security.

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Representation Learning for Spatial Reuse in IEEE 802.11ax-Compliance Edge Intelligence

Stephen Azeez and Shagufta Henna

Abstract IEEE 802.11ax standard supports dense deployment of access points (APs)/edge devices, with a focus on robustness and uplink transmission. Dense deployments of IEEE 802.11ax APs use virtual carrier sensing to mitigate the effects of interference. Other challenges of IEEE 802.11ax compatible edge devices under dense deployment include homogeneous and heterogeneous coexistence and backward compatibility with legacy devices. To address these challenges, in this paper, two representation learning approaches based on graph neural network (GNN), called as direct-affinityGNN and skip-affinityGNN. Extensive evaluations demonstrate the effectiveness of both the approaches to enable high-capacity edge intelligence.

Keywords IEEE 802.11ax WLANs · Edge intelligence · Representation learning for networks

1 Introduction

Wireless local area networks (WLANs) based on IEEE 802.11 standards have become popular with improved throughput under dense deployments [1]. These WLANs are expected to be compatible with existing and next-generation wireless APs/edge devices. Nonetheless, IEEE 802.11-based WLANs have a limited number of non-overlapping channels, thereby resulting in interference from neighboring APs. Another challenge in IEEE 802.11ax is its incompatibility of high-efficiency (HE) devices with legacy or non-HE. Current channel access solutions based on orthogonal frequency division multiple access (OFDMA) are inefficient for channel access fairness and backward compatibility. Specifically, under heterogeneous WLAN deployment scenarios, coexistence between HE and non-HE/legacy devices results in performance degradation [2]. TCP-aware scheduling techniques have also

S. Azeez (✉) · S. Henna
Department of Computing, Atlantic Technological University, Letterkenny, Donegal, Ireland
e-mail: L00162428@atu.ie

S. Henna
e-mail: shagufta.henna@atu.ie

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been proposed to improve multi-user uplink and downlink transmission performance [3]. They are based on transmission opportunities (TXOP), with a tradeoff between goodput and latency. Other alternatives to IEEE 802.11 uplink scheduling focus improvement of multi-user throughout using multiple input multiple outputs (MIMO) under a varying number of STAs [4].

Deep learning approaches have been used to improve the overall efficiency and throughput of IEEE 802.11-based WLANs [5]. Schmidt [6] proposes a deep convolutional neural network-based wireless interference strategy. Other proposals to adapt deep learning to address the challenges of wireless systems include [7–9]. In [10], VGG16 convolutional neural network is utilized to determine whether the signals are interfered by jamming, thereby identifying the type of interference. Another work proposed random edge graph neural network (REGNN) as a parameterization for resource management policy. Naderializadeh [11] investigates the challenge of bilateral link scheduling where a power control policy is learned using GNN that acts as the basis to transform channel matrix to graph embeddings series by utilizing interference graph. Another GNN-based approach is presented in [12] to enhance the efficiency of greedy schedulers such as Longest-Queue-First. This result is compared to the interference model known as the conflict graph model, which only records binary correlations between edges. In [13, 14], a GNN-based MAC algorithm is proposed to obtain maximum throughput with low time complexity.

This research address the issue of homogeneous and heterogeneous coexistence problem, a crucial challenge in IEEE 802.11ax WLANs under dense deployments. Specifically, we also focus on legacy IEEE 802.11 edge devices, causing contention to IEEE 802.11ax that are essential for enhancing throughput and channel efficiency resulting in substantial performance degradation. Further, multiple edge devices coexisting in dense scenario transmit simultaneously interfere with each other resulting in higher delay. To address these challenges, this paper proposes a direct-affinityGNN model that captures homogeneous interference among IEEE 802.11ax devices. The proposed direct-affinityGNN 's message passing enables edge devices/APs to make appropriate configuration predictions by gathering neighborhood information. Further, to capture heterogeneous interference with IEEE 802.11 legacy devices, we have proposed a skip-affinityGNN approach that considers both the direct and indirect affinity in 2-hop neighborhood to learn optimal configurations.

2 System Model

In a dense scenario, medium access control, i.e., carrier sense multiple access with collision avoidance (CSMA/CA), helps to prevent simultaneous transmissions, resulting in limited reuse.

Suppose, heterogeneous network as shown in Fig. 1. STA2-B receives a radio signal from AP1 with an RSSI larger than the clear channel assessment (CCA) threshold. In the figure, AP1 is a high-efficiency IEEE 802.11x edge device, and STA2-B is a STA in legacy's edge device. As a result, when AP2 broadcasts to STA2-B, AP1 will detect the channel as being busy.

3 Graph Model

IEEE 802.11ax APs are randomly dispersed with each AP with the capability to communicate with its nearby neighbors. An undirected graph $G = (V, E)$ is used to characterize and simulate the wireless network's interaction relationships. $V = v_1, v_2, \ldots, x_N$ is the vertex array for the Nth AP. The edge array $E \in (V \times V)$, where (v_i, v_j) simply exists if node i and node j can interact (Fig. 2).

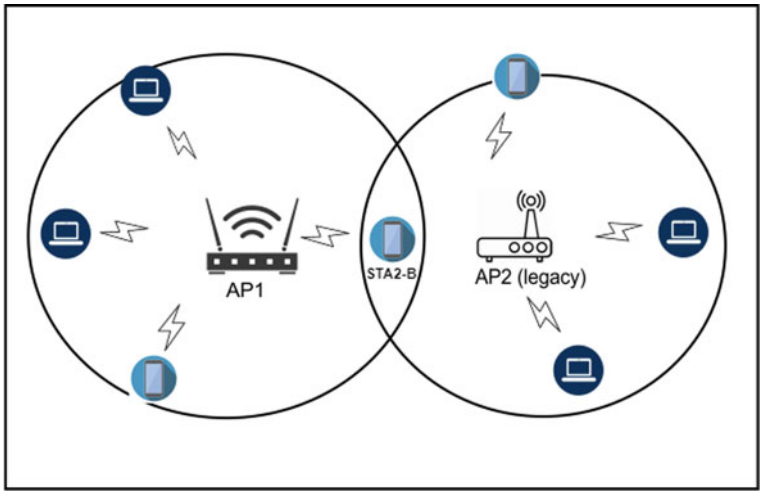

Fig. 1 Coexistence in IEEE 802.11ax

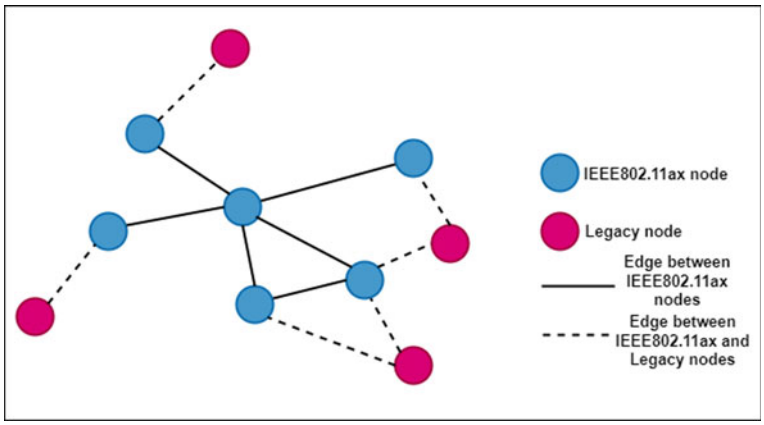

Fig. 2 An illustration of the graph model G

4 Proposed Representation Learning Approach

In this section, using the GNN approach, affinityGNN is applied on the skip graph to model the communication in IEEE 802.11ax. In order to combine both the direct affinity of a homogenous network and skip affinity for a heterogeneous wireless network, i.e., IEEE 802.11ax—legacy network, an iterative integration of fusion gate coupled with aggregation gates is introduced for affinityGNN to effectively fuse and allow the direct affinity and skip affinity connections to learn from each other. The encoded vector is sent to the output layer using the decoder to compute the probability. A simple layer-wise propagation rule is given:

$$N^{(l+1)} = \sigma\left(AN^{(l)}W^{(l)}\right) \tag{1}$$

where $N \in \mathbb{R}$ is convoluted matrix, $W \in \mathbb{R}$ and A is the input adjacency matrix. The limitation of this propagation is that A is not normalized, therefore the need for symmetric normalization of A using the degree matrix D, we have:

$$A_{\text{norm}} = I + D^{1/2}AD^{1/2} \tag{2}$$

Hence from (7), our new rule propagation is

$$N^{l+1} = \sigma\left(D^{1/2}\bar{A}D^{1/2}N^{l}W^{l}\right) \tag{3}$$

where $\bar{A} = A_{\text{norm}}$. Since our aim is to learn computationally the correspondence interpolating direct affinity and skip affinity in the resulting last embedding layer automatically in the model, an iterative integration of fusion gate coupled with aggregation gates is designed to iteratively fuse together both direct and skip affinity features. This is to depict wireless networks in a generalize dense possible situation design and with node embedding effectively representing their communication interaction functions with both skip and direct affinities (Fig. 3).

Let (G_D, G_S) represents direct and skip affinity graph respectively. Suppose (D^l, S^l) are node embedding at the lth layer of (G_D, G_S), we iteratively let both GNNs of G_D and G_S to integrate, in place of not just aggregating the GNN output of the original graph G_D from the node embeddings that captures the direct affinity and aggregates skip graph G_S to capture skip affinity. Therefore via the new propagation in (7), the iterative fusion for direct affinity results to:

$$D^{l+1} = \sigma\sum\left(MD^{(l)}W^{(l)}{}_0, M_S S^{(l)}W'^{l}\right) \tag{4}$$

such that $M = D^{1/2}A'D^{1/2}$ and $M_S = D^{1/2}A'_S D^{1/2}$. The iterative fusion results to:

$$S^{l+1} = \sigma\sum\left(M_S S^{(l)}W^{(l)}{}_S, MD^{(l+1)}W'^{l}\right) \tag{5}$$

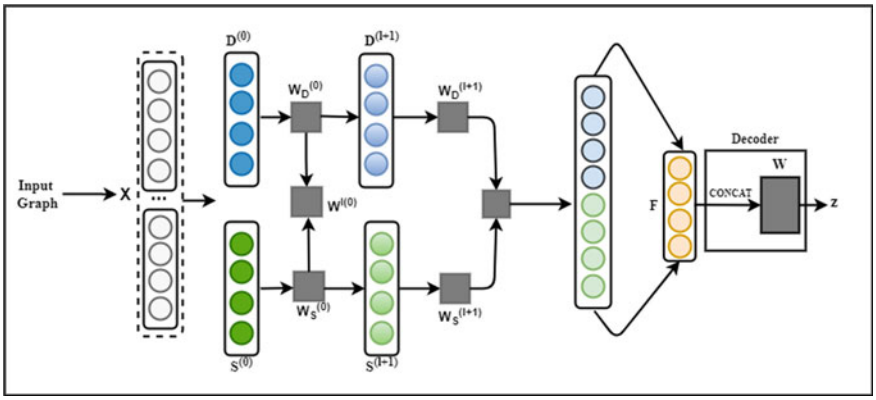

Fig. 3 Direct-affinityGNN takes graph G as input to find the representation of the graph as a real vector, denoted by $D^{(0)}$ and $S^{(0)}$ that are iteratively fused with respective weights W_D^0, W_S^0. Resulting node embeddings are updated, i.e., $D^{(l+1)}$ and $S^{(l+1)}$ in each layers using weights $W_D^{(l+1)}$ and $W_S^{(l+1)}$ to the last layer for the final embeddings F

W_0^l, $W_0^{\prime(l)}$, W_S^l are the propagated transformed weights. $\sum$ represents the aggregate gate in the equation. In this case, a summation gate. Equations (4) and (5) explains initial direct affinity graph embeddings. The embeddings for initial graph D^{l+1} is pre-eminently updated using the node embedding of the preceding layer, D^l, fusioned with the embedding of that of the skip affinity graph S^l in every iteration performed, which is also then updated, S^{l+1} after it computationally retrieves the complete update of direct affinity graph embedding D^{l+1}. In order to get the final node embedding output, the final node embedding F is derived using Eq. (4).

$$F = \sum \left(M D^{(l)} W^{(l)}{}_0, M_S S^{(l)} W^{(l)}{}_S \right) \tag{6}$$

To convert the encoder output into the decoded state, the architecture of affinityGNN decoder uses a neural network to homogenize the node embedding pairs $(f_p, f_q) \in F$ to their target APs (p, q).

$$z_{pq} = \sigma \left(B + W \times \text{CONCAT}(f_p, f_q) \right) \tag{7}$$

The combined embedding through the concatenation function is then provided through the neural network parameterized using weight (W) as well as the binary indicator bias (B) to capture the probability of interference. The probability z_{pq} is a binary variable in which 1 denotes the probability that there exists an interference in the communicating AP_p and AP_q and 0 representing otherwise.

The algorithm for affinityGNN is shown in Algorithm 1. AffinityGNN receives as input affinity graph G using adjacency matrix A to obtain network information which is then used to construct direct G_D and skip affinity G_S graph in the architecture. Aggregation functions in direct-affinityGNN in Algorithm 1 ensure adaptability and representation power. They construct graph-level representations based on all node representations and update this using neighborhood information. Ultimately, our final representation is passed through a linear activation layer RELU to obtain the last layer representation.

Algorithm 2 shows skip-affinityGNN model. Skip interactions/affinity is obtained by using 2-hop neighborhood information. This approach generates a G_S for neural message interchange among the skipped nodes. Hence, the adjacency matrix for skip affinity graph, A_S, is calculated using $A_S = \text{sign}(AA^T)$. This requires that, if the input for node p, q in AA^T is greater than 0, indicating them as skipped node. The A_S is then generated by converting the positive input to 1. To find the representation of the graph as a real vector, the initial access point nodes embeddings are then generated using node2vec. The embeddings are iteratively fused with respective weight parameters of the input adjacency matrices. As each layer is iteratively completed, the resulting node embeddings are updated, i.e., $D^{(l+1)}$ and $S^{(l+1)}$. This loop of a process is repeated with every resulting updated embedding computationally transformed in each layer through the weight matrices to the last layer for the final embeddings.

Algorithm 1 Direct-affinityGNN

INPUT: affinityGraph $\mathbf{G} = (\mathbf{V}, \mathbf{E})$
$\mathbf{A} \leftarrow$ Adjacency Matrix
$\hat{\mathbf{A}} \leftarrow Normalization(A)$
$\mathbf{D} \leftarrow Node2vec(\hat{A})$
    COMPUTE AND UPDATE EDGE FEATURES
    For *each edge pair* $\mathbf{e_{(p,q)}}$ in layer **L do**
        $\mathbf{d^l_{e_{(p,q)}}} \leftarrow (\mathbf{d^l_{v_p}}, \mathbf{d^l_{v_q}})$
        $\mathbf{l} = l + 1$
    End
    AGGREGATE EDGE FEATURES
    For *each node* $\mathbf{v_p}$ in **L do**
        $\mathbf{d^l_{v_p,e}} \leftarrow \sum_{\mathbf{q}} \mathbf{d^{(l+1)}_{e_{(p,q)}}}$
        COMPUTE OUTPUT
        $\mathbf{O} \leftarrow \Phi(\mathbf{d^l_{v_p}}, \mathbf{d^l_{v_p,e}})$
    End
    return O

PREDICT($\mathbf{O}$)

Algorithm 2 Skip-affinityGNN algorithm

INPUT: AFFINITYGRAPH G = (**V**,**E**)
A ← Adjacency matrix of network AffinityGraph **G**
$\bar{\mathbf{A}} \leftarrow Normalize(\mathbf{A})$
$\mathbf{X} \leftarrow Node2Vec(\bar{\mathbf{A}})$
  For every iteration $\mathbf{t} = \mathbf{1}, \mathbf{2}, \ldots, \mathbf{t_{max}}$.**do**
    Initializing the initial state of the network to be 0
    COMPUTE AND UPDATE THE DIRECT EMBEDDINGS
    $\mathbf{D^l} \leftarrow \mathbf{Fuse}(\mathbf{D^0}, \mathbf{S^0})$ from (3)
    COMPUTE AND UPDATE THE SKIP EMBEDDINGS
    $\mathbf{S^l} \leftarrow \mathbf{Fuse}(\mathbf{S^0}, \mathbf{D^0})$ from (4)
    COMPUTE FINAL EMBEDDING OF THE INTEGRATION
    $\mathbf{F} \leftarrow \mathbf{FuseGate}(\mathbf{D^l}, \mathbf{S^l})$
    DECODER- PROBABILITY OF AFFINITY
    For *eachp* in **F do**
      For *eachq* in **F do**
        if(there is affinity between p and q)
          $\mathbf{Z}[p, q] \leftarrow 1$
        else
          $\mathbf{Z}[p, q] \leftarrow 0$
        End
      End
    $\mathbf{z} \leftarrow \mathbf{Z}[p, q]$
  End
  return z

5 Experiments and Evaluations

We evaluate and compare the performance of affinityGNN with direct-affinityGNN under coexisting IEEE 802.11ax wireless network scenario. We have tuned the affinityGNN model using 20 random runs based on cross validation. The learning rate for the model is selected from the range [$1e^3$, $5e^4$, $1e^4$, $5e^5$]; and minibatch has been varied from [32, 64, 128, 256, 512]. To reduce overfitting problem, we have varied dropout varying from 0.05 to 0.2. The dataset is split into training (70%), validation (15%), and test (15%). We have tuned the hyperparameters of the model using the validation set to generalize the affinityGNN model.

Figure 4 shows the training and validation loss results for the direct- and skip-affinityGNN model for 1800 epochs. The validation loss is same as training loss and gradually decreases with faster convergence. In contrast to training loss, it is evident that the convergence of validation loss takes longer. Our proposed models, direct-affinityGNN and skip-affinityGNN, have higher training and validation accuracies as shown in Fig. 5. Results show that F1 score as shown in Fig. 6 has better performance of skip-affinityGNN as compared to direct-affinityGNN.

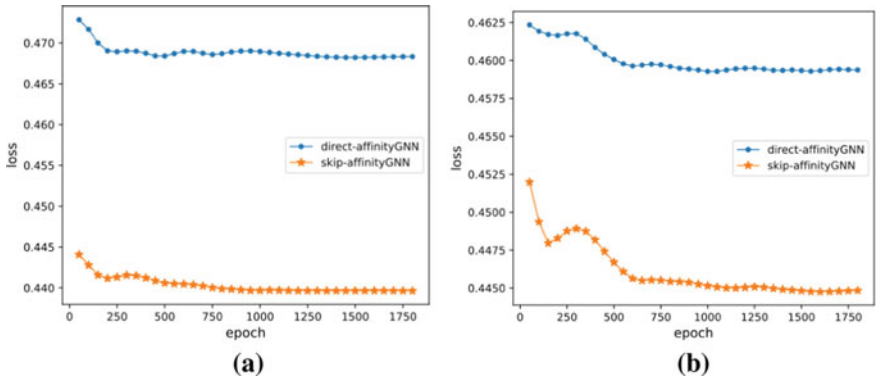

Fig. 4 Average loss **a** training, **b** validation

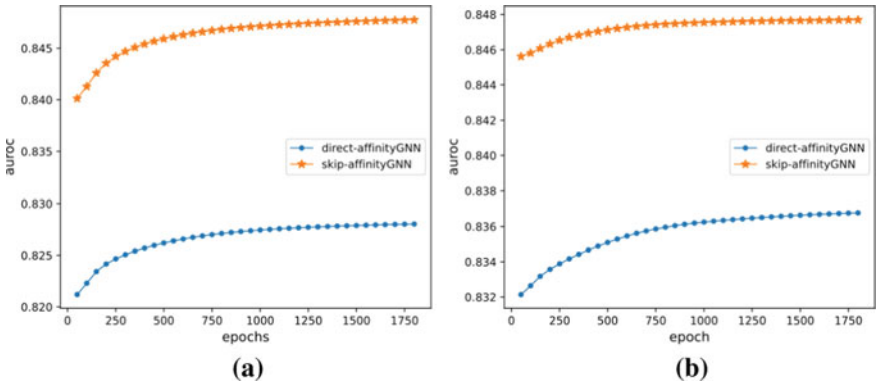

Fig. 5 AUROC curve per epoch steps for **a** training, **b** validation

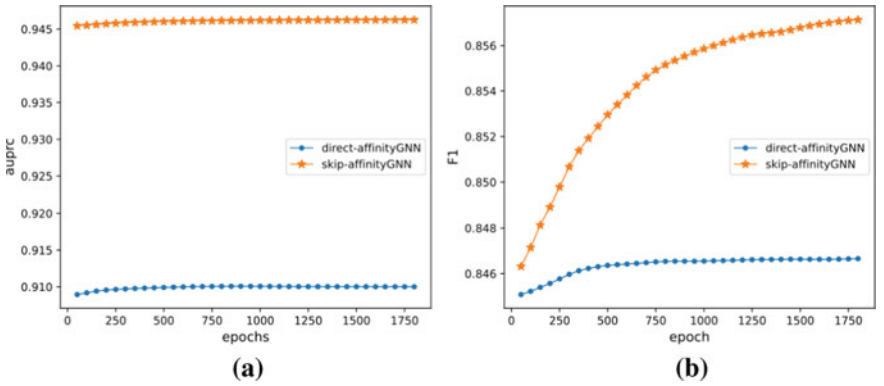

Fig. 6 Validation plot per epoch steps. **a** AUPRC, **b** F1 test

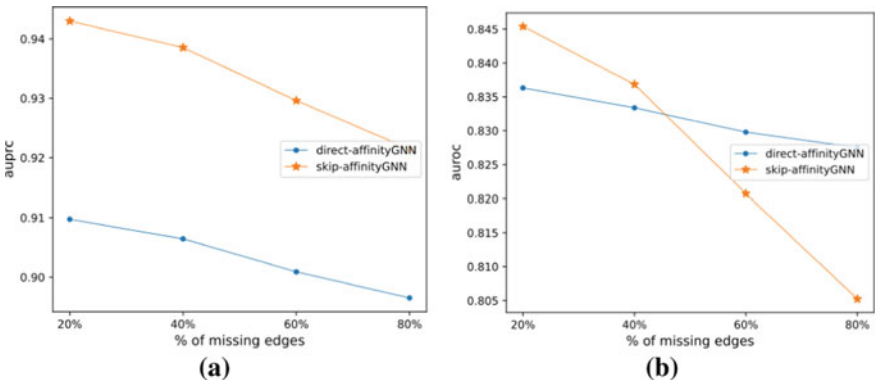

Fig. 7 Performance of models under network dynamics. **a** AUPRC, **b** AUROC

5.1 Effect of Missing Edges

To fully assess the model performance under incomplete topologies/graphs, we evaluate affinityGNN's learning robustness over missing edges in the observed network scenario. Using the model, we assign each incomplete link in an observed network a relative probability of being missing edges by training the model on 20, 40, 60, and 80% of the edges. As shown in Fig. 7, skip-affinityGNN appears to achieve the best performance and the most robust performance as it captures the true communicating mechanisms that structure the network in the presence of the incomplete interacting network. The model shows the increased performance when a greater fraction of interactions had been observed. Additionally, in nearly every single percentage point, skip-affinityGNN obtained better results than the direct-affinityGNN. However, it can be seen in Fig. 7 that the ROC-AU performance of skip-affinityGNN dribbled as the percentage point of the incompleteness increased compared to direct-affinityGNN. More importantly, from the experiments performed, there exists a significant improvement in accuracy despite the incompleteness of network links via classification.

5.2 Impact on Throughput Performance Estimation

In this network scenario, the impact of the number of the network transmitting APs on its overall efficiency in the IEEE 802.11ax was analyzed. In the first experiment, we varied the number of IEEE 802.11ax APs in the network, from 2 to 9, to study the impact on throughput performance. The results shown in Fig. 8 depicted the direct-affinityGNN against the baseline feedforward neural network performance in estimating network throughput performance. The results confirm observations that increase in IEEE 802.11ax APs standard is highly beneficial to overall through-

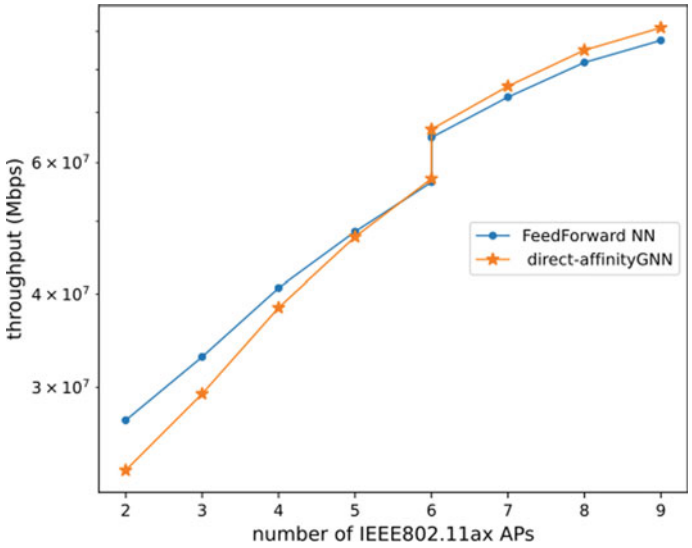

Fig. 8 Network throughput versus APs

put because more parallel transmission can be initiated. In the studied scenario, it improves transmission per AP from 2 to 9, which means that throughput was increased. From the result, it is important to know that FFN takes significantly more IEEE 802.11ax AP connection to outperform direct-affinityGNN. This is expected since each affinityGNN is made up of multiple FFNs. However, direct-affinityGNN still outperformed baseline FFN in estimating network throughput transmission output as the number of IEEE 802.11ax APs increases up to 5APs. In Fig. 9, collisions occurring with the increase in the number of transmitting legacy devices continue to degrade the overall transmission throughput. Result in Fig. 9 has shown that skip-affinityGNN achieves a better performance characteristic and shows a considerable amount of throughput improvement in presence of increasing legacy devices compared to direct-affinityGNN.

6 Conclusion

IEEE 802.11ax wireless local area networks aim high capacity under highly dense deployment scenarios that is subject to high coexistence interference in the presence of homogeneous and heterogeneous APs. To address this problem, this paper proposed affinityGNN model that can learn the interference in the network and therefore can increase the spatial reuse. Experimental results show that the proposed affinityGNN model improves the performance in terms of accuracy, loss, and network throughput under various scenarios, such as dynamic networks. The second pro-

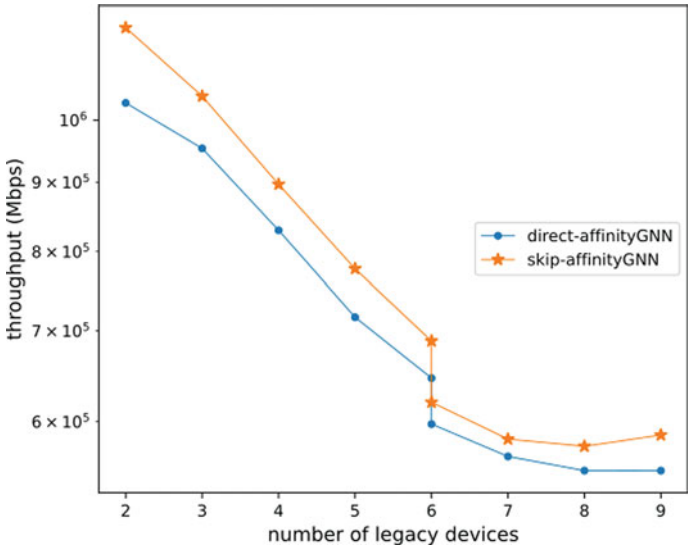

Fig. 9 Throughput versus legacy devices

posed model skip-affinityGNN leverages 2-hop neighborhood information to learn complex network structure that enables better learning performance and throughput in contrast to affinityGNN in the presence of heterogeneous interference.

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Antisocial Behavior and the Dopamine Loop on Different Technological Platforms and Industries: An Overview

Igor Stupavský and Pavle Dakić

Abstract The aim of this review is to explore the relationship between the architecture of microservices and antisocial behavior. Microservice architecture is a software design approach that involves decomposing a system into small, independent services that can offer benefits such as flexibility and scalability. Expected result is to analyze dataset of statuses, which defines the length of time the status displays on the user's device. Because people spend time on social networks at every opportunity, even for hours. When combined with the time-valued, we try to gain a deeper understanding of social networks and users behavior. They are forced into this behavior through the feedback loop mechanism of the neurotransmitter Dopamine. Main goal is to understand how to minimize the impact of antisocial behavior on social networks and what exactly makes users spend a disproportionate amount of time on these platforms.

Keywords Dopamine loop · Addiction · Antisocial behavior · Social media · Microservices

1 Introduction

Throughout history, there have been written and unwritten rules of behavior for each era. This creates a kind of acceptable norm of behavior in the form of social behavior that is accepted in most societies; if someone does not adhere to these rules

I. Stupavský (✉) · P. Dakić
Faculty of Informatics and Information Technologies, Institute of Informatics, Information Systems and Software Engineering, Slovak University of Technology in Bratislava, Bratislava, Slovakia
e-mail: igor.stupavsky@stuba.sk

P. Dakić
e-mail: pavle.dakic@stuba.sk

P. Dakić
Faculty of Informatics and Computing, Singidunum University, Belgrade, Serbia

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of behavior, then we are talking about antisocial behavior. It starts with inappropriate remarks about a certain population group and goes through bullying and vandalism to harm.

Scientific knowledge shows in which direction the substance dopamine, which is a neurotransmitter, can be largely responsible for antisocial behavior in the online environment. In an acceptable amount, it induces motivation in the individual and satisfaction from a job well done. But in large amounts, it forces a person to risky behavior and to a higher degree of impulsivity. This can become harmful not only for the individual but also for society.

Conducting research attempts to approximate the complexity and background that must be provided in order to understand the wide range of applications for the proposed system. The chemical reactions in the human brain that affect behavior are very complex and still poorly researched scientifically. At the same time, external factors, such as genetics, but also various social influences of the environment can also influence the emergence of antisocial behavior.

2 Paper Organization and Key Contributions

This paper is organized as follows:

1. Materials and methods: We used a social network data scraper to design our network. They will ensure that enough current data are at the entrance and that they are regularly updated.
2. Personality disorders: In this part of our work, we defined the individual disorders that can occur when the dopamine loop is misused. It leads from addiction to the total disintegration of the personality.
3. The historical aspect of antisocial behavior: We present the gradual historical development of selected manifestations of antisocial behavior. Their scope is still not precisely determined, and new forms are constantly being found.
4. Results and discussion: Here, we evaluated the resulting architecture of our solution. It consists of individual microservice modules that communicate with each other and thus ensure the development of individual modules independently.
5. Conclusions final evaluation and direction of further research in this area.

The following are the key contributions of the paper:

1. Understanding the Creation of Microservices: In our approach, each module within the architecture is separated as a microservice. For this reason, it is also developed separately and thus allows to support for the increase of the computing capacity of individual modules in the event of an onslaught. We are using Pub-Sub frameworks, such as Apache Kafka, for communication between individual modules.

2. Differences in the method of service-oriented architecture: As opposed to monolithic architecture, this architecture (SOA) uses faster data processing and can be expanded relatively cheaply if higher performance is needed.
3. Overview and understanding of the differences when creating different architectures and services.

2.1 Materials and Methods

Through research, we want to collect certain relevant information on statuses from several different social networks. As a result of adaptation of collected literature and editing using NLP methods, we can determine the main idea of each status by extracting keywords. When combined with the time-valued, we gain an insight into machine learning. It is expected that the time the status is displayed and the Dopamine loop effect the status leaves on the user will correlate. A methodological approach should better explain the advantages (pros) and disadvantages (cons).

2.2 Research Questions

Initial research bases will be initiated based on observed observations in the form of research questions. That, as such will have a basis in literature search in relevant interdisciplinary fields. The process of collecting material will involve trying to answer some of the questions posed below:

1. How do dopamine changes occur when using social networks?
2. How do social networks influence in the creation of antisocial behavior and exclusion from society in real life?
3. Why do people become addicted and what causes antisocial behavior and various disorders?

3 Personality Disorders

A personality disorder is a long-term condition in which an individual's personality is damaged or disintegrated. Psychiatrists and psychologists mainly deal with their classification. Treatment is long term and most often includes only alleviating symptoms of the disorder. Thus, the patient can largely function within normality. Without treatment, the individual's symptoms of the disorder continue to worsen, and gradually, the complete disintegration of the personality may occur [17].

3.1 Antisocial Personality Disorder (NHS)

Antisocial personality disorder is most often manifested by reduced respect for others and their rights. Furthermore, empathy is reduced, and such an individual is prone to aggression and violence. Most often, various other external and internal factors are added to such a predisposition. From the point of view of our research, the most important social factors appear to us. Each antisocial personality disorder is unique and it is the responsibility of clinicians how to classify these manifestations.

Personality consists of emotions, feelings, and perceptions of other individuals, and all these factors define an individual and his behavior toward his surroundings. A personality disorder is an overall difference between an individual's behavior and what is generally considered socially acceptable by society [17].

3.2 Antisocial Personality Disorder (ASPD)

The amount of easily obtained dopamine causes the receptors in the user's brain to overwhelm [22]. As a result, he becomes partially resistant and develops antisocial personality disorder (ASPD). ASPD is one of nine recognized types of PD according to the International Statistical Classification of Diseases and Related Health Problems (ISCDRHP) and is defined by the ISCDRHP 10th Revision (ICD-10) as disregard for social obligations and callous unconcern for the feelings of others [17].

Antisocial disorder can be presented in the following list [19]:

- First is the list is about exploiting, infringing or manipulating other people.
- Other forms can be manifested through different types of regrets, lack of concern for other people and their problems.
- Indicators of this form of behavior are also manifested through the inability to control the outburst of anger.
- There are evident problems in the shortcomings of the sense of guilt, which is why they do not learn from their mistakes.
- The best indicators of carelessness is reflected in forms of irresponsible and inadequate social behavior.
- Another of the strongest indicators of this form of behavior is the difficulty in maintaining or achieving long-term relationships of different types with people of the same or different sex.
- Blaming problems in life on other people in their environment or in politics.
- It can be said that one of the main indicators of this type can be seen in the continuous violation of the law.

3.3 Dopamine

One of the important roles of Dopamine is in the regulation of pleasure and reward. When we engage in activities that are pleasurable or rewarding, dopamine is released in the brain, which contributes to feelings of pleasure or satisfaction. This can help reinforce the behavior and make it more likely that we will repeat it in the future.

Dopamine is also involved in other functions such as movement, attention, and memory. For example, dopamine is involved in the control of movement, and deficits in dopamine signaling are associated with conditions such as Parkinson's disease. Dopamine is also important for attention and focus, and abnormal dopamine signaling has been implicated in conditions such as ADHD. Dysregulation of dopamine signaling is associated with a range of mental health conditions such as addiction, depression, and schizophrenia [4].

3.4 Chemical Composition of Dopamine

Dopamine Fig. 1 ($C_8H_{11}NO_2$) is a naturally occurring type of neurotransmitter [4]. As a result of Dopamine, the brain experiences good feelings. It serves as a reward when we do something right. It may motivate us to do something that makes us happy. Historically, dopamine fueled our survival instincts by motivating us to do things that were helpful. For example, after finding food, eat it to survive as an individual.

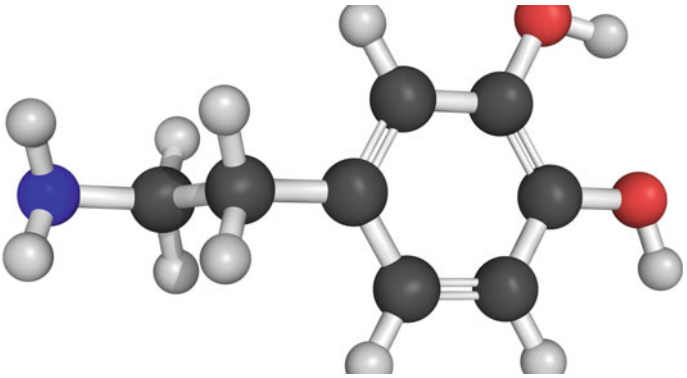

Fig. 1 Chemical 3D structure dopamine. *Source* [1]

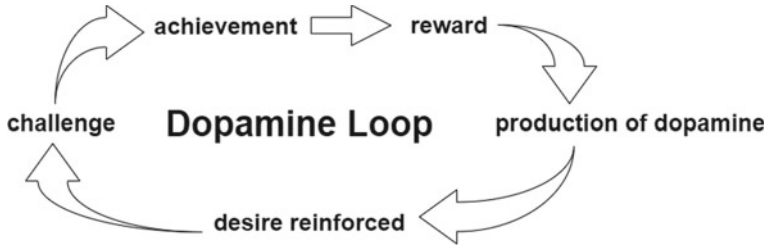

Fig. 2 Dopamine loop. *Source* [15]

Table 1 Total minutes spent on social media per day

Year	Time (min)	Year	Time (min)
2012	90	2017	134
2013	95	2018	142
2014	104	2019	145
2015	111	2020	145
2016	128	2021	152

Source [10]

3.5 Dopamine Loop

According to the research [4, 12, 21], users' brains experience rewards when they use social networks. As with addiction, rewards are often based on a similar principle. Scientists at the world level have certain agreements on certain conclusions that are presented in a book written by Zichermann and Cunningham. The attached findings and the consensus of opinion regarding the process of a challenge-success-reward game loop that promotes dopamine production inside our brain, by reinforcing our desire [28].

We can see the effects of dopamine on some of the most popular networks, such as Facebook. According to the statements and words of the vice president of Facebook Chamath Palihapitiya, we can see a changed way in which society functions and that we have essentially destroyed the historical way in which we have communicated so far [13]. One of the reasons is that the impact of dopamine on our organism in the form of a dopamine loop mechanism described in [15] is shown schematically in Fig. 2.

The time spent on social networks increases every year. Table 1 shows the average number of minutes that users spend daily on specific social networks.

For the needs of our proposed method, it will be necessary to program your own scriber in the social network environment. In addition to commonly available data, it will be necessary to calculate the display time of each post on the user's device. We record the system time of the first and last view. We can determine the display time from their difference, that is, the time that the user devoted to an individual post.

3.6 The Historical Aspect of Antisocial Behavior

The history of antisocial behavior is a broad term that includes a large number of different forms of it. Therefore, we will focus only on some manifestations that are relevant to the future direction of our research.

3.7 Propaganda

Historians consider the first mention to be the inscription on Mount Behistun (c. 515 BC), where the king described his acquisition of the Persian throne [18]. Reformation ideas were mainly disseminated using the then new printing technique (c. 1450 AD). In this period, they used the works of reformation thinkers, as well as the counter-reformation movement, to spread their ideas [9].

Before the world wars, the film "Triumph des Willens" was created, which was created by the German Empire for the needs of propaganda of its idea. It originated as an official document from the 6th Party Congress in Nuremberg in 1934 [2]. From more recent history, we can mention the film "Fahrenheit 9/11" from 2004. It presented a more patriotic view of the events on the part of the government than it was in reality [8].

3.8 Conspiracy Theories

The prevailing opinion is that conspiracies are a product of the modern age, as they spread rapidly through the online space [26]. And that we now live in the "Age of Conspiracy" [20]. However, research has clearly shown that conspiracy theories have been with us for practically all of history [5].

3.9 Misinformation or Disinformation

For example, European imperial powers used misinformation to dehumanize indigenous peoples, delegitimize indigenous histories, knowledge, and societies, and portray them as "colonized" [16, 24].

The study of disinformation began to attract the attention of scientists only after the presidential election in the USA in 2016 [11, 25]. This surprising result of the election interested scientists so much that they became more interested in this area, which had a relevant impact on social events and world history.

4 Results and Discussion

In the microservice architecture proposed by us, we focused on dividing individual parts into a set of elementary parts (microservice). Individual modules (parts) communicate with each other using the Apache Kafka tool. At the same time, each module is designed as an independent unit capable of development, deployment, and testing independently of any other service in CI/CD or REST-API [6, 14, 23].

4.1 Microservice and Social Networks

Microservices are a method of approaching software architecture, which enables scalability of the system on both a horizontal and a vertical level. This allows us to update individual parts of the system as needed.

Social networks are applications for connecting users based on their various characteristics. They allow them to communicate with each other, exchange information, and statuses, or share common events. A typical representative of social networks is, for example, Facebook or Instagram.

A large number of social networks are based on microservice architecture [7]. This architecture is divided into microservices, such as profile management, or other tasks according to the necessary specification of the given network, which will enable it to flexibly adapt to changing conditions (requirements).

4.2 Web Microservice Architecture Diagram Proposal

The use of a microservice architecture has several advantages. It enables scalability and modification of the individual modules that make up the architecture. Modifying one module does not affect the rest, and thus, in addition to scalability, we also achieve greater stability.

The advantage of building and maintaining the system, which is easier than with a monolithic architecture, followed from the previous one. Each of the modules (services) can be implemented in the best possible way, as it does not affect other modules. Apache Kafka [3] will be used for communication in our model (Fig. 3).

4.3 Web Service

The Web Service (WS) architecture can also be used within SOA. The suitability of the WS architecture points to the exchange of data between devices in different formats (for example, JSON). In the course of the conducted research, we had the

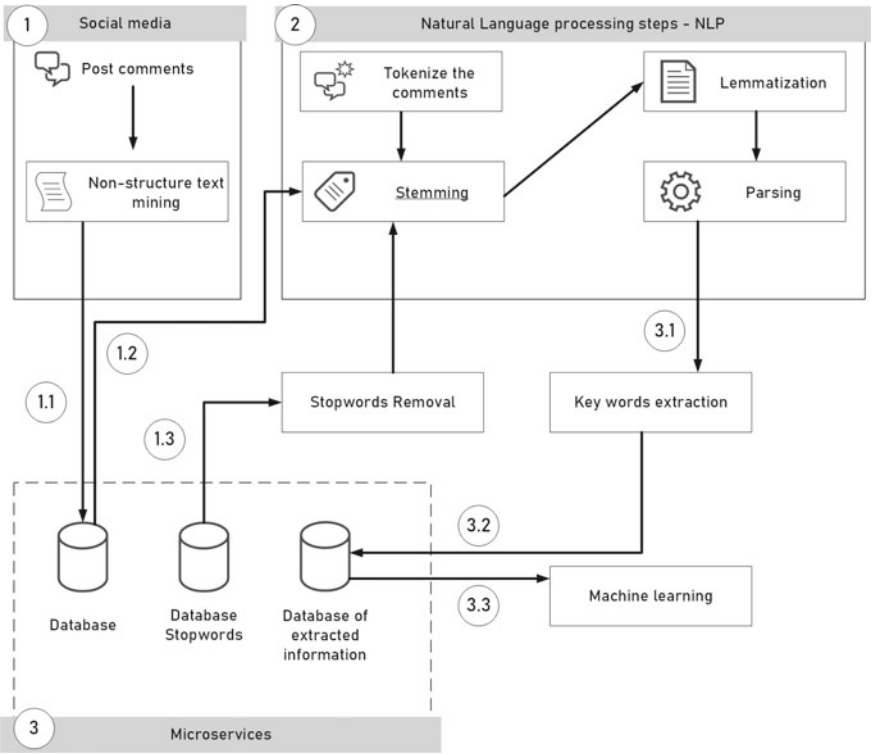

Fig. 3 Architecture diagram proposal. *Source* Author's contribution

opportunity to learn about the shortcomings of microservices and its complexity in terms of understanding the necessary steps during implementation [27].

5 Conclusions

In our research, we addressed antisocial behavior using an architecture made up of microservices. At first glance, it may seem that these are two distant and unrelated topics. Microservice architecture is about the approach to the logic of the application architecture, such as social networks. From the point of view of antisocial behavior in online communities (on social networks), its unacceptable effects on other users must be minimized. Actions that can arise from antisocial behavior are harmful; they create violations of social norms and often the laws of society. Research in this area is complex, and different scientific fields must participate in its solution because this issue is multidisciplinary. Dopamine, as a neurotransmitter in the brain, has a significant influence on the behavior of users. The relationship between dopamine and

behavior is complex, and the development of antisocial behavior cannot be oversimplified. This is a more complex problem that requires further scientific investigation of their interrelationships.

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File Formats and Digital Data Transfer for Dental Needs

Diana Pavlova, Tihomir Dovramadjiev, Dimo Daskalov, Rozalina Dimova, and Beata Mrugalska

Abstract The use of CAD/CAM in dentistry makes it possible to optimize the treatment process in case of a violation of parts of the orofacial complex. It contributes to the rationalization of the production process of the dental prosthetic structure by transferring file formats between different software programs for design, design visualization, simulation, and post-production through an additive or subtractive process. This electronic process has the ability to store larger amounts of medical data with different formats and transfer them between different software.

Keywords CAD/CAM · 3D · CNC · Dental practice · Dentistry · Healthcare · Data transfer · File format

D. Pavlova (✉) · D. Daskalov
Dentaprime Dental Clinic, Varna, Bulgaria
e-mail: diana.pavlova@dentaprime.com

D. Daskalov
e-mail: dimo.daskalov@dentaprime.com

T. Dovramadjiev
Department of Industrial Design, Faculty of Shipbuilding, Technical University of Varna, Varna, Bulgaria
e-mail: tihomir.dovramadjiev@tu-varna.bg

R. Dimova
Department of Communication Engineering and Technologies, Faculty of Computer Sciences and Automation, Technical University of Varna, Varna, Bulgaria
e-mail: rdim@abv.bg

B. Mrugalska
Faculty of Engineering Management, Poznan University of Technology, 60-965 Poznan, Poland
e-mail: beata.mrugalska@put.poznan.pl

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1 Introduction

Modern dental care is a comprehensive process characterized by the transfer of information electronically. It starts with importing source files containing dental digital data that is obtained from intraoral cameras, run through design software and sent to production machines. Data management and transfer are an important part of running a dental practice. This leads to workflow changes, improving productivity and improving the patient experience. A preliminary idea and a predictable result combined with mathematical accuracy are important for the strength of the construction, the possibility of rapid production of prototypes through 3D printing that directly affects the psychological moment for a patient. Unifying the use of file formats by different software gives a fast workflow, no need to converge and overwrite the information. The use of the correct file formats for the transfer of digital data is a necessity, which depends on the construction of a correct technological methodology covering the whole or partially working process in the design practice [1–3]. Referring to the digital transfer of data for dental needs, file formats are specially applied. This is related both to an individual design approach and to the available material base [4–7].

2 Materials and Method

2.1 Diagnosis

After performing the relevant administrative activities (including informed consent), a thorough examination is performed by the treating dentist. The specific situation, the problems, pains, ailments, and other features characteristic of the clinical case are discussed with the patient/s. It concludes with the formulation of a treatment strategy and plan.

- Choice of dental treatment methodology, preliminary forecasting, materials, and technologies.

2.2 Physical Aspect

Materials. For the manufacture of dental implants and abutments, the titanium alloy Ti6Al4V, which has been proven to be effective in recent years, is most often used. Photopolymer materials are used to make temporary crowns, and zirconium ZrO_2 is used for final dental crowns.

(Clarifications:

- In certain cases, other types of materials can be used for implants and crowns, such as other titanium alloys, gold, and platinum as long as they have biocompatible qualities. In the specific clinical cases in the presented research, they are not present.
- Also practicable is the application of additional bioactive materials such as Hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$ and Titanium Dioxide TiO_2, through plasma treatment in order to provide conditions for faster osseointegration) [8].

2.3 Psychological and Emotional Aspect

Psychological and emotional aspect: It is mainly related to the patients confidence that their dental problems will be solved. Then, discomfort during dental procedures will be minimal, pain minimized to a maximum. Digital Smile imaging software is technologically used, which further motivates the patient/s to resolve the disease.

(Clarification: In some people, there is no need for dental treatment, and they decide for dental corrections with a purely esthetic motive).

2.4 Technologies

Software: In the present time, the software products of 3Shape, AutoDesk Mesh-Mixer MillBox, 3D Sprint, and others are mostly used to optimize the three-dimensional polygon-mesh obtained after three-dimensional scanning and to create solid volumes. These softwares are also used to generate Digital Smile images and other applications that are semi or fully automated in their operation.

(Clarification: 3D commercial software can be used such as CAD: SolidWorks, Autodesk Inventor, SolidEdge, Catia, and others; CAE: Comsol, Abaqus, and others; polygonal-mesh: 3DS Max, Cinema 4D, Maya, and others; and free and open source: Blender, Dental Blender Add-ons, FreeCAD, and others) [9].

2.5 Additive Technologies

- Computed tomography machines. By means of CT machines, X-rays are taken of a section of the jaw for the relevant clinical case or panoramic X-rays of the entire jaws (upper and lower).
- 3D intraoral scanners. They serve for direct imaging of the oral cavity, which allows teeth to be digitized in polygonal-mesh models.
- 3D printers: Work by adding material. They allow virtually any dental geometry model to be reproduced from compatible computer file formats containing digital dental data. They are often used for actual fabrication of temporary dental crowns and adjacent dental test models (parts of jaws or whole specimens) in order to test the quality of the three-dimensional geometry. 3D printers allow the fabrication of partial temporary prostheses.
- CNC machines. They work by removing material. With CNC machines, the finished final models of Ti6Al4V dental implants and ZrO_2 crowns are precisely manufactured.
- Other machines. Include various machines for additional processing and firing of the material (mainly for zirconia crowns [10]).

2.6 File Formats

List of file extensions used for 3D graphics file formats associated with 3D graphics software, CAD/CAM software, and 3D visualization tools. 3D computer graphic file formats are graphic files that use a three-dimensional representation of geometric data with the possibility of the operator making changes to them even with remote access [4], they are stored in the computer for the purpose of performing calculations and rendering 2D images of dental structures or animations (simulations) of jaw movements. Such images can be used for real-time viewing or later display. 3D computer graphics uses many of the same algorithms as 2D computer vector graphics in the wireframe model and 2D computer bitmap graphics in the final rendered display. In computer graphics software, the distinction between 2 and 3D is sometimes blurred, as 2D applications may use 3D techniques to achieve effects such as lighting, and primarily, 3D applications may use 2D rendering techniques [11]. Scans in the 3Shape Dental System software have the option to save files as DCM, PLY, OBJ, ACR, and STL [12] (Table 1).

Table 1 File formats

Software	Fail format	Function
Newton 3 shape 3D sprint basic Mill box	Stl	The stl file extension is associated with Standard Tessellation Language, a common CAD stereolithography format for 3D modeling, prototyping, and for use in 3D printers The stl file describes the surface geometry of a 3D object without any representation of color, texture, or other common CAD model attributes. It exists in both binary and ASCII format [13]
3Shape	Acr	The acr file extension is related to image format used in medicine The acr file is saved in the Digital Imaging and Communications in Medicine (DICOM) image format [14]
	OBJ	OBJ file extension—3D object graphics format represents the 3D geometry, such as the position of each vertex, the texture coordinate associated with a vertex, the normal at each vertex, and the faces that make each polygon
Newton 3Sshape	PLY	Polygon graphics: The ply file consists of a header followed by a list of vertices and then a list of polygons. The header specifies how many vertices and polygons are in the file and also states what properties are associated with each vertex, such as (x, y, z) coordinates, normal, and color [15]

3 Technical Realization

3.1 Dental Technician Craft Process

The professional competence of dental technicians (software specialists and practices) who know the applicable dental materials is very important. In the present clinical cases, the biocompatible dental materials Ti6Al4V for the implants and ZrO_2 for the crowns were applied.

[Clarifications:

- Some of the materials may be different at the discretion of the treating dentist. For example, if the patient has a strong intolerance to certain metals (this is specified already at the stage of administrative preparation of the documents). Application of other biocompatible titanium alloys, zirconium for dental implants, and others is possible].
- Provided that the dental clinic can afford its own research center, it works in partnership with universities, institutes, etc., or according to joint programs and projects, CAD/CAM studies are performed to increase the final dental results. For example, SolidWorks software is proven to be one of the leading best software for designing solid three-dimensional geometry that can be studied in a computer

environment using finite element analysis (FEA) [16] to ensure and obtain preliminary results. When performing computer simulations in a SolidWorks environment, static loads are very often applied, and the results are expressed in mathematical values of the factor of safety (FOS). The calculation of the results is expressed in mathematical values (in parallel, they are visualized graphically, and samples can be taken), where it is of the greatest importance that the design of the three-dimensional geometry with the defined material has minimum values of the factor of safety (FOS) to be between 1.5 and 3.0, which provides the required strength quality of the material [17]. In certain cases, computerized software systems (SolidWorks, FreeCAD, and others) working with FEA are used to pre-predict the strength of three-dimensional dental geometry in a digital environment. This gives additional confidence that the development of a dental design will be maximally resistant under load [18, 19].

A big advantage of using this software is precisely the availability of a standardized material base where basic dental materials are present [20]. In this case, the materials titanium, titanium alloy Ti6Al4V, and zirconium are specified (Table 2).

3.2 Dental Clinical Cases and Full Recovery

In Dentaprime Dental Clinic, the following two clinical cases were registered, where complete restoration of dental jaws is required.

Clinical case 1: Restoration of dental jaws of a man (Fig. 1).

Clinical case 2: Restoration of the dental jaws of a woman (Fig. 2).

4 Discussion

Following the implementation of the defined methodology, the dental jaws of the two patients (male and female, respectively) were successfully restored. After carrying out the dental treatment manipulations, the patients passed the monitoring time distance, and no problems were reported.

The obtained positive results were achieved not only due to the right choice of technological support but also appropriate psychological and emotional state of the patient.

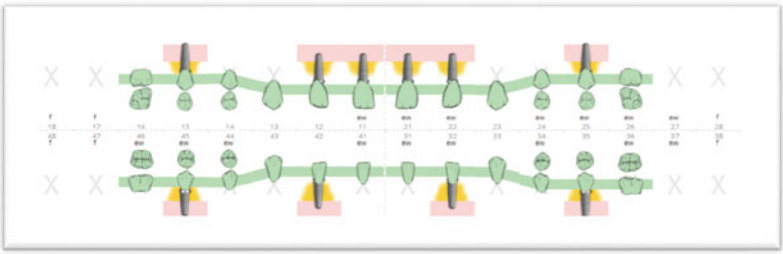
The problems of the recognition of the emotional and psychological aspects are an essential component of treatment and its success often depends on the emotional state of the patient [21]. Therefore, it is suggested to the dentist to be aware of practical-problem-oriented approach [22, 23] which focuses on patient management and maintaining and improving dental health as a part of the total healthcare services. It is emphasized that such service should be available to the elder patients [23] or with psychosomatic disorders [24] as in a case of the investigated dental clinic where the

Table 2 Standardized dental materials available in SolidWorks software database [20]

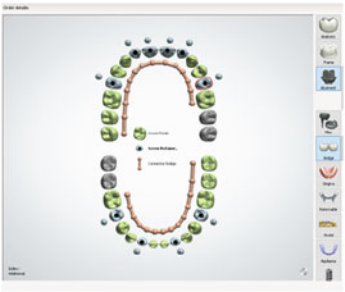
SolidWorks software materials from internal database[a]	Property	Value	Units
Ti6Al4V	Elastic modulus	1,068,659.241	kgf/cm^2
	Poisson's ratio	0.31	N/A
	Tensile strength	10,706.955	kgf/cm^2
	Yield strength	8436.7836	kgf/cm^2
	Tangent modulus	–	kgf/cm^2
	Thermal expansion Coefficient	9e−006	/°C
	Mass density	0.00442878	kg/cm^3
	Hardening factor	0.85	N/A
Titanium	Elastic modulus	1,121,681	kgf/cm^2
	Poisson's ratio	0.3	N/A
	Shear modulus	438,475.3	kgf/cm^2
	Mass density	0.0046	kg/cm^3
	Tensile strength	2396.3185	kgf/cm^2
	Compressive strength	–	kgf/cm^2
	Yield strength	1427.594	kgf/cm^2
	Thermal expansion Coefficient	8.8e−006	/ºC
	Thermal conductivity	0.0525813	cal/(cm s ºC)
	Specific heat	109.943	cal/(kg ºC)
	Material damping ratio	–	N/A
Zirconium	Elastic modulus	1,009,512.9	kgf/cm^2
	Poisson's ratio	0.34	N/A
	Shear modulus	367,095.6	kgf/cm^2
	Mass density	0.0066	kg/cm^3
	Tensile strength	3568.985	kgf/cm^2
	Compressive strength	–	kgf/cm^2
	Yield strength	601.6289	kgf/cm^2
	Thermal expansion Coefficient	1.1e−005	/ºC
	Thermal conductivity	0.0040631	cal/(cm s ºC)
	Specific heat	69.3117	cal/(kg ºC)
	Material damping ratio	–	N/A

[a] The SolidWorks database also contains data for other precious metals such as gold and silver. If it is necessary to add material that is missing from the database, it can be entered manually (taking care to ensure the accuracy of the entered information) or standardized material can be purchased from a distributor company

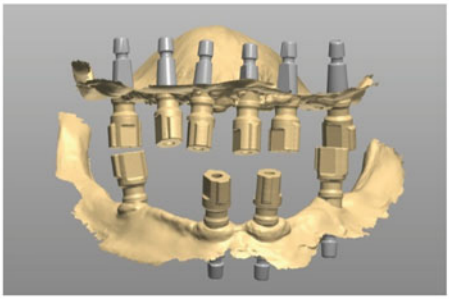
most of the patients are in the group of above 60 years old. In the literature, we can also find approaches which refer directly to body loss and image as psychological and emotional disturbances. It is underlined that such situations lead to the development of anxiety, depression, post-traumatic stress disorders, panic disorders, poor cognitive functions, and poor quality of life [25] what can be increased due to the process related to human body decline, decay, and death in the life cycle. Moreover, it can even result in a patient's response to any other therapy or even in maladaptive thought, images, or behavior [26, 27]. The loss of the tooth can be also perceived as being disable and a handicap leading to social stigma instead of natural aging process [28]. Such patients avoid some food, less enjoy food or even avoid laughing in public what influence



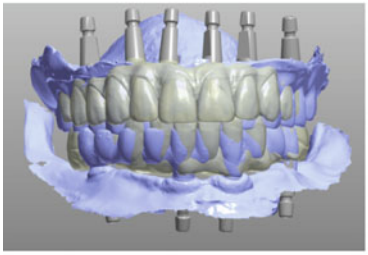
(a)



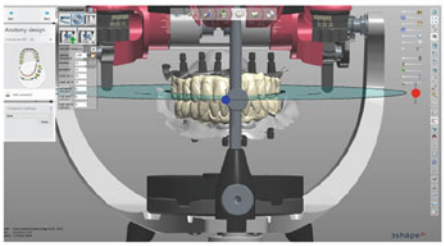
(b)



(c)



(d)



(e)

(f)

(g)

◀**Fig. 1** Clinical case 1: restoration of dental jaws of a man. **a** Dental status of the patient, position of implants. **b** Order form in the 3shape software—shows the position of the titanium (Ti6Al4V) implants, connecting the teeth in an arch for the upper and lower jaw. **c** Digital impressions of upper and lower jaw in bite with scan bodies placed on the implants, and visualization of the laboratory analog of the implant in gray. **d** Overlaid images in blue are digital impressions of the temporary PMMA prostheses, and gray is the new design with applied corrections and increased esthetics in relation to the healing dental gums. **e** Anatomical prototype design—check for bite accuracy and fit of occlusal contacts in a virtual articulator. **f** 3D printed prototype of PMMA, after a sample in the patient's mouth and registration of a real bite with a silicone key. **g** 3D printed laboratory working models placed laboratory analogs of implants and printed soft gingiva on models. On the right, it is shown a 3D printed PMMA prototype, on the left—cut zirconium arches

directly self-confidence and self-image. Therefore, there is a need to identify problem patients before actually starting the treatment [29]. The other important aspect is the access to the dental history. Therefore, in the case of Dentaprime dental clinic, the dentist has a direct contact with the previous partner clinics as these clinics direct the patients upon common approval, and also after the treatment, the patient is under supervision of the clinic at home location.

The Dentaprime dental clinic is visited more by an above-average number of anxiety patients. Its statistics show that this proportion is around 20%, whereas in other dental clinics, this figure is ca. 10% [30]. For anxious patients, the treatment is done under general anesthetic or sedation where the treatment is monitored by an anesthetist and dental assistant. The anesthetist intravenously administers anesthetics and sedative treatment to keep the patient from feeling pain during this medical procedure. Moreover, special psychosomatic expertise is neutralized due to understanding, empathy, and patience. In any private clinic, the dentist spends much more time with the patient in comparison with public healthcare centers [31]. During the treatment at any time by means of a hand signal, it is allowed to stop the procedure. Such comments as "Oh, it's nearly over" or "well, you shouldn't feel anything" pushing the patient to stay calm are not acceptable. The whole medical procedure is presented in details before and during the treatment. In order to do it, the dentist uses the terms that the patient can understand avoiding technical words and phrases. The patients should be able to understand the message as people do not perceive well the service when they have to ask for clarification and finally lead to the conclusions on your own way. Moreover, during visits the dentist not only shows the dental instruments but also the tooth in question on the multimedia screen by using an intraoral camera. It helps to understand the medical treatment and facilities the process of relaxing. The current researches also support that there is an evidence to play music to moderate anxiety within the clinical setting in dentistry [32, 33].

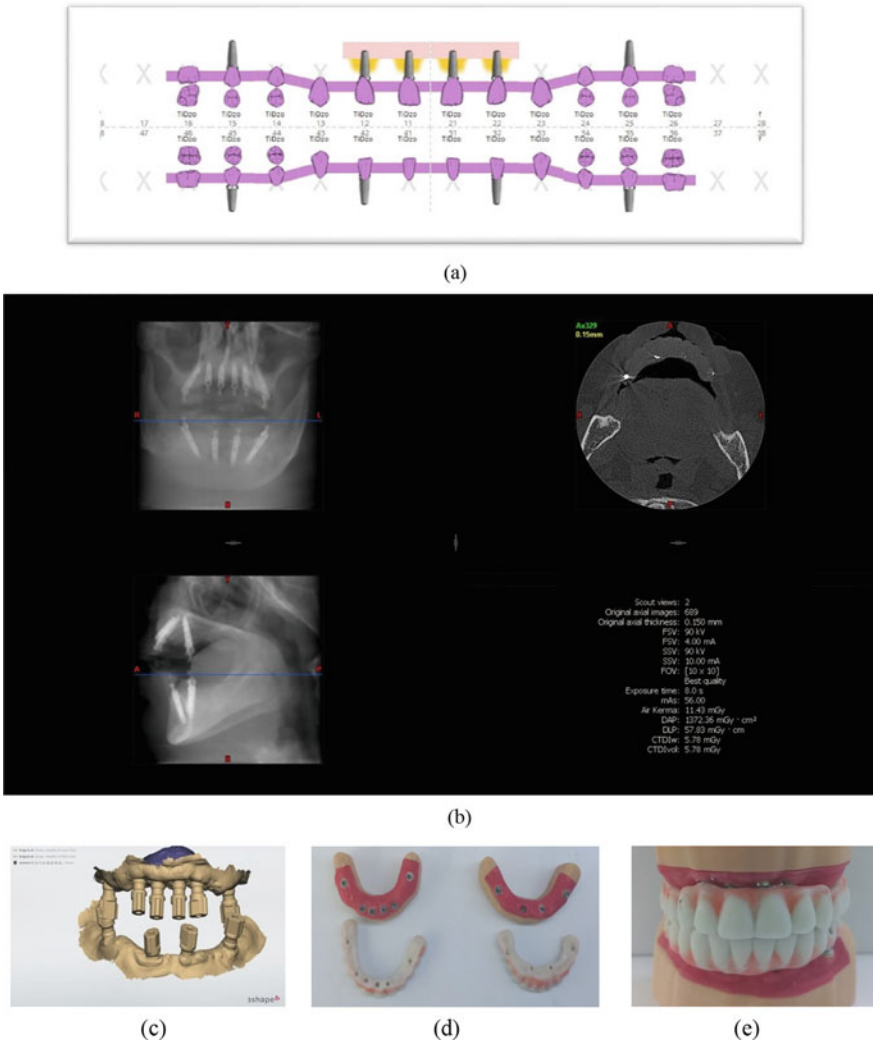


Fig. 2 Clinical case 2: restoration of the dental jaws of a woman. **a** Dental status of the patient, showing position of titanium (Ti6Al4V) implants. **b** Computed tomography (CT) image with placed implants. **c** Digital impressions of the upper and lower jaw obtained after intraoral scanning. **d** 3D printed working models with laboratory analysis and soft gingiva and PMM prototypes. **e** Shows a sequence of photographs of the complete recovery of a female patient. In sequence, real photos of the problem, treatment strategy, full recovery, and final prototype version.3D printed sample prototypes for a patient in a bite

5 Conclusion

The research done covers file formats and digital data transfer for dental needs. Up-to-date software applications with their working file extensions compatible with additive engines are theoretically presented. Two real clinical cases of fully completed dental structures of a man and a woman are presented. In the work process, modern almost automated technological implementations are applied, ensuring maximum quality of the finished dental structures, which are fully developed with the help of all present technologies. This ensures patients which receive the best possible care. This research is presented in detail that would be useful to dental health professionals, patients, and all government stakeholders.

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Local Communities Information Development Based on Functioning of National Nature Parks

Alina Yakymchuk, Taras Mykytyn, and Mykola Shershun

Abstract National parks are a driving force for the development of territorial communities, as they are an economic tool for the functioning of tourism, recreation, educational activities, etc. Therefore, today the global nature of environmental problems, which partially allow national parks to be solved in accordance with the sustainable development concept, must be implemented with the help of information technologies. The backwardness of national parks in informational development inhibits the achievement of sustainable development. There should be a reasonable combination of safe technologies with the preservation of the environment and biodiversity of national parks, a competent economic tireless policy regarding tourist activities. Today, the national park is not only a nature conservation, cultural, ecological, social center, but above all, an information center. This new role requires the improvement of information activities both in the national parks themselves and in territorial communities and the search for new ways of cooperation between the authorities and nature.

Keywords Information development · National parks · Territorial community · Economy · Sustainable development

A. Yakymchuk (✉)
University of Information Technology and Management in Rzeszow, Sucharskiego, 2, 35225 Rzeszow, Poland
e-mail: ayakymchuk@wsiz.edu.pl; alinayakim@ukr.net

Lesya Ukrainka Volyn National University, Pr. Voli, 13, Lutsk 43025, Ukraine

T. Mykytyn
Rivne State Humanity University, Stepana Bandery Str., 12, Rivne 33028, Ukraine
e-mail: tapac_m@ukr.net

M. Shershun
Institute of Environmental Management and Agroecology of the Ukraine's National Academy of Agrarian Sciences, Metrological Str., 12, Kyiv 03143, Ukraine
e-mail: shershun_mh@ukr.net

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1 Introduction

National parks in the world create a positive image of territorial communities and should become part of a single information network for their development. Many European countries have successfully implemented a policy of sustainable environmental development, in which biodiversity and natural resources are a pillar of sustainable development, both social and economic. At the same time, an important part is occupied by information resources and information technologies, since the so-called information society is being built. The rational use of resources of nature and their protection for the benefit of current and future generations is the basis of the environmental state policy of any civilized country in the world.

For example, significant progress has been made in Poland in sustainable development sphere, improvement of the quality of life and population health condition, effective protection of biodiversity and natural resources, which is the result of the environmental protection financing system operating in this country [1–4]. Such a financing system was flexibly adapted to new challenges and has been based on a combination of domestic and international funding sources [5]. At the same time, a national park, for example in the USA, Great Britain, France, Germany, Holland and other countries, is considered not only a nature protection institution, but also an informational one [1–3, 6–13]. In addition, in these states, there is a certain specificity of environmental protection financing, which consists in the targeted, strictly defined funds' spending from fees and penalties for the environment usage in the field of sustainable development. The "polluter pays" principle in Poland has been implemented since the political transformation beginning, and the funds received in this way are directed to projects that reduce environmental pollution and preserve national parks [6, 7, 9, 14]. Also, there play a fundamental role different environmental funds, both regional (local) and national, in the distribution of foreign funds intended for environmental protection. The system of funds supports the implementation of the environmental policy of the Republic of Poland. It is a financial and organizational tool of the Minister of the Environment [15–17]. Such positive achievements in the field of nature conservation are a positive example for modern Ukraine, which is losing biodiversity through the war, explosions, lack of funding, deforestation, and biodiversity. That is why information resources are an important tool in strengthening the system of national parks, developing external communication, and seeking dialogue between territorial communities and the administration of the national park.

The article defines the strategies of advanced information development of national parks and territorial communities, investigates how they affect state economic development; the connection between the implementation of information technologies and the effectiveness of national parks' nature conservation is determined; the prospects of the informational growth of the national parks of Ukraine in the conditions of war in accordance with the directives of the European Union are determined.

2 Methodology

Theoretical and methodological basis of this study has been an information and economic theory fundamental provisions. In this research were applied some general scientific methods as systematization—to analyze information and economic condition of territorial communities of Ukraine and developed countries; method cause and consequences—to investigate the influence of the war and economic crisis on national parks' condition in Ukraine; strategic method—development of the foundations for building an information communication strategy between the territorial community and the national natural park for effective information circulation, profit maximization, and achievement of sustainable development goals. The following special methods were applied as dialectical method—studying the relationship between the influence of the development of territorial communities and their information development and smart technologies in the functioning of national natural parks; costs and benefits analysis—for economic efficiency estimation of implementation of best information technologies in optimization of activity on national parks in the world. The basis of the methodology of this article was the works of outstanding nature protection scientists. Authors A. Babczuk, Z. Buryk, M. Colchester, J. Coppell, R. Ciborowski, J. Dedrick, M. Kachniarz, I. Skrodzka, V. Gurbaxani, and K. Kraemer express a clear position that information technologies in the activities of national natural parks allow to accelerate the economic development of the territories where they are located, fill the local budget, and develop tourism, transport infrastructure, and recreation [2, 6–8, 18, 19]. All this indicates the need to introduce smart technologies into the economic activity of parks. However, another position has been expressed by a group of scientists, for example, B. Charnay, S. Doney, I. Fung, F. Forget, J. John, K. Kasprzak, E. Kalbarczyk, R. Kalbarczyk, P. Krajewski, K. Królikowska, O. Korkuna, E. Kozieł, O. Kulyk, K. Lindsay, J. Leconte, B. Raszka, A. Pottier, R. Wordsworth, who emphasize another, in their opinion, more important problem—there is a conflict between human and nature, the result of which is climate change, ecologically exhausting tourism and greenhouse gas emissions [3, 9–13, 20, 21]. These scientists suggest creating a system of awareness about national parks and the actions of local communities and focusing more attention on taking into account the local residents interests. Such social conflicts in national parks can be partially resolved on the basis of informational development of communities.

3 Results and Discussion

In recent years, information technologies have been rapidly developing in all areas of the economy. Such technologies have a positive effect on the labor productivity growth; they are a multiplier of economic growth and significantly improve people's quality of life. The development of national parks is impossible without the support of the territorial community within which they are located. Often, one park can be

located within several communities. That is why supporting Community Driven Park Development (CDPD) is to facilitate the information flow between all groups in any community, to facilitate the flow of funds into the local community, and the development of tourism and recreation. Well-designed long-term information and communication (IEC) strategies can help reduce information asymmetry between all stakeholders (local government, national park's administration, community). Usually, the lack of information becomes an obstacle and limitation of the ability of territorial communities to participate in the development of the national park. Communication strategies are critical to improving the effectiveness of local territorial communities and ensuring transparency and accountability in all aspects of their activities. To facilitate access to national park information can be used a variety of media, from posters and illustrated guides to newspapers, role-playing games and public radio, mobile applications. Today, it is information communication that is a powerful tool for mobilizing the interests of territorial communities and their communities in preserving the biodiversity of national parks and providing them with the information, knowledge, and opportunities necessary for active participation in the development process. The strategy clearly defines in the minds of stakeholders their respective roles and responsibilities. In particular, in the context of community-oriented development, information communication plays a key role in community empowerment. Such a strategy can also take into account the interests of the poor and vulnerable sections of the population, who are otherwise deprived of the opportunity to be heard [22].

Thus, communication strategies for the development of territorial communities are aimed at:

- Increasing the efficiency of management of national parks, attracting grant programs and projects;
- Facilitating the education of the local population, training and behavioral changes related to the functioning of the national park, its economic opportunities and benefits for the population;
- Promote trust relations between all interested parties—the territorial community, the national park management body and local residents.

The potential for planning the development of the territorial community based on the sustainable tourism, recreation in the national park, the creation of additional infrastructure and amenities [23–25]. In the world, national parks have been using information technologies for a long time. The use of modern technical means—remote surveillance cameras is no longer uncommon. For example, visitors can see brown bears in the wild at Alaska's Katmai National Park by standing on a platform and watching the bears catch fish from the Brooks River, or by helicopter to watch them feast on shellfish at Hello Bay. In order to remotely and safely observe bear behavior in the wild, visitors can use several cameras that broadcast footage live. An equipped underwater river camera has also been implemented, capable of showing bears paddling inspiredly in pursuit of salmon. It is worth noting that Katmai is not the only park that has a camera for observing wildlife. The Kelp Cam of the Channel Islands National Park captures fish, anemones, and sea lions [26].

The Smart Parks network is very popular in the activities of national parks in Europe. The first in Europe equipped with such a system is Zuid-Kennemerland Dutch National Park. The park administration introduced the use of intelligent sensor technology, which expanded its capabilities to collect information about the behavior of large pastures. This information is useful in complex issues of park management and contributes to establishing a stable balance between the load on natural complexes, pastures and recreation in them. The use of sensors in the Smart Parks network, which are more cost-effective and energy-efficient compared to GPS collars, has increased the ability to monitor more animals for longer periods of time. This shows that the technology can now be developed even better and ultimately contribute to the protection of wildlife around the world. Such experience is incredibly relevant in Ukraine, where there is a war and the loss of biodiversity is colossal due to active hostilities. Such a system will allow accounting for the loss of biodiversity, and perhaps, in the future, it will be possible to prevent such loss of flora and fauna [1].

American parks are extremely advanced in terms of information. A project to mark plants with QR codes has been implemented here so that visitors can discover additional information. Technology has created many new opportunities and breakthroughs in the activities of national parks. For example, the NPS and Google have joined forces to offer visitors an online look at the natural beauty, biodiversity, and historic and cultural highlights of more than three dozen national parks. Visitors to the Grand Canyon can use their cell phones to listen to rangers talk about various natural sites along the South Rim, from Native American history to rare plants and animals, even geology and air quality. National Parks' adoption of podcasts is a new trend in information technology, ideal for on-the-go listening when there's no radio or cell phone coverage on country roads. For example, the Grand Canyon podcasts about wildlife and geology of the park, the Bryce Canyon prairie dogs' podcasts, and the Mammoth Cave podcast about the park's ubiquitous bats are in demand [26].

Table 1 includes information about data standards widely used by US national parks, data tools such as APIs, basic types of tabular and spatial data.

There are different datasets and tools in nature park's activity. Main of them are data processing tools such as geospatial data, APIs, information about data standards such as the IRMA Data Store. They allow you to use the advanced search option according to the necessary criteria and thereby speed up the search for the necessary information. Geological maps, as geospatial and tabular data products, include bedrock maps, special purpose surface maps, such as geological hazard maps or geomorphological maps. Data for mapping and general GIS analysis (National Park Service unit boundaries) not adapted for engineering purposes. NPS ArcGIS Online—presents combined spatial content, applications, and maps. Also, GIS, cartography and NPS mapping is the starting point for NPS geospatial resources. Modern national parks use such geospatial and tabular data as vegetation maps, which are the result of a standardized inventory of flora species in more than 270 US parks. Landscape Dynamics Map Viewer measured systems—include population density, road density, and others. NPMap is also an important web mapping toolkit available to NPS staff and partners. It includes a set of basemaps and links to the NPS symbol library. Also, parks have collecting and recording data on air

Table 1 Modern data sets and information tools of national natural parks of USA

Geospatial data service unit boundaries	Tabular and spatial data sets	Rest services and APIs	Data standards
NPS GIS, cartography, and mapping	Air quality and ozone data	GIS data services directory	NPS core spatial data standard
NPS ArcGIS online	Hydrographic and impairment statistics	IRMA services	NPS cultural resources—spatial data transfer standards
Vegetation maps	Water quality and quantity data	IRMA portal	NPS building spatial data standard
Geology maps	Water quality portal	Water quality portal web services	Heritage documentation standards
NPS geodiversity atlas	Photogrammetry		NPS trail spatial data standard
Landscape dynamics map viewer	Natural resource inventory and monitoring data		Minimum database implementation standards
NPMap	Visitor spending effects	NPS APIs	Core database standard

Source Compiled according to the data [14]

quality and ozone, analyze access to information on exceedances, live and historical data, data downloads. Air quality in the national park is subject of monitoring using available data on air quality status and trends, including ozone, visibility, nitrogen and sulfur, and particulate matter. The current Water Quality Portal—managed by the National Water Quality Monitoring Council, which inventories data on natural resources—has 32 networks across the country. Estimating the impact of visitors on costs is a significant economic contribution of national parks at the national, state, and park levels. Data sets IRMA services, for applications hosted on the IRMA portal, include data warehouse, park units, taxonomy, NPS species, park statistics, landscape dynamics, and hydrographic disturbances. The main database standards are Natural Resource Inventory and Monitoring Standards which is a guide for developing databases for the storage and management of biodiversity and natural resource inventory and monitoring data in national parks. Minimum database implementation standards are the baseline standards for databases developed by inventory and monitoring networks. NPS Trail Spatial Data Standard is a Trail Centerline Data Model and Implementation Document, Cultural Resources, NPS as Spatial Data Transfer Standards, addresses the spatial representation of cultural resources, data accuracy, and feature-level metadata [14, 26].

The use of smart technology allows national parks to connect with a technology-oriented younger generation. Such parks are able to provide places for communication, physical exercise, and spending time in the fresh air. For many visitors, free Wi-Fi and charging stations are of great importance, which is an incentive for people

to go outside their homes. A technical upgrade of each park can attract special interest groups, such as the elderly or families with small children, to visit the park. Many parks use information technology to visualize the various facilities they care for, such as playgrounds, office buildings, picnic areas and fountains, and to assign and update work tasks. Using the app helps employees get tasks done, so the app helps increase efficiency and reduce operational costs. Local authorities are interested in, and often even finance, such innovations in national natural parks, because with the help of such a system, it is possible to improve work management and improve the system of tracking and monitoring flora and fauna objects. In addition, information technology helps save money, for example, by allowing early detection of water leaks or power outages, tracking equipment and mechanisms, and scheduling garbage collection based on needs.

4 Conclusions

The information campaign should be aimed at the development goals of the national parks and take into account the needs of the community. A large-scale information campaign can be effective in raising public awareness of the biodiversity and resources of national parks and the corresponding debate on how to properly manage and effectively conserve them. Undoubtedly, there is an obvious impact of the information campaign of the national park on trust in the authorities at various levels, as well as on reducing the loss of biodiversity, of fauna and flora valuable species.

In the resource-extracting areas and territories, there is the first level of tension in the relationship between the authorities and the national park; there are even certain conflicts between them, which are localized within specific territories. All this requires an effective information policy with the use of advanced information technologies. Appropriate management of local population expectations and implementation of inclusive management processes as resources are explored can be a key factor in avoiding local conflict.

For the effective territorial communities development, the introduction of information technologies is necessary, including the preservation of biodiversity in national natural parks. There are many information technologies and resources that have good proven themselves: smart information technologies with tagging plants with QR codes, Smart Parks network, NPS GIS, cartography, and mapping, hydrographic and impairment statistics, national parks' adoption of podcasts, visitor spending effects, water quality portal web, and so on. All of them allow to strengthen interaction and create an information platform for effective cooperation between local authorities, the national park's administration, and the local population (people). Such interaction and mutual understanding are necessary for the effective preservation of nature and biodiversity for current and future generations. Such an information policy should be systematic and have a clear sequence of actions and algorithms. First of all, well informed communities about the content of each outreach program create the conditions, as well as their roles and responsibilities. Mass communication campaigns,

which ensure wide public distribution of this material, help transfer control into the hands of local communities, clients, and local elites and are designed to eliminate the risks of manipulation by politicians. National park information campaigns must use simple and innovative means that best fit the culture and context of the community to be effective. An important component of any national park's information company is to provide community members with comprehensive, reliable information and a body of knowledge that will contribute to the understanding of the need for nature conservation, to improve and build relationships between various public community groups, both government and markets, and allow them to learn from the experience of other public organizations.

Modern national parks require support and technical information, including accounting and management skills, to make decisions and implement activities. It is important to ensure that communication between the territorial community, national park, and the local population is a continuous process that not only provides information but also creates accountability and transparency. This article was published under the Lane's Kirkland Research Program 2022/2023.

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Virtual Sensor Data Imputation Using Generative Adversarial Imputation Nets and Pearson Correlation

Nguyen Thanh Quan, Nguyen Quang Hung, and Nam Thoai

Abstract The term Internet of things (IoT) was introduced into every areas of life; more and more devices are connecting and operating that rely on information collected by IoT sensors. As a matter of fact, sensor failures may either kill the operation of a system or make it malfunctioning because of the interrupted flow of data. Consequently, missing data is a pervasive problem with real-world datasets. Besides that, machine learning methods have recently been applied in several applications and achieved state-of-the art results. Therefore, this work leverages machine learning methods to resolve the missing-data problem. This paper proposes a novel method named PGAIN Virtual Sensor (PGAIN-VS) based on virtual sensors to impute missing data. Remarkably, PGAIN-VS uses the Pearson metric to evaluate the correlations of data among data-collected devices to remove noise and bias potentially causing inaccurate data imputation. PGAIN-VS can produce good estimates for the missing values, so it is absolutely capable of replacing physical sensors during failure time. We evaluated our method on several datasets and compared it to other recent works. Furthermore, the experiments showed that our approach achieved better performance up to 20% in the considered datasets with different metrics.

Keywords IoT · Virtual sensor · ML · Missing data imputation

N. T. Quan (✉) · N. Q. Hung · N. Thoai
High Performance Computing Laboratory, Faculty of Computer Science and Engineering, Advanced Institute of Interdisciplinary Science and Technology, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam
e-mail: ntquan.sdh20@hcmut.edu.vn

Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc District, Ho Chi Minh City, Vietnam

N. Q. Hung
e-mail: nqhung@hcmut.edu.vn

N. Thoai
e-mail: namthoai@hcmut.edu.vn

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1 Introduction

The Internet of things is one of the most important and promising technological topics today. Some market researchers estimate that there are more than 20 billion connected devices and counting, the number will be 73 billion IoT devices by 2025 according to IHS Markit [1]. IoT helps people live and work smarter, as well as gain complete control over their lives. IoT is essential to business when it provides businesses with a real-time look into how their systems really work, enable companies to automate processes, and reduce labor costs. Different applications require different sensors to gather data from the environment. Therefore, any problem which occurs with sensors can cause missing data and surely impact the operation of such applications.

This paper proposes a novel approach based on the generative adversarial networks (GAN) [2] to create virtual sensors. Fundamentally, our proposed method is inspired by GAIN [3], which is also based on the GAN architecture. However, unlike the GAIN method, our proposal leverages the statistical properties of collected data from neighbors' physical sources to enhance the performance by calculating the Pearson correlation to select the most correlative data to join virtual sensor creation.

In general, this work brings two main contributions:

- Practical contribution: The approach is considered as an essential data pre-processing method as it assures the operation of applications/systems relying complete data.
- Academic contribution: The approach improves the accuracy and reliability of GAIN in imputing missing data.

There are six sections in this paper. The related work is discussed in Sect. 2. Section 3 presents the problem description and built components of PGAIN-VS. Section 4 describes the algorithm and the configuration of PGAIN-VS. Additionally, we analyze and discuss further the experimental results in Sect. 5. Section 6 will discuss drawbacks of our work and propose some future directions to improve them.

2 Related Work

Virtual sensor has been introduced and applied in different contexts. Ilyas et al. [4] introduced virtual sensor as an independent estimator trained through machine learning algorithms, namely artificial neural network (ANN), linear regression (LR), and support vector regression (SVR) using historical data and data from neighboring sensors. Similarly, the authors in [5] also created in the same manner to keep an indoor tracking system operating in case one physical sensor stops working. Vitale et al. [6] proposed a way in which a virtual sensor was developed by using other available parameters obtained to produce completely new data. In another work [7], a virtual sensor was considered as a mediator between applications and communication interfaces. Furthermore, the relations between data sources can be mined to deduce

new knowledge. According to the authors [8], there are three available methods: a white box model, for example, [9], physical relations were defined as mathematical equations because all relations were expected to be known. A black box model [6], for instance, neural networks if the self-learned model was purely based on the data. A gray model [8] if correlations between various data are assumed. Nevertheless, the true inner relationship of data was not considered in those approaches when doing imputation. The authors [10] added label distribution on top of the standard GAIN, called conditional generative adversarial imputation network (CGAIN) which can be seen as a virtual sensor to make the estimation better, but the solution was more likely to work with classification problems only. A virtual sensor mentioned in [11] was created with the purpose of solving an optimization problem. The authors in [11] wanted to reduce the number of physical sensors used in an indoor environment by determining the best subset of sensors that are worth keeping in a given room and replace the unnecessary ones by virtual sensors. According to the work in [12], virtual sensors can be a candidate to offer a solution to reduce the criticality of high-risk failures, to increase detection ability. The authors of the research in [13] wanted to use virtual sensors in the healthcare domain and used them to handle additional responsibilities that physical sensor devices cannot.

3 Problem Description

Consider the space where sensors are placed establishes a network with a d-dimensional space $\mathbb{S} = S_1 \times \cdots \times S_d$ where S_i is the dimension of sensor $\mathcal{S}_i$. Let $\mathbf{X} = (X_1, \ldots, X_d)$ is an observed variable of sensor $\mathcal{S}$ (regardless of being continuous or binary) taking values in $\mathbb{S}$, whose distribution will be denoted $P(\mathbf{X})$. According to GAIN architecture, there is $\mathbf{M} = (M_1, \ldots, M_d)$ which is a random variable taking values in $\{0, 1\}^d$ derived from the $\mathbf{X}$. We will name $\mathbf{X}$ the data vector observed by sensor $\mathcal{S}$, and $\mathbf{M}$ the mask vector.

With each $i \in \{1, \ldots, d\}$, a new space $\tilde{\mathbb{S}}_i = \mathbb{S}_i \cup \{*\}$ is established, where $*$ is simply a point not in any $\mathbb{S}_i$, representing a value at the time sensor $\mathcal{S}$ has problems and cannot observe data. Let $\tilde{\mathbb{S}} = \tilde{\mathbb{S}}_1 \times \cdots \times \tilde{\mathbb{S}}_d$. A new random variable $\tilde{\mathbf{X}} = (\tilde{X}_1, \ldots, \tilde{X}_d) \in \tilde{\mathbb{S}}$ is also defined in the following way Eq. (1):

$$\tilde{X}_i = \begin{cases} X_i & \text{if } M_i = 1 \\ * & \text{otherwise} \end{cases} \tag{1}$$

in order that $\mathbf{M}$ expresses which components of X are observed by sensor $\mathcal{S}$. $\mathbf{M}$ can be easily recovered from $\tilde{\mathbf{X}}$ (Fig. 1).

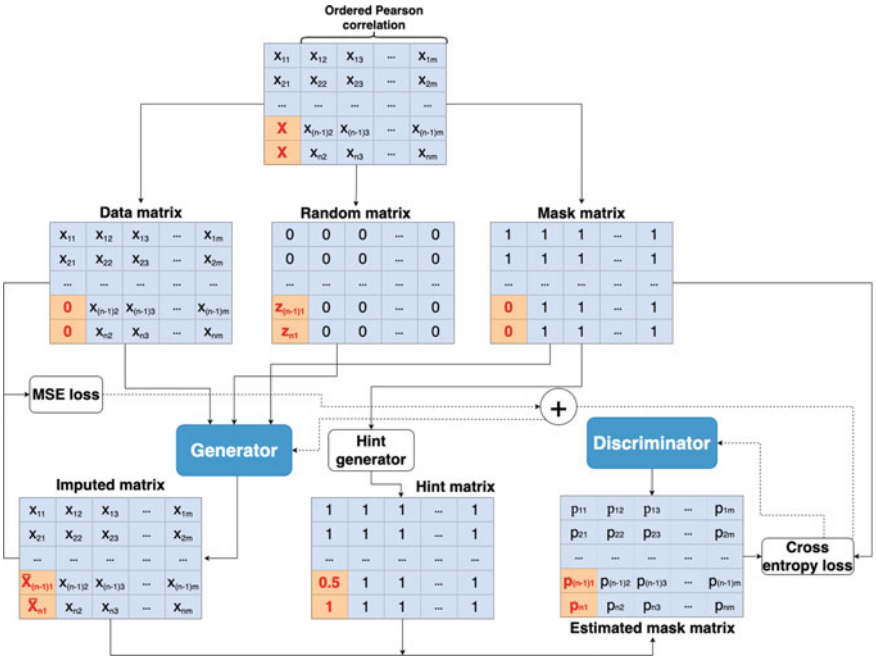

Fig. 1 The general architecture of PGAIN-VS

3.1 Generator in PGAIN-VS

The generator of PGAIN-VS, G, takes the three variables $\tilde{\mathbf{X}}$ with Pearson correlation **Pc** arrangement, **M**, noise **Z** as inputs and produces the predicted $\bar{\mathbf{X}}$.

Basically, the random variables are defined $\bar{\mathbf{X}}$, $\hat{\mathbf{X}}$ as Eqs. (2) and (3):

$$\bar{\mathbf{X}} = G(\tilde{\mathbf{X}}|\mathbf{Pc}, \mathbf{M}, (1 - \mathbf{M}) \odot \mathbf{Z}) \tag{2}$$

$$\hat{\mathbf{X}} = \mathbf{M} \odot \tilde{\mathbf{X}} + (1 - \mathbf{M}) \odot \bar{\mathbf{X}} \tag{3}$$

where $\odot$ is the element-wise multiplication. $\bar{\mathbf{X}}$ is the imputed values vector which the data points should have been observed by the virtual sensor $\mathcal{S}$. $\hat{\mathbf{X}}$ is the complete data vector after imputation of the faulty sensor that includes the historical data extracted from the partial observation $\tilde{\mathbf{X}}$ and replacing $*$ with the corresponding value of $\bar{\mathbf{X}}$.

Based on GAIN, the noise passed into the generator is $(1 - \mathbf{M}) \odot \mathbf{Z}$, because the target distribution is $P(\mathbf{X}|\tilde{\mathbf{X}})$.

3.2 Discriminator in PGAIN-VS

As the traditional GAN architecture, the discriminator, D, will be considered as an adversary to train G. Similar to GAIN, D of PGAIN-VS tries to distinguish which components are observed by sensor or predicted by PGAIN-VS.

Generally, the discriminator can be described by the function D: $\mathbb{X} \rightarrow [0, 1]^d$ with the ith component of $D(\hat{\mathbf{X}})$ corresponding to the probability that ith value of $\hat{\mathbf{X}}$ is observed normally by sensor $\mathcal{S}$.

3.3 Our Proposal: Pearson Arrangement for PGAIN-VS

In order for PGAIN-VS to be able to learn the trending distribution of dataset, we arrange the most correlative sensors being adjacent to the missing data sensor. The higher correlative the sensor is, the more adjacent it is to the faulty sensor based on Pearson. The sensor network space will be rearranged as follow Eq. (4):

$$\mathbf{X} = (X_{fs}, X_{p1}, X_{p2}, \ldots, X_{pd}) \tag{4}$$

where X_{fs} is the variable observed/unobserved of the missing data sensor, X_{p-ith} are respectively from the most correlative sensor to the worst one.

By calculating the correlation, "noise" or "bias" can be ignored in the process of making data imputation that improves the performance of algorithms like ANN [14] and support vector machine [15].

3.4 Hint

There is no difference between hint used in this paper and the one defined by Yoon et al. [3]. The hint is described as a random variable H which gets its values in a hint space $\mathbb{H}$. D is supported by the hint vector since the hint tells D some values imputed by PGAIN-VS and some observed by real elements which allows the D to make decision for other values.

3.5 Objective

D is trained with the expectation to maximize the probability of correctly predicting M. On the contrary, G is trained with the hope that it can minimize the probability of D accurately predicting M. The general objective function and loss function of our solution are Eqs. (5) and (6):

$$\min_{G}\max_{D}\mathcal{L}(D, G) \tag{5}$$

$$\begin{aligned}\mathcal{L}(D, G) = \mathbb{E}_{\mathbf{X}|\hat{\mathbf{Pc}},\mathbf{M},\mathbf{H}}[\mathbf{M}^T \log D((\mathbf{X}|\hat{\mathbf{Pc}}, \mathbf{H}) \\ +(\mathbf{1} - \mathbf{M})^T \log(1 - D(\mathbf{X}|\hat{\mathbf{Pc}}, \mathbf{H})))]\end{aligned} \tag{6}$$

4 PGAIN-VS Algorithm

Similar to any other models inspired by GAN, PGAIN-VS also trains D and G. G and D are modeled as fully connected neural networks.

We first optimized D with a fixed G using mini-batches of (128 samples) data, 10,000 iterations by default. At each loop, n independent samples of $\mathbf{Z}$, $\mathbf{B}$, $\mathbf{M}$ with Pearson correlation arrangement included are drawn to compute the imputed data $\tilde{\mathbf{X}}$ according to Eqs. (2) and (3). After that, the hint vector H proposed in [3] is produced. Then, the estimated mask $\hat{\mathbf{M}}$ calculated by $D(\hat{\mathbf{X}}|\mathbf{Pc}, \mathbf{H})$ followed by the optimization of D.

The next step is to update G by preserving the newly trained D fixed. Repeatedly, n independent samples of $\mathbf{Z}$, $\mathbf{B}$, and $\mathbf{M}$ are drawn for every mini-batch to compute $\mathbf{H}$ and update G until training loss converges.

5 Experiments

To evaluate PGAIN-VS, we conducted experiments on solar power (21 sensors) [4] [16], traffic (207 detectors) [17] and Raspihat temperature (12 sensors) [11] datasets, which were also widely used in other works. Then, we compared our approach with the original GAIN model on 20% missing data.

Table 1 show more about the characteristics of the faulty sensor having missing data used in this work.

5.1 Performance of the Proposed PGAIN-VS

The performance of PGAIN-VS approach was given in Table 2. We reported the root mean square error (RMSE); actually, it is normalized root mean square error (NRMSE), mean absolute error (MAE), the total missing points and the number of predictors which were the physical sensors having the correlative score passing the defined threshold on each dataset.

Table 1 Characteristics of the faulty sensor's dataset

Parameters	Solar	Raspihat	Traffic
Samples	24,000	769,658	34,272
Mean	9255	30.9	60
STD	13,978	1.3	16
Min	0	14.3	0
Max	83,988	38	70
25%	0	30.3	63
50%	2669	30.8	65
75%	12,550	31.5	66

Table 2 PGAIN-VS performance of 20% missing data

Dataset	Model	RMSE	MAE	#Missing points	#Predictors
Solar	GAIN	0.058 ± 0.002	805 ± 68	4597	20
	PGAIN	$\mathbf{0.057 \pm 0.002}$	$\mathbf{769 \pm 27}$	4594	18
Traffic	GAIN	0.041 ± 0.001	1.80 ± 0.04	6855	50
	PGAIN	$\mathbf{0.041 \pm 0.001}$	$\mathbf{1.76 \pm 0.05}$	6855	42
Raspihat	GAIN	0.046 ± 0.02	0.37 ± 0.12	1667	11
	PGAIN	$\mathbf{0.037 \pm 0.002}$	$\mathbf{0.31 \pm 0.01}$	1667	10

Bold indicated highlight the results of PGAIN-VS are really better the baseline GAIN in terms of RMSE and MAE on all the 3 datasets

Table 2 shows that the RMSE and MAE of applying GAIN for the available datasets where the missing data proportion is 20%. Our proposed PGAIN-VS approach provided ideal performance compared to purely applying GAIN only on the datasets. All the experiments were performed with fivefold cross validation in order to evade model over-fitting or biases.

As mentioned, we made a comparison between our proposed approach with the state-of-the-art GAIN approach [3] which had been publicly published on GitHub[1] code of GAIN. Our PGAIN-VS[2] consistently outperforms GAIN on the selected datasets and was robust 20% missing data. The virtual sensor provided a lower RMSE and MAE, so the imputed data can surely fill the missing data during the time the physical sensors stops working.

The different number of physical sensors (predictors) taking part in predicting missing data is mentioned in Table 2 also shows that PGAIN-VS completely inherits the robustness and sustainability of GAIN. It still preserves the performance with various feature dimensions.

To be more precise, PGAIN-VS consistently scored (normalized) RMSE below 0.1 which was deemed to be ideal. There was up to **23%** of RMSE improvement

[1] https://github.com/jsyoon0823/GAIN.

[2] https://github.com/thanhquanse/PGAIN-VS-SRM.

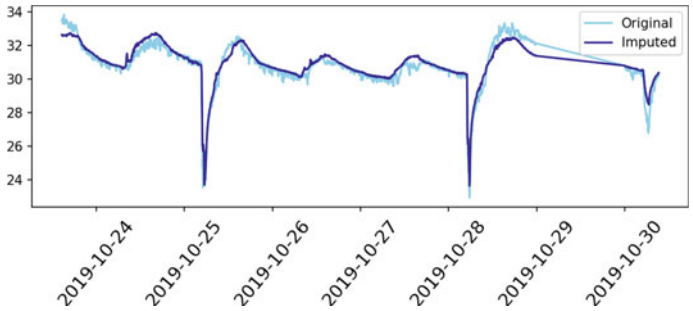

Fig. 2 PGAIN-VS performance on Raspihat dataset—20% missing data

compared to GAIN for the Raspihat collection, whereas in terms of the two remaining datasets, the percentage of improvement was lower. Similarly, MAE score was also around **20%** better with Raspihat and around under **10%** with the rest. However, all the results still looked good and comparable with GAIN. The different performance can be understood and explained through the characteristics of the three datasets. The correlation among features of the Raspihat data was high because sensors were placed in a spacious room to observe information, so the trending variability of data was not much distant between positions. On the contrary, sensors used in solar and traffic datasets were installed outside in a geographic area; hence, the distance from one device to another was quite far, and this definitely impacted the similarity of the observed data.

5.2 PGAIN-VS Prediction Accuracy

Figures 2, 3 and 4 show the images of imputed and actual data. Obviously, the distance between predicted and observed data is not too large. The imputed ones still assure the overall value distribution of the datasets on 20% missing data. Thus, the virtual sensor is potentially able to produce data more accurately. By eliminating the least correlative sensors based on Pearson correlation, it removes bias in data and helps PGAIN-VS be able to learn the trending variability of a dataset, then makes better predictions. The experimented results also reveal a potential benefit for businesses when the number of sensors installed in reality can be smaller, so the deployment and management costs are surely lower, and the productivity is higher.

As mentioned, our approach is, however, expected to be working with environmental sensor data, so it requires that the data input must be satisfied with Pearson as Pearson is most appropriate for measurements taken from an interval scale. In contrast, the accuracy can be reduced.

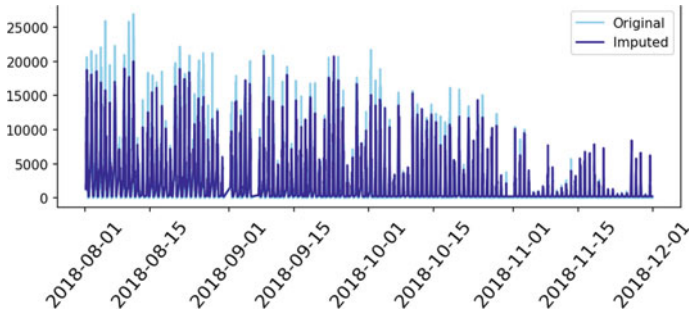

Fig. 3 PGAIN-VS performance on solar power dataset—20% missing data

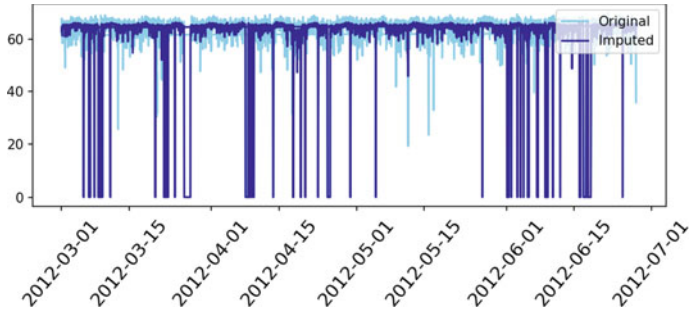

Fig. 4 PGAIN-VS performance on traffic dataset—20% missing data

6 Conclusions and Future Work

In this work, a novel virtual sensor approach, PGAIN-VS, is able to work with the missing data problem basing on using historical data of the faulty sensor and data correlation calculation of data source nearby. Various experiments with real-world datasets have been done to prove two beneficial possibilities about ensuring the accurate operation of the applications, the systems depending on complete data and improving the imputation accuracy of GAIN.

Future work will investigate how to apply PGAIN-VS into physical sensor optimization problem to reduce the number of physical ones to collect information. Consequently, the cost of sensor deployment and management can be optimized significantly. Time series is a promising factor including temporal information [18], data compression techniques [19] for optimal sensor placement [20, 21] problem should be considered.

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A Comparative Study of Dimensionality Reduction Techniques for Satellite Image Analysis

Timothy James Hardman and Jules-Raymond Tapamo

Abstract An investigation into the use of dimensionality reduction on hyperspectral images and its effect on further classification is presented. The use of 5 different dimensionality reduction techniques along side 4 different classifiers has been done. The effect of the dimensionality reduction on the two datasets chosen, ROSIS City of Pavia and ROSIS University of Pavia, showed that there is merit to using dimensionality reduction on these datasets, and the results generated are comparable to those found in literature. Further investigation is also conducted on the use of a multiple classifier system, and the results generated by this method are better than any individual classifier on its own.

Keywords Dimensionality reduction · Ensemble · Hyperspectral images · Pseudocode · Satellite images

1 Introduction

High dimensionality datasets are not being exploited to their full potential without dimensionality reduction (DR) and as such investigations into using the correct DR technique as well as the correct classifier have a wide scope. High dimentionality, often referred to as the Hughes phenomena [8], causes the classifiers to be overloaded with information, a lot of which is not useful for classification purposes. DR methods have proven to be useful techniques in resolving this problem, but their performances are dependant on the nature of the data and the classifier used for the task [2]. Thus, the final result can often be worsened by a subjective decision about which DR technique and classifier to use. Thus, it is required that DR techniques be implemented correctly when using a satellite imaging classification model. A way to solve this problem is

T. J. Hardman (✉) · J.-R. Tapamo
School of Engineering, University of KwaZulu-Natal, Durban 4041, South Africa
e-mail: 217002164@stu.ukzn.ac.za

J.-R. Tapamo
e-mail: tapamoj@ukzn.ac.za

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to include a multiple classifier system (MCS), otherwise known as an ensemble classifier [1, 4], which handles the strengths and weaknesses of the many classifiers and DR techniques, in an purposeful way.

This paper involves the investigation of two datasets, the Pavia University and Pavia City Centre. Four classifiers: linear discriminant classifier (LDC), logistic regression classifier (LRC), Naive Bayes classifier (NBC), and minimum distance classifier (MDC) along side 5 DR techniques being, independent component analysis (ICA), principle component analysis (PCA), minimum noise fraction (MNF), discrete wavelet transformation (DWT), and kernel principle component analysis (KPCA), were chosen. For the MCS combination schemes, 6 combinations were tested, namely majority voting (MV), mean rule (avg), maximum rule (max), minimum rule (min), median rule (med), and product rule (prod).

The rest of this paper is organised as follows: Section 2 discusses the background of related works about DR, classifiers for satellite imaging and MCS. Methods used are presented in Sect. 3. Experimental results and discussion are presented in Sect. 4, and Sect. 5 concludes the paper and outlines future work.

2 Background and Related Works

DR is a powerful tool used to help manage large datasets. It provides the ability to reduce the amount of data used for classification, while making sure minimal information is lost. There are many different techniques of DR, but only some of them used for spectral information processing and satellite imaging will be discussed.

The most common DR methods include PCA, KPCA, ICA, and MNF. These techniques are based on statistical transformations that project the data into new coordinate system which minimises or maximises certain aspects of the data. PCA and MNF maximise the variance in the transformed components, ICA maximises the non-Gaussianity of the transformed components, and the KPCA is an extension of the PCA where the input data points are transformed into feature space by a non-linear transformation. This allows for the KPCA to capture higher order statistics and provide better class separability over PCA [3].

DWTs are also very useful for DR as they can denoise 2 dimensional images. The DWT of a signal can be calculated by passing it through a series of low and high pass filters. The output from the high pass filter gives the DWT's detail coefficients, and the low pass filter gives the approximation coefficients [12].

DR techniques have been used in hyperspectral image (HSI) applications. Journaux et al. [9] investigated how the redundancies in HSI datasets can be removed to enable a more accurate classification of the items in the images. Damodaran et al. [3] discussed the use of a DCS that combined multiple classifiers and DR techniques simultaneously to generate a better MCS system that was previously available for HSI classification. They investigate the use of their DCS on 5 different HSI including the two that are used in this paper. Results showed that their DCS was able to

outperform typical MCS techniques as well as a SVM method and the performance of their methods were significantly influenced by the combination technique used.

3 Methods and Techniques

An explanation of how the 5 DR techniques used in the paper were implemented is provided in the form of pseudocode. The most basic DR technique used and most widely studied is PCA. PCA makes use of the maximisation of variance within the chosen components, and this is achieved using the covariance matrix which helps generate the eigenvectors and eigenvalues of all the components in the dataset. For the eigen-analysis, it needs to be stated that V is a $N \times (N-1)$ matrix with the eigenvectors as columns, and Λ is a $(N-1) \times (N-1)$ diagonal matrix with the eigenvalues. The input to the procedure is X, with f features and n data points, and the output is Y, where Y is the DR reduced data points with d features, with $d < f$. The pseudocode for PCA can be found in [14].

For KPCA, the specific algorithm used is called online KPCA which is specifically designed for large datasets and avoids having to use batches. The idea is that whenever new data is fed into the system it can update itself without having to re-explore all previously captured data [6]. This process can be seen in Algorithm 1, where X is the input to the procedure with f features and n data points, Y is the output with d features, with $d < f$, m is the model order, κ is the kernel function, ω is the direction, K_m is the m-by-m Gram matrix of the m kernel functions, α_t and β_t are vectors of n entries, and η_t is the step-size parameter.

For ICA, the method used is called FastICA, and it tries to compute the independent components by maximising the non-Gaussianity. This can be hard to compute with the use of Negentropy which has a strongly positive correlation with non-Gaussianity. An approximation for this, proposed by Hyvärinen et al. [7], can be seen in Eq. (1), where V is a standardised non-Gaussian random variable, U is a standardised Gaussian random variable and $\phi()$ is a non-quadratic function. The FastICA method rearranges this formulae and the pseudocode for it can be seen in Algorithm 2 [10], where X is the input to the procedure with f features and n data points, W is the unmixing matrix output with d features, $d < f$, w_i is the column-vector of W, and $E(\cdot)$ is the mean.

$$N(V) = E(\phi(V)) - E(\phi(U))^2 \tag{1}$$

The MNF main goal is to reduce the noise found in the spectral components. This is achieved by first applying a noise whitening process on the original dataset, which is the HSI, and then applying a PCA to the noise-whitened data. The principle components (PC) are then sorted by their signal to noise (SNR) values to determine which components to keep [13]. This process can be seen in Algorithm 3, where X is the input to the procedure with f features and n data points, Y is the output with d features, $d < f$, $\sum_K$ is the covariance matrix of X, $\sum \eta_i^2$ are the diagonal elements

Algorithm 1: Online Kernel Principle Component Analysis [6]

KPCA (X);
Input : n data points of dimension f, $X = \{x_1, x_2, \ldots, x_n\}$
Output: n data points of dimension d, $Y = \{y_1, y_2, \ldots, y_n\}$
Initialisation: $m = 1, \omega_1 = 1, K_1 = \kappa(x_1, x_1), \beta_1 = 1$;
At each instant $t \geq 2$***, upon acquisition of*** x_t***:*** ;
begin
  Compute $\kappa(x_t)$*:* $\kappa(x_t) = \left[\kappa(x_{\omega_1}, x_t) \ \ldots \ \kappa(x_{\omega_m}, x_t)\right]^T$;
  Subspace representation of $\kappa(x_t, \cdot)$*:* $\beta_t = K_m^{-1}\kappa(x_t)$;
  Compute (square) distance to subspace: $\epsilon_t^2 = \kappa(x_t, x_t) - \kappa(x_t)^T\beta_t$;
  if *the distance criterion is satisfied:* $\epsilon_t^2 \geq \nu$ **then**
    Increment the model order: $m = m + 1, \omega_m = t, \alpha_t = \left[\alpha_t^T \ 0\right]^T$;
    Update the inverse of the Gram matrix: $K_m^{-1} = \begin{bmatrix} K_{m-1}^{-1} & 0 \\ 0 & 0 \end{bmatrix} + \frac{1}{\epsilon_t^2}\begin{bmatrix} -\beta_t \\ 1 \end{bmatrix}\left[-\beta_t{}^T \ 1\right]$;
    Update the empirical kernel map $\kappa(x_t)$*:* $\kappa(x_t) = \left[\kappa(x_t)^T \ \kappa(x_t, x_t)\right]^T$;
    Update the representation of $\kappa(x_t, \cdot)$*:* $\beta_t = \left[0_{m-1}^T \ 1\right]^T$;
  end
  $\psi_t(x_t)$*:* $y_t = \alpha_t^T\kappa(x_t)$;
  Update the coefficients: $\alpha_{t+1} = \alpha_t + \eta_t y_t(\beta_t - y_t\alpha_t)$;
end

Algorithm 2: Independent Component Analysis [10]

ICA (X);
Input : n data points of dimension f, $X = \{x_1, x_2, \ldots, x_n\}$
Output: d vectors $W = \{w_1, w_2, \ldots, w_d\}$
begin
  start: *Initialisation:* $w_i = random$;
  update: *Update* w_i*:* $w_i^+ = E(\phi'({w_i}^T X))w_i - E(x\phi({w_i}^T X))$;
  Normalise w_i*:* $w_i = \frac{w_i^+}{\|w_i^+\|}$;
  if $i = 1$ **then**
    goto *check*
  end
  end *Orthogonalization of* w_i*:* $w_i^+ = w_i - \sum_{j=1}^{i-1} {w_i}^T w_j w_j$;
  Normalise w_i*:* $w_i = \frac{w_i^+}{\|w_i^+\|}$;
  check: **if** *not converged* **then**
    goto *update*
  end
  goto *start* with $i = i + 1$ until d components are extracted
end

of $\sum_K^{-1}$, P is the noise-whitening matrix, $\sum_{\text{MNF}}$ is the noise-whitened input, and U is the eigenvector of $\sum_{\text{MNF}}$.

Algorithm 3: Minimum Noise Fraction

MNF (X);
Input : n data points of dimension f, $X = \{x_1, x_2, \ldots, x_n\}$
Output: d vectors $Y = \{y_1, y_2, \ldots, y_d\}$
begin
  Subtract the mean: $\overline{X} = X - \mu$;
  Calculate the covariance matrix: $\sum_K = Cov(X)$;
  $\eta_i^2(i = 1, 2, ..., L) = diag(inv(\sum_K))$;
  Estimate the covariance matrix of the noise: $\sum_n = diag\{\frac{1}{\eta_1^2}, \frac{1}{\eta_2^2}, ..., \frac{1}{\eta_L^2}\}$;
  Calculate the noise-whitening matrix: $P = inv[sqrt(inv(diag(inv(\sum_K))))]$;
  Perform noise-whitening on the input: $\sum_{MNF} = P^T \sum_K P$;
  Calculate eigenvectors of $\sum_{MNF}$ *:* $U = eig(\sum_{MNF})$;
  MNF transformation on HSI: $Y_{MNF} = U^T P^T X$;
  Gather d principle components: $Y(1:d) = Y_{MNF}(:, :, 1:d)$;
end

DWT decomposes HSI through a Daubechies filter, with the outliers in the image being discarded and the approximate coefficients being reconstructed. The different levels of decomposition approximate the different amounts of DR of the HSI. The following technique is used to generate the decomposition of the HSI seen in Algorithm 4. Considering $W \in \mathbf{R}^{m \times m}$ is the wavelet matrix, and $\mathrm{Im} \in \mathbf{R}^{m \times m}$ is the original HSI image; given w_i, the ith row of W, the c_i, the ith column of the transformed image C can be computed as [5]

$$c_i = W \times (w_i \times \mathrm{Im}^T)^T \tag{2}$$

MCS is performed using combination rules. Equations (3)–(8) present the 6 different combination techniques adopted in this paper [11], where T, C, and J represent the total number of classifiers, total number of classes, and the class that received the largest total vote, respectively; and $d_{t,j}(\mathbf{x})$ is the decision of the tth classifier for the jth class. Each one of these rules is separately applied to the pairs of classifiers and DR techniques.

Algorithm 4: Discrete Wavelet Transformation

```
1  DWT (Im);
   Input  : Original image Im
   Output: Transformed image C
2  for j = 1 to m do
3  |  b = 0;
4  |  for k = 0 to m − 1 m do
5  |  |  a = W_jk × Im_jk; b = b + a;
6  |  end
7  |  t_j = b;
8  end
9  for j = 0 to m − 1 do
10 |  b = 0;
11 |  for k = 0 to m − 1 do
12 |  |  a = W_jk × t_k; b = b + a;
13 |  end
14 |  c_j = b;
15 end
```

$$\textbf{Mean Rule}: \ \mu_j(\mathbf{x}) = \frac{1}{T}\sum_{t=1}^{T} d_{t,j}(\mathbf{x}) \tag{3}$$

$$\textbf{Maximum Rule}: \ \mu_j(\mathbf{x}) = \max_{t=1,\ldots,T}\{d_{t,j}(\mathbf{x})\} \tag{4}$$

$$\textbf{Minimum Rule}: \ \mu_j(\mathbf{x}) = \min_{t=1,\ldots,T}\{d_{t,j}(\mathbf{x})\} \tag{5}$$

$$\textbf{Median Rule}: \ \mu_j(\mathbf{x}) = \operatorname*{med}_{t=1,\ldots,T}\{d_{t,j}(\mathbf{x})\} \tag{6}$$

$$\textbf{Product Rule}: \ \mu_j(\mathbf{x}) = \prod_{t=1}^{T} d_{t,j}(\mathbf{x}) \tag{7}$$

$$\textbf{Majority Voting}: \ \sum_{t=1}^{T} d_{t,J}(\mathbf{x}) = \max_{j=1,\ldots,C}\sum_{t=1}^{T} d_{t,j} \tag{8}$$

Using Eqs. (3)–(8), the final decision is the class j (the final classification) that receives the highest $\mu_j(x)$ value after the algebraic expression has been applied to the individual supports obtained, which is calculated as

$$h_{\text{final}}(\mathbf{x}) = \arg\max_{j}\left(\mu_j(\mathbf{x})\right) \tag{9}$$

3.1 Flowchart of Experiment

Figure 1 shows flowchart of the process that was followed in order to generate the dataset, apply the DR techniques, train and test the classifiers, and then generate an MCS from the found results.

4 Experimental Results and Discussion

4.1 Experimental Setup

The two datasets chosen for experiments were the ROSIS Pavia City Centre and ROSIS Pavia University. The makeup of these two datasets can be seen in Table 1a, b. These datasets were reduced to 1000 items per class where possible in both cases. This was chosen as the Shadows class in the ROSIS Pavia University dataset only contained 947 items, and the number of items in each class was kept similar to reduce biases; they were then split into 90% training and 10% testing and the datapoints chosen for this experiment were taken at random.

The overall accuracy (OA) was calculated by taking the number of correctly predicted datapoints over the total number of the respective training dataset. This was repeated for each of the DR/classifier pairs that were found, and the highest of these accuracies was shown in Table 2. The Kappa coefficient (KC) was calculated with the use of the empirical probability of agreement p_o and the expected agreement when both annotators assign labels randomly p_e of the sample. Using this, Eq. (10) can be generated.

$$\kappa = \frac{p_o - p_e}{1 - p_e} \tag{10}$$

4.2 Results and Discussion

Results achieved on the two datasets can be seen in Table 2. And Table 3 shows results generated with tests performed on different methods of non-trainable combination techniques.

It was observed that LRC classifier dominated in accuracy predictions of almost all the DR techniques. It must be noted that in the raw data comparisons, the accuracy of LDC was very close to LRC using the same DR techniques, only being outperformed by 1–2% in most cases. The MDC classifier does not appear to compete with the other classifiers always being much lower in all cases. This outlier might be due to the fact that it was not correctly implemented for this task or simply does not perform as well as the other classifiers in question. Comparing all the DR techniques

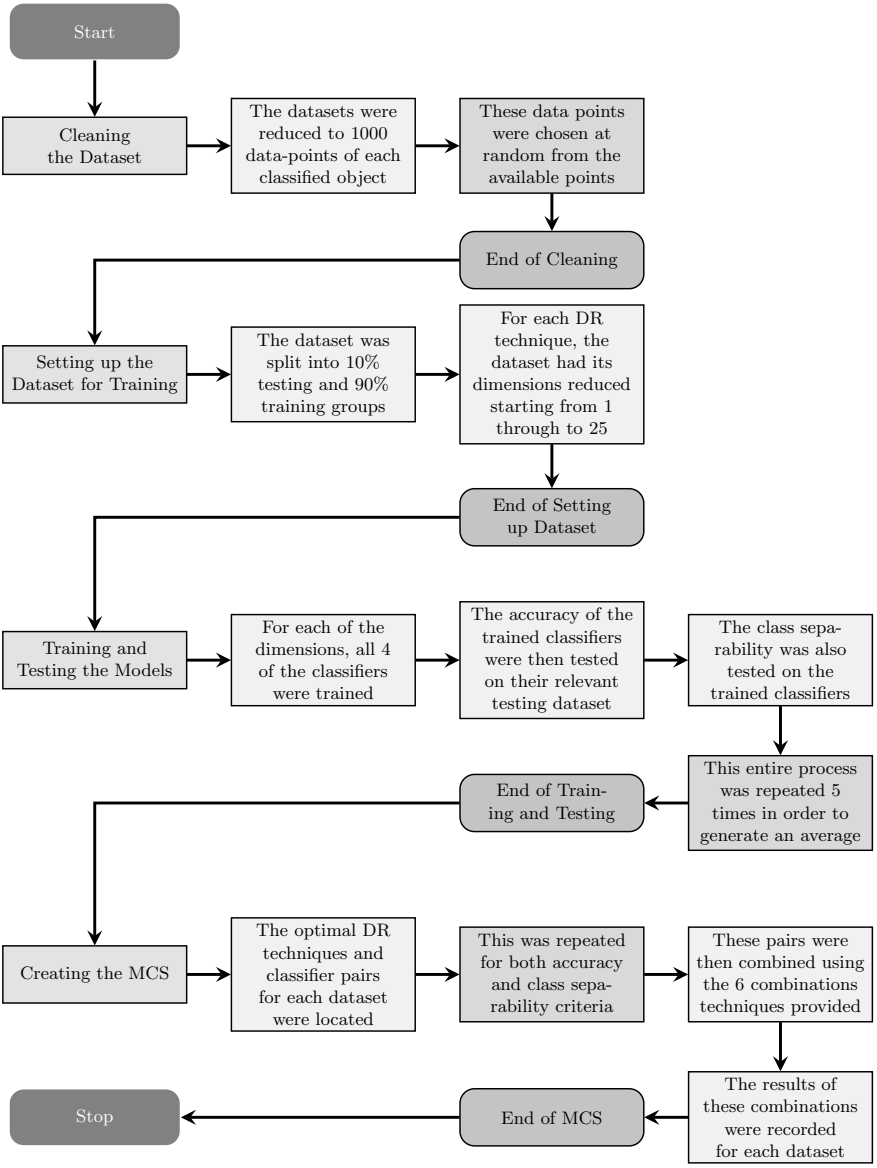

Fig. 1 Flowchart of experiments process

Table 1 Dataset classification types

#	Class	Samples
(a) *ROSIS Pavia University*		
1	Asphalt	6631
2	Meadows	18,649
3	Gravel	2099
4	Tree	3064
5	Painted metal sheets	1345
6	Bare soil	5029
7	Bitumen	1330
8	Self-blocking bricks	3682
9	Shadows	947
(b) *ROSIS Pavia City Centre*		
1	Water	65,909
2	Tree	7598
3	Asphalt	3090
4	Self-blocking bricks	2685
5	Bitumen	6584
6	Tiles	9241
7	Shadows	7287
8	Meadows	42,826
9	Bare soil	2863

Table 2 Results generated from the two datasets

Hyperspectral image	Selected classifiers relative to DR methods					Classification accuracy	
	ICA	PCA	MNF	DWT	KPCA	OA	KC
(a) *Optimal dimensions of DR method based on training samples classification*							
ROSIS University	LRC (2)	NBC (15)	LRC (20)	LRC (1)	NBC (2)	83.691	0.794
	42.056	73.414	83.606	83.691	78.243		
ROSIS City of Pavia	LRC (14)	NBC (1)	LRC (17)	LRC (3)	LRC (3)	93.593	0.909
	45.368	75.087	93.593	92.675	81.158		
(b) *Optimal dimensions of DR method based on class separability measure*							
ROSIS University	LRC (8)	NBC (3)	LRC (10)	LRC (10)	LRC (2)	82.243	0.764
	39.279	71.492	79.678	82.243	77.407		
ROSIS City of Pavia	LRC (1)	NBC (1)	LRC (3)	LRC (10)	LRC (2)	92.377	0.895
	41.97	75.087	89.624	92.377	79.684		

Table 3 MCS results generated from the two datasets

Hyperspectral image	MV	Avg	Max	Min	Med	Prod
(a) *Optimal dimensions of DR method based on training samples classification*						
ROSIS University	87.196	88.995	80.847	80.847	87.725	89.524
ROSIS City of Pavia	95.444	94.333	88.0	88.0	91.556	95.778
(b) *Optimal dimensions of DR method based on class seperability measure*						
ROSIS University	84.444	85.926	83.492	83.492	85.397	86.243
ROSIS City of Pavia	90.222	92.222	88.0	88.0	90.333	93.0

on the ROSIS City of Pavia dataset, the ICA technique clearly does not perform as well as the other DR techniques for this application as its highest accuracy achieved in these experiments was only 45.37%. This could be due to the nature of the data used, with unique features, which is usually what ICA helps to achieve, not being the defining factor for the data. The PCA technique also lacks the accuracies generated by the other DR techniques, although the accuracies are much higher than ICA, at a maximum of 75.09%. KPCA, at a maximum of 81.16%, improves slightly compared to PCA, and this could be attributed to the non-linear transformation of the KPCA helping distinguish the input data better for classification. However, the training times for KPCA were up to 10 times longer than the PCA, and this would increase drastically with an increase in the dataset size. MNF and DWT were by far the best DR techniques used, at 93.59% and 92.68%, respectively, and the results they generated were very similar, this clear difference between these DR techniques and the other two could be an indication that the dataset is very noisy, as these techniques are very good at denoising the input data to help get better results.

The overall accuracy achieved by the classifiers is similar to that presented in [3]. Differences between results produced could be attributed to the choice of data points in the dataset and the differences in classifiers setup.

MCS techniques used showed that the best performing combination was the product method as it provided the best classification accuracy for both datasets with 89.52% and 95.78%, respectively. The minimum and maximum combination techniques performed the worst in both cases, and this may be due to the low number of DR/classifier pairs used for the combinations. It is important to note that the best combination techniques outperformed any single DR/classifier pair on its own, thus showing that the MCS techniques can help enhance classification accuracy, with an improvement of 5.83% on the ROSIS University dataset and 2.185% on the ROSIS City of Pavia dataset.

5 Conclusion

It has been shown that with the right use of DR techniques, the classification accuracy on HSI datasets can be improved and this can be further improved by pairing the DR technique with the correct classifier.

Possible future works are the use of DR techniques along side feature extraction techniques to improve the accuracy of classification. The possible use of genetic algorithm-based optimisers to find better pipelines. Lastly, the techniques explored in this paper can be expanded to other applications with high dimensional data. Some limitations encountered were the limited access to specialised datasets, the training times encountered that hinder the extension of certain techniques, such as the KPCA, and the ability to generate completely unbiased results due to the small scale nature of the experiments conducted.

Acknowledgements The authors would like to thank Prof. P. Gamba, University of Pavia, for allowing the ROSIS data set to be open source.

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Systematic Approaches for Telemedicine and Data Coordination for COVID-19 in Baja California, Mexico

Cristian Castillo-Olea, Carlos Vera-Hernandez, and Ameyalli Mendias-Alarcon

Abstract We provide a model for systematic implementation of telemedicine within a large evaluation center for COVID-19 in the area of Baja California, Mexico. Our model is based on human-centric design factors and cross disciplinary collaborations for scalable data-driven enablement of smartphone, cellular, and video Teleconsultation technologies to link hospitals, clinics, and emergency medical services for point-of-care assessments of COVID testing, and for subsequent treatment and quarantine decisions. A multidisciplinary team was rapidly created, in cooperation with different institutions, including: the Autonomous University of Baja California, the Ministry of Health, the Command, Communication and Computer Control Center of the Ministry of the State of Baja California (C4), Colleges of Medicine, and the College of Psychologists. Our objective is to provide information to the public and to evaluate COVID-19 in real time and to track, regional, municipal, and state-wide data in real time that informs supply chains and resource allocation with the anticipation of a surge in COVID-19 cases.

Keywords Telemedicine · COVID-19 · System design · Digital health

1 Telemedicine in Mexico

The State of Baja California in the year 2019 had a total population of 3,682,063 inhabitants; 68.57% or 2,524,740 people were covered by the Mexican Institute of Social Security (IMSS); the Institute of Security and Social Services for State

C. Castillo-Olea (✉)
CETYS Universidad, Mexicali, Mexico
e-mail: Cristian.castillo@cetys.mx

C. Vera-Hernandez · A. Mendias-Alarcon
School of Medicine and Psychology, Autonomous University of Baja California, Tijuana, Mexico
e-mail: cvera@eng.ucsd.edu

A. Mendias-Alarcon
e-mail: amendias@uabc.edu.mx

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Workers (ISSSTE) represents 5.17%, with 190,324 people on its roll; the Institute of Security and Social Services for Government and Municipal Workers of the State of Baja California (ISSSTECALI), 3.79%, with 139,494 beneficiaries, and the population with affiliation to the Popular Insurance accounts for 170,751 people, which corresponds to 29.08% of the total population of the State [1, 2].

There are 12 Red Cross ambulances and 1 firefighter's ambulance. The prevalent diseases in Baja California are acute respiratory infections, intestinal infections from other organisms, urinary tract infections, gingivitis and periodontal diseases, conjunctivitis, ulcers, gastritis and duodenitis, arterial hypertension, obesity, non-insulin-dependent diabetes mellitus (Type II), and asthma and asthmatic conditions [3, 4].

The Autonomous University of Baja California (UABC) offers the subject of Telehealth in the Faculty of Medicine and Psychology since 2016, reinforcing its experience in the area of Telehealth. We use the Telmedx platform for practice, in the first approach, 4 years ago, 10 Teleconsultations in the area of pediatrics were conducted, from San Quentin—with tutors and students—to Tijuana, Baja California. Five specialists from Tijuana were contacted in the areas of Genetics, Neurology, Ophthalmology, Dermatology and Orthopedic. The student located in San Quintin enters through the Telmedx platform in his Smartphone. For the realization of the Teleconsultation, the values are given in Table 1, where the total number of services used for Teleconsultation are presented. Three relevant cases were detected, which were subsequently followed up.

Another Telehealth tool that is used is the EMS track system. The objective is the optimization of the Prehospital Emergency System. This tool was created due to the overwhelming scope of action for the Red Cross: 98% of Emergency Services are attended by the Red Cross Tijuana, and there are 13 ambulances and a population of 1,559,683 people. This system was designed in collaboration with the UABC-Faculty of Medicine and Psychology, the University of California at San Diego (UCSD), and the Technological Institute of Tijuana (ITT) [5].

Telemedicine allows doctors, nurses, and patients to communicate 24/7, using smart phones or computers with webcams. This makes it easier to assess the progress of patients who are in home quarantine. Several studies have presented the potential for the use of telemedicine in disasters and public health emergencies [6–8]. According to some studies, the potential benefits of an alternative integrated mobile health program include improved resource utilization, reduction of unnecessary emergency department visits that contribute to crowding, and access to care [9].

Table 1 Data: Teleconsultation case in San Quintin-Tijuana

Total number of services that used Teleconsultation	Important cases	Students at San Quintin	Doctors in San Quintin	Specialist doctors
12	3	4	2	5

2 Multi-dimensional Data Coordination

Authorities from the three levels of government, as well as Civil Protection and Red Cross are concentrated in the Control Center, Communication and Computer Command (C4) to attend emergency calls (911). The C4 also has a power backup, so that in case of a blackout, continues conducting redundant telephony, digital mapping of the city, closed circuit security systems, thermal cameras to operate without lighting, as well as a fingerprint access control. An average of 461,981 calls are received monthly in the state. C4 started operations in 2001 [10].

3 Creating a Telemedicine Evaluation Center for Rapid Triage of COVID-19

Researchers from the Faculty of Medicine and Psychology met to discuss support for the community in view of the contingency. The idea was to create a COVID-19 Telehealth evaluation center and, since it had human resources, it was decided to create a center for the evaluation of Telehealth, which would be staffed by internal doctors, medical interns, and students of medicine, psychology, and nutrition. Since it needed infrastructure for receiving calls, computers and all technological equipment, the State Government was contacted for the C4, whose command, communication and computer centers under the State Government's control. It is where the emergencies are dispatched, having the physical structure, the technological structure and the equipment. Likewise, the Ministry of Health was contacted to coordinate and not to duplicate efforts (see Fig. 1).

The Faculty of Medicine and Psychology has students of Psychology and Nutrition. The total number of human resources is given in Table 2.

A call for volunteer support was created for professionals, retirees, and students of health and administrative careers, who are willing to be a second line if necessary in the care of the contingency. Likewise, a Facebook group called Telehealth COVID-19 was created with the purpose of updating volunteers with the information that was available on a daily basis. The college of psychologists joined the volunteering, resulting in collaboration and multidisciplinary cooperation. The number of volunteers is 1526.

Two tools are used in the COVID-19 Telehealth evaluation center: Telmedx and EMS track. The Telmedx platform is a tool for transmitting video and image in a synchronous (bidirectional) way where annotations or drawings on the photo or close-ups can be made. For reasons of data protection, Telmedx does not save any patient information. They are HIPAA and HITECH compliant. It can be installed on any smart device, available for Android and IOS [11]. The EMS track tool is used to dispatch units for patients with COVID-19, the unit is tracked by GPS through the real-time app, and the receiving physician is notified by SMS message.

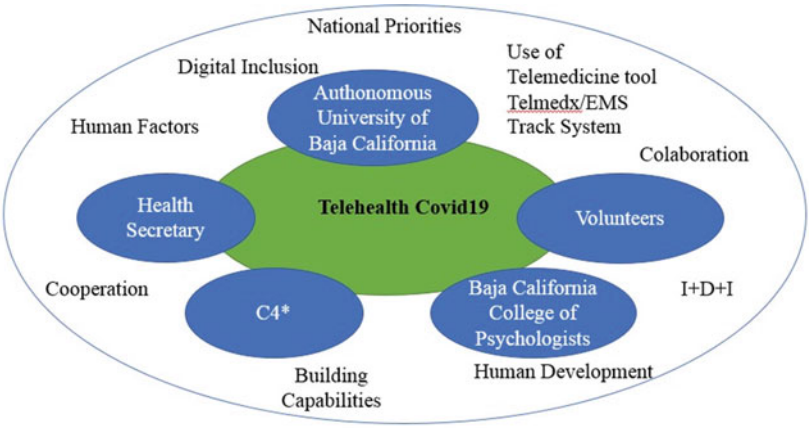


Fig. 1 Governmental and non-governmental institutions integration into the contingency plan

Table 2 Total number of FMP students

Program	Basic	Discipline	Terminal	Total
Psychology	250	213	145	608
Medicine	422	415	164[a]	1001[a]
Nutrition	68	81	24	173
Total	740	709	333	1782

[a] Of the total 164 terminally ill medical students (MIP + MPSS), we have only approximately 27 of the 57 MPSS in the university program, although this number may increase as non-priority services are closed

3.1 Operational Model

First contact doctors. 2–3 doctors will be assigned to be physically present at C4 to capture incident data and channel calls to volunteers.

Volunteer Advisors. There are three levels of telephone advisors to meet the following consultation needs (see Fig. 2):

(A) Medical Consultation

1. Level 1: General recommendations at community level
2. Level 2: Monitoring of suspected patients in home confinement
3. Level 3: Specialist medical advice.

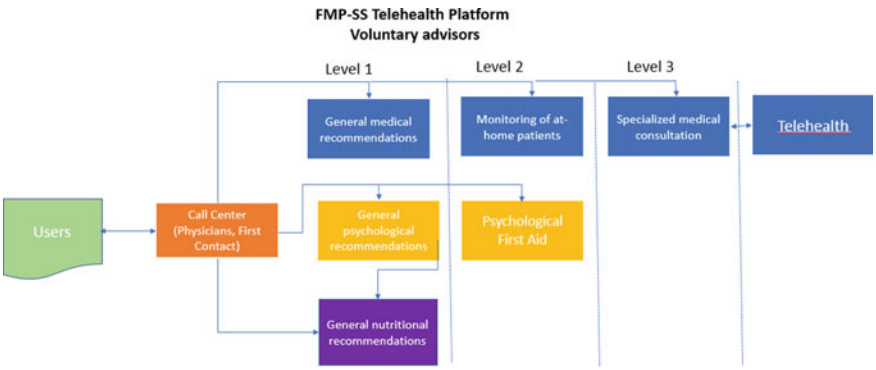


Fig. 2 Conceptual design of the Telehealth system

(B) Psychological Consultation

1. Level 1: General psychological recommendations
2. Level 2: Psychological First Aid.

(C) Nutritional Consultation

1. Level 1: General nutritional recommendations.

The following procedure is followed for the training of volunteers:

(A) Medical Consultation

1. Community telephone counselors (Level 1) are required to complete the following training:
   Complete and accredit the Prevention and Control of Infections (PCI) caused by the new coronavirus (COVID-19) [12].
   To know and implement the algorithm of medical telephone advice on the general and control recommendations of the COVID-19 (Developed by the Secretary of Health).
   i. Online course.
   ii. Online training video.
2. Telephone monitoring advisors for patients in home confinement (Level 2), in addition to Level 1, will be required to complete the following training:
   a. Know and implement the algorithm for telephone monitoring of suspected homebound patients (developed by the Ministry of Health).
3. The specialized advisors (Level 3), in addition to what is considered in the previous levels, must have current training and certification of specialization or postgraduate medical degree in the area they wish to advice.

(B) Psychological Consultation

1. General Counselors (Level 1) are required to complete the following training:
   a. Complete and accredit the Prevention and Control of Infections (PCI) caused by the new coronavirus (COVID-19).
   b. To know and implement the algorithm of psychological telephone advice on the general and control recommendations of the COVID-19 (Developed by the Secretary of Health).
      i. Online course.
      ii. Online training video.
2. Psychological First Aid consultants (Level 2), in addition to Level 1, will be required to complete the following training:
   a. Psychological First Aid Course.

(C) Nutrition Consultation

1. General nutritional advisors (Level 1) are required to complete the following training:
   a. Complete and accredit the Prevention and Control of Infections (PCI) caused by the new coronavirus (COVID-19).
   b. To know and implement the algorithm of nutritional telephone advice on the general and control recommendations of the COVID-19 (Developed by the Secretary of Health).
      i. Online course.
      ii. Online training video.

The COVID-19 Telehealth Assessment Center is physically located at C4 on the first floor, where the medical area is located (6 doctors) who make rotating guards. Each shift is 12 h long. On the second floor, there is the area of psychology (2 psychologists). In both cases they take calls from users.

4 Telemedicine in Mexico

The dispatcher performs the following procedure:

1. Call Center Procedures

1.1. Medical Call Procedure

1.1.1. Identification of Cardinal Medical Signs: Do you or anyone you have had contact with in the last 7 days have any of these signs and symptoms?

- Cough
- Fever
- Headache in adults/Irritability in children

1.1.2. Complementary Medical Signs: Have these signs been accompanied by …?

- Difficulty in breathing
- Joint pain
- Muscle pain
- Sore or burning throat
- Nasal flow
- Red eyes
- Chest pain

1.1.3. Medical Call Transfer

- 911: If an emergency is being reported in which there is immediate danger to life.
- Medical Advisor Level 1
  If you only require general information or have medical questions.
  If someone you have had contact with in the last 7 days shows the signs.
- Medical Advisor Level 2
  If the person reporting presents 2 of 3 of the cardinal signs.

Figure 3 shows the patient care route. It starts when you receive the call referring to the advisor to make the evaluation of the patient, once you have the data referred to the service you need.

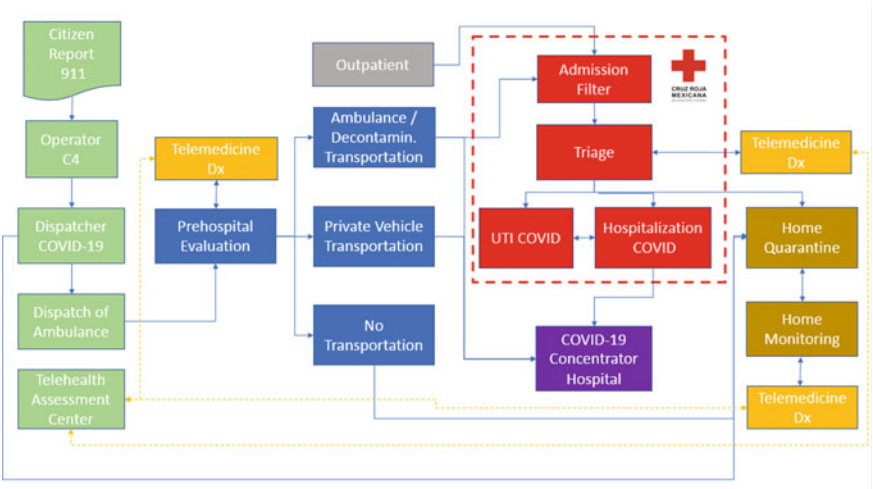


Fig. 3 Path of care

The criteria used by the hospital triage (red rectangle) for their decision are based on the Guide for COVID-19 Critical Patient Care (Appendix A). For home monitoring, Telmedx is used (yellow rectangle in Fig. 3); the patient is daily monitored until they recover. This monitoring is performed by volunteer doctors participating in the COVID-19 Telehealth project: fever, dry cough, headache, difficulty in breathing, joint pain, muscle pain, sore throat, runny nose, conjunctivitis, chest pain, and the ROTH scale is used to determine oxygen saturation.

4.1 Intake of COVID-19 Calls and Contingency Plans

The contingency plan has two lines: The first is to receive calls to 911, the second the Telehealth evaluation center. The Telehealth system requires at least one central station that is responsible for providing medical services and one or more remote units, where the patient and the specialist doctor are located; both units will have some elements such as mobile phone or computer with webcam. Figure 4 presents a diagram for the application of the COVID-19 Telehealth contingency plan.

When a user calls 911, the first contact physician asks a series of questions that are presented below:

1. Receiving the call and capturing initial data
    1.1. Give a welcome message "Thank you for calling the COVID-19 Telehealth system," then request the following information:
        - Address
        - Name

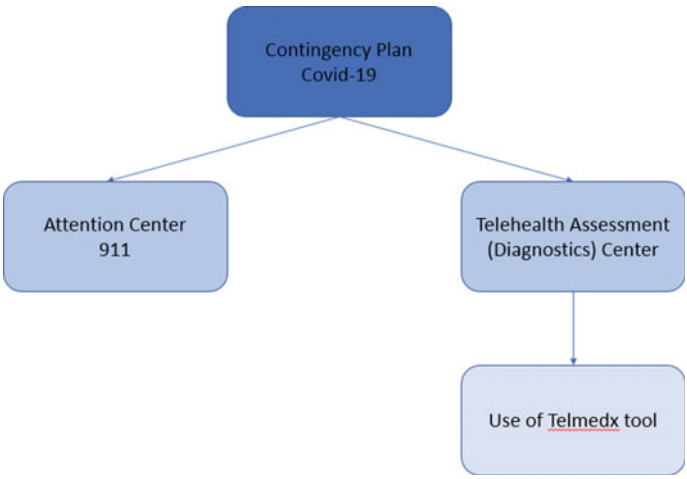


Fig. 4 General diagram

- Age
- Sex
- Ask: Are you or anyone in your household quarantined for having symptoms of COVID-19?
- Ask: What is the reason for your call?
  If the reason for the call is medical, follow the Medical Call Procedure.
  If the reason for the call is for psychological reasons, follow the Psychological Call Procedure.
  If the reporting person or someone living in your home is quarantined for symptoms of COVID-19, follow the Home Quarantine Procedure.

If technical or advanced medical advice is required, follow the Telemedicine Procedure.

5 Telehealth for Psychological Care

A fundamental issue that is being integrated into the ecosystem is psychological care, since an increase in anxiety has been observed during health crises. Public health emergencies may affect the health, safety, and well-being of both individuals (causing, for example, insecurity, confusion, emotional isolation, and stigma) and communities (due to economic loss, work and school closures, inadequate resources for medical response, and deficient distribution of necessities). Extensive research in disaster mental health has established that emotional distress is ubiquitous in affected populations, a finding to be echoed in populations affected by the COVID-19 pandemic [13–15].

In the case of psychological assistance, the following procedure is carried out.

5.1 Psychological Call Procedure

Identify the patient's age group (adult or child/adolescent) Ask: Does the patient have any of these symptoms? In adults:

- Sadness
- Depression
- Anxiety
- Fear and concern for their own health and that of their loved ones
- Changes in your sleeping or eating patterns
- Difficulty sleeping or concentrating
- Worsening of chronic health problems
- Increased use of alcohol, tobacco, or other drugs.

In children and adolescents:

- Excessive crying or irritation in young children
- Returning to behaviors they have outgrown (e.g., having "accidents" [wetting or soiling underwear] or wetting the bed)
- Excessive worry or sadness
- Unhealthy eating or sleeping habits
- Irritability and impulsive behavior in adolescents
- Poor school performance or avoiding school
- Difficulty paying attention and concentrating
- Avoiding activities that were enjoyed in the past
- Headaches or body aches with no apparent cause
- Use of alcohol, tobacco, or other drugs.

Identification of active crisis state: ask if the patient has a crisis state

- State of disorganization/invaded by emotional stress
- "Tunnel vision"
- Difficulty for thinking or making decisions
- Excess activity without objective or immobilization
- Cognitive impairment, accompanied by concerns or ideas distorted by events such as the perception of being unable to overcome obstacles, problems, or experienced events
- Changes in behavior such as aggression, impulsiveness, hyperactivity
- Changes in emotional state with feelings of confusion, tiredness, exhaustion, guilt, helplessness, alienation, anger, irritability, fear, sadness, depression, nightmares, anguish, anxiety, panic, mental tension, indecision, lack of confidence, and feelings of inadequacy
- Vulnerability to crying with bursts of tears.

Psychological call transfer

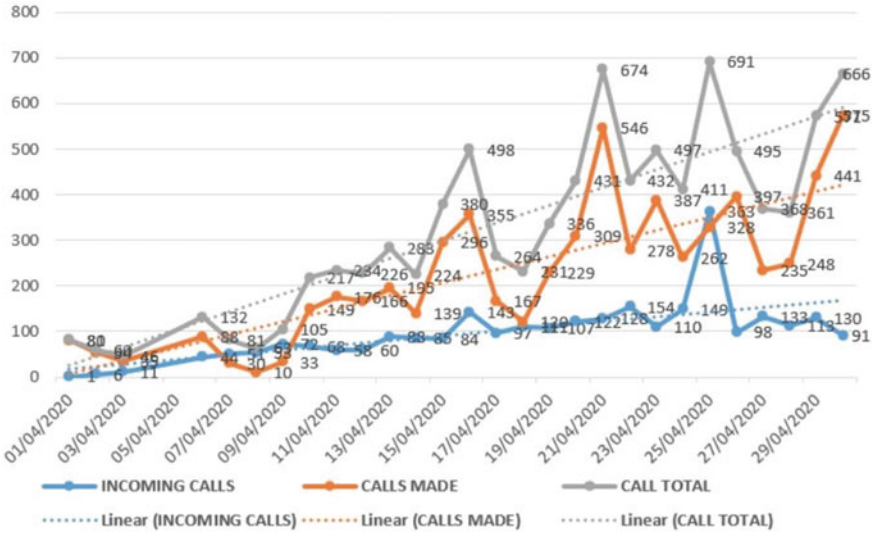
- 911: If the reporter feels that they want to harm themselves or others
- Psychological Counselor Level 1: If you have any of the psychological symptoms or require general psychological counseling
- Psychological Counselor Level 2: If you have an active crisis state (have any of the above symptoms).

6 COVID-19 Data

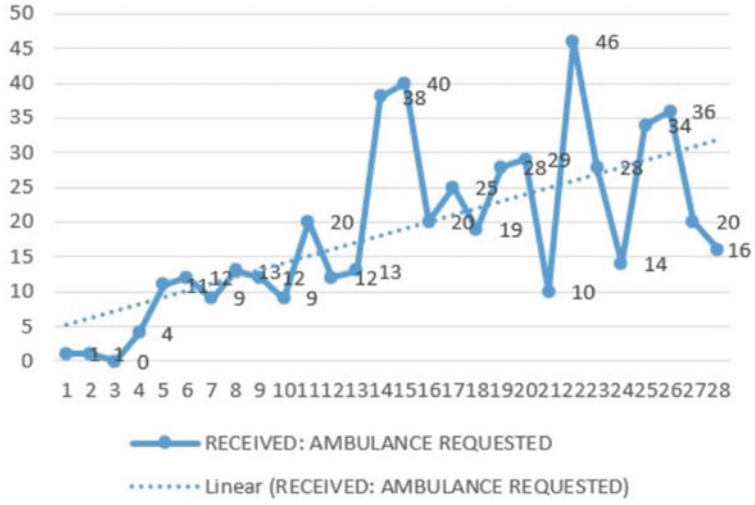
Graph 1 shows the number of calls received, calls made by the COVID-19 Telehealth System team, and the total number of calls during a period of 29 days during the month of April, that is, and the period from April 1 to 29.

Graph 2 shows the number of calls when ambulances were requested. The presence of an ambulance was requested on 520 occasions, due to the severity of the patients' symptoms (this represents 18.8% of the calls received).

Graph 3 shows the percentage of ambulances required, which represents 18.8% of calls received.

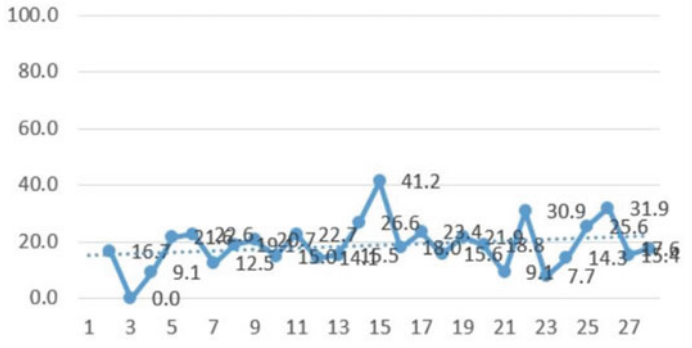


Graph 1 Telehealth system COVID-19 calls handled per day April 2020

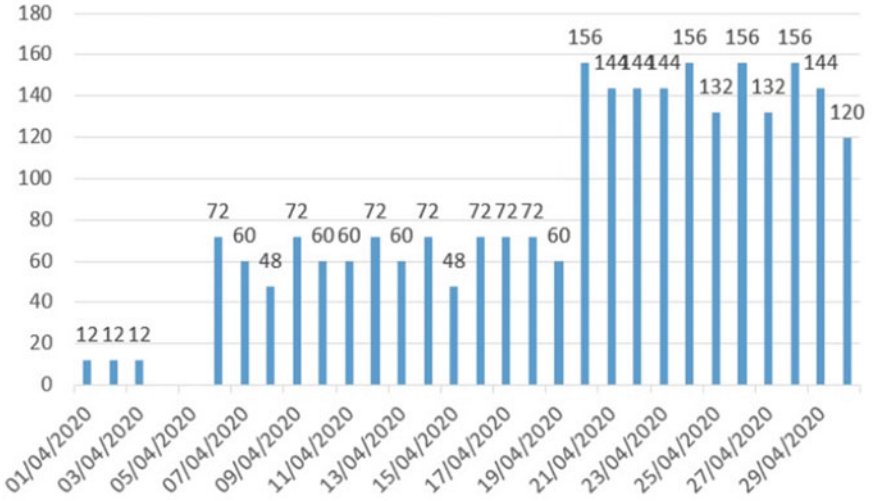


Graph 2 Telehealth system COVID-19 calls requiring ambulances dispatch April 2020

Graph 4 shows the worked hours by volunteers located in the C4 where the COVID-19 Telehealth Assessment Center is located. During the 29-day period, a total of 2520 operator hours were worked in 24-h shifts starting on April 1.



Graph 3 Telehealth system COVID-19 percentage of received calls requiring ambulance April 2020



Graph 4 Telehealth system COVID-19 hour worked April 2020

7 Conclusions

It is possible to appreciate the contribution of Information and Communication Technologies to Teleconsultation. It is observed that, besides facilitating the communication between doctors, a faster and more effective diagnosis can be made, which allows the optimization of time and transportation costs. From the perspective of Health Institutions, it is possible to offer a better, more efficient service and reduce diagnosis and treatment periods, which is not only important to make health sector services more operational, but also to increase their coverage and social impact, particularly in this COVID-19 contingency. It was concluded that telehealth offers

capabilities for remote detection, care, and treatment; helps with supervision, surveillance, detection and prevention; and to mitigate the effects of health care indirectly related to COVID-19.

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Using the GNS3 Platform for Characterizing the Traffic in a VoIP Network and Study Its Performance

Ivan Nedyalkov and Georgi Georgiev

Abstract The present work proposes the use of the GNS3 IP network modeling platform to study VoIP networks. The applicability and capabilities of the platform will be demonstrated with a practical example of a working VoIP network model. In order to get a full idea of the possibilities of the GNS3 for studying VoIP networks, the modeled network will be connected to the Internet and to a real physical network, and video calls will be built between subscribers in the modeled network and real physical network. The study is conditionally divided into two parts—characterization of the traffic in the modeled network and study of the performance of the modeled VoIP network.

Keywords GNS3 · Network modeling · Performance analysis · Traffic characterization · VoIP

1 Introduction

The VoIP technology is rapidly entering all walks of life. From a technology originally created to be used to build enterprise telephone networks to replace old digital telephone technologies in order to improve the quality of existing telephone services. Today this technology is constantly growing, as a result of which it is no longer limited to use to build institutional telephone networks. VoIP is already used in the mobile networks of the new generation under the name Voice over LTE (VOLTE) [1]. In the near future, VoIP will be asserted as the only public land telephone network, displacing technologies such as ISDN—for example, in the UK, from 2025, ISDN support will be discontinued and ISDN subscribers will have to switch to the VoIP technology [2]. This rapid entering of the VoIP technology is mainly due to the

I. Nedyalkov (✉) · G. Georgiev
South-West University "Neofit Rilski", 66 Ivan Mihailov Str, 2700 Blagoevgrad, Bulgaria
e-mail: i.nedqlkov@swu.bg

G. Georgiev
e-mail: g.georgiev@swu.bg

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fact that the IP technology, i.e., IP networks, is the hegemon of telecommunications networks at the moment.

Because of the above, specialists and technicians must be prepared and trained to be able to design, build, and maintain VoIP networks. The best way to learn is the practical training of these specialists. This means that training organizations must have the appropriate network equipment to be able to build experimental VoIP networks to simulate various practical problems, case studies, and other issues that would arise in the operation of such networks. Such network equipment is expensive and not every training organization can afford to purchase it. How can this problem be solved? The solution to this problem is the use of IP network modeling platforms [3–7]. Modern IP network modeling platforms are so well developed that the modeled networks operate and behave almost like real ones. These platforms are also suitable for using for distance learning [8].

The aim of the present work is to demonstrate, with practical examples, the application of an IP network modeling platform for traffic characterization, and VoIP network study. The study in the present work is tentatively divided into two parts—characterization of the traffic in the modeled VoIP network and study of the performance of the modeled VoIP network. The obtained results will present the advantages of using such platforms in VoIP network research.

2 Why the GNS3 Platform?

GNS3 has been chosen as the IP network modeling platform to be used to carry out the study [9]. The platform has the following advantages and capabilities:

- Using disk images of real operating systems of real network devices. The thus created models of IP networks are almost close to real networks built with such network devices;
- Ability to connect to working real, physical IP networks. This option is very suitable and convenient to use during the design process of an IP network, because it will be able to monitor and track how the performance of the modeled network changes after connecting it to a real, physical IP network;
- Integration with various IP network monitoring and studying tools. Thanks to this functionality, every single node in the modeled network can be monitored. This will provide a lot of data that can then be used to assess the network performance;
- Last but not least, this platform is completely free. All the above capabilities and functionalities are available without the need to pay any additional licenses, which is not the case with some other IP network modeling platforms. This makes this platform suitable for use by anyone willing to explore and study IP networks.

Of course, there are also drawbacks that can be said to be present with all such platforms, namely the demands of the computing capabilities of the workstation that will be used to model the IP networks. They should be as high as possible so that the modeled network works smoothly and without problems.

The platform can also be used for studying of power electronic devices (PED). The only one condition for the successful implementation of the research is that the PED must have network capabilities—the ability to connect to IP networks [10].

3 Used Tools and Method of Carrying Out the Study

For the purpose of the study, several well-known and easy-to-use IP network monitoring tools will be used. The used network protocol analyzer is Wireshark [11]. Thanks to its integration with GNS3, it is possible to monitor all nodes in the modeled network. In the studying process of the modeled VoIP network, all nodes in the network will be monitored, and after the end of the monitoring, the packets that are caught by Wireshark will be further processed by the analyzer, using its capabilities for analyzing Real-time Transport Protocol (RTP) streams. The resulting jitter, packet loss, and other data will be used in the performance analysis of the modeled network.

To measure the round-trip delay (RTD) in the modeled network, the following two tools will be used—Colasoft Ping Tool [12] and Solarwinds Traceroute NG [13]. These two tools will continuously measure what is the round-trip delay between the subscribers and the IP PBX—The Asterisk Free PBX.

To characterize the traffic in the modeled network, the Capsa Enterprise 15 tool [14] will be used. It is a network performance analyzer, through which it is possible to monitor different parameters: the generated traffic, the used ports, the ports that generate the most traffic, the protocols that generate the most traffic and many other data.

The carried out research is based on the passive monitoring method of IP networks.

4 Topology of the Modeled VoIP Network and the Real Physical Network

Figure 1a presents the topology of the studied modeled network. The network is composed of four routers (R1–R4), three virtual machines (VM1–VM3), which are used as subscribers to the IP telephone exchange. Asterisk Free PBX is used for IP PBX. To this exchange, there are also subscribers that are located in the real, physical IP network (Fig. 1b) to which the modeled network is connected. The connection between the real and the modeled network is made with the help of pfSense, which is used as a router-firewall.

Figure 1b represents the topology of the physical network. It consists of the GNS3 Workstation (the GNS3 platform, which is used to model the studied VoIP network, is installed on this machine) and several other devices. In this network, there is a wireless router through which the various devices in this network connect to the

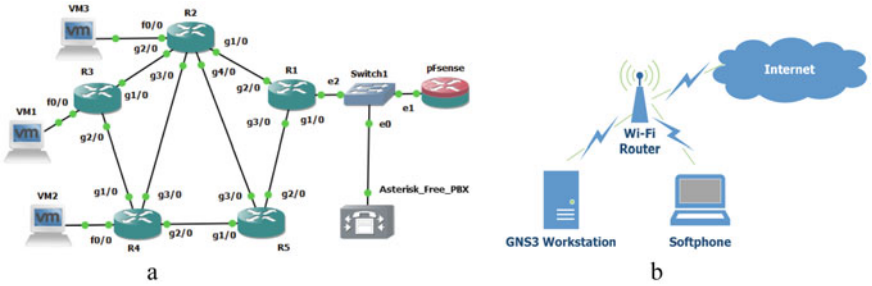

Fig. 1 **a** Topology of the modeled network and **b** topology of the physical network

Internet. One of these devices, a laptop, is used as a subscriber to the Asterisk Free PBX which is in the model network. In this way, calls external to the IP telephone exchange are simulated.

5 Results

5.1 Characterization of the Traffic

Characterizing the traffic in an IP network is of great importance because through the characterization process, potential problems in the network can be detected [15–23]. Figure 2 shows the traffic that was generated in the network for the entire study period. The results are from the Capsa Enterprise 15. This traffic is a combination of voice traffic and video traffic (video calls), so its value is much higher than if the traffic was only voice. As it can be seen, it is almost constant, which indicates that the network is functioning normally. Dropouts are due to the termination of existing calls and the establishment of new ones.

Figure 3 presents the distribution between multicast and broadcast packets for the entire study period. As it can be seen from the graph, multicast packets are much more than the broadcast packets, which is normal for a multimedia-type network, such as the studied modeled VoIP network.

Figure 4 presents the ports (TCP or UDP) from which the most traffic is generated. As it can be seen the traffic is mainly generated from UDP ports which is normal and expected for a multimedia-type network where the traffic is mainly exchanged via UDP.

Figure 5 presents the distribution of the SIP calls according to different criteria, for the entire period of the study. As it can be seen, the number of successful and active SIP calls is much higher than the number of unsuccessful or abandon calls.

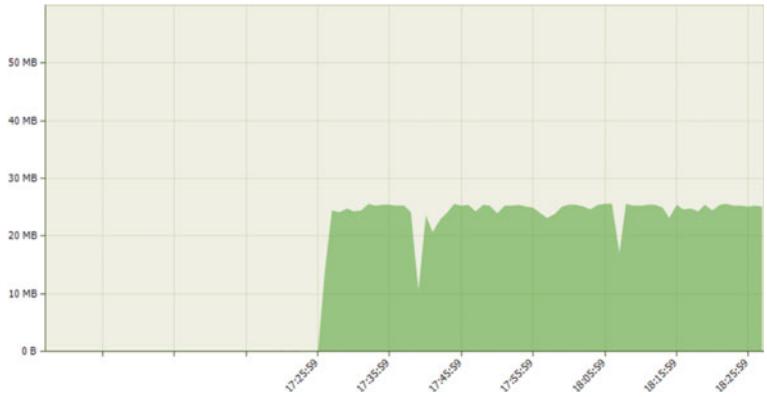

Fig. 2 Total generated traffic

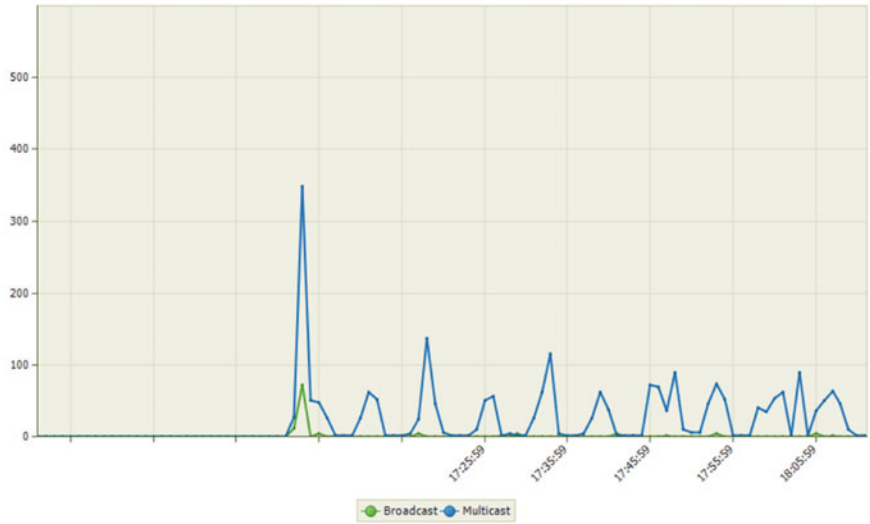

Fig. 3 Multicast versus broadcast packets

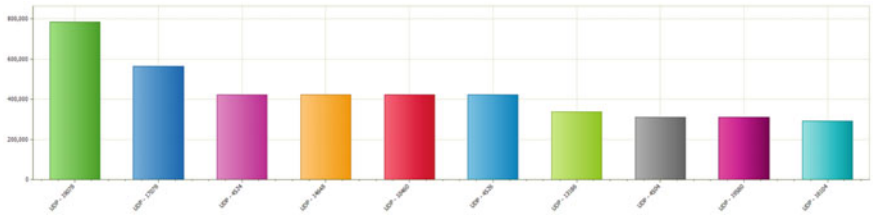

Fig. 4 Top ports by total traffic

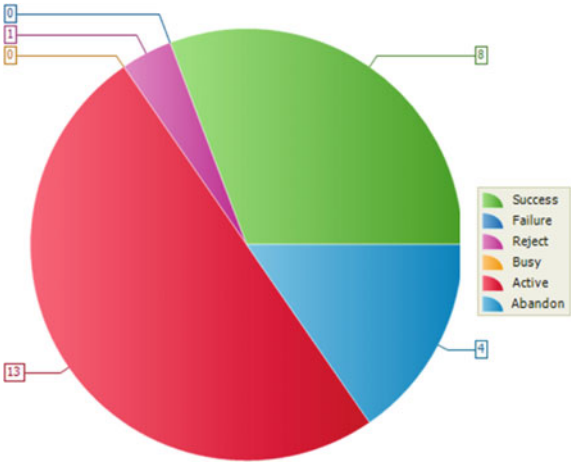

Fig. 5 SIP calls status distribution

5.2 *Analysis of the Performance of the Modeled VoIP Network*

Figure 6a presents summarized results for a voice stream that is exchanged between VM1 (192.168.20.2) and the Asterisk (192.168.100.5). Figure 6b presents the summarized results for a voice stream that is exchanged between the laptop (192.168.1.10) on the physical network and the Asterisk (192.168.1.16—the Nat address of the Asterisk). The results were obtained by using Wireshark's features to analyze RTP streams. Combined, the two streams represent the voice stream that is exchanged between VM1 in the modeled network and the laptop in the physical network. The voice stream is split into two streams because at the Asterisk Free PBX the voice stream is not exchanged between the two subscribers directly, but goes through the server.

Forward		Reverse	
192.168.20.2:7078 → 192.168.100.5:17680		192.168.100.5:17680 → 192.168.20.2:7078	
SSRC	0x9ae0f14a	SSRC	0x1c021fc8
Max Delta	267.48 ms @ 599586	Max Delta	3090.43 ms @ 664554
Max Jitter	29.17 ms	Max Jitter	208.96 ms
Mean Jitter	2.58 ms	Mean Jitter	8.10 ms
Max Skew	-248.00 ms	Max Skew	-4321.40 ms
RTP Packets	84096	RTP Packets	83830
Expected	84096	Expected	84082
Lost	0 (0.00 %)	Lost	252 (0.30 %)
Seq Errs	0	Seq Errs	132
Start at	2847.126126 s @ 599575	Start at	2847.462559 s @ 599596
Duration	1682.00 s	Duration	1681.67 s
Clock Drift	-0 ms	Clock Drift	33 ms
Freq Drift	8000 Hz (-0.00 %)	Freq Drift	8000 Hz (0.00 %)

a

Forward		Reverse	
192.168.1.10:17078 → 192.168.1.16:15972		192.168.1.16:15972 → 192.168.1.10:17078	
SSRC	0xdbe624ca	SSRC	0x6e2c1308
Max Delta	40.28 ms @ 956725	Max Delta	978.72 ms @ 752710
Max Jitter	4.40 ms	Max Jitter	121.52 ms
Mean Jitter	0.93 ms	Mean Jitter	6.47 ms
Max Skew	21.35 ms	Max Skew	-1805.39 ms
RTP Packets	84117	RTP Packets	83881
Expected	84117	Expected	84091
Lost	0 (0.00 %)	Lost	210 (0.25 %)
Seq Errs	0	Seq Errs	101
Start at	2503.660552 s @ 566306	Start at	2504.304330 s @ 566380
Duration	1682.31 s	Duration	1681.62 s
Clock Drift	20 ms	Clock Drift	74 ms
Freq Drift	8000 Hz (0.00 %)	Freq Drift	8000 Hz (0.00 %)

b

Fig. 6 **a** Summarized results for a voice stream from VM1 to the Asterisk and **b** summarized results for the voice stream from the laptop to the Asterisk

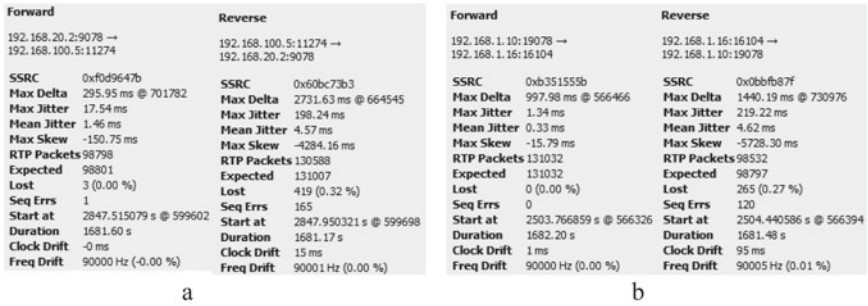

Fig. 7 **a** Summarized results for a video stream from VM1 to the Asterisk and **b** summarized results for the video stream from the laptop to the Asterisk

To evaluate the performance of a VoIP network, the following parameters are monitored: average/mean value of the jitter. It should be below 30 ms [24]. The second monitored parameter is the lost packets or packet loss, which should be below 1% [25]. The obtained results show that the both values are below the mandatory limits.

Video calls are also made between VM1 and the laptop. Figure 7a, b presents summarized results for the voice streams studied in Fig. 6a, b, but for the video stream exchanged between the two subscribers. For evaluating the performance of a VoIP network with video calls, again the mean/average value of the jitter and packet loss are monitored. From the obtained results, it can be seen that the values of the both parameters are again well below the maximum allowed values.

In the modeled network, voice streams are also exchanged only within the modeled network. These are calls between VM2 (192.168.30.4) and VM3 (192.168.10.2). Figure 8a shows the summarized results for the voice stream exchanged between VM2 and the Asterisk, and Fig. 8b presents the summarized results for the voice stream between VM3 and the Asterisk. Here again it is observed that the average value of jitter and percentage of the lost packets are far from the acceptable limits. This indicates that the modeled VoIP network is functioning normally.

Figure 9 presents graphically the variation of round-trip delay (RTD) for the entire study period between VM1 and the Asterisk. The results were obtained using the Colasoft Ping Tool and post-processing to obtain a graphical appearance. In the VoIP technology, whether there are only voice streams or both voice and video streams, the RTD value should not exceed 150 ms in one direction or 300 ms in total [24, 25]. Both voice and video streams are exchanged between the VM1 and the Asterisk because video calls are taking place. As it can be seen from the graph, the value of RTD is very far from the permissible value of 300 ms. The value varies around 50 ms, with a few single peaks that also do not exceed the allowable value. These peaks are network lags, which are due to delays caused by the computing work of the workstation that models the work of the VoIP network—a short-term delay in the computing work. The more computing power the workstation has to model these IP networks, the smaller these peaks will be.

Forward		Reverse	
192.168.30.4:7078 → 192.168.100.5:10460		192.168.100.5:10460 → 192.168.30.4:7078	
SSRC	0x5a754e1b	SSRC	0x30724e1f
Max Delta	264.12 ms @ 1229249	Max Delta	1066.56 ms @ 1268209
Max Jitter	19.07 ms	Max Jitter	31.51 ms
Mean Jitter	2.60 ms	Mean Jitter	4.11 ms
Max Skew	-332.65 ms	Max Skew	-580.87 ms
RTP Packets	164964	RTP Packets	164871
Expected	164965	Expected	164940
Lost	1 (0.00 %)	Lost	69 (0.04 %)
Seq Errs	1	Seq Errs	11
Start at	1409.297794 s @ 947699	Start at	1409.413359 s @ 947839
Duration	3299.37 s	Duration	3299.27 s
Clock Drift	14 ms	Clock Drift	-96 ms
Freq Drift	8000 Hz (0.00 %)	Freq Drift	8000 Hz (-0.00 %)

a

Forward		Reverse	
192.168.10.2:7078 → 192.168.100.5:14648		192.168.100.5:14648 → 192.168.10.2:7078	
SSRC	0xa3fba271	SSRC	0x6e8940fc
Max Delta	352.58 ms @ 511274	Max Delta	417.20 ms @ 521781
Max Jitter	22.90 ms	Max Jitter	28.49 ms
Mean Jitter	2.95 ms	Mean Jitter	3.70 ms
Max Skew	-599.26 ms	Max Skew	-496.72 ms
RTP Packets	164961	RTP Packets	164957
Expected	164961	Expected	164960
Lost	0 (0.00 %)	Lost	3 (0.00 %)
Seq Errs	0	Seq Errs	3
Start at	1419.715672 s @ 390360	Start at	1420.096541 s @ 390471
Duration	3299.72 s	Duration	3299.27 s
Clock Drift	-99 ms	Clock Drift	13 ms
Freq Drift	8000 Hz (-0.00 %)	Freq Drift	8000 Hz (0.00 %)

b

Fig. 8 **a** Summarized results for a voice stream from VM2 to the Asterisk and **b** summarized results for the voice stream from VM3 to the Asterisk

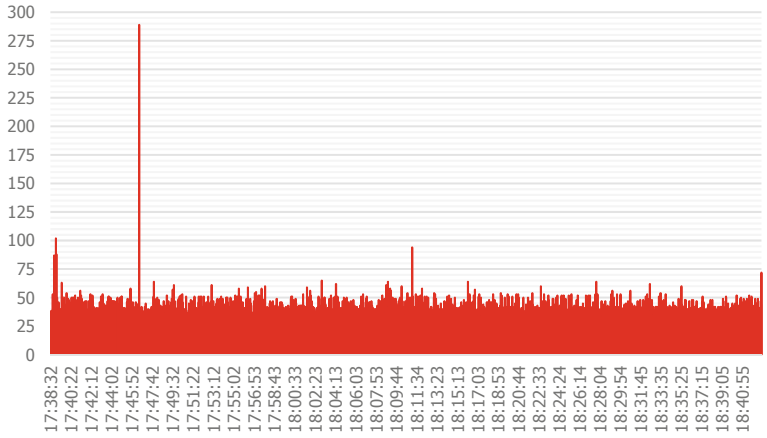

Fig. 9 Amendment of the RTD between VM1 and the Asterisk for the whole study period

Figure 10 presents the instantaneous RTD values between VM1 and the Asterisk. The results were obtained from the Solarwinds Traceroute NG tool. 192.16820.1 is the gateway address of the VM1, 10.0.5.1 and 10.0.1.1 are router ports through which the packet passes, and 192.168.100.5 is the address of Asterisk. As it can be seen from the results, again the values are far from the permissible limit.

Hop	IP	PL (%)	Now (ms)	Avg (ms)	min Latency max
1	192.168.20.1	0.0	4.1	6.7	==
2	10.0.5.1	0.0	19.7	17.7	==========
3	10.0.1.1	0.0	37.5	37.5	==========
4	192.168.100.5	0.0	34.5	34.5	==========

Fig. 10 Instantaneous values of the RTD between VM1 and the Asterisk

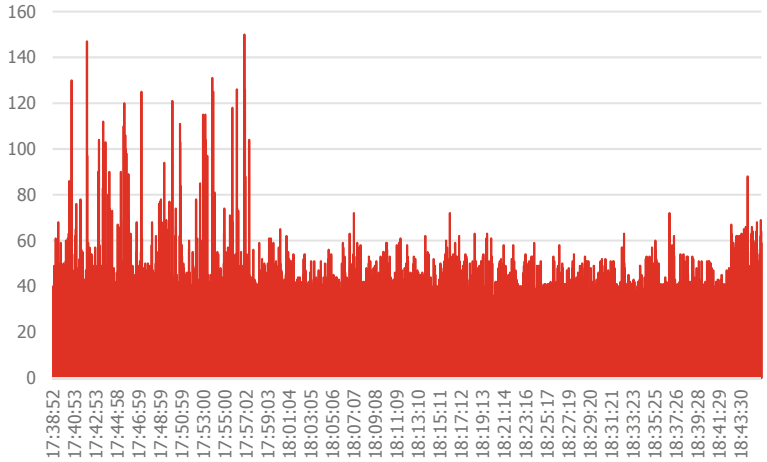

Fig. 11 Amendment of the RTD between VM2 and the Asterisk for the whole study period

Hop	IP	PL (%)	Now (ms)	Avg (ms)	min Latency max
1	192.168.30.1	0.0	12.8	9.9	=======
2	10.0.7.2	0.0	17.1	17.6	=========
3	10.0.2.1	0.0	27.5	27.5	==========
4	192.168.100.5	0.0	33.8	33.8	==========

Fig. 12 Instantaneous values of the RTD between VM2 and the Asterisk

Figure 11 presents graphically the variation in the round-trip delay for the entire study period between the VM2 and the Asterisk. Only voice streams are exchanged between the VM2 and the Asterisk. As it can be seen from the graph, the value of RTD is very far from the permissible value of 300 ms. The value varies around 60 ms. More peaks are observed here, but their values are again well below the allowable value.

Figure 12 presents the instantaneous RTD values between the VM2 and the Asterisk. 192.168.30.1 is the gateway address of the VM2, 10.0.7.2 and 10.0.2.1 are the router ports through which the packets pass, and 192.168.100.5 is the address of Asterisk. As it can be seen from the results, again the values are far from the permissible limit and are close to those of Fig. 10.

6 Conclusions

A working model of a VoIP network has been created in which both voice and video traffic is successfully exchanged.

The results of the study carried out to characterize the traffic in the modeled VoIP network show that the network functions normally. The obtained results are typical for a multimedia-type network. This is also very well seen from the results for the distribution between broadcast and multicast packets, where multicast packets are much more than broadcast packets. As for the used data exchange protocol in the modeled network, UDP is mainly used, which can be seen from the results for the ports generating the most traffic in the network. This is also typical for a multimedia-type network.

The results of the carried out studies on the performance of the modeled VoIP network show that it works normally. From the obtained values for the average jitter, packet loss and the round-trip delay, it can be seen that the obtained values are far from the maximum permissible values. Their variations during the entire study period are always within the permissible limits.

From the obtained results of the carried out research, it can be argued that the GNS3 platform successfully models a VoIP network that behaves almost like a real one, regardless of the fact that it is made of models of network devices. The study proves that the platform can be used to study IP networks, in particular VoIP networks. Thus, the GNS3 is an ideal replacement for the expensive network equipment. The platform can be used to train specialists who will be responsible for the design, construction, and maintenance of VoIP networks. The main requirement for the trouble-free use of the GNS3 is that the workstation that will be used to model the IP networks must have very high computing capabilities.

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The Impact of Different Compatibility Schemes on the Static Bus Load in Vehicle Networks

Andreas Vetter, Philipp Schumacher, Bernd Hedenetz, and Eric Sax

Abstract The automotive industry is currently facing significant transformations with the shift toward electric vehicles, automated driving, and the increasing connectivity (between vehicles and smartphones, the Internet, and infrastructure like traffic lights). This results in an increase in complexity of the electric/electronic (E/E) architecture, measurable, for example, by the number of signals (i.e., pieces of information transmitted) in in-vehicle networks, which show an exponential growth. Improvements to the development processes, to tackle the resulting challenges, are part of active research. One of the recently proposed concepts is the introduction of backward compatible interfaces between the electronic control units (ECUs). Backward compatibility is achieved, by transmitting both new and old versions of the signals of an ECU, which results in increased bandwidth usage. To assess the applicability of this concept, for the cost-sensitive automotive industry, we analyzed the increase in bandwidth consumption in detail. By using historic data of a real-world vehicle network development process, we simulated development processes following two different backward compatibility schemes and calculated the bandwidth consumption caused by each of them. Our results show that the concepts are applicable within some limits, and that a hierarchical backward compatibility scheme induces a smaller increase than a simple backward compatibility scheme.

Keywords Vehicle network · Bus load · Bandwidth · Real-time · Automotive · Compatibility · Versioning · Change-management

A. Vetter (✉) · P. Schumacher · B. Hedenetz
Mercedes-Benz AG; MB.OS Base SW Development, Sindelfingen, Germany
e-mail: andreas.a.vetter@mercedes-benz.com

E. Sax
Institute for Information Processing Technologies (ITIV), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
e-mail: eric.sax@kit.edu

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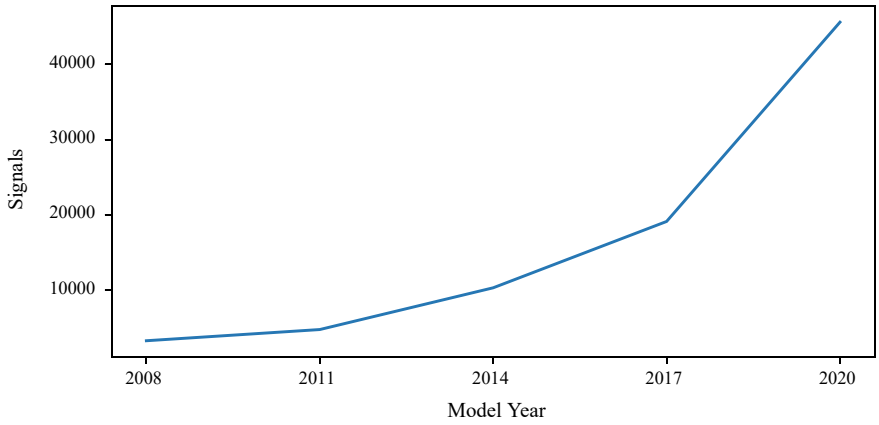

Fig. 1 Number of signals in different generations of a luxury vehicle line. Data taken from the Mercedes-Benz communication matrix database, see Sect. 3.1 for details

1 Motivation

Four megatrends are currently transforming the automotive industry [6]:

- Connectivity (vehicle-to-vehicle, vehicle-to-infrastructure)
- Advanced driver-assistance systems (ADAS) and (semi-) automated driving
- Sharing (i.e., one car will be used by many drivers)
- Electrification (battery management, vehicle-to-grid).

These trends also affect the electric/electronic (E/E) architecture, i.e., the electronic control units (ECUs) and the network of different data buses and gateways connecting them.

For vehicle networks, there are hard constraints that have to be fulfilled, to make sure that the vehicle operates regularly, and fulfills the different safety and security regulations of different markets. Especially, safety can cause requirements like real-time behavior, error detection and error correction, and deterministic network behavior [20]. In order to not only fulfill these requirements but also show that these requirements are fulfilled during, e.g., type-approval, vehicle networks are statically designed [3].

There are different possibilities to quantify the complexity of vehicle networks (e.g., bandwidth needs, number of ECUs, and others). We chose the number of signals (i.e., individual pieces of information transmitted) as the best suited measurement, since it is independent of network topology and technology (which can have an influence on, e.g., bandwidth needs). Figure 1 shows a graph of the number of signals in different generations of a luxury vehicle line over time. In these twelve years, the size of the network doubled every three years. This is comparable to Moore's Law, predicting the growth of semiconductors [17]. In [1], the author chose the number of lines of code (LOC) throughout the vehicle as a measure for complexity, reported

around 100 million LOCs in the year 2020, and observed an increase by factor ten for every ten years. This growth is increasing the development costs of vehicle networks drastically. It is expected that in 2025, the development costs for embedded software for vehicle networks can make up to 40% of the total vehicle development costs [7, 9].

Besides the increasing complexity and the development costs, there is a third factor which has to be considered. The different ECUs are developed in different cycles. ECUs belonging to mature systems (e.g., engine control, anti-lock braking system, etc.) have large update intervals for their software (one year or longer), while those belonging to new, innovative systems (e.g., ADAS, entertainment, etc.) are updated very frequently (once a month or more) . If those updates cause changes to the network configuration, all control units must be updated. If all ECUs were updated in the frequency of the most demanding one, the development costs would increase, since units with a lower frequency must deliver a new software (to adapt to the new network configuration) which would not be necessary otherwise. In general, the speed of innovations is increasing [15, 24], which is challenging [13].

These unnecessary ECU updates in vehicle networks can be prevented during development, if the new development version of the vehicle network is unchanged or at least compatible, to the previous one. But prohibiting network modifications, restricts the level of possible changes between two versions of the vehicle network, and thus hindering the development of the faster-paced ECUs.

In [25], two approaches to keep changes backward compatible, while still enabling high-paced development, by offering different versions of incompatible signals within the network, are presented. These approaches will cause higher bandwidth usage, which may prohibit the usage of the compatibility schemes in the cost-sensitive automotive domain. To get a reliable estimation for the bandwidth increase, we will analyze its magnitude in detail, by using historic data of a real-world vehicle network development, simulating the effects of both schemes and will compare the results.

2 State of the Art and Related Work

2.1 Automotive Network Development

Modern vehicle networks are developed using the automotive open system architecture (AUTOSAR) standard [2]. This standard which is developed by vehicle manufacturers, their suppliers as well as partners from semiconductor and software industry defines not only how the communication within the vehicle networks shall work but also provides exchange formats to describe the complete communication behavior of a network. The model containing all the communication of a vehicle is called communication matrix (C-matrix or CM), based on early forms where all signals and ECUs were displayed as tables [26]. To save development costs, so-called net-

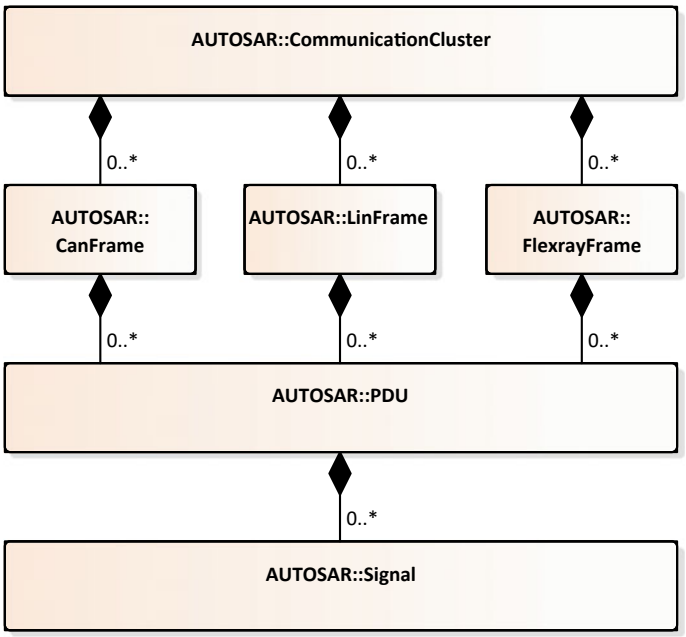

Fig. 2 Hierarchy of AUTOSAR communication elements. Image taken from [25]

working platforms are created [19], which are super-sets or 150% versions of the vehicle networks for multiple model series [11, 21].

The main entity to exchange data on a bus system within the AUTOSAR description of a network is the so-called protocol data unit (PDU). A PDU represents a series of signals which have a defined length and a defined position within the PDU.

How the PDU is transferred on the network depends on the underlying network type. For LIN and CAN 2.0, so-called frames are used. Both bus types support only one PDU in the frame. Other bus systems like FlexRay, CAN-FD, and Ethernet support several PDUs within a frame. For these cases, it is possible to use either fixed positions within the frame for the PDU or using a so-called PDU-header-ID. In case of using a PDU-header-ID, the PDU is identified by the header-ID itself, and the length of the PDU is given next to the header-ID in front of the PDUs itself. So, the ECUs can identify the data and extract it from the frame without the need to define an absolute position.

Frames, PDUs, and signals are transmitted and received by so-called communication connectors (CCs) which connect an ECUs with physical channels (in AUTOSAR called "communication cluster"). In [25], it has been pointed out that the AUTOSAR communication elements can be considered a hierarchical structure as shown in Fig. 2.

The development of a communication matrix is structured within cycles (e.g., three months, see Sect. 3.1 for details). During each cycle, ECU projects have the

opportunity to request changes, to fix bugs, improve existing, and add new features, based on the experiences that have been made while testing the previous release. All these change requests are consolidated, based on a change management process, and result in a new C-matrix release, which concludes the cycle. Current development systems based on fixed release cycles are conflicting with the increasing demand for fast software innovations [14].

At the beginning of the development of a new networking platform, the number of changes per release is high. It decreases with growing maturity of the platform (for details, see Sect. 3.1/Fig. 5).

2.2 Bus Load Calculation

The bandwidth requirements of automotive networks are measured as the percentage of available bandwidth, which is used by actual transmissions. This percentage is called bus load L. The generally accepted method to calculate the bus load [16, 26] works by calculating the partial load l_i for every PDU on the bus considering its size b_i in bits, its cycle time t_i in seconds, and the bitrate of the bus B in bits/s:

$$l_i = \frac{b_i}{t_i \cdot B} \tag{1}$$

and summing up all partial loads l_i:

$$L = \sum_{\forall i} l_i \tag{2}$$

For CAN-FD, the calculation of the partial load is split into two parts for the high and low bit rate parts of each frame. For the calculation of size b_i not only the size of the PDU, but also the address/arbitration bits, the CRC sum, and the bit stuffing have to be considered [10]. The exact numbers, used in this paper, were taken from the ISO standard for CAN/CANF-FD [12].

2.3 Timing Constraints

CAN is based on a carrier sense/multiple access (CSMA) arbitration scheme, which means that with an increasing busload, the probability of any message transmission, having to wait for another transmission to finish, increases. To meet latency requirements, the busload must be limited (to values of less than 100%) [22].

Without optimizations, not more than 30–40% of the available bandwidth should be used. By adjusting cycle times, priorities, and by considering the individual latency requirements of each message, bus utilization of up to 80% becomes possible [4, 5].

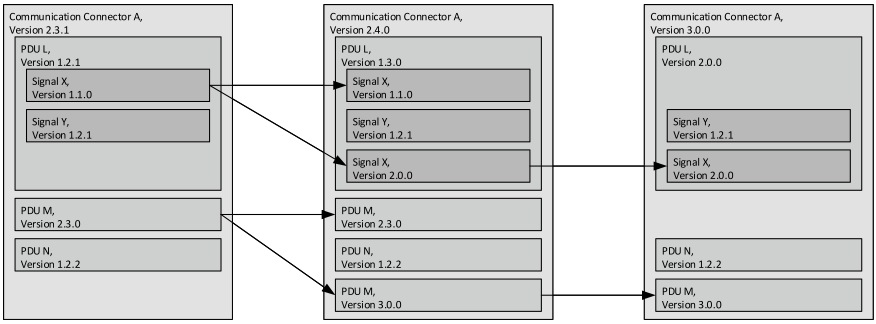

Fig. 3 A series of three development releases of a communication connector. Image taken from [25]

2.4 Compatible Extensions

Compatibility on network level depends on the used communication mechanisms. In general, a definition A and a modified definition B of frames, PDUs, and signals are considered to be compatible if an ECU with the definition A can still retrieve the same data from the definition B by using the information from definition A only.

Compatibility can be maintained, by duplicating modified communication elements and leaving the original one unchanged. The two approaches presented in [25] do this either on a single level of the hierarchy of communication elements (see Fig. 2) which is called **"simple backward compatibility"** (SBC) or on two hierarchy levels (e.g., signal- and PDU-level) which is called **"hierarchical versioning"** (HV). The compatibility status of each element is declared through a semantic version number [23]. Figure 3 shows an example of compatible and incompatible versions of a communication connector.

The first definition of a communication connector (version 2.3.1) is compatible to the second CC definition (version 2.4.0) because

- All signals and PDUs from version 2.3.1 are still present in version 2.4.0
- All signals and PDUs from version 2.3.1 still have to same position.

Since the two structures are compatible, they have the same major version 2. Version 2.4.0 is compatible to 2.3.1. But 2.3.1 on the other hand is *not* compatible to 2.4.0. That is because a communication connector with version 2.3.1 will still get all the expected information from a version 2.4.0 CC. On the other hand, a CC with version 2.4.0 cannot retrieve signal X in version 2.0.0 from a communication connector in version 2.3.1 and thus is incompatible.

Version 3.0.0 of the CC is incompatible to both other versions (2.3.1 and 2.4.0). That is because a communication connector with version 2.3.1 or 2.4.0 cannot retrieve, e.g., signal X in version 1.1.0 from a CC with version 3.0.0.

The duplication of elements (signal x in both versions 1.1.0 and 2.0.0 and PDU M both in versions 2.3.0 and 3.0.0) in the backward compatible version 2.4.0 of the communication connector causes an increase in bandwidth. Eventually, when all

ECUs of the network have migrated to the newer versions, a cleanup is performed, and version 3.0.0 of the CC has a decreased bandwidth requirement.

More information about hierarchical versioning and compatible definition of communication behavior can be found in [25].

3 Concept for Simulation of Communication Matrix Development

3.1 Real-World Communication Matrix Development

In the beginning of vehicle network development, when communication matrices still were actual tables with signals on one axis, and ECUs, on the other, standard office software like Microsoft Word or Excel were sufficient tools for communication modeling. The size and complexity of modern networks and the parameters necessary to configure AUTOSAR base software require the application of specialized modeling software [8, 18].

At Mercedes-Benz, a database backed communication modeling tool is used, which not only stores communication matrices with all their elements and parameters for all releases, but also links the different versions of each communication element. This gave us the opportunity to analyze the changes that have been made during the development phase of a recent model series. Based on that we could calculate the bus load for each of the real c-matrix releases, simulate the two compatibility schemes with different parameters, and calculate the bus load for the simulated c-matrix releases.

The current development is structured into three-month-long cycles, resulting in CM releases named after year and calendar week (e.g., "Release 2019–42") with releases in the weeks 05, 17, 29, and 42. In theory, this would lead to four releases per year, in reality, these "A-releases" are shortly followed by B- and sometimes C- or D-releases with last-minute bug-fixes. Eventually, this results in roughly ten releases per year. All release times are marked on the x-axes of the following diagrams, with annotations for the A-releases. Due to public holidays, the dates are not perfectly even-spaced.

The data used in this paper is from the communication matrix of the "Standard Architecture 3" (STAR3) networking platform of Mercedes-Benz [19]. This platform was the basis for the 2020 S S-Class, the 2021 EQS and later model series.

3.2 Preliminary Analyzes

Before going into any simulations, we start with calculating and plotting the bus loads over the development time of the unmodified networks. Figure 4 shows what

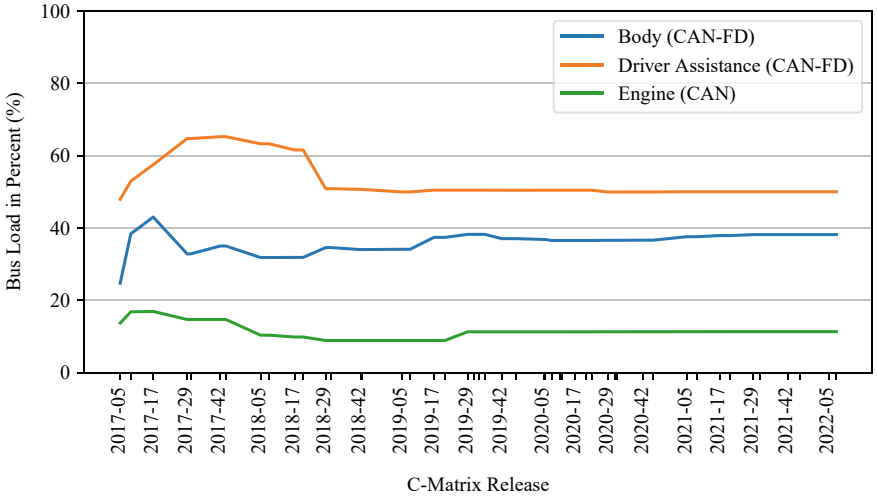

Fig. 4 Base loads of selected networks.

we call the "base load" of different buses. This base load will be the lower bound of the bus loads after applying any compatibility schemes to them.

The compatibility schemes work by redundantly transmitting signals that have been changed. Thus, the increase in bus load will depend on the rate by which signals are changed between releases. Changes of the communication are caused by development and improvements within the various ECU projects and by issues which are found and subsequently fixed during the various testing stages. Figure 5 shows for each release the percentage of signals which have been changed since the previous release. The change rate starts out high, with almost 80% of all signals being changed between the first A- and B-release, followed by a decline with increasing maturity of the networking platform. The small increase following release 2021–17 is caused by the start of work toward the face-lift versions of the respective model series.

Offering simple backward compatibility works by duplicating an entire PDU, if a signal within has changed. In contrast, hierarchical versioning will try to duplicate the changed signal and only resort to duplicating the entire PDU, if the signal duplication is not possible due to PDU length limitations. To estimate the probability of successful signal duplication, we checked the sizes of all CAN and CAN-FD PDUs. The results are plotted in Figs. 6 and 7. By far, the most common PDU size is 8 bits, both for CAN and CAN-FD. This leaves plenty of room to extend PDUs and thus makes an advantage of hierarchical versioning against simple backward compatibility probable. Notable is also the relatively small amount of CAN-FD PDUs larger than 64 bits, suggesting that CAN-FD is mostly used for the increased transmission speed, rather than the greater frame size.

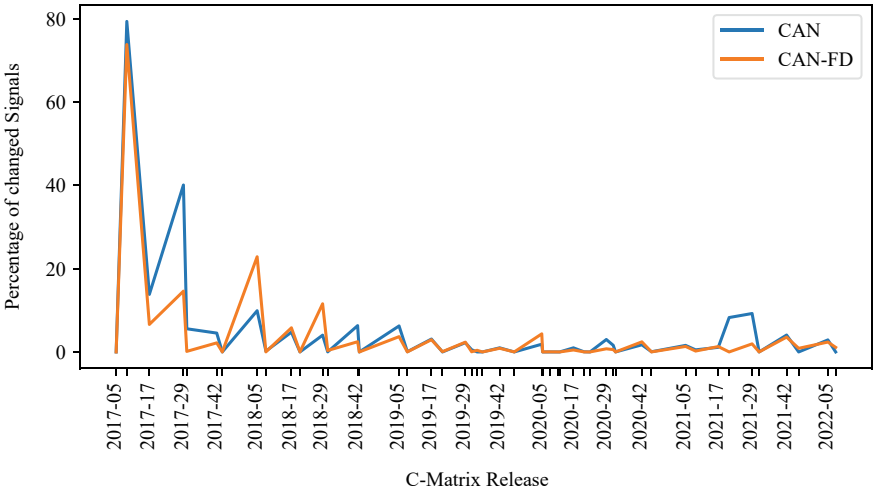

Fig. 5 Signal changes per release

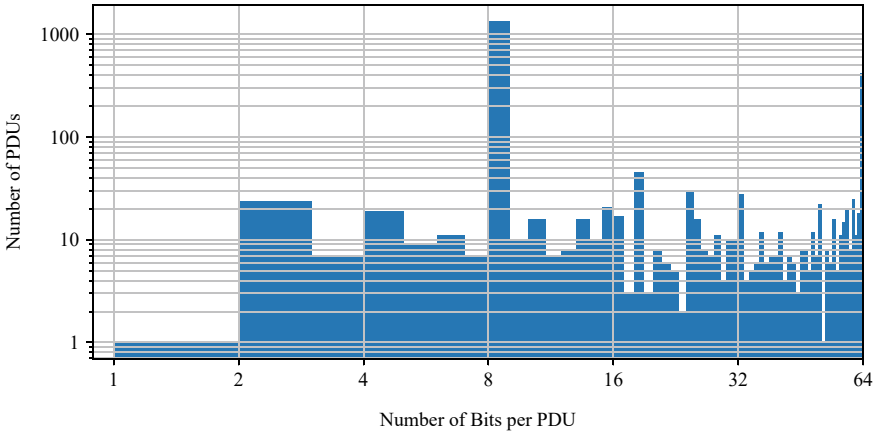

Fig. 6 Distribution of PDU sizes over all CAN buses

3.3 Parameters for Re-iterating the C-Matrix Development

To precisely answer if either or both of the compatibility schemes could be used without exceeding the bandwidth limitations of the existing buses, we built a simulation re-iterating the entire C-matrix development process, based on the signals and PDUs in the real C-matrix, building alternative C-matrices according to the rules presented in [25].

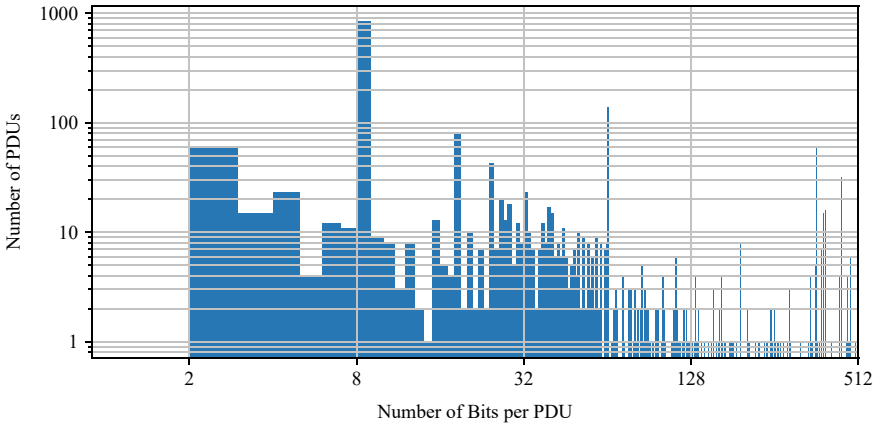

Fig. 7 Distribution of PDU sizes over all CAN-FD buses

The simulations three main parameters:

- An offset (measured in "number of A-releases"), indicating how many A-releases after the initial release the compatibility mechanisms should be enabled.
- The duration (measured in "number of A-releases"), for which interfaces are to be kept compatible (for simplicity, we used the same lifetime for all interfaces).
- A switch between hierarchical versioning and simple backward compatibility.

In [25], a few rough estimations using statistics about the overall vehicle network were made, regarding the applicability of the proposed scheme. In contrast to this, our simulation was set up considering:

- exact number of bits of each signal and PDU
- different ID lengths (11bit vs 29 bit) for each PDU
- different amounts of stuffing bits and lengths of CRCs according to the ISO11898-1 standard [12]
- different cycle times of each signal and PDU
- individual bit rate(s)[1] of each bus.

Having accounted for all these details, we are confident to provide accurate values for the bus loads of our simulated C-matrices.

[1] In case of CAN-FD networks, the different configurations for arbitration and transmission bit rates have been considered.

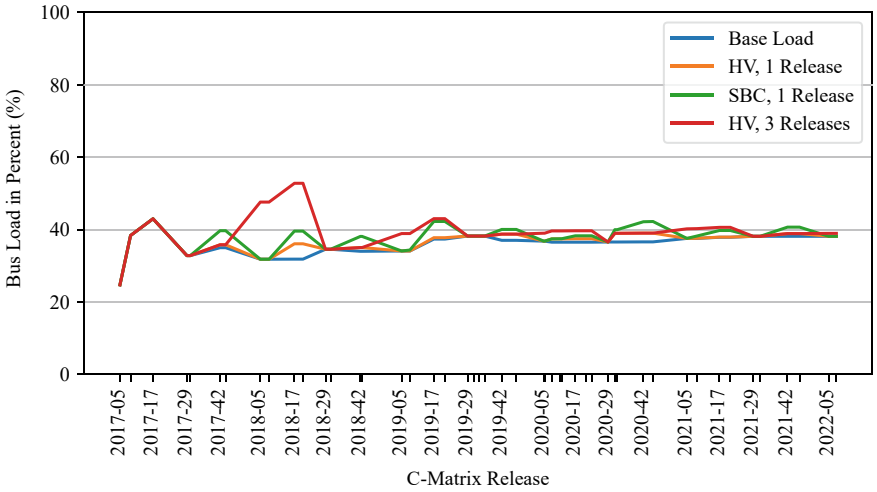

Fig. 8 Simulation results for different configurations on the body CAN-FD bus

4 Results

4.1 Different Offsets

Initial runs of the simulation with different offsets showed a great difference between even and odd offsets. Looking at Fig. 5, it becomes apparent why: The A-releases of weeks 05 and 29 bring in most years more changes than the releases in the weeks 17 and 42. Therefore, all further simulations were performed with a fixed offset of one. The results of these simulations, for the three buses presented in Fig. 4, are presented in the diagrams in Figs. 8, 9, and 10. Each showing four different configurations:

- base load for that bus (as in Fig. 4)
- hierarchical versioning is used to add one compatible release (six months)
- simple backward compatibility is used to add one compatible release
- hierarchical versioning is used to add three compatible releases (one year).

Adding one compatible release means alternating between compatible and incompatible releases, resulting in two mandatory (i.e., which ECU has to integrate) releases per year. Adding three compatible releases reduces the mandatory releases to one per year.

In each of the three diagrams, the base load forms the lower bound for all the simulated bus loads. The compatible extensions are removed for incompatible releases, which causes a return to the base load. Evaluation of the results works by comparing the increases between the base load and the simulated loads for the compatible releases.

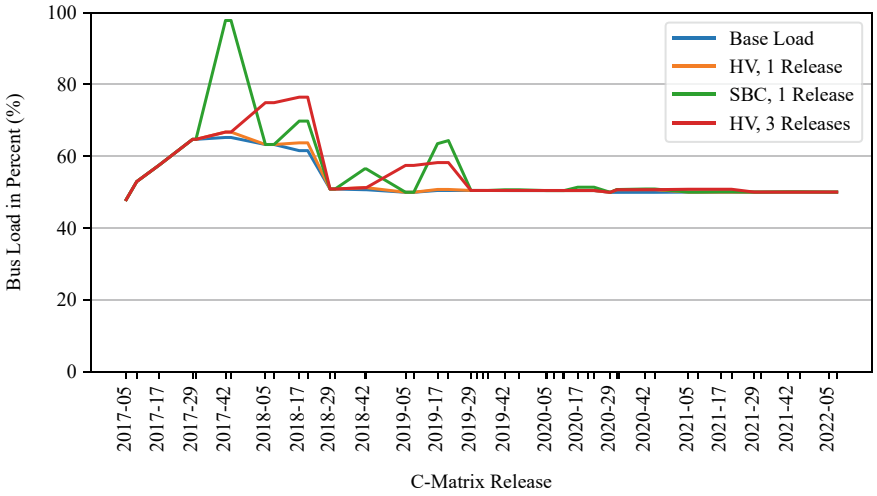

Fig. 9 Simulation results for different configurations on the driver-assistance CAN-FD bus

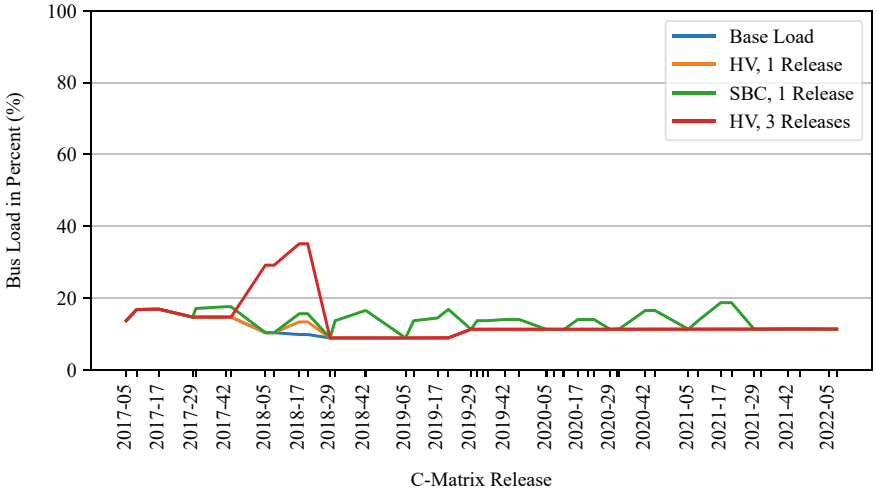

Fig. 10 Simulation results for different configurations on the engine CAN bus

4.2 Simple Backward Compatibility Versus Hierarchical Versioning

The increase in bus load of the green SBC-curve is above the orange one-release-HV-curve at all times. This confirms the advantage of hierarchical versioning over simple backwards compatibility, which was expected due to the distributing of PDU sizes (Fig. 6).

In many releases, the SBC-curve is much higher than the HV-curve (each compared to the base load), in some (e.g., Release 2018–17 for the Engine CAN), the difference is smaller. This fluctuation is caused by the varying composition of the changes made to a network: If the changes are made to PDUs which are too full for extension on signal level, the increase in bus load gets closer to the SBC-curve.

4.3 Hierarchical Versioning of Different Durations

Comparing the orange one-release to the red three-release-HV-curves shows the same values for the 05-releases. For the half-year-HV, the following week 17 releases are mandatory or cleanup releases, where the redundancies are cleared out, and the load drops back down to the base load. The one-year-HV also has to keep these releases compatible, and thus, the curves go even higher above the base load here.

The sharp increase toward the week 17 release shows the importance of setting a correct offset: There can either be two steep and one low increase, or two low and one steep increases.

The increase toward the third compatible release is steeper than the increase in the half-year HV-curve. This is because due to the two previous compatible releases, which led to fuller PDUs and therefore a reduced probability of signal level extension.

5 Conclusion

5.1 Impact on Bus Loads

Our analyzes have shown that backward compatibility schemes cause an increase in bus load just as expected. As discussed in Sect. 4.2, they have confirmed that hierarchical versioning causes less overhead than simple backward compatibility.

Depending on the limits for the maximum busload, which different manufacturers may define differently (and might even define different for each bus, see Sect. 2.3), the increased load would fit within.

Regarding the simulated busloads as well as the measured change rate between different releases, we recommend starting the development process with hierarchical versioning, with a compatibility duration of half a year. Later, once the network has reached sufficient maturity (e.g., Release 2019–29 in the analyzed data), the compatibility duration may be increased to a full year.

5.2 *Future Work*

Our analyzes are based only on the data of Mercedes-Benz. It should be examined, if the C-matrix development processes of other car manufacturers (with potentially different release frequencies and change rates) yield similar results.

So far, we focused on CAN and CAN-FD. A next step will be, to extend the simulation to also cover Ethernet networks. For these, we expect two major differences: Firstly, due to the topology of switched point-to-point connections, the individual loads of each link must be considered. Secondly, due to the service-oriented nature, extensions do not necessarily increase the load (e.g., an ECU offers two versions of a service, but only one version is requested by a subscriber, and therefore, only one version is transmitted).

Since the simulations have shown the applicability of hierarchical versioning, a next step will be to select a subnetwork (e.g., a single bus) and a few ECUs, to be developed in faster cycles than the rest of the network, with compatible intermediate releases, to gather practical experience.

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Proposal of Knowledge Network Model Education for STEM/STEAM Education

Hisami Nakata, Kunihiko Takamatsu, Kenya Bannaka, Ryosuke Kozaki, Katsuhiko Murakami, Sayaka Matsumoto, Aoi Kishida, and Yasuo Nakata

Abstract Information and communication technology (ICT) education is important for the younger generation because of the rapid evolution of technology. Both science, technology, engineering, and mathematics (STEM) and science, technology, engineering, the arts, and mathematics (STEAM) educations are important in the twenty-first century. Why do we have to think about STEM/STEAM education for the young generation? The answer lies in both creativity for the younger generation as well as a better quality of life (QOL) in the future. ICT technology is quickly evolving, and in the future, the younger generation will have to use more ICT technology. Actually, this paradigm shift is promoted in the new era of Industrial 5.0 and Society 5.0. In this research, we investigate how can we create new knowledge using knowledge graphs in education for 21st education, Industry 5.0 or Society 5.0. We show the visualization of complex networks of keywords that is too difficult to understand. Moreover, we show the simpler network by text mining. In STEM/STEAM education, it is important for the Industry 5.0 or Society 5.0 era. Therefore, we propose knowledge network model education for STEM/STEAM education or 21st education for ICT.

Authors Hisami Nakata and Kunihiko Takamatsu contributed equally to this work.

H. Nakata (✉) · K. Bannaka · Y. Nakata
Kobe Tokiwa University, Kobe 653-0838, Japan
e-mail: h-nakata@kobe-tokiwa.ac.jp

K. Takamatsu · S. Matsumoto
Tokyo Institute of Technology, Tokyo 152-8550, Japan

R. Kozaki
Hyogo University of Teacher Education, Hyogo 673-1415, Japan

K. Murakami
Tokyo University, Tokyo 108-0071, Japan

A. Kishida
Kobe City Nishi-Kobe Medical Center, Kobe 651-2273, Japan

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Keywords ICT · Complex network · Knowledge network · STEM/STEAM education · 21st education

1 Introduction

Information and communication technology (ICT) education is important for the younger generation because of the rapid evolution in technology. There are many international conferences and congresses on ICT [1]. On the other hand, coronavirus disease 2019 (COVID-19) restricted our life style and strongly promoted learning methods from physical to online [2].

Science, technology, engineering, and mathematics (STEM) education is one of the most important education for the twenty-first century [3]. In 2010, Bybee introduced the importance of STEM education in the famous scientific journal "Science" [4]. The article titled, "What Is STEM Education?" discussed the importance of STEM education in dealing with not only science and mathematics but also technology and engineering for citizens in the twenty-first century. STEM education is important for scientific literacy for younger generations.

Moreover, both art and STEM created a variant discipline referred to as science, technology, engineering, the arts, and mathematics (STEAM) [5] that assists in improving creativity for the younger generation, which is important. Therefore, STEAM education is one of the important disciplines of STEM education. This means that STEM/STEAM education is important for both higher education as well as pre-primary education, primary education, and secondary education because students. There has already been research in early childhood education for STEM/STEAM education [6, 7].

Why do we have to think about STEM/STEAM education for the young generation? The answer is creative development for the younger generation as well as improved quality of life (QOL) for their future. In the future, younger generations will have to use more ICT technology that is constantly evolving. Actually, this paradigm shift promotes the new era of Industrial 5.0 [8] and Society 5.0 [9, 10].

Society 5.0 is a concept for a future society [11]. The Japanese cabinet office defines Society 5.0 as follows. It refers to Society 1.0 as the hunting society, Society 2.0 as the agricultural society, Society 3.0 as the industrial society, Society 4.0 as the information society, and Society 5.0 is the future (new) society [11] (Fig. 1).

In the era of Society 5.0, education is not the same as Society 1.0 to 4.0. For example, the Organization for Economic Co-operation and Development (OECD) has proposed competency-based education, distinguishing between technical and core competencies [12]. OECD describes "Technical competency requirements to successfully perform a given job are defined in job vacancy announcements [13]." Further, the OECD defines core competencies as delivery-related cluster, interpersonal cluster, and strategic cluster [12]. Therefore, education in the twenty-first century includes both simple knowledge, the use of knowledge and how to create new knowledge.

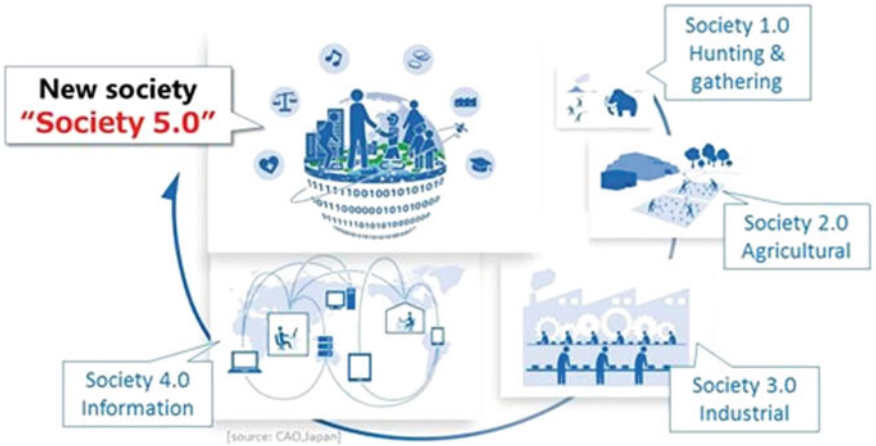

Fig. 1 Society 5.0 [11]

In this research, we investigate how we can create new knowledge using knowledge graphs. The technical term, "Knowledge Graph (KG)" has been used in the fields of Semantic Web [14]. KG is synonymous for any graph-based knowledge representation [15] and there are many definition of KG [14]. Already we propose making new KGs using network models as a three-step network model [16] and tag-based network models, both similar to KG [17]. Additionally, we propose data-driven theoretical research on reading picture books based on these three-step or tag-based network models [18]. To answer our research question, we propose new education using reading books for primary education for new the ICT era to continue STEM/STEAM education in secondary and higher education.

2 Material and Methods

2.1 Data Preparation

We gave the students a homework assignment, which is to create three keywords against one picture book. Meaning students must set three keywords against one hundred pictures. Therefore, one student makes three hundred keywords. In this research, which took place between 2019 and 2020, students made 23,853 keywords from 7951 picture books. The data collected were used in this research.

2.2 *Analysis Software*

We use Cytoscape [19] version 3.9.1 and KH-coder [20, 21] to analyze and visualize these complex networks.

3 Results and Discussion

We visualize 23,853 keywords of 7951 picture books (Fig. 2) to investigate the complex networks of picture books and their keywords. Each book includes three keywords (Keywords 1, 2, and 3). We constructed networks by setting keywords as nodes, and co-occurrence of the keywords in the same book as edges. We prepare whole combinations (in this case $3 = {}_3C_2$) and import these data by Cytoscape [19] to visualize the complex network. We show summary statistics in Fig. 2 (number of nodes is 5487; number of edges is 23,853; average number of neighbors is 7.113; network diameter is 9; network radius is 5). We show the degree (the number of edges both from and to a node) and the number of nodes (Fig. 3).

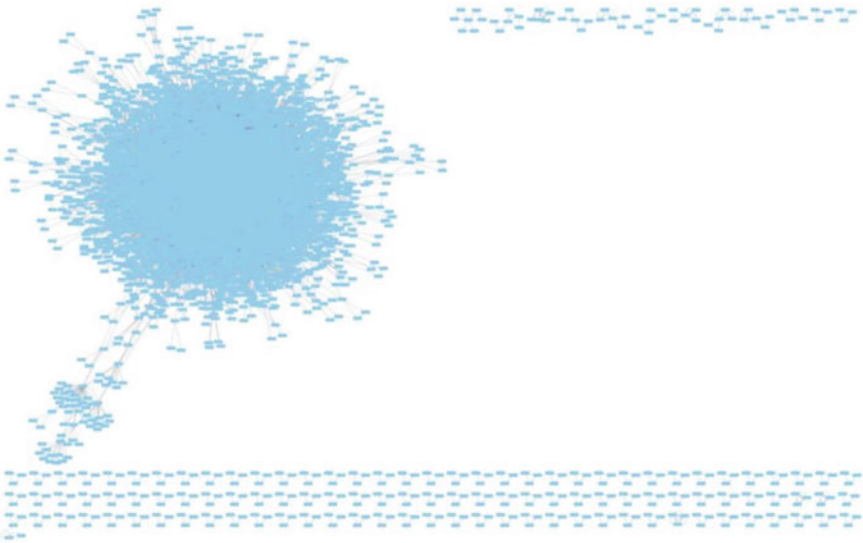

Fig. 2 Visualization of complex network 23,853 keywords of 7951 picture books in total. Each node shows keywords

Fig. 3 Degree and number of nodes of complex network. *X*-axis shows degree of node, and *y*-axis shows number of nodes

Maximum degree is 1712 and the node is animal. We then show the top 50 nodes by degree (Table 1). Unfortunately, it is too difficult to understand the network. Therefore, we used the top 45 nodes about degree and visualized their network. However, situation is similar to Fig. 1 (data not shown). To understand complex network, we performed text mining against the prepared data using the KH-coder [20, 21]. We show the top 45 words in Table 2.

We then compared Tables 1 and 2. The number of common nodes and keywords is thirty-one; in Table 1 "ghost" is 6th place; however, we could not locate "ghost" in Table 2.

Next, we show co-occurrence network of text mining in Fig. 4. When we compare Figs. 1 and 2, we can easily understand the relationship between keywords; each edge shows the picture book. However, we have to note that sometimes keywords are spirited to other keywords by separation programming in text mining. This shows that we can make book reading order using this co-occurrence network.

Table 1 Top 45 nodes about degree

Order	Node (keyword)	Degree	Order	Node (keyword)	Degree	Order	Node (keyword)	Degree
1	Animal	1728	16	Nature	226	31	Color	156
2	Fun	690	17	Christmas	210	32	Girl	156
3	Interesting	590	18	Parent–child	208	33	Impression	156
4	Friend	450	19	Wonder	206	34	Baby	152
5	Family	448	20	Mother	198	35	Kindness	148
6	Ghost	430	21	Exciting	196	36	Apple	142
7	Rabbit	382	22	Winter	190	37	Bread	142
8	Growth	334	23	Pal	186	38	Play	142
9	Pretty	304	24	Imagination	184	39	Psychological growth	142
10	Mouse	262	25	Food	178	40	Child	140
11	Cute	250	26	Dog	172	41	Pleasant	136
12	Interesting	246	27	Cooperation	168	42	Life	134
13	Bear	242	28	Elephant	164	43	Boy	130
14	Adventure	240	29	Fun	164	44	Woods	128
15	Cat	238	30	Night	158	45	Sea	128

As described in Sect. 1, twenty-first century education includes simple knowledge as well how to use knowledge and create new knowledge. In this research, we investigate how to create new knowledge using KGs in education for the 21st education, Industry 5.0, or Society 5.0. We usually think about connection when we read books. In this research we show the relationship between books using three keywords. However, in Fig. 1, we understand that three simple keywords is too difficult to understand the relationship in a complex network. Therefore, we propose knowledge network model education for STEM/STEAM education for twenty-first century education for ICT.

Table 2 Top 45 keyword about occurrences in text mining

Order	Keyword	Occurrences	Order	Keyword	Occurrences	Order	Keyword	Occurrences
1	Animal	942	16	Kind	117	31	Human	85
2	Fun	451	17	Christmas	107	32	Impression	83
3	Interesting	308	18	Color	102	33	Picture	81
4	Growth	243	19	Mother	101	34	Girl	81
5	Friend	236	20	Exciting	101	35	Child	78
6	Family	234	21	Think	98	36	Sea	74
7	Picture book	178	22	Winter	96	37	Forest	71
8	Imagination	170	23	Dog	94	38	Cat	71
9	Cute	152	24	Baby	94	39	Words	70
10	Adventure	126	25	Pal	94	40	Birth	70
11	Heart	123	26	Night	92	41	Boy	70
12	Nature	122	27	Play	91	42	House	66
13	Parent–child	121	28	Food	90	43	Fish	65
14	Wonder	119	29	Cooperation	86	44	Mouse	64
15	Bread	118	30	Life	86	45	Important	64

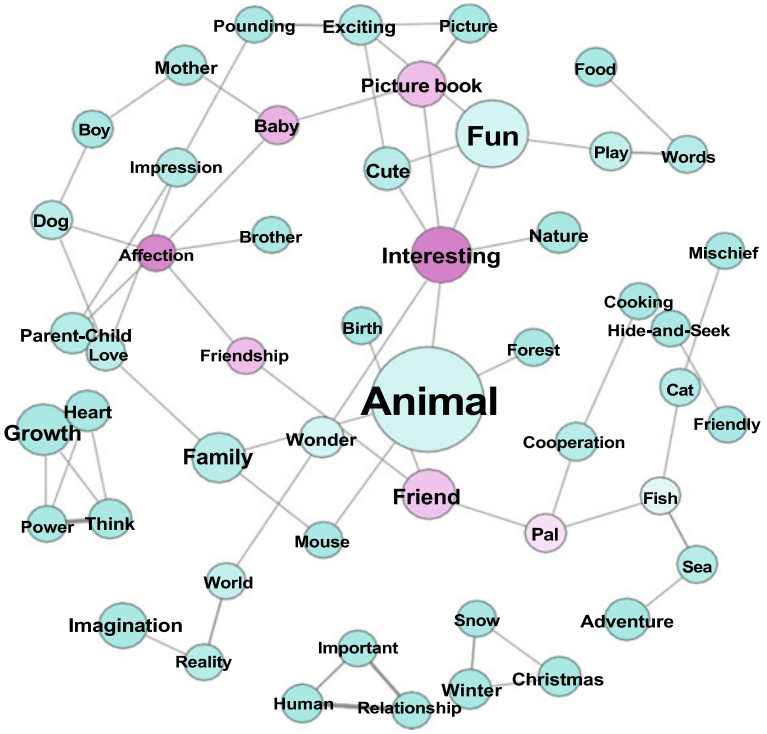

Fig. 4 Visualization of co-occurrence network about 23,853 keywords of 7951 picture books in total. Each node shows keywords books

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Underwater Object Detection Through Analysis and Data Augmentation of Underwater Datasets

Atsuki Imada, Takafumi Katayama, Tian Song, and Takashi Shimamoto

Abstract Nowadays, with the rapid development of artificial intelligence (AI) technologies, more and more jobs can be fulfilled by underwater drones. Particularly, object detection with deep learning becomes an important issue which can significantly improve the performance of underwater drones. In this work, we analyzed and augmented an existing underwater dataset and proposed a new object detection dataset for inshore aquaculture. The renewal dataset is used for the training of the network for real-time object detection. The simulation results showed that the existing underwater dataset has a class imbalance problem. In addition, it is shown that although large objects are detected with high accuracy, rocks and small shadows are sometimes mis-detected as targets. It is due to the distance between the target object and the camera lenses, simulation of the background, and the object detection model not learning the difference between background and target. This indicates that object detection accuracy could be improved by the dataset that can accurately learn object features.

Keywords Deep learning · Object detection · Underwater

A. Imada (✉) · T. Katayama · T. Song · T. Shimamoto
Tokushima University, Minami-Josanjima 2-1, Tokushima, Japan
e-mail: c612134055@tokushima-u.ac.jp

T. Katayama
e-mail: katayama@ee.tokushima-u.ac.jp

T. Song
e-mail: tiansong@ee.tokushima-u.ac.jp

T. Shimamoto
e-mail: simamoto@ee.tokushima-u.ac.jp

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1 Introduction

With the rapid growth of the inshore aquaculture, more and more cutting edge technologies are introduced in oceanic engineering. Especially, modern artificial intelligence is introduced for more and more underwater jobs and some special underwater operations. As an emerging industry, underwater drones with current AI technologies are expected to not only improve the possible underwater operations but also the information collection ability. Underwater drone exploration of the ocean and monitoring of inshore aquaculture are important technologies for solving food problems in items that realize a sustainable world. Underwater operations by humans are inefficient because of the high risk and the many restrictions on dive time and depth imposed by safety regulations. In addition, the economics of large-scale inspections are very problematic because of the large equipment required. If the underwater drone has water pressure resistance and a stable power supply for operation, there is no limit to the depth of the dive or the duration of the operation.

Even underwater, where the underwater environment is strongly influenced by the sea environment and visibility is limited, sonar and multiple sensors that can search the surrounding area using sound waves will play an important role in realizing low-cost and efficient inshore aquaculture.

In an underwater environment, color components differ significantly from those on the ground due to light attenuation. Components with longer wavelengths, such as red, are more easily attenuated than those with shorter wavelengths, such as blue. Therefore, contrast bias is observed. In addition, terrestrial organisms living in water are difficult to detect due to the occlusion problem, in which the objects are often small in size, hidden in the sand, or densely packed together, making it difficult to distinguish them from the background and to recognize the areas between objects. Therefore, publicly available underwater image datasets for inshore aquaculture are more challenging than ground image datasets. Therefore, some previous works use image preprocessing tools to achieve color correction firstly, then try to improve the object detection efficiency by improving the quality of the dataset [1, 2]. This previous works propose easy_URPC2018, an underwater image dataset for inshore aquaculture with low difficulty of object detection models for aquaculture by screening and difficulty classification of existing underwater datasets.

We investigate by comparing object detection results before the usefulness of the data augmentation and the problem in the underwater images. Our contributions can be concluded as follows: (1) Proposed a novel dataset to evaluate object detection accuracy in inshore aquaculture. (2) Analyzed the proposed dataset to solve the class imbalance problem. (3) Evaluated the usefulness of the object detection algorithm of the proposed dataset.

2 Related Works

2.1 Object Detection

Object detection is the identification of the location and type of objects in an image. Object detection techniques can be broadly classified into two categories. The first is one-stage object detection, which simultaneously recognizes the position of an object and classifies it into a class. The second is the two-stage object detection method, which recognizes the position of an object and then classifies the objects in the area into classes. Typical algorithms for one-stage are YOLO [3], and for two-stage, R-CNN [4]. In 2021, YOLOX is presented by Ge et al. [5]. It is designed with YOLOv3-SPP, which consisted of adding an SPP layer to the YOLOv3 backbone. Various branches are employed as learning strategies, and multi-scale, mixup and mosaic are used for data augmentation. It also introduced anchor-free, SimOTA, and decoupled head as important contributing techniques of it. These effects resulted in a 6% decrease in FPS but a 1.8% increase in AP compared to YOLOv5, the most recent model at the time, on a 640 $\times$ 640 resolution coco dataset.

2.2 Data Augmentation

With recent advances in neural networks, deep learning has made great strides in the field of computer vision. However, the performance of deep learning models are significantly affected by datasets. Therefore, both the quantity and quality of data are necessary. In addition, the problem faced when training neural networks are that the vast amount of accurately labeled training data is generally not sufficient. Data augmentation is often used to address this problem. Data augmentation refers to the process of augmenting the number of data by processing a portion of the training data when the training data required for a deep learning model to make predictions is small [6]. In the field of image processing, rotation of an image to a certain angle based on its center, flipping an image symmetrically along the x and y-axis, and cropping a portion of an image to resize it are used to create new training data.

Rotation: Data augmentation methods that rotate the center of an image by a specific angle are commonly used. These transform the image geometrically so that the environment in which the object is photographed has changed and can be considered new data. However, some objects in the image have meaning in the structure itself, and the risk of altering them must be considered. However, slight rotations within the range of 1–30° have been found useful to improve accuracy of image recognition.

Flipping: It is a different data augmentation technique from rotation, both of which are mirror images with inverted x- and y-axis symmetry. Also, like rotation, it has the potential to change the structure of an object. However, flipping is highly dependent

on the type of input data. Therefore, in the case of data containing numbers or text, flipping may make the data unsound as information.

Cropping: Cropping is a data augmentation that has the same effect as a geometric transformation. It will reduce the size of the processed image. Cropped images can help to improve the quality of the training data.

3 Proposed Methodology

3.1 Underwater Datasets

This study uses the open underwater robot picking contest dataset URPC2018 provided by the National Natural Science Foundation of China and the Dalian Municipal People's Government. The dataset used here consists of a total of 7600 datasets, consisting of images with clean annotation data and images with annotation data containing blur. However, this dataset contained a lot of strong blur and mislabeling. Therefore, we regret and screen the dataset.

First, the images containing strong blur are removed. Next, the relabeling of the remaining data is corrected according to the policy. As a standard for the box size, the size of the object is calculated from the image width, camera viewing angle, and distance from the camera to the object [7]. This study uses a width of 720 pixel, a height of 405 pixel, a camera viewing angle of 80°, and a camera to object distance of 1.5 m to obtain the size of the object in one pixel. The labeling policy for each class is

Sea urchin: Bounding box including spines with box size at least 25 pixels wide and 20 pixels high.

Starfish: Rectangular box, 14 pixels wide and 10 pixels high or more.

Scallops: Rectangular box, 20 pixels wide and 15 pixels high or more.

Sea cucumbers: Labeling the all objects we found, 14 pixels wide and 10 pixels high or more.

In addition, starfish and scallops are defined to be given a box up to the overlapping area if either one of the sides exceeds the threshold or if there is an overlap of objects. Finally, after modifying the labels based on the policy, the threshold process removes boxes that differ from the policy.

As the result, URPC2018 consisted of 2522 images instead of 7600.

3.2 Object Detection with YOLOX

The proposed object detection is consider to be mounted on an underwater drone. Therefore, a lightweight but highly accurate with an excellent trade-off between both high detection accuracy and processing speed. YOLOX-s is selected as the baseline model in our experiments. To train these models, we defined easy_URPC2018 as a total number of 951 images with only $1 \sim 4$ instances. However, when we analyzed the number of instances, we found that the number of scallops is small, so we augment the train and eval data.

We added 125 images to the train data, augmented by flop and random crop, and 120 images to the eval data, augmented by random crop. Final dataset of 886 train images and 310 eval images, for a total of 1196 images. The original image resolutions are resized to 720×405.

As a hardware solution, NVIDIA TITAN RTX GPU is used for all the simulations. The epoch number is set to 300. The final adjusted dataset is analyzed for the number of instances and instance size in the dataset according to the MSCOCO paper [8].

4 Result

Figure 1 shows the results of the analysis of the datasets before and after the augmentation. As Fig. 1 shows, the dataset before augmentation is found to contain class imbalance problems. Also confirmed that these imbalance problems are eliminated by data augmentation. We believe that the data augmentation allowed the model to counteract overlearning and adjust the detection difficulty level during inference with respect to the training data.

The experimental results before and after data augmentation are given in Tables 1, 2 and Figs. 2, 3. Table 1 shows the average precision (AP) for each YOLOX-s model before data augmentation. Table 2 shows the AP and the mean AP (mAP) for the YOLOX-s model after data augmentation. In addition, the processing times for inference process are evaluated by the frames per second (FPS). It can be seen that the mAP before and after the augmentation improved by about 1.4%. In terms of AP for a single class, scallops with augmentation show an improvement of about 11.4%. However, APs of sea cucumber decreased by 6.7%.

Next, we show the influence of data augmentation on the detection results. Figures 2 and 3 show results when using the proposed dataset. Object detection is assumed in the management of inshore aquaculture. Therefore, it is sufficient if only objects close to the camera on the drone can be detected. The detection results show that objects with large instance sizes are successfully detected. However, it shows that the sea cucumber displayed large in the center of the screen is not detected. Also, in cases of detection failure, it is observed that small shadows and haze are mistakenly detected as sea urchins, curves with clear edges as sea cucumbers, rocks as scallops, and sea cucumbers that appeared large in the center of the screen failed. Many

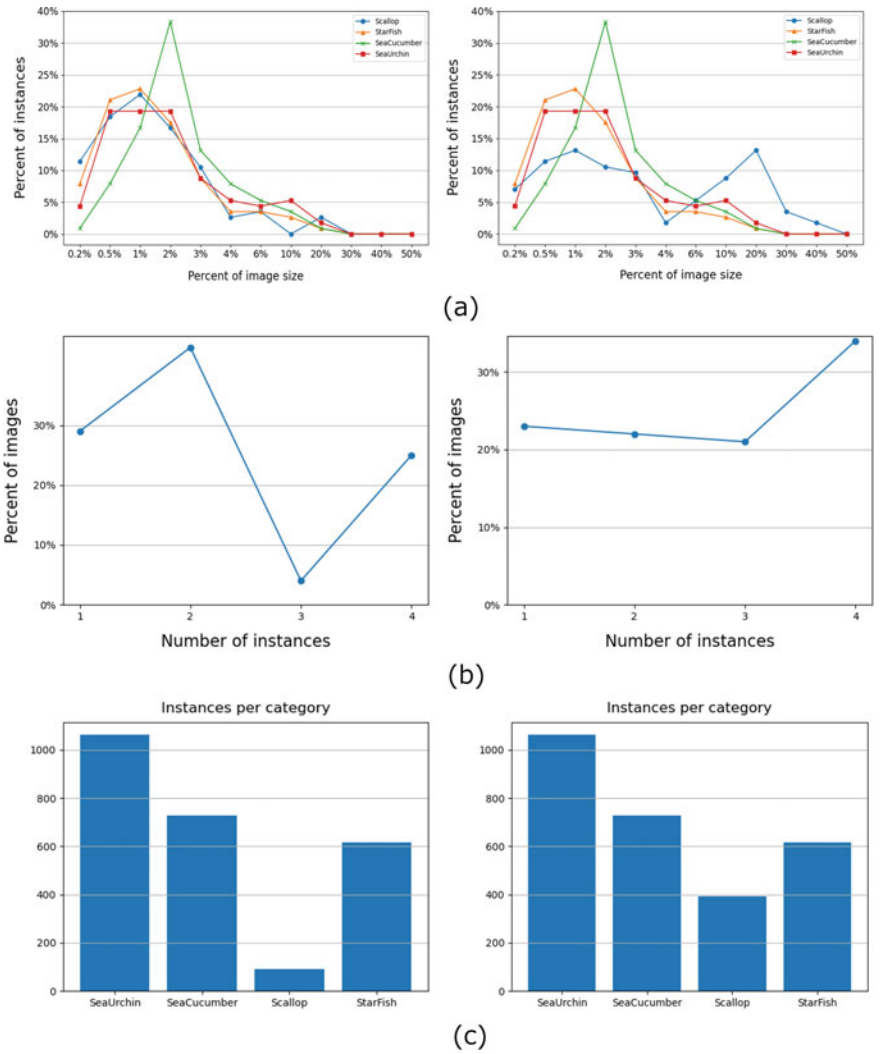

Fig. 1 Before augmentation (left) and after augmentation (right). **a** The distribution of instance sizes for easy_URPC2018. **b** Number of annotated instances for easy_URPC2018. **c** Number of annotated instances per category for easy_URPC2018

Table 1 Simulation result of before augmentation

	Average precision for each class (%)				mAP (%)	FPS
	Sea cucumber	Sea urchin	Scallop	Starfish		
YOLOX-s	82.0	85.1	71.1	81.8	80.0	43.0

Table 2 Simulation result of after augmentation

	Average precision for each class (%)				mAP (%)	FPS
	Sea cucumber	Sea urchin	Scallop	Starfish		
YOLOX-s	75.3	86.5	82.5	81.3	81.4	49.2

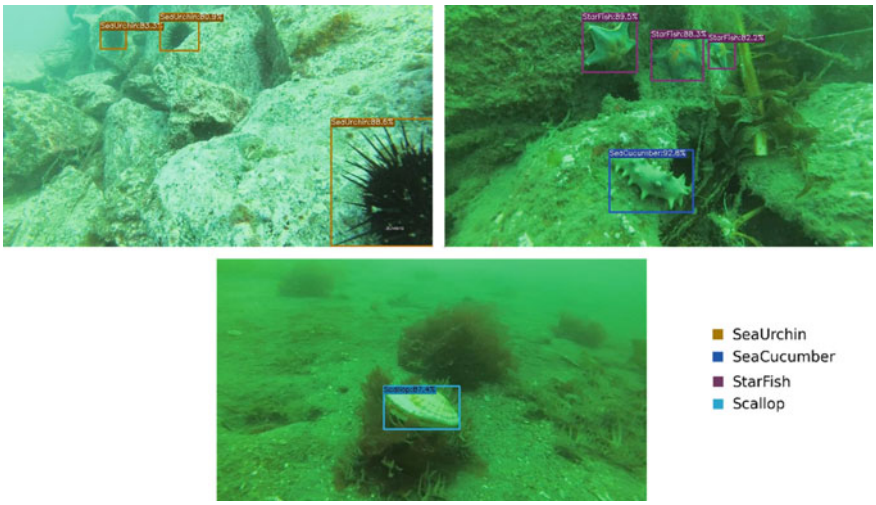

Fig. 2 Example of successful detection

underwater animals are small in size and cover themselves with sand. This makes it difficult to find the features, which may lead to confusion between the background and the objects during learning. Features of underwater structures include spines for sea urchins and sea cucumbers and patterns for scallops. Successful results show that the bounding box includes spines on sea urchins and sea cucumbers, indicating that the model learns the distinctive parts of objects. However, other features include the color and shape of the object. We believe that learning these features has led to false positives because shadows far from the camera and rocks in the background are similar to features of underwater structures.

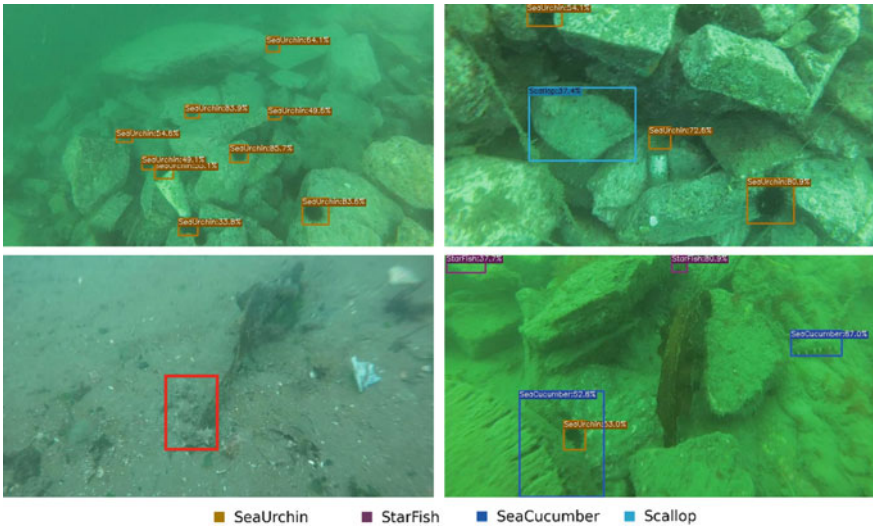

Fig. 3 Example of failure detection

In addition, underwater structures simulating the background are undetectable because they are assimilated into the background, making it difficult to recognize their edges.

Therefore, we believe that improving the quality of the dataset and implementing an architecture that can successfully capture object features will lead to improved detection accuracy.

5 Conclusion

In order to evaluate a highly accurate object detection model for aquaculture, we analyzed and augmented an existing underwater object detection dataset and proposed a new underwater dataset for inshore aquaculture. The proposed dataset focuses on the class imbalance problem and object detection for aquaculture. The training results of the model indicate that underwater organisms simulate the background and that the object detection model learns not only object-specific features but also overhead features during training, which makes it difficult to learn accurate features during training, leading to false positives and undetected objects. Therefore, there remains the possibility of improving object detection accuracy by introducing a network architecture that can accurately learn the quality of the dataset itself and object features.

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IoT: Security and Mobility in IPv6

Serigne Mbaye and Khadidiatou Wane Keita

Abstract The IoT is evolving into a more present, mobile, and secure ecosystem, supported by the Internet. However, all elements are addressable by IPv6, and they hold all relevant IP protocols such as the mobility protocol MIPv6 and the security protocol IPsec. It is not possible that all objects and resources integrated in IoT ecosystems are associated with these protocols designed according to device considerations. The IPv6 protocol defines the home agent or mother agent (MIPv6), which contains the association table of all the mobiles visiting the network and is provided by the security mechanism called IPsec. The MIPv6 protocol is designed to manage mobility in IPv6 networks with IPsec.

Keywords IoT · IPv6 · IPsec · MIPv6

1 Introduction

The field of communications is a fast-growing area, with the arrival of laptops and wireless technology (Wi-Fi networks) [1]. Through the auto-configuration mechanism, the terminals access the connection in order to communicate with the rest of the world. This auto-configuration mechanism is provided by the IPv6 protocols. This protocol supports all IoT security needs with reliable mechanisms for its operation. In IPv6, security is an integral part of the protocol. It is largely provided by IPsec with several modes of operation and using certain mechanisms [2]. In addition, the principle behind IPv6 mobility is to separate the identification and location functions, both traditionally provided by the IP address.

S. Mbaye (✉)
Cheikh Anta Diop University (UCAD), Dakar, Senegal
e-mail: serigne3.mbaye@ucad.edu.sn

K. W. Keita
Polytechnic Institute (ESP), Dakar, Senegal
e-mail: wane.keita@esp.sn

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After an introduction we will deal in Sect. 2 with the needs of IoT (security and mobility), the security and mobility of IPv6 will be discussed in Sect. 3, the relationship between IoT and IPv6 needs will be made in Sect. 4, and we draw a conclusion in Sect. 5.

2 IoT Needs: Security and Mobility

2.1 Security

Security is an aspect encompassing authenticity, authority, integrity, and confidentiality. These aspects are provided by protocols and algorithms.

IoT security is an important concept and is highlighted after the existence security protocol like IPsec for IPv6. It is not overly widespread and deployed due to the difficulties of configuration for clients and the lack of management. As a result, the most of Internet transaction continues to be transmitted unprotected.

On other hand, the IPsec protocol set (IKE and ESP) as well as other access layer protocols are also being considered [3]. Thus, the objectives to be solved for the security bases are the following:

- The primary objective is to optimize the algorithms for the represented protocols.
- The second objective analyzes and estimates the effect of the IP security protocol (IPsec) for the affected devices.
- The final objective analyzes the opportunities of new protocols that meet scalability and management.

2.2 Mobility

Mobility provides a lot of challenge for network and protocol performance, as mobility protocols are composed with the distinctions belonging to the IoT, which are difficult application cycles, reduced perseverance and care capabilities, and limited bandwidth [4].

Mobility organization is composed of two fundamental phases:

- Motion detection makes that the device is moving and therefore needs to be connected to another network.
- Indication and verification information needed to be sure of location changes to networks and clients relating to the moving device.

Thus, a study is made on the support of security and mobility in IPv6 to better understand the needs of IoT.

3 Support for Security and Mobility in IPv6

3.1 Security in IPv6

Security is an important part of IPv6. It is largely provided by IPsec with several modes of operation and using certain mechanisms.

3.2 IPsec Operating Principle

The elements are combined in such a way as to indicate the consistent functional method in the security tool [5] (Fig. 1).

This scheme illustrates the whole security process based of IPv6 established on IPsec. We can explain it under two traffic patterns which are

- Outgoing traffic: When the IPsec layer obtains information to send, it consults the Security Policy Database (SPD) to find out how to handle the data. If the SPD tells it that the traffic needs to have security mechanisms applied, it retrieves the required characteristics for the suitable SA and goes to the SA Database (SAD). The existence of the SA is made to settle the transaction issue. In contrast, IPsec uses IKE to create a new SA with the required features.
- Incoming traffic: The packet coming from the network is consulted by the IPsec layer to know if it is applied in several IPsec functions and if so, what are the SA parameters. It thus goes through the SAD to find out what elements to adopt for verifying with/without decrypting the packet. If the packet has been verified

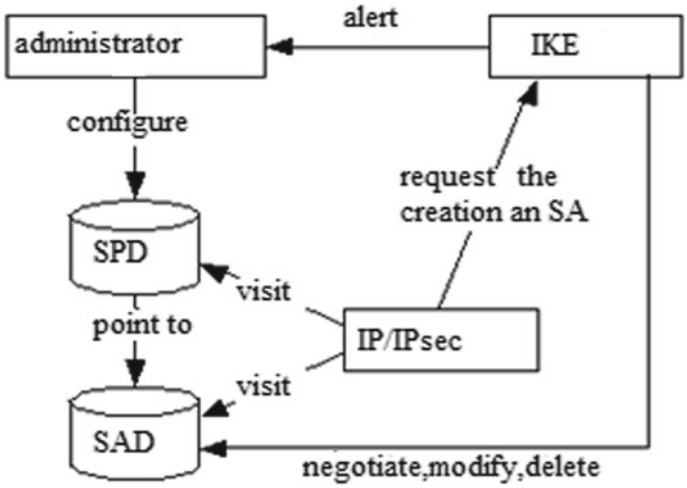

Fig. 1 IPsec operating principle

with/without decrypted, the SPD is consulted to find out whether the security association applied to the packet corresponds to that required by the security policies. The SDP allows to distinguish the classic packet when it is received by the administrator.

After security, we deal with mobility in IPv6 taking into account all functionalities.

3.3 Mobility in IPv6

The first IPv6 feature that facilitates the management of IP mobility of a terminal is auto-configuration. There are two of them:

- The stateful auto-configuration is provided by DHCP. The DHCP server assigns an IPv6 address to the requesting node and keeps a record of this assignment.
- Stateless auto-configuration, where the node configures its own IPv6 addresses from the address prefixes received.

The uniqueness of these IP addresses is verified through the execution of the Neighbor Discovery Protocol-based DAD algorithm that finds a valid address for the mobile IPv6 to communication in a host network through DHCPv6 [6].

In addition, NDP uses five types of messages: the information request given by a mobile node to request the default router (RS), the information in return to the mobile's request for information by the router (RA), the link neighbor discovery information issued by the mobile or the router (NS), the redirection indicator (IR), and the information in return to the link neighbor discovery information (NA) (Fig. 2).

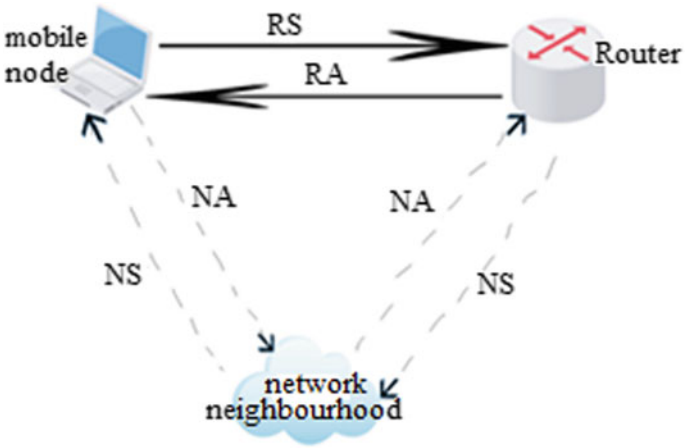

Fig. 2 NDP exchange message

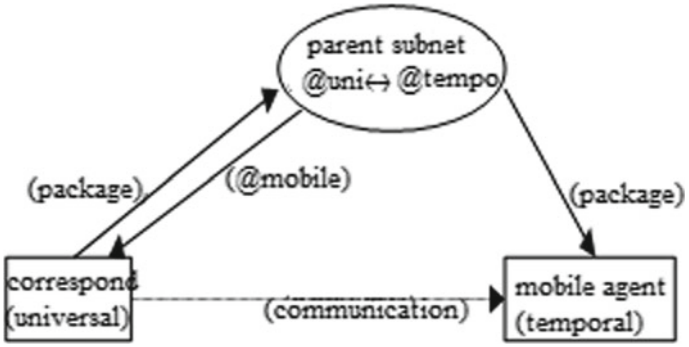

Fig. 3 IPv6 mobility principle

This procedure only happens in a secure manner. Mobility under IPv6 is largely provided by the NDP giving the MIPv6 protocol. For this purpose, a unique global IPv6 address is assigned to each mobile node and identifies it to the correspondent [7] (Fig. 3).

We notice that the priorities of MIPv6 are that it has a high overhead for data packets when the mobile node is roaming.

4 IoT Needs/IPv6 Support

Thanks to its interconnection framework and these characteristics IPv6 has the connectivity and reliability with heterogeneous resources. In addition, the exchange structure is required to provide superior exchange functionality which is security and mobility [8]. They introduce two protocols that are integral to IPv6 such as IPsec and MIPv6. IPsec provides all the security of IPv6 and intervenes on mobility through variable mechanisms. Therefore, it avoids all security vulnerabilities that can prevent mobility from working. In addition to MIPv6, the necessary protection of mobility signaling traffic via IPsec is not just a proposal made lightly. It comes from real thought and the availability of a suitable implementation environment. IPsec security operation is related to active protocols like IKE to avoid scalability issues [9]. MIPv6 provides a way for the nomadic user to retain their IP address regardless of the host network and IPsec protects them from attack. However, the contribution of IPv6 to the needs of IoT is considerable thanks to these protocols and the auto-configuration mechanisms (Table 1).

This table shows us how IPv6 supports mobility and security IoT needs. So we can say that this protocol handles and offers better performance than the latter. In addition, we have made a representation on the evolution between these two protocols and IoT needs over the years (Fig. 4).

Table 1 Comparison of IoT needs/IPv6 support

Needs IoT		Support IPv6	Report
Mobility	NDP	DHCP	Provides the link between object and application
	Auto-configuration		
Security	Confidentiality	ESP/IPsec	Need to protect and partition the data
	Authentication	AH/IPsec	The effectiveness of managing and protecting identities
	Interoperability	IPsec/MIPv6	Heterogeneity and diversity
	Scalability	IKE&NDP	Handling key management and storage

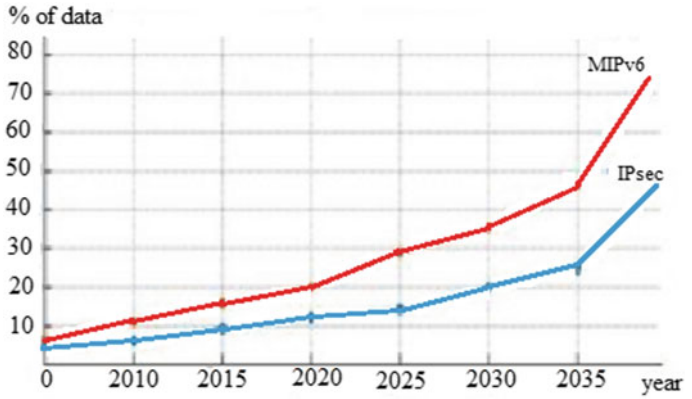

Fig. 4 Evolution of MIPv6 and IPsec

We notice that the evolution of MIPv6 is proportional to the evolution of IPsec from one year to the next. This means that there is no mobility without security, so IPsec makes the IoT work.

5 Conclusion

IPv6 is a new internet protocol with multiple features such as security and mobility that manage the operation of devices. It does not offer safety accuracy, but there are improvements that can be used appropriately for a clear safety improvement. Similarly, IPsec was considered unfeasible because it requires expensive algorithms. We can say that the MIPv6 and IPsec protocols have presented a clear improvement to the needs of IoTs ensuring also the integration and operation of IoTs in the future.

In perspective, we will see how the adaptation of IPv6 in IoTs is evaluated and recommended.

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Association Rules for Buffer Overflow Vulnerability Detection Using Machine Learning

Intisar Al-Mandhari, Ahmed AlKalbani, and Abdulaziz Al-Abri

Abstract Buffer overflow (BoF) vulnerability can be exploited by cyber-attackers to gain access and take control of information systems. As a result, effective vulnerability detection has become critical for information security in systems development. Using machine learning techniques, this study proposes a method for effective BoF vulnerability detection based on feature selection algorithms and association rule mining. The proposed method shows a significant enhancement of detection accuracy with 64% and 89% improvement, respectively, for two predefined BoF intrusion scenarios.

Keywords Buffer overflow · Vulnerability · Association · Algorithms · Feature

1 Introduction

The emergence of cyber-attacks has led organizations to adopt effective cybersecurity practices. The information flow through the network is often subjected to various cybersecurity attacks. These attacks are usually executed by exploiting systems' vulnerabilities, such as buffer overflow (BoF) [1]. In 2021, the National Vulnerability Database has shown that there are over 19,537 vulnerabilities that have been exploited by cyber-attackers, resulting in theft of valuable or sensitive data, and business disruption [2]. This shows the need for adequately addressing systems' vulnerabilities in ensuring information security in organizations.

I. Al-Mandhari (✉) · A. AlKalbani · A. Al-Abri
Advanced Cybersecurity Academy, Muscat, Oman
e-mail: intisar.almandhari@aca.om

A. AlKalbani
e-mail: ahmed.alkalbani@aca.om

A. Al-Abri
e-mail: abdulaziz.alabri@aca.om

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BoF vulnerability refers to the exploitation of systems' buffer by submitting more data than can fit in the allocated memory block causing the execution of malicious code [1]. It has been used by most existing malicious worms to propagate themselves by compromising the virtual address space [3]. In many cases, BoF vulnerability may be carried out by exploiting methods that are vulnerable by default, for example, if a programmer does not perform proper input validation such as size checking, this weakness can be easily used to successfully overflow the buffer. As a result, timely detecting BoF vulnerability is becoming critical for protecting organizational information.

Software development and code complexity increase exponentially. This means that the detection of exploiting BoF vulnerability attacks requires further analysis at the network applications and systems [4]. The literature shows three well-known methods for BoF vulnerability detection including static, dynamic, and hybrid [2]. The static method illustrates different approaches that analysis based on patterns and similarity of codes [5–7]. The dynamic method represents the use of fuzzy systems to send unintended data to check for anomalies using symbolic values to identify the vulnerabilities in the targeted system [8, 9]. The hybrid method combining both the static and the dynamic methods [10]. These methods have demonstrated their applicability under various circumstances for detecting BoF vulnerability with some successes.

The detection of BoF vulnerability attacks is complex and challenging. There is no existing predefined model that can timely define the series of cyber-attacks in a strict order [11]. The rule matching logic, for example, in most network security applications such as intrusion detection or prevention systems is rarely taken into account the context, such as the payload of incoming packets, in which BoF attacks take place. Recent studies have shown utilizing machine learning-based methods can significantly enhance the detection performance for cybersecurity attacks [1, 2, 4]. The use of machine learning enables the vulnerabilities detection by learning the defined vulnerable features of the abnormal traffic to distinguish them from the others [5].

With the predefined vulnerable features to detect anomaly behaviors within network packets, it is most likely that a packet content will match multiple features, which enable to trigger, for example, multiple alerts. Likewise in another situation, a cyber-attack may contain multiple instructions that are encapsulated in the content of different packets, which will enable to trigger multiple alerts. These two situations have illustrated the need for an intrinsic association of the predefined vulnerable features that are indivisible to detect a specific cyber-attack [12]. Using the predefined vulnerable BoF features [13–16], this study proposes a method using machine learning for effective detection of BoF vulnerability attacks. This paper is structured as follows: Sect. 2 presents a comprehensive literature review, Sect. 3 introduces the proposed methodology, followed by the discussion in Sect. 4. Finally, the conclusion, limitation, and future research of this study are given in Sect. 5.

2 Literature Review

2.1 Buffer Overflow

BoF vulnerability is one of the most emergent threats of network intrusion, as it continues to be used by many cyber-attackers [17]. There are two variants of exploiting typical BoF vulnerability. The first is called 'code injection attack' in which the cyber-attackers inject the malicious code into the targeted application and transfer the control of the application to the malicious code [18]. The second is referred to as 'return-to-libc attack', the cyber-attackers try directly to steer the control of the targeted application using the address space of a pre-existing function such as library function [18]. In both types of BoF vulnerability exploitation, attackers are trying to hijack the control of the targeted application by modifying the address space location either in the stack or in the code region [18].

There are different approaches for detecting BoF vulnerabilities. Shahriar and Haddad [14], for example, use a source code-based approach that analysis the semantics and syntax without modifying the application functionality to detect BoF vulnerabilities. Andresson et al. [18] propose a detection approach by analyzing the source code in a black box using random strings with different lengths to find BoF vulnerabilities in software. Duraes and Madeira [15] develop test parameters to determine the authenticity of the suspicious function in the executable code. These studies primarily focus on the applications source code to detect BoF vulnerabilities. There are, however, many other approaches relating to feature matching to improve the accuracy of BoF detection.

The use of feature matching approaches for detecting BoF vulnerability attacks is becoming increasingly popular in the literature [14]. Homoliak and Sulak [16], for example, use signature matching between packets' payload and the behavioral of network flow for detecting BoF vulnerability. This matching method, however, cannot detect the attack code without obvious features as little information about the attack programs at the network packet level is provided [18]. The exploitation of BoF vulnerabilities attacks usually targets user privilege escalation. The detection features are embedded in the payload of the packet known as content-based features. These content-based features need to be extracted for the detection of BoF attacks, unlike other types of cyber-attacks, such as DoS attacks [19]. One way to extract the content-based features is to use data mining algorithms to compute patterns from the network payload packets.

2.2 Features' Selection for BoF

Features selection refers to the process for selecting relevant features to a specified cyber-attack [20–22]. Each cyber-attack has its own way of exploiting systems'

vulnerabilities. Therefore, it needs to determine the unique features for each cyber-attack. The selected features are used in a way to optimize the classifiers performance in machine learning for better cyber-attacks detection [21]. There are three well-known phases for typical features selection processes that include subset generation, evaluation, and validation [22]. The subset generation uses search strategy and pattern analysis that apply heuristic and random approaches to produce features subsets. Each generated subset features are compared using evaluation criteria that may include score, correlation, consistency, entropy, and accuracy. Finally, the subset features can be validated in either a virtual environment or real infrastructure implementation [23]. This feature selection process is used, for example, in network intrusion detection to eliminate the irrelevant data and the redundant false alerts [23].

The literature shows the effort for identifying relevant features to enhance the detection of BoF vulnerability attacks. Lappas and Pelechrinis [24], for example, focus on detecting the number of operation instructions (NOP) in the packet content by dissembling and interpreting the appearance sequence. Andersson [18] uses system calls for detecting BoF attacks having the assumption of detecting more than two threat level one system calls such as 'setuid and setgid'. The literature further shows other predictive features for detecting BoF attacks, such features include 'hot indicators' that counts, for example, the creation of directories, access to system directories, and the execution of programs [25], 's-error rate' that is based on the Internet control message protocol (ICMP) [26], and remotely 'executable shellcode' [18]. Further, Aljedaani [27] shows the C library functions that are counted vulnerable for BoF attacks, such functions include strcmp(), strcpy(), gets(), memcpy(), and scanf() [28]. Taking strcpy function in shellcode, for example, can be truncated with '0x00' during the execution causing the shellcode to be incomplete [27]. These studies have shown the vulnerable features that can be used for BoF detection.

The common attackers' strategy for exploiting BoF is to perform a stack overflow by injecting the malicious code in the vulnerable program's address space in the stack memory, and this technique is called shellcode [29]. The malicious code will run with the vulnerable program's privileges, giving the attacker a sufficient privileges to gain remote or complete access to the targeted system [30]. The 'Bobek' attack tool, for example, tries to gain root privileges remotely by exploiting WU-FTPD (a freely available FTP server) using different machine instruction such as '/bin/sh' command [18]. Considering the above mentioned, Table 1 summarizes the relevant features for detecting BoF vulnerability attacks [25].

Using all BoF relevant detection features, it does not guarantee the accuracy of detection, however, it may generate massive number of alerts that may mislead the intrusion detection [29]. Recent studies have shown utilizing machine learning-based methods which has a positive impact of selecting particular features of abnormal traffic for intrusion prediction and detection [31–35]. Three methods are well used by machine learning for features selection. Such methods include filter, wrapper, and embedded [35]. The filter methods calculate the correlations between features and select the top ranked features as feature subsets [21], taking the advantage of not relying on a specific classification algorithm [32]. The wrapper methods are model-based that optimize the search of features subset to obtain the best [31].

Table 1 BoF relevant features

Content-based feature	Description
hot	Hot indicators
num_failed_logins	Attempts of failed system logins
logged_in	Logged in successfully = 1, otherwise = 0
lnum_compromised	Number of compromised conditions
lroot_shell	Root shell obtained = 1; otherwise = 0
lsu_attempted	'su root' command attempted = 1; otherwise = 0
lnum_root	Number of 'root' accesses
lnum_file_creations	Number of operations for file creation
lnum_shells	Number of shell prompts
lnum_access_files	Number of operations on access control files
lnum_outbound_cmds	Number of outbound commands in an ftp session
is_host_login	Hot login (e.g.; root, admin) = 1, otherwise = 0
is_guest_login	'guest' login = 1; otherwise = 0

These methods have advantage of good performance but require a search of feature space that causes a long search time [33]. The embedded methods combine the best of both the filter and wrapper methods by applying specific classification algorithm [36]. These three methods can determine the significant features and inform various relations among these feature subsets [21, 22, 37].

2.3 Association Rules Mining

Association rules mining aims to identify the relation between features within the data in the network to define the association rule for intrusion detection [35]. The association rules contain a group of features or items and transaction of data items. The implication of the association rule is defined as G → H; G is network-based intrusion detection. H is item sets of {i1 = v1, i2 = v2, i3 = v3, …, in = vn}, where 'i' is item name, and 'v' is an item value. The association rule G → H satisfies the minimum confidence and support [38]. The association rule is computed in percentage of transaction in both G and H by measuring both the relation between the significance of items in the item sets and the frequency of item in the database for the support. The association rules are obtained after satisfying the minimum support and confidence threshold value [39].

The literature shows the use of the association rule mining algorithms in network security [40–42]. Prasenna et al. [40], for example, obtain fuzzy weighted association rules using the Apriori association algorithm to evaluate the anomaly detection. Lalli and Palanisamy [41] use Apriori association algorithm along with the artificial neural network filters to enhance the detection accuracy of network traffic features. Jie et al. [42] propose the use of clustering model based on Apriori association algorithm to find the high risk of distributed denial of service (DDoS) attacks. These studies have shown the value of using the association rule mining algorithms for enhancing the detection accuracy. To extend the literature on BoF detection [43], this study aims to use the association rule mining algorithms along with feature selection for better detection accuracy results in addressing BoF vulnerability attacks.

3 Experimental Methodology

To define the association rule/s of the predefined BoF features (Table 1) using machine learning for high detection accuracy, this study uses the experimental methodology that is divided into three steps including data preparation, features' selection, and association rule mining, as shown in Fig. 1.

3.1 Step 1: Data Preparation

This study uses NSL-KDD dataset as a test bench for machine learning to apply feature selection and association rule mining methods. A pre-processing step takes place to achieve dataset balance such as circumventing skewed class distributions and removing of duplicated records using resampling value 0.1. The results show three samples of BoF. After resampling, the count of 659 sample values is generated to train the machine learning algorithm for both feature selection and the association rules mining. Further, this study uses cross validation of 10-folds to obtain a good accuracy rate [39].

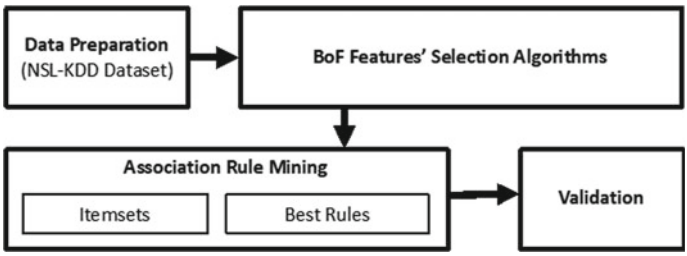

Fig. 1 Experimental methodology steps

3.2 Step 2: Features' Selection Algorithm

The feature selection step aims to determine the significant features in order to increase the detection accuracy of BoF vulnerability attacks. Based on the balanced dataset obtained in step 1 (3.1), Weka tool (version 3.8) is used for developing classifiers using a machine learning [44]. For the wrapper method, this research uses the classifier-based subset evaluator on the full machine learning training dataset (659 sample) with best first search engine to evaluate sets of attributes. As wrappers require an inductive classifier with the use of Naïve Bayes (NB) to produce the subsets which is resulted in the highest accuracy and receiver operating characteristics (ROC). Furthermore, this study uses the filter method to determine the less important features based on the information gain filter with ranker search engine [44].

A total of thirteen relevant features for BoF (Table 1) are analyzed. Seven algorithms are deployed for ranking the relevant features by rating their effectiveness in detecting BoF attacks, as shown in Table 2. Features with high value of the average merit in all the seven algorithms are selected. Further, these features are examined using NB for accuracy detection. The results show that four features including hot, Iroot_shell, lnum_Compromised, and lnum_File_creations are significant features that need to be considered for BoF vulnerability detection. Other features like 'logged_in', for example, are not selected, although it has been ranked high by two algorithms (CorrelationAttributeEval and InfoGainAttributeEval) since their rank is low with big gap compared to the other features.

3.3 Step 3: Association Rule Mining

The detection of cyber-attacks is complex as it has no fully predefined models that can define them in a strict order [11, 43]. To give a whole view of BoF vulnerability attacks, the association rule mining is used to inform the various relations between the predefined features within the data in the network [12]. This step involves identifying the frequent item sets that support transaction in the network traffic with level of confidence.

This study uses the Apriori association rule mining algorithm based on two stages of operations. Table 3 shows the outcome of the Apriori algorithm first operation giving four sets of the large item sets that have been obtained with level of 0.1 support and 0.9 confidence. Based on the Apriori algorithm second operation, Table 4 shows the best association rules that reflect the definite exploitation of BoF vulnerability taking into account the level of confidence, leverage, and conviction. These identified rules are supporting the item sets in Table 3. Overall, the results obtained provide a perception of using the features' selection algorithms along with association rule mining algorithms to enhance the accuracy of detecting the exploitation of BoF vulnerability.

Table 2 Intrusion content-based features

No.	Feature selection algorithms	Top ranked features	Average merit rank	NB (%)
1	Cfs (best first)	Hot	100%	99.6
		lnum_ Compromised	100%	
		lroot_shell	100%	
		lnum_File_ creations	100%	
2	CorrelationAttributeEval	lroot_shell	0.757 ± 0.004	99.5
		lnum_file_ creations	0.235 ± 0.009	
		Hot	0.215 ± 0.003	
		lnum_ compromised	0.083 ± 0.014	
		logged_in	0.046 ± 0	
3	GainRatioAttributeEval	lroot_shell	0.748 ± 0.006	99.6
		lnum_ compromised	0.635 ± 0.028	
		lnum_file_ creations	0.361 ± 0.006	
		hot	0.361 ± 0.003	
4	InfoGainAttributeEval	hot	0.043 ± 0	99.5
		lroot_shell	0.036 ± 0	
		lnum_ compromised	0.034 ± 0.001	
		lnum_file_ creations	0.023 ± 0	
		logged_in	0.003 ± 0	
5	OneRAttributeEval	lroot_shell	99.65 ± 0.005	99.4
		lnum_ compromised	99.607 ± 0.006	
		hot	99.594 ± 0.006	
		lnum_file_ creations	99.348 ± 0.008	
		lnum_root	99.195 ± 0.002	
		lnum_shells	99.18 ± 0	
		is_host_login	99.18 ± 0	
6	SymmetricalUncertAttributeEval	lroot_shell	0.616 ± 0.006	99.6
		lnum_ compromised	0.557 ± 0.013	

(continued)

Table 2 (continued)

No.	Feature selection algorithms	Top ranked features	Average merit rank	NB (%)
		hot	0.459 ± 0.003	
		lnum_file_ creations	0.344 ± 0.006	
7	ReliefFAttributeEval	logged_in	0.204 ± 0	99
		is_guest_login	0.004 ± 0	
		hot	0.002 ± 0	
		lnum_access_ files	0.002 ± 0	

4 Discussions

After obtaining the optimal features selection and association rules, this section discusses the results by constructing BoF intrusion scenarios using virtual environment and analysis their outcomes.

4.1 Scenario-Based Results Validation

Based on the results in Sect. 3, two BoF intrusion scenarios with multiple cases are constructed for validation as follow.

Intrusion Scenario A: Gaining System Privileges

In order to exploit BoF vulnerability, attackers always aim to compromise the targeted victim machine by launching different shell codes to overflow the system and gain higher system privileges (e.g.; root/admin). The assumption for gaining system privileges scenario is that if the execution of at least one of the shellcodes (e.g.; system call, jump to call, NOP sledge and NOP unicode) along with full administrative privileges is in the same packet, this is considered to be high positive prediction for the exploitation of buffer overflow vulnerability. Further if access to hot system directories or system file creation has been observed, this also gives a solid positive prediction for buffer overflow attack. The positive prediction for this intrusion scenario is constructed under the following cases:

if one signature of compromised conditions is present in the packet along with root shell signature, an alert will be generated.
if one signature of compromised conditions is present in the packet along with root shell signature with hot access, an alert will be generated.

Table 3 Sets of large item sets L(1) to L(4)

Item set No.	List of attributes	Supp.	Conf.	Result	
1	Hot, num_failed_logins, logged_in, lnum_compromised, lroot_shell, lsu_attempted, lnum_root, lnum_file_creations	0.1	0.9	hot = 3	334
				lnum_compromised = 2	147
				lnum_compromised = 4	135
				lroot_shell = 1	404
				lnum_file_creations = 1	253
2	Hot, lnum_compromised, lroot_shell, lnum_file_creations	0.1	0.9	hot = 3 lnum_compromised = 2	104
				hot = 3 lnum_compromised = 4	135
				hot = 3 lroot_shell = 1	314
				hot = 3 lnum_file_creations = 1	163
				lnum_compromised = 2 lroot_shell = 1	147
				lnum_compromised = 4 lroot_shell = 1	115
				lnum_compromised = 4 lnum_file_creations = 1	115
				lroot_shell = 1 lnum_file_creations = 1	163
				hot = 3 lnum_compromised = 2	104
				hot = 3 lnum_compromised = 4	135
				hot = 3 lnum_compromised = 2	104
3	Hot, num_failed_logins, logged_in, lnum_compromised, lroot_shell, lsu_attempted, lnum_root, lnum_file_creations	0.1	0.9	hot = 3 lnum_compromised = 2 lroot_shell = 1	115
				hot = 3 lnum_compromised = 4 lroot_shell = 1	115
				hot = 3 lnum_compromised = 4 lnum_file_creations = 1	163

(continued)

Table 3 (continued)

Item set No.	List of attributes	Supp.	Conf.	Result	
				hot = 3 lroot_shell = 1 lnum_file_creations = 1	115
				lnum_compromised = 4 lroot_shell = 1 lnum_file_creations = 1	115
4	Hot, num_failed_logins, logged_in, lnum_compromised, lroot_shell, lsu_attempted, lnum_root, lnum_file_creations	0.1	0.9	hot = 3 lnum_compromised = 4 lroot_shell = 1 lnum_file_creations = 1	334

Table 4 BoF association rules based on Apriori algorithm

No.	Rule	Sample	Quality of service matrix			
			Conf.	Lift	Lev.	Conv.
1	lroot_shell = 1 lnum_file_creations = 1 ⇒ hot = 3	163	1	1.97	0.12	80.39
2	hot = 3 lnum_file_creations = 1 ⇒ lroot_shell = 1	163	1	1.63	0.1	63.07
3	lnum_compromised = 2 147 ⇒ lroot_shell = 1	147	1	1.63	0.09	56.88
4	lnum_compromised = 4 135 ⇒ hot = 3	135	1	1.97	0.1	66.58
5	lnum_compromised = 4 lroot_shell = 1 ⇒ hot = 3	115	1	1.97	0.09	56.71
6	lnum_compromised = 4 lnum_file_creations = 1 ⇒ hot = 3	115	1	1.97	0.09	56.72
7	lnum_compromised = 4 lnum_file_creations = 1 ⇒ lroot_shell = 1	115	1	1.63	0.07	44.5
8	lnum_compromised = 4 lroot_shell = 1 ⇒ lnum_file_creations = 1	115	1	2.6	0.11	70.85
9	num_compromised = 4 lroot_shell = 1 lnum_file_creations = 1 ⇒ hot = 3	115	1	1.97	0.09	56.71
10	hot = 3 lnum_compromised = 4 lnum_file_creations = 1 ⇒ lroot_shell = 1	115	1	1.63	0.07	44.5

if one signature of compromised conditions is present in the packet along with root shell signature with system file creation, an alert will be generated.

Intrusion Scenario B: System Interruption for Exploitation

In this scenario, attackers aim to compromise the targeted victim machine by launching different system calls and interruption instructions to overflow the system

for exploitation. The first assumption for the system exploitation scenario is that if two or more of system calls are detected in a packet, and one of them is a threat level one, this case is considered to be a high positive prediction for exploiting buffer overflow vulnerability. The second assumption is that if an interrupt instruction has been detected within 20 bytes after the system call and/or with hot access and jump instruction, this case is also considered to be a positive prediction for exploiting BoF vulnerability. The intrusion scenario cases are constructed as follow:

if two or more of system calls threat level one conditions are presented in the packet and one of them is threat level one, an alert will be generated.
if system calls threat level one conditions are presented in the packet along with an interrupt instruction within 20 bytes, an alert will be generated.
if system call threat level one conditions are presented in the packet along with an interrupt instruction within 20 bytes with hot access, an alert will be generated.
if system call threat level one conditions are presented in the packet along with an interrupt instruction within 20 bytes with jump to call, an alert will be generated.

4.2 Results Analysis

To examine the accuracy of detection for the above constructed intrusion scenarios (A and B) with their cases, Suricata Version 6 is used to compile the syntax rules. Two test datasets are used. The first dataset using a packet captured file of approximately 2.1 GB obtained from a production network environment, and the results show no buffer overflow exploit which has been detected in this dataset. The second dataset, a traffic generator, named 'IXIA', is used to generate attacks for exploiting BoF vulnerability giving a total of 2036 packets of dataset. The results for the intrusion scenario (A) before applying the association rules give 210 alerts based on 41 rules covering different operating systems and protocols. These alerts can be either an actual attack (true positive) or attempt (false positive).

After applying the association rule, only 74 alerts of BoF exploitation attacks (true positive) are detected. This shows a reduction of 64% of an inaccurate identification (false positive) of alerts that were considered as BoF exploitation attempts. This effectiveness of reduction and the accuracy of the alerts (true positive) are enriched due to the logical knowledge and the association rules that are used to build the scenario and all its related cases. Take into consideration that in most cases, attackers will execute at least one compromise condition to gain root privilege. Further, the detection accuracy has been improved in terms of attack certainty. Some attackers, for example, will send a shellcode (compromised condition) to overflow the system but for some reason the attacker will stop the attack, thus causing no alerts to be triggered unless root privilege is obtained. With this result from scenario A, the effectiveness and the accuracy for BoF detection have been enhanced.

For intrusion scenario (B) with all its cases show that 121 alerts are generated before applying the association rules, and this number of alerts is reduced to 13 after association; which means 89% of false positive alerts are evaded. This states

Table 5 Association rules effectiveness

	Association		True positive (attack)	False positive (attempt)	Enhancement (%)
	Before (alerts)	After (alerts)			
A	210	74	74	136	64
B	121	13	13	108	89

that the existence of threat level one of system call will not exploit the system if it is not executed using interrupt instructions. Table 5 shows the effectiveness of the association rules on the two scenarios. Overall, the outcome results from the experimented scenarios show the effectiveness and the accuracy of BoF intrusion detection.

5 Conclusion

In this study, an efficient intrinsic association method is used to enhance the detection of exploiting BoF vulnerability attacks. Based on the outcomes of the feature selection along with the defined association rules supported, two content-based BoF intrusion scenarios with multiple cases are constructed for validation. The results show the effectiveness and accuracy of detection for buffer overflow attacks.

This study contributes to advancing the role of machine learning for enhancing the detection accuracy of BoF vulnerability attacks. Further, it simplifies the investigation and incidents response processes as the number of alerts are reduced. However, several limitations of this study can be addressed in future. First, the study focuses on BoF content-based features to construct intrusion scenarios and cases for accurate detection. Improvements for future research direction are to consider the traffic-based features along with the content-based features. Second, the findings also remain limited, since these findings have been validated based on machine learning prediction algorithms that have room for improvement. A fruitful avenue for future research would be to replicate this study on other cybersecurity attacks such as DDOS with having different detection features.

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Data-Driven Design in e-Commerce: Contribution of Customer Data Applied to User Experience

Joana de Matos Monteiro and Firmino Oliveira da Silva

Abstract e-Commerce has grown exponentially in recent years, because of the pandemic situation, the world has gone through and the growing need to digitise business. Customers of this highly competitive online market have increasingly demanding characteristics, needs, and expectations, seeking a personalised and differentiated shopping experience. The definition of design and marketing strategies based on data collected from customers interactions, enabling different interfaces and contents according to each customer characteristics, allows to increase loyalty which are determining for e-Commerce. This study aims to explore the state of the art and analyse best practices in the application of data-driven design (D3) strategies in user experience of e-Commerce platforms. The paper focuses on the importance of using data-driven strategies to improve the user experience on these types of platforms and serve as a guide for applying a methodology in digital businesses. This research paper proposes a methodology based on strategies to improve the e-Commerce user experience using D3 and digital marketing techniques across platforms and a discussion on their practical application. As a result, a conceptual methodology entirely based on the literature review will be built, with the future perspective of being tested in a case study.

Keywords e-Commerce · UX · Data-driven design · Digital marketing

J. de Matos Monteiro (✉) · F. O. da Silva
Research Center, ISLA—Instituto Politécnico de Gestão e Tecnologia, Gaia, Portugal
e-mail: a22100998@islagaia.pt

F. O. da Silva
e-mail: firmino.silva@islagaia.pt

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1 Introduction

1.1 Contextualisation

As technology has evolved, Web 2.0 represents a Web paradigm shift with an emphasis on supporting social collaboration and reasoning about data semantics. The new way of interaction has introduced a radical innovation in e-Commerce, moving the focus to context awareness and personalisation. On one hand, these innovative features improve platform conversion and product sales, but also significantly impact the way new e-Commerce platforms are designed [1]. User experience (UX) thus presents itself as one of the most critical factors for the success of an online shop, and as such, it has become a competitive requirement [2]. Improving the design of an e-Commerce Website, interface that should be responsive for any kind of device size from desktop to mobile, with user experience principles, creates an advantage in satisfying the customer, however, creating a decent Website in terms of usability and UX principles can be quite a challenging task [3].

Digital platforms, through their broker position as an intermediary between different user groups, allow online retailers to reach significantly more customers, and the resulting transactions generate a large amount of data that can be collected, evaluated, and used to improve the user experience on the platforms. The data generated can be personal (such as names, address, and age) or non-personal (such as number of visits, sales of a particular product, and number of returns) and can relate directly to other information about the customers, online shop, or the product. The data that these retailers have in their possession can also be advantageous for operating on the platform as it helps to better meet customers' needs through product selection and quality and improve the services offered or increase sales through optimised digital marketing, which in turn can give directions on how to make platforms more attractive in terms of UX for new users [4]. In this way, electronic businesses can stay ahead of their competitors if they offer personalised products and services to individual customers, using existing customer data, through strategies such as recommender systems and persuasive technologies [5].

1.2 Objectives

Based on the research question "how to apply data collection to improve user experience strategies in e-Commerce platforms"? the aim of this paper is the creation of a methodology that explores the use of e-Commerce strategies, based on quantitative (e.g. usability testing or net promoter score—NPS) and qualitative (e.g. user research or text evaluation) data collection analytical techniques, which aim to provide future researchers with grounded knowledge to improve user experience in practical application of e-Commerce platforms.

1.3 Applied Methodology

The applied methodology of this study is as follows: the first step starts with the literature review that enables the study of the most relevant state of the art of the of data-driven design oriented to e-Commerce platforms (detailing the various elements that contribute to the design of user experience improvement in online shops based on the available data); the second step will analyse the best practices in the application of data-driven design (D3) strategies in user experience of e-Commerce platforms; thirdly, based on the information analysed, a methodology for implementation will be proposed; the last step will discuss the opportunities and challenges of the proposed methodology.

The paper structure is as follows: Sect. 2 depicts the literature review; Sect. 3 details the proposed methodology of this study; Sect. 4 presents a brief discussion about the study, and Sect. 5 finishes the article with a conclusion of what has been accomplished.

2 Literature Review

The research criteria applied for exploration and review of bibliographic elements were “e-Commerce”, “user experience”, and “data-driven design” in published scientific papers, relevant university thesis and dissertations, and technical reviews.

2.1 User Experience (UX)

The UX concept was created by Donald Norman, so the “user experience” covers all aspects of the interaction between the user and the platform, services, and products (all the emotions, beliefs, preferences, perceptions, physical and psychological aspects, responses, behaviours, and achievements that occurred before, during, and after the use), having as basic dimensions to be measured the effectiveness, efficiency, error, ease of use, satisfaction, attractiveness, and visual appeal [6]. UX thus refers to what users did, felt, and thought when using or operating a platform, so a positive experience can bring credit and profitability to the Website, increasing the user’s willingness to make a return visit, purchase intention and satisfaction, as well as increasing the product’s reputation. On the other hand, negative experience can bring adverse effects, reducing user’s willingness to return, decreasing the desire to purchase and satisfaction, as well as influencing the reputation of the product or service [7]. A poorly designed interface will result in a poor user experience, so it is necessary to consider the design before, during, and after the development of a project. Thinking about UI design is thinking in designing an interface that does not convey a feeling of insecurity to the user that clearly defines the results of their actions

and ensures that they perform all tasks simply and efficiently [8]. User experience has different degrees of impact on online shopping in terms of usability (ease of use of the interface), functionality (convenience and speed), content (authenticity and details in the contents), and performance (speed and responsiveness of the transaction process) [9].

Although Jakob Nielsen's usability heuristics [10] are the most popular and well-known choice of tools for Website evaluation and construction, these UX guidelines were created for user interface design in general and not specifically for Web platforms. To provide context for heuristics, Web metrics can be usefully applied in a Website design project, so creating a framework for measurement becomes critical for future evaluation of the success and value of strategic but intangible investments such as designed information architecture. Traffic data can generate insights into user behaviour and measure how well a Website's design meets their needs [11]. By comparing analytical Web data with the heuristic evaluation of a Website, it is possible to validate and measure in a more accurate way the success of the designed platform, for example, by creating key performance indicators (KPI) based on the available intelligence base, so otherwise, it would only be a subjective evaluation [12]. The construction of a Web design process is fundamentally characterised by the problem–solution approach, created based on creativity, experience, and heuristics [7]. However, due to the explosion of currently digitally collected data, this data can and should be considered in the development of a platform [13]. China's largest e-Commerce group, Alibaba Groups Inc. is consistently developing and implementing sophisticated data mining algorithms and retail automation processes that help them analyse volumes of datasets collected from different Website pages but also dramatically grow their business [14]. Understanding the data collected from e-Commerce activities and how to generate business value from it is the core challenge for many companies today [12].

2.2 e-Commerce

e-Commerce is the approach that a company adopts to become a profitable business on the Internet [15], being the process of buying or selling products or services that is done through online medium, being already widespread and established its roots in our society, becoming as vital as traditional shops [16].

User experience in e-Commerce environments has been widely studied in the past, and many strategies have been applied to attract and retain customers [17]. As popular strategies we can list: (1) the tracking of customer behaviour on the e-site during a session to discover more hidden behavioural patterns combined with behavioural analytics that helps to understand the different types of actions and the ways users use the site; (2) personalisation strategy by offering personalised services and products to customers, which plays a significant role in improving the user experience and retaining customer loyalty; (3) sentiment analysis which is the collection of text created by customers about services or products, analysing these

ratings, opinions, or comments and classifying them as positive, negative, or neutral; (4) customer satisfaction is the opinion of the consumer about the service provided, which helps to maintain a strong relationship with them, so customer satisfaction is a primary objective for any successful business in this new competitive environment; (5) customer segmentation which is the process of dividing customers into a specific number of groups, being a very significant strategy mainly for retail companies, because it is usually the initial process for analysing customer behaviour, based on the data collected from the transactions of the same customers [12].

2.3 Data-Driven Design (D3)

Data collection is only one aspect of the data-driven design process, as quantitative data gives an idea of what is happening on the Website, but qualitative data is needed to shed light on why users do what they do so look for trends in the data as well as discrepancies. User research is one of the most exhaustive data collection methods and where the most resources are required, but it can also be the most valuable, especially for new platforms that have no existing primary data to draw on [18]. It is thus fundamental for studying customer (user) behaviour, to understand their motivations and needs in a specific context, and some of its user methods include card sorting, contextual interviews with real users, focus groups, online questionnaires, and heuristic analysis, as well as creating personas and use cases [19]. UX-based e-Commerce Websites are "user-centric"; therefore, we should analyse the target users; understand the consumers' online shopping flow through the steps of analysing their behaviour, for example, develop a questionnaire and summarise the survey results; study the online shopping behaviour survey analysis report and collect data; segment the user and understand the behavioural shopping requirements in order to understand the touch points of online shops and improve their user experience [9].

Third-party analytics applications are also an immediate tool to collect more user data, implementing advanced tools like heat maps (e.g. Hotjar tool), pixel tracking, and real-time user session visualisation, very interesting to understand more complex buying patterns [14]. Interface usage flows, which are, for example, tracked using the Google Analytics tool, show how users scroll through the site from the first page they visit to the abandonment page and demonstrate if the platform has UX issues [18]. Conducting A/B tests has also become popular to collect the information about explicit user behaviour and understand the effect of a certain change in the platform by showing different variants of the product to different users, aggregating, analysing, and comparing behavioural and performance metrics, extracting data that help decision-making in the development of the platforms [20]. To measure customer satisfaction, methods such as NPS can be used [19], and usability tests can be performed on the design of the Websites, where users are analysed to evaluate the platforms in terms of completion time of proposed tasks, success rates, or number of page views per test performed [3].

Another strategy is through the approach of filtering and selecting concrete recommendations, in which designers can use their creativity to determine the most promising target, and in e-Commerce, recommendation systems (RSs), a method of artificial intelligence/machine learning, are widely adopted to recommend a new product or service to target users [13]. Since recommendations are typically personalised, they benefit users, through, for example, recommendations to filter the full range of available possibilities, which is currently indispensable in the development of online shops, as users find it difficult to make the appropriate choice amongst the wide range of items and services on these sites [21]. The presentation of an online product to a customer is crucial in the customer's final purchase decision, because as he cannot search for the product as he would in a physical shop, it is essential that products are presented to online customers in such a way that they are encouraged to buy them, and in this sense, online recommendation systems focus on delivering the right message and generating suggestions about products that are suitable to the interests of the impacted user, based on his history of interactions [5]. The decisive factor for customer ownership is the presence of the retailer in the users' lives through points of interaction with the user, collecting data that creates unmatched knowledge and multifunctional customer profiles, allowing to apply data-driven marketing, sending information or offers that customers perceive as relevant, but also discovering needs and desires that customers did not even think about [22].

Customer lifetime value (CLV) is the name given to customer retention metrics in e-Commerce, with email marketing being one of the most popular ways to keep users in reach [22]. The use of marketing automation software (marketing automation) streamlines these processes of integrating customer data and managing personalised campaigns [23].

2.4 e-Commerce Data Collection

Artificial intelligence has had a lot of impact on RS implementations on e-Commerce platforms, so machine learning systems have become a crucial factor in every aspect of the automation and personalisation process, and whilst there are many benefits, there are several negative factors associated like customer privacy, through the increase in cases of data theft on platforms such as Amazon, Flipkart, and unauthorised data sharing between commerce companies and third-party entities (banks, lenders, and creditors) that have weakened the perception of overall customer trust in such systems and created a negative feedback loop [24]. It is thus necessary to identify that when using personalised services or receiving personalised recommendations, customers' behaviour is influenced by their trust towards the online provider, privacy concerns, their emotions towards the service as well as their previous experience, making it necessary to work on these issues to understand how these interactions can provide a deeper understanding of online behaviour and how they can more easily lead to purchase intentions [17]. The use of primary data (first-party data), collected directly by the company through its platform, are the best source of data that can be

analysed and worked on strategically as they help create trust to the users who visit the Website and use the products, as there is an expectation of privacy with that same data before the customers and facilitate compliance with existing data privacy regulations, being necessary the creation of data privacy policies generating transparency and trust between consumers and the company [25].

3 Proposed Methodology

The proposed methodology intends to serve as a guide for the application of digital tools that gather and deliver relevant data to improve the user experience in e-Commerce Websites. Through this study, it is supposed to be possible know how to apply UX enhancements validated by data, in the various components that make up the success of an online shop. In that sense, Table 1 relates and compares the UX strategies in online shops that have been studied and applied currently with the quantitative and qualitative data collection techniques, referenced in the literature review explored in the state of the art, with exemplification of their practical use on the platforms.

Thus, in Fig. 1, a methodology is proposed that relates the e-Commerce UX strategies, considering the D3 techniques and tools presented on Table 1, to be applied to the fundamental parameters in construction, maintenance, and uplift of online shops, such as 1. design, which refers to the Website user interface (UI) design creation, related to the pages layout, visual components and multimedia contents, that could be improved through customer segmentation strategy; 2. interaction, which refers

Table 1 e-Commerce UX strategies and D3 techniques

e-Commerce UX strategies	Data collection techniques	Examples of application
Customer behaviour tracking [12]	Usability testing [3] A/B testing [20]	Interface design evaluation
Customer segmentation [12]	User research [18]	Sending segmented notifications
personalisation [12]	Recommendation systems [18] Marketing automation [23]	Products cross-selling and upselling
Sentiment analysis [12]	Text evaluation [12]	Website's feedback collection
Customer satisfaction [12]	NPS [19]	After-sales satisfaction rating
Interface usage flows [18]	Google analytics [18] Heat maps [14]	Analyses of interaction between pages

Fig. 1 Parameters and strategies UX for e-Commerce

to user interactivity with the platform in terms of overall Website functionality and usability and could be improved by applying customer behaviour tracking strategies; 3. structure, which refers to the Website navigation construction that could be improved through interface usage flows strategies, in terms of platform architecture and task completion assessments; 4. conversion, which refers to assess the effective purchasing process in the online shop, evaluated through conversion rate and optimised by applying personalisation strategies in the Website; 5. retention, which refers to customer retaining and user adhesion on the platform, evaluated through sentiment analysis strategy collecting feedback for Website interface improvements; and 6. loyalty, which refers to customers fidelity with the aim that the user returns with recurrence, evaluated, and improved by applying customer satisfaction strategies, collecting purchase process feedback.

These parameters, despite being demonstrated in an orderly manner, can and should be evaluated constantly and endlessly, as digital platforms are constantly evolving, and the data collected serve as KPIs to be considered in order to align all user experience improvements to be implemented.

4 Discussion

Although the table and the methodology proposed in the methodology section are intended to serve as a guide for implementing UX strategies and D3 techniques in online shops, its implementation and evaluation were not tested in a concrete case study, which will be part of future work, being entirely based on the literature review performed. Thus, this article only presents the methodology explores. In the future work, it will be applied it in a defined use case and get concrete results.

The proposal explored in this article is also not limited, since the digital and technological evolution is growing, existing consequently a future evolution in the strategies to be adopted in e-Commerce as in the techniques and tools for data collection and analysis, being that in the future works, new parameters, strategies, techniques, and tools that complement this research can be added to this methodology.

It is also possible to highlight that the use of this methodology does not exclude the performance of heuristic evaluation of usability, in order to complement the analysis of the data collected from the parameters described, this being complementary and accurate to determine more rigorously the good user experience and usability of the platforms.

However, knowing that the behaviour of users in e-Commerce is influenced essentially by their trust in the platform, the success of this solution depends on the need

to assure customers that the use of data-driven design strategies does not jeopardise the privacy of their data, using transparent information about its use.

We can also point out that there may be obstacles whilst pursuing the study or whilst receiving the results because if the progression of the study is based on the examination of data generated in different existing e-Commerce Websites, all the techniques and tools presented in the methodology may not be used on the platforms to be studied and the professionals who manage them may not have the knowledge and expertise to handle these tools.

5 Conclusion

With the digital evolution, nowadays, consumption in online shops is already a mass activity, with increased competition between companies. On the other hand, digitalization has also given access to more tools that allow extracting and analysing the data collected on the platforms, which can be used to improve customer experience. In this way, it is possible and necessary to implement strategies in e-Commerce platforms that can improve the user experience, designed through the knowledge extracted about customers, which will later translate into profits for companies.

This paper aims to serve as a guide to implement UX strategies based on data collected in e-Commerce platforms, proposing a methodology that explores the use of techniques and tools that can be used.

The contributions of this research are current and relevant because they present an innovative approach to generate a better data-driven and personalised experience for online shop users. When implemented, the proposed solution aims to increase conversion and loyalty on e-Commerce platforms using relevant data that allows to meet customer needs and desires in a concrete and reliable way. For future work, this methodology will be applied in a real digital business context in order to obtain conclusive results on its validation.

With this study, we are able to conclude that the most effective practice to design e-Commerce Websites with a high level of user experience could be through the analysis of data generated by online customers and which can be collected from the platforms themselves.

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CTARNS: Improving Capacity Estimation of Lithium-Ion Battery by Using Convolutional Transformer with Nested Sequence Models

Hung Bui, Thien Pham, and Tho Quan

Abstract Lithium-ion batteries are rechargeable and have been used widely in mobile phones and even autonomous vehicles because of their lightweight and high energy density. Therefore, predicting the State-of-Health (SoH) of a battery becomes significant and challenging because of its capacity regeneration. Artificial intelligent methods, especially long short-term memory (LSTM), have been applied and achieved fantastic results. However, previous studies either did not account for possible features in a battery cycle or required a long training time because they were based on LSTM. In this research, we propose a nested sequence model called Convolutional Transformer Autoregression Nested Sequence (CTARNS) to improve accuracy and reduce training time. The results show that our proposed model performed approximately 39.13% (RMSE) and 43.95% (MAPE) better than the baseline on the NASA dataset and 14.67% (RMSE) and 23.78% (MAPE) on the CALCE dataset.

Keywords Lithium-ion battery · Nested sequence models · Capacity estimation · Relaxation effect · Dilated causal convolution · Transformer

H. Bui · T. Pham · T. Quan (✉)
Faculty of Computer Science and Engineering, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam
e-mail: qttho@hcmut.edu.vn

H. Bui
e-mail: hung.bui0089@hcmut.edu.vn

T. Pham
e-mail: pcthien.sdh20@hcmut.edu.vn

Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam

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1 Introduction

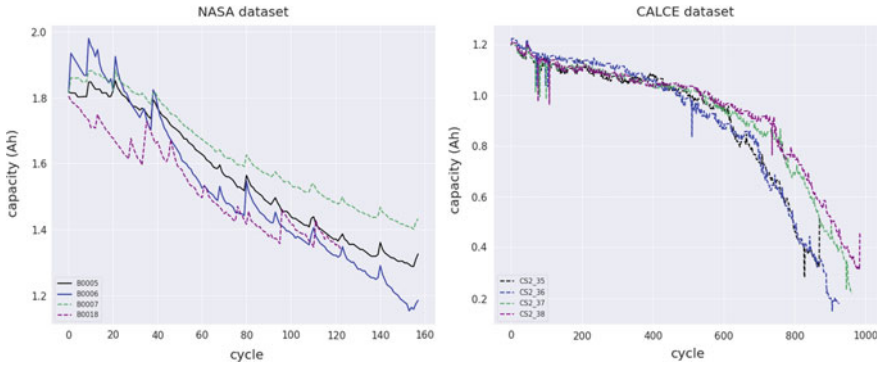
Lithium-ion batteries (LIBs) are dominating portable electronic devices, autonomous vehicles [1] and is potential in grid-level energy storage systems [2]. However, the capacity of LIBs decreases over time, resulting in decreased performance [3]. Therefore, Battery Manage System is created to ensure the safe, reliable operation of LIBs by monitoring their parameters such as voltage, State-of-Health (SoH) [4]. In addition to monitoring, predicting SoH is also crucial since a catastrophe may occur if the battery drains out in the middle of a process, for example, energy for flying objects such as UAVs. The formula calculating SoH is depicted in Eq. (1). In the formula, 100 and C_{nom} are constant, so SoH prediction problem can be converted into a capacity prediction issue.

$$\text{SoH} = \frac{C_{\text{max}}}{C_{\text{nom}}} * 100 \tag{1}$$

where C_{max} is current maximum capacity and C_{nom} is manufacturing capacity.

Since complex electrochemical interactions occur inside a LIB, the capacity degrades unexpectedly. Therefore, the capacity prediction problem becomes complicated. Figure 1a and b show each battery pack's capacity recorded over time in NASA and CALCE datasets. There are some spikes in the capacity graphs, meaning that an amount of capacity has recovered. This phenomenon is called "relaxation effect", which can be explained by the fact that if a battery does not charge or discharge for a while, its capacity can recover.

In the past, model-based methods were applied to estimate SoH, but these methods required us to have domain knowledge about physics and chemistry. Recently, artificial intelligent methods have achieved good results in many fields. Regarding the SoH



(a) (b)

Fig. 1 Capacity degradation over time, **a** capacity over time of each battery pack in NASA dataset [5], **b** capacity over time of each battery pack in CALCE dataset [6]

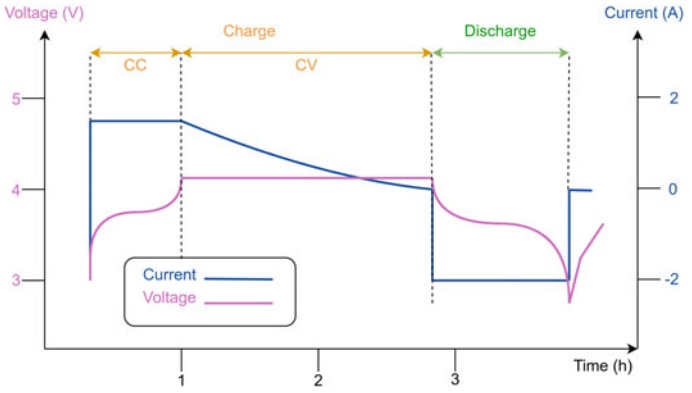


Fig. 2 Charge–discharge profile, where charge profile follows a CC–CV method

prediction problem, sequence-based architectures such as long short-term memory have gained a great performance such as Part et al. [7]. Our previous work ARNS [8] leveraged Bidirectional LSTM and took advantage of possible features in a battery cycle to extract more helpful information. ARNS has outperformed many techniques in capacity prediction but suffered from long training time, which is a drawback of LSTM. Therefore, in this research, our main contribution is to improve our previous work by replacing LSTM-based modules with more advanced information-extracting and fast-training modules, which combine convolutional neural network (CNN) and transformer.

The remainder of this paper is organized as follows. Section 2 gives background information. Section 3 describes related works. Section 4 demonstrates our improved model. Section 5 shows our experiment settings and results. Section 6 gives our conclusion.

2 Background

2.1 Charge–Discharge Operational Profiles of LIBs

LIB charging profiles follow a constant current–constant voltage (CC–CV) method, shown in Fig. 2. In the CC stage, a LIB is charged at a specific current until its voltage reaches the predetermined limit. In the CV stage, a LIB is charged at a fixed voltage until its current decreases to the predefined limit.

2.2 Possible Features in Predicting LIB Capacity

Potential features can be separated into channel-wise data and cycle-wise data.
Channel-wise data A LIB cycle includes three phases: charging, discharging and relaxation. The internal channels such as current, voltage, temperature and internal resistance are monitored. However, we will not get all multi-channel data in a cycle but sample them. Due to rapid change and slow change of data in discharging and relaxation process, respectively, we only sample data in the charging process, which creates three vectors with length Z denoted by D_k^{chan}.

$$D_{\text{chan}}^k = \begin{cases} v_1^k, v_2^k, ..., v_Z^k \\ i_1^k, i_2^k, ..., i_Z^k \\ t_1^k, t_2^k, ..., t_Z^k \quad (or\ r_1^k, r_2^k, ..., r_Z^k) \end{cases} \tag{2}$$

where v_z^k and i_z^k are the z-th voltage and current at k-th cycle, respectively. While t_z^k is the temperature used to be a feature in the NASA dataset, r_z^k is the internal resistance as a feature in the CALCE dataset. Z is the length of a channel.

Important sampling in [9] includes 11 data points in the CC process, which are at 35, 52, 70, 88, 90, 92, 94, 96, 98, 99 and 100% of the length of the CC period in charging phase. Each data point consists of three features, temperature, current and voltage for NASA dataset and resistance, current and voltage for CALCE dataset. This sampling method is also utilized in this research.
Cycle-wise data Apart from channel-wise data, which are considered time series data, we can extract five important features from the CC–CV period as discussed in [10]. These five features are listed below and depicted in Fig. 3.

- x^1: Initial charge voltage.
- x^2: CC charge capacity, the area below the current graph over CC period.
- x^3: CV charge capacity, the area below the current graph over CV period.
- x^4: Final charge voltage.
- x^5: Final charge current.

Besides the capacity at the k-th cycle, our previous research [8] introduced a new feature called T_{rest}, representing the relaxation time of a LIB before a new cycle begins. The relaxation time at the k-th cycle (T_k^{rest}) is calculated using Eq. (3), where t_k^s is the calendar datetime of the k-th cycle. P, a binary variable, indicates the peak status of battery capacities. P is 1 if the current capacity is greater than the average of the last five battery capacities, otherwise 0.

$$T_k^{\text{rest}} = t_k^s - t_{k-1}^s \tag{3}$$

Thus, cycle-wise features are ultimately an 8-tuple vector, shown in Eq. (4).

$$D_k^{\text{cycle}} = (x_k^1, x_k^2, x_k^3, x_k^4, x_k^5, C_k, T_k^{\text{rest}}, P_k) \tag{4}$$

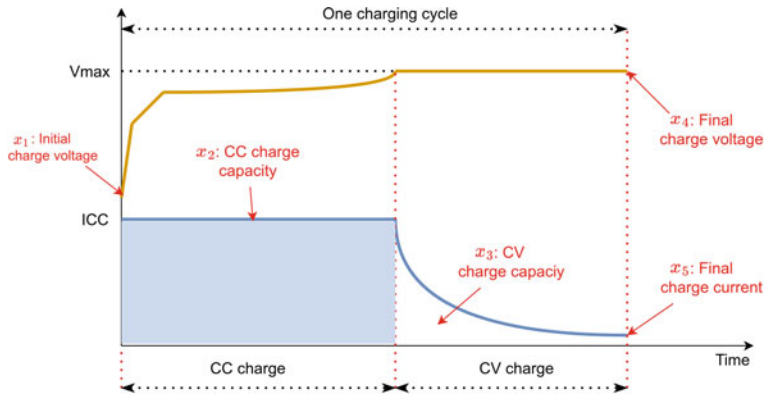


Fig. 3 Five features extracted from CC–CV process

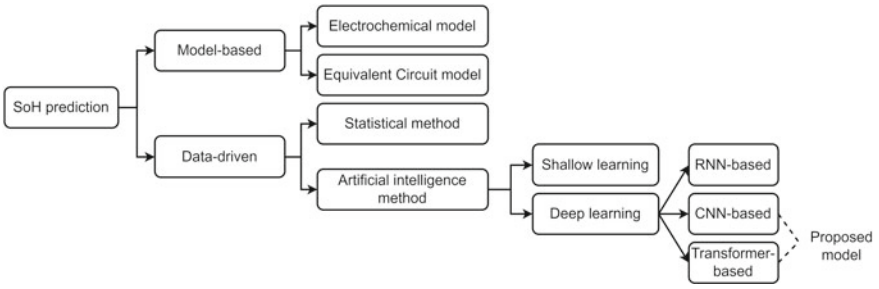


Fig. 4 Technique taxonomy of SoH prediction

2.3 1D Dilated Causal Convolutional Neural Network

Dilated convolution [11] is used to expand the kernel size but keep the same number of parameters; hence, it can broaden the receptive field. By this, the model can capture more data over a long period to encode, so it has more helpful information but has a low computation cost. The causal convolution layer is suitable for dealing with temporal data because it preserves the time order in the process of the convolutional operation. In other words, the current value depends only on past values and cannot see future values. The 1D dilated causal convolutional neural network (1D-DCCNN) was first introduced in WaveNet [12]. In the architecture, 1D-DCCNN incorporates causal CNN and dilated CNN to take advantage of these two CNN, which are causality and broad receptive fields.

3 Related Works

Generally, the technique taxonomy of SoH prediction is illustrated in Fig. 4.

3.1 Model-Based Methods

The model-based methods require domain knowledge and have two types. The first is electrochemical model methods [13, 14], based on the theory about electrodes to build a model. The electrochemical model method can precisely identify the movement law lithium-ions and the change tendency of active materials in positive and negative electrodes at different SoH values. However, the model is complex, has poor generality and cannot be used for real-time prediction.

The second method in model-based methods is equivalent circuit model [15, 16], which is based mainly on the perspective of electrotechnics. Its aim is to build a circuit model to describe the capacity degradation characteristics. This method is simple and widely used in practical engineering applications. However, the model cannot meet the precision requirements (accuracy).

3.2 Data-Driven Methods

Data-driven methods only care about data. Data-driven methods have two subcategories, statistical methods and artificial intelligent methods.

Statistical methods These methods are to extract and regenerate clean data from noise data [17]. Basically, the statistical methods are applied to do noise filtering, then a prediction model which uses probability theory or stochastic processes is built to do the forecasting. Some filtering methods include *Kalman filtering* [18] and *particle filtering* [19]. Statistical methods can be efficient and gain high accuracy with data which are collected systematically but decline when dealing with complicated distribution data.

Artificial intelligence methods With the development of technology, shallow learning methods have been used to solve the LIB capacity prediction. For example, Hu et al. [20] combine sample entropy technique with predictive Bayesian model, and Piao et al. [21] propose hidden Markov model. Although reported to have remarkable results, shallow learning methods have trouble processing large data.

Besides shallow learning methods, deep learning methods have also been applied for LIB capacity prediction and proven to be efficient in leveraging large data. Wu et al. [22] built a multilayer perceptron (MLP) combined with improved particle filter technique. A more sophisticated deep learning model is the long short-term memory (LSTM), which is known for its ability to handle sequence data. For instance, Park el at. [7] upgraded their LSTM by adding multi-channel features. In 2017, transformer [23] was introduced and had a great effect on many fields. In the issue of LIB capacity prediction, Hu and Zhao [24] proposed using wavelet threshold denoising [25] to filter data and leverage transformer architecture. Chen et al. [26] used variational autoencoder [27] to do the noise filtering and adapted transformer for LIB capacity prediction. Their results were remarkable, and training time was fast.

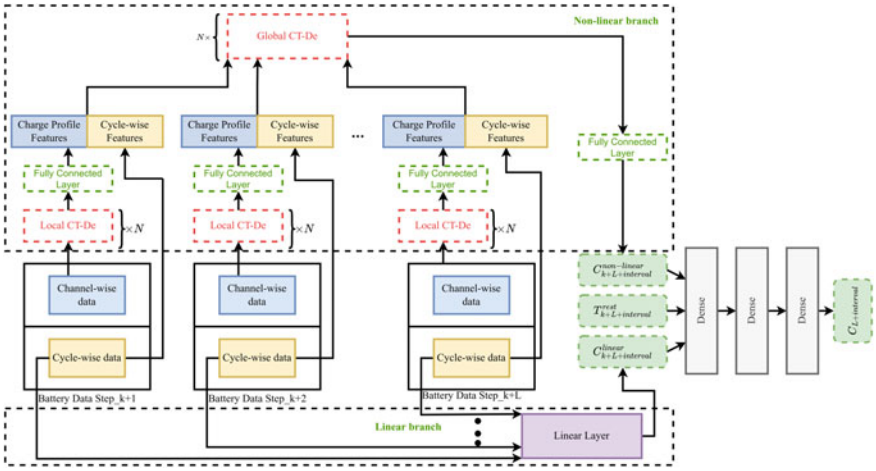


Fig. 5 Architecture is composed of two branches, linear branch and nonlinear. The improved parts are local CT-De and global CT-De, which replace BiLSTM.

Our previous work Pham el at. [8] adapted Bidirectional LSTM and leveraged nested sequence architecture [28] to extract carefully the information in each cycle. In addition, we utilized and analyzed the possible features in a cycle. The results were exceptional, but the architecture suffered from long-time training, which is a drawback of LSTM. Therefore, we can improve by replacing LSTM with a module which can train faster, and transformer is a potential candidate. Kim and Kim [29] proposed a variant of transformer to be suitable for time series data. Their results were astonishing when they could beat famous variants of transformer in time series such as Informer [30] in some benchmark datasets for time series. Inspired by their results, we adapt their architecture to enhance our previous work's performance and training time.

4 Proposed Model

Our previous work Pham et al. [8] suffered from long-time training because it was based on LSTM. To improve our previous architecture, we propose to replace each LSTM-based block with a decoder block in Kim and Kim [29]. A decoder block consists of N identical decoder layers. From now on, we call a decoder layer *CT-De*. A CT-De consists of 1D-DCCNN, self-attention and point-wise CNN. The 1D-DCCNN is suitable for time series data because of their causality and dilation, which can help extract more helpful information. Furthermore, the CNN and self-attention mechanism are much faster than LSTM because they can be parallelizable. The architecture of the model proposed is shown in Fig. 5.

The architecture consists of two parts, the linear branch and the nonlinear branch. The linear branch is an autoregression model. The nonlinear branch is more complicated, where each cycle has N local CT-De layers to extract its channel-wise data. Then, all the extracted information concatenated with cycle-wise data goes through N global CT-De layers and a fully connected layer to produce a capacity prediction of the nonlinear branch, $C^{\text{nonlinear}}_{L+\text{interval}}$.

4.1 Linear Branch

Linear branch is used to capture the trend of the data. The linear branch is an autoregression model whose output is linearly dependent on L (number of cycles) historical capacities as variables and described in Eq. (5).

$$C^{\text{linear}}_{k+L+\text{interval}} = \sum_{i=1}^{L} \phi_i * C_{k+i} \tag{5}$$

where ϕ_1,…,ϕ_L are parameters and C_{k+i} is capacity measured in (k+i)-th cycle.

4.2 Nonlinear Branch

The nonlinear branch, which is more complicated, is utilized to capture spikes. First, the channel-wise data, including 11 data points in the CC process of each cycle, go through a positional encoding layer (PE) and N local CT-De layers to produce an output having the same shape as the input. This process is depicted in Fig. 6. In detail, the input has the shape (B,3,11) where B is the batch size, 3 represents voltage, current and temperature, and 11 represents 11 time steps. The input is added positional encoding value by the PE layer, depicted in Eq. (6)

$$\begin{aligned} \text{PE}(\mathbf{x}_i, 2k) &= \mathbf{x}_i + \sin\left(\frac{\mathbf{x}_i}{10000^{\frac{2k}{t}}}\right) \\ \text{PE}(\mathbf{x}_i, 2k+1) &= \mathbf{x}_i + \cos\left(\frac{\mathbf{x}_i}{10000^{\frac{2k}{t}}}\right) \end{aligned} \tag{6}$$

where $\mathbf{x}_i$ is the multivariate vector $\mathbb{R}^d$ at the i-th time point, here d=3 and t=11.

After that, these embedded input go through N identical CT-De layers to produce the output having the same shape $(B, 3, 11)$, which then goes through a fully connected layer to create charge profile feature having shape $(B, 3)$. We apply this process for C cycles to obtain the output $(B, C, 3)$. This 3-dimensional tensor is then concatenated with the 3-dimension cycle-wise data tensor (B, C, CWD), where B is the batch size, C is the number of cycles, and CWD is the number of cycle-

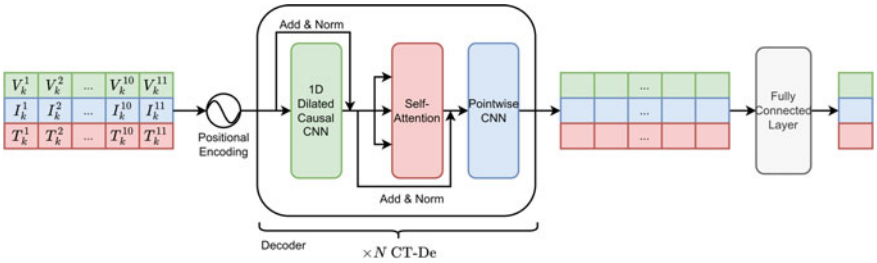


Fig. 6 Local CT-De for a cycle. The input has shape (B,3,11), and the output has the same shape (B,3,11)

wise features to obtain $(B, C, 3 + CWD)$ tensor. This tensor will be reshaped into $(B, 3 + CWD, C)$ and then go through N identical global CT-De layers. Therefore, the result will be a $(B, 3 + CWD)$ tensor and will go through a fully connected layer to obtain $(B, 1)$ tensor, where 1 represents nonlinear capacity $C^{\text{Nonlinear}}_{k+L+\text{interval}}$.

Finally, after $C^{\text{Linear}}_{k+L+\text{interval}}$ and $C^{\text{Nonlinear}}_{k+L+\text{interval}}$ are produced, they will be concatenated with $T^{\text{rest}}_{k+L+\text{interval}}$, which is the relaxation effect of the cycle *k+L+interval* and go through 3 fully connected layers to obtain the final result, $C_{k+L+\text{interval}}$.

5 Experiment Settings and Results

5.1 Datasets

We utilized two datasets, NASA [5] and CALCE [6], which were collected under controlled laboratory conditions and employed the CC–CV charging method.

5.2 Data Processing

Before training, we clean the data. The discharge capacity in a cycle indicates the capacity of that cycle. Any missing capacity value is interpolated by the nearest value. The data are then normalized by Min-Max-Scaler, depicted in Eq. (7).

$$z_k^s = \frac{x_k^s - \min(x)}{\max(x) - \min(x)} \tag{7}$$

where x represents a collection of selected features from the datasets and x_k^s refers to the s-th sample of the selected feature from the k-th charge cycle.

5.3 Cross-Validation

To validate, we use a cross-validation technique. For each battery in a dataset, we use it as a test set, and the rest batteries are used to be train and validation set with a proportion 90:10. For example, in the NASA dataset, there are 4 batteries, #5, #6, #7 and #18. To test for #5, we use #6, #7, #18 to be the train and validation sets with the proportion 90:10.

For performance metrics, we use root mean squared error (RMSE) and mean absolute percentage error (MAPE), depicted in Eq. (8).

$$\text{RMSE} = \sqrt{\frac{1}{K} * \sum_{k=1}^{K} (C_k - \widehat{C}_k)^2}, \text{MAPE}(\%) = \frac{100}{K} * \sum_{k=1}^{K} \frac{|C_k - \hat{C}_k|}{C_k} \quad (8)$$

5.4 Results

We use the multi-channel LSTM (MC-LSTM) of Park et al. [7] as baseline because their results are good enough. Furthermore, we implement Gaussian fitting (GF), support vector regression (SVR) and multilayer perceptron (MLP). Besides, we execute other transformer-based methods such as DeTransformer [26]. We predict the next cycle's capacity, which means *interval* = 1. The overall results for NASA and CALCE datasets, which are averaged over the datasets and also include the peak and non-peak test set, are demonstrated in Table 1. From the results, our proposed model is better than MC-LSTM, DeTransformer and also ARNS in both NASA and CALCE datasets. Here, we use 1 (NASA) and 2 (CALCE) identical local CT-De layers for each cycle; 2 identical global CT-De; dilation = 1; and kernel size = 5 in 1D dilated causal CNN.

Furthermore, we compare the number of parameters and the training time of our previous work and the proposed model to prove that CNN mechanisms together with the self-attention mechanism is faster than LSTM-based architecture, which is illustrated in Table 2. The training was executed on Google Colab with GPU. The results show although CTARNS has more number of parameters than ARNS, CTARNS's training time is much faster than that of ARNS. Particularly, CTARNS is approximately 11 times faster on the NASA dataset and 29 times faster on the CALCE dataset.

6 Conclusion

In this research, we have leveraged transformer-based architecture to improve not only the performance but also the training time of our previous work. The effect was come from the 1D dilated causal CNN and self-attention mechanism, which were

Table 1 Overall results for NASA and CALCE datasets

		NASA dataset			CALCE dataset	
Method	Overall RMSE, MAPE	Peak RMSE. MAPE	Non-peak RMSE, MAPE	Overall RMSE, MAPE	Peak RMSE, MAPE	Non-peak RMSE, MAPE
MC-LSTM (baseline)	0.0322, 1.6315	0.0440, 2.1346	0.0298, 1.5515	0.0184, 1.6894	0.0188, 1.9132	0.0183, 1.629
GF	0.0910, 5.3457	0.0885, 5.1514	0.0961, 5.7894	0.0952, 10.8519	0.1044, 12.9689	0.0926, 10.2953
SVR	0.0862, 5.0716	0.0852, 4.9768	0.0873, 5.2244	0.1043, 12.1913	0.1148, 14.7382	0.1013, 11.5202
MLP	0.0318, 1.6062	0.0332, 1.6149	0.0275, 1.5063	0.0256, 2.2374	0.026, 2.5131	0.0255, 2.1618
LSTM	0.0420, 2.1801	0.0429, 2.1964	0.0395, 2.1036	0.0274, 2.3188	0.0276, 2.4992	0.0274, 2.2688
DeTransformer	0.0235, 1.1052	0.0260, 1.1483	0.0186, 1.0188	0.0170, 1.4874	0.0173, 1.5434	**0.0153**, **1.2134**
ARNS	0.0230, 1.0474	0.0261, 1.1566	0.0165, 0.8605	0.0166, 1.5223	0.0175, 1.8004	0.0163, 1.4480
CTARNS	**0.0196**, **0.9145**	**0.0219**, **0.9814**	**0.0145**, **0.7843**	**0.0157**, **1.2877**	**0.0158**, **1.3964**	0.0157, 1.2584
CTARNS (%) improvement	39.13, 43.95	50.23, 95.40	51.34, 49.51	14.67, 23.78	15.96, 27.01	14.21, 22.65

Table 2 Training time of NASA/CALCE dataset

Dataset	NASA dataset				CALCE dataset			
	Testing batteries	No. of parameters	No. of epochs	Training time (second)	Testing batteries	No. of parameters	No. of epochs	Training time (second)
ARNS	#5	5253	1000	634	CS2_35	5233	100	260
	#6	5253	1000	645	CS2_36	5233	100	258
	#7	5253	1000	637	CS2_37	5233	100	265
	#18	5253	1000	682	CS2_38	5233	100	259
			Average	0.65 s/epoch			Average	2.60 s/epoch
CTARNS	#5	5646	3000	192	CS2_35	6658	3000	281
	#6	5646	3000	191	CS2_36	6658	3000	280
	#7	5646	3000	188	CS2_37	6658	3000	282
	#18	5646	3000	192	CS2_38	6658	3000	279
			Average	0.06 s/epoch			Average	0.09 s/epoch

proven to be effective in extracting meaningful information from LIB data through our experiments. Particularly, through experiments on the NASA dataset, our proposed model performed approximately 39.13% (RMSE) and 43.95% (MAPE) better than the baseline. Besides, our proposed model created improvements of 14.67% (RMSE) and 23.78% (MAPE) on the CALCE dataset. In the future work, we can evaluate the model's performance on real-condition dataset. Additionally, we can implement transfer learning techniques to improve the model's accuracy by training it with new, continually collected data.

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Federated Autonomous Orchestration in Fog Computing Systems

Manuel Dworzak, Marcel Großmann, and Duy Thanh Le

Abstract Autonomous computing is the key concept for service orchestration in next-generation cloud computing environments. Virtualization supplements it by adding an abstraction layer to the services, as well as to the underlying infrastructure including the network layer. IP flows are calibrated by Software Defined Networks to address virtualized services directly, which is conceptually described as Network Function Virtualization. Side by side exists a diversity of devices in the cloud-to-fog continuum, which are geographically distributed, can connect to a multitude of networks, and are prone to churn. Their behavior increases the manageability and maintenance efforts needed to deploy services dynamically. To achieve a MAPE-K like service distribution, we adopt machine learning concepts to react to infrastructure changes and service requirements. Due to the distributed nature, we focus on federated machine learning to improve overall performance without cluttering single nodes.

Keywords Fog computing · SDN · Orchestration · Federated Learning

1 Introduction

In nowadays, infrastructures like fog computing applications are empowered to be distributed over the network, where the number of devices increased from a thousands of servers to millions or billions of nodes. Capabilities of devices in those networks are manifold and need to be considered in orchestration and scheduling paradigms. Besides the classical significant factors like CPU, RAM, and disk space, location

M. Dworzak · M. Großmann (✉) · D. T. Le
Computer Networks Group, University of Bamberg, Bamberg, Germany
e-mail: marcel.grossmann@uni-bamberg.de

M. Dworzak
e-mail: manuel.dworzak@uni-bamberg.de

D. T. Le
e-mail: duy-thanh.le@uni-bamberg.de

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heavily impacts the placement of computing resources, which shall be nearby to end-users to minimize latency. On the other hand, several factors need to be satisfied to fulfill the needs of distributed micro-services. Here, virtualization is of uttermost importance to increase manageability and simplify maintenance. Actually, on small scale machinery this issue is addressed by containers especially with the rise of Docker and its native Single Board Computer (SBC) support for different architectures.

In recent considerations for healthcare, Azimi et al. [1] present a monitoring, analysis, planning and execution over the knowledge base (MAPE-K) architecture, which is used in combination with healthcare Internet of Things (IoT) devices. Machine learning (ML) is used as an analysis component in the cloud while the fog and edge layer contain the remaining parts of the MAPE-K architecture. Chou et al. [6] provide an approach for federated machine learning (FL) in which a central server groups nodes together such that it only communicates with a single node from the group. Additionally, a limited network connectivity increases convergence time significantly due to mitigation of the straggler effect. Beside that central global server idea, Savazzi et al. [10] propose a fully decentralized FL approach for massive IoT networks. Containerized functions, which are capable to run in the cloudless computing paradigm [7], are the foundation for the proposed container orchestrator. In the same fashion, the cloudless resource monitoring (CRM) framework of Le et al. [9] is designed to run on any node in the cloud-to-fog-continuum, which is used to collect the characteristics of deployed services.

We want to give insights, if the MAPE-K architecture is feasible for container orchestration, where many failure scenarios occur due to the high degree of interconnectivity. To avoid a decreasing Quality of Experience (QoE), an autonomous system shall be able to detect and handle such faults. We want to provide an infrastructure that allows dynamic event handling mechanisms with the possibility to change, during runtime, the mechanism to influence the current state in a standardized way. For fog computing scenarios we need to re-think node scalability since currently existing orchestration platforms embed a central solver with global knowledge for node scoring. However, a central solver is not feasible as the decision complexity for deployment considerations increases at least linearly. Hence, we want to find a distributed node scoring solution. Due to the limited resources on edge devices, we need an intelligent container resource estimation before a container is deployed to avoid the overloading of a node.

2 Orchestration Architecture

Similar to Azimi et al. [1], our proposed architecture, depicted in Fig. 1, is spread over the cloud-to-fog continuum. The *cloud* layer aims to analyze the metrics of the *edge* nodes, which run the virtualized applications packaged by Docker. Hence, the detectors can investigate anomalies and detect failures on nodes. Then, events will be sent to the *fog* layer, which, e.g., interacts with the *Software Defined Network*

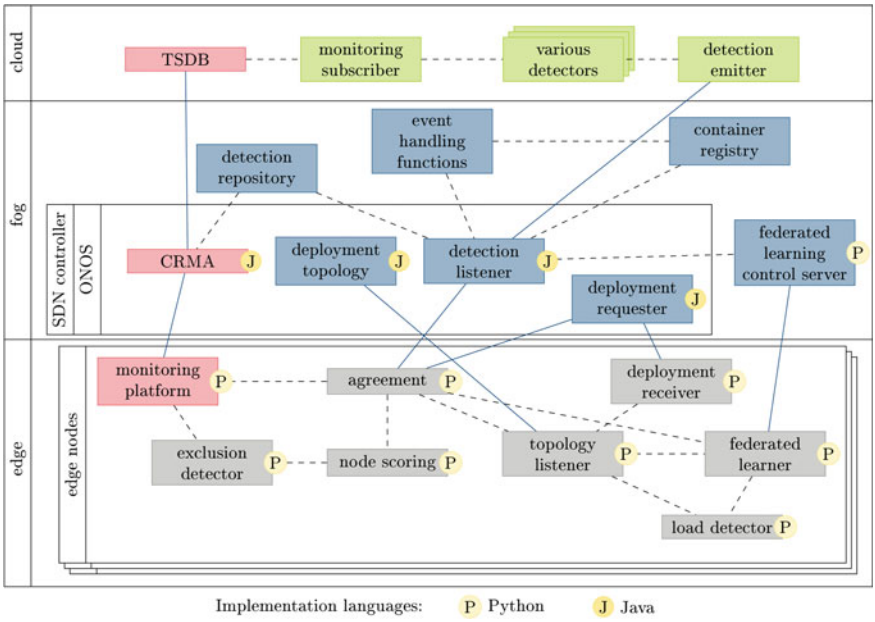

Fig. 1 High-level architecture

(SDN) controller to run functions from the *event handling functions* server or starts a FL process. This *event handling functions* server allows us to program custom event handling mechanisms like sending mails as a notification or making deployment requests to the orchestrator such that the application is scaled out. The services, which the orchestrator requests, run on the *edge* devices. The orchestrator also executes a distributed agreement protocol to decide where the containers shall be deployed. As a characteristic of fog computing networks are large-scale with a massive number of devices. We map nodes into hierarchies, where nodes can be labeled with arbitrary depth. As shown in Fig. 2, one could put many nodes in a single hierarchy, as we show it for "Region A", or there can be sub-levels for nodes with a lot of disk storage or fast storage where one keeps all data-related apps, as in "Region B", or applications are assigned to specific nodes directly, as done in "Region C".

The red-colored components of Fig. 1 depict the *monitoring platform* [9], which collects node and container metrics on the edge devices and sends them in a fixed interval to the *SDN controller*, in our case the *Open Network Operating System (ONOS)*, which stores the metrics in a *Time Series Database (TSDB)*. The *CRM application (CRMA)*, which is integrated into ONOS, forwards the monitoring data of the *edge* devices to the *cloud* layer. The *analysis* capability is color-coded in green, where the *monitoring subscriber* subscribes to any new entry in the *TSDB*. If any of the *detectors* fires events, we send a message to the *detection listener*, which is the `planning` component of the MAPE-K architecture that looks up event handling strategies. The infrastructure tools support the *planning* layer, as they

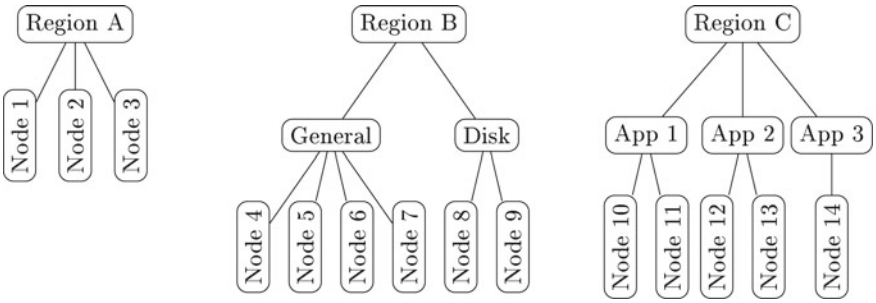

Fig. 2 Hierachy of nodes for filtering

are the *execution* components. We can store custom functions in the *event handling functions*, which triggers when conditions from the *detection repository* are fulfilled, where the function URLs are stored. Additionally, once there is a global low load, the *FL control server* starts and manages an FL process. We assign each node to a hierarchy with the *deployment topology* service.

The last capability is the orchestrator, which selects where containers are deployed. For the scheduling decision, it needs to know the current node utilization and the required resources for the new container. The current utilization is measured by the *monitoring* platform. However, we currently have no way to determine the container resources of a new deployment and therefore ask the application provider to fill out a radar chart.

To learn about container resources, the *FL control server* interacts with the *federated learners* to approximate the requested resource function. The *node scoring* module calculates a score with the estimated resource usage for each deployment request. All eligible nodes run a distributed *agreement* algorithm to vote for the highest scored node, which then deploys the container using the *deployment receiver* component. The *load detector* component detects when the FL shall learn the local model and broadcast it over the network.

2.1 Cloud Layer

When the whole system has overall low resource usage, we want to start the FL process such that the learning process does not have a QoE impact on currently running services. When a hierarchy has overall high resource usage, we want to store the resource usage information about each container in a node-local database. The FL process uses this data for learning. Hence, we need to store one global model and one model for each hierarchy.

The ML process aims to approximate a function that reflects the resource usage at the given time. A two-layer neural network for function approximation receives the timestamp as input and returns the expected $score_{resources}$ value, which averages the CPU and memory usage (cf. Eq. 1).

$$score_{resources} = \frac{cpu\_usage + mem\_usage}{2} \tag{1}$$

2.2 Fog Layer

The *detection listener* is the *P* in our MAPE-K architecture. It reacts to the analysis done by the cloud layer by looking up event handlers in the *detection repository*. If we specify an event handler for the given scenario, the *detection listener* makes an HTTP call to the event handler URL.

The *deployment requester* deploys new containers and interacts with edge nodes for agreement and scoring. It needs to know the hierarchy for the application deployment with its container configurations. Additionally, we provide a radar chart for every container, which contains its estimated resource usage on a scale from 0 to 10, such that ML processes can generate an estimation. With this resource estimation, a service can be deployed on an appropriate node.

Given the hierarchy information, the *deployment requester* sends the container ratings to the edge devices for the agreement phase, where every edge node from the given hierarchy replies with its score value or a timeout if the node is not available. Having received the score values, the *deployment requester* sends the configuration to the node with the highest score, which then replies with the deployment log to see if the deployment failed or succeeded.

The *event handling functions* server is an instance of OpenFaaS [8]. It deploys and runs services for the event handling, the *E* in MAPE-K. We are using OpenFaaS as an event handling platform, providing a standardized and generic way to handle events dynamically. The *container registry* stores those functions. In OpenFaaS, a serverless function runs as an isolated, self-contained container. These containers offer arbitrary code from the application providers to handle specific events. By function chaining arbitrarily complex behavior can be modeled.

2.3 Federated Learning Control Server

The *FL control server* implements the previously introduced FL with some adaptations. Unfortunately, the original algorithm of Chou et al. [6] splits the network evenly to create *L* networks of almost equal size. It is not the case for our approach as we reuse already existing hierarchies, which are not guaranteed to be equally sized. Hence, we changed $\theta_G^{t+1} \leftarrow L^{-1} \sum_{l=1}^{L} \theta_{Z_l}^{t+1}$ to $\theta_G^{t+1} = \sum_{l=1}^{L} \gamma_l \theta_{Z_l}^{t+1}$ where $\gamma_l = \frac{|D_l|}{\sum_{l=1}^{L} |D_l|}$ is

the amount of datapoints for learning by the current hierarchy divided by the amount of datapoints for learning by all hierarchies combined.

We learn once every day when the *load detector* predicts a global low load. Every hierarchy simultaneously learns how to finish the FL process as fast as possible.

2.4 Edge Layer

The *deployment receiver* on each edge node deploys Docker infrastructure like containers, networks, and volumes. It does so by forwarding the deployment request to the *builder daemon* of the *monitoring platform*. The *deployment receiver* also sends back the deployment log from the *builder daemon* to the *deployment requester* such that the application provider knows if the deployment succeeded.

The *federated learner* learns to estimate the container resource usage from a chart diagram. It is the counterpart of the *FL control server*, which only aggregates the models by each hierarchy. The learner itself learns from the local data model. An elected leader will then aggregate the learned models of its hierarchy and send them to the *FL control server*.

Once a day, the *load detector* module on each node receives a message about a high load and stores the resource usage of each container in a local database. We want to store the resource usage only at high load moments because it is better to overshoot with the resource estimation than undershoot. Overshooting resource estimations leads to more node exclusions from the agreement, especially for nodes with fewer available resources. Hence, we only learn with values from high load moments to force overshooting instead of undershooting, as fog and edge computing have the characteristic of an enormous amount of computing devices to balance out mistakes by our overshooting approach.

The *node scoring* module uses the FL model and additional host information to calculate a score value for each deployment request. The required metrics are gathered by the *monitoring platform*. We calculate the node CPU capacity by the provided usage time in milliseconds, whereas memory and disk capacity are hardware bound. The network capacity is culled from the network interface card (NIC). For the node scoring process, we reuse the main concepts of the Kubernetes scheduling schema, which is analyzed in Wei-guo et al. [11]. As our target devices are edge devices, we also want to add factors like disk usage and network usage to the set of metrics M and calculate their utilization. Combining the exploitation factor f, where f is in $[0, 1]$, with the resource utilization equations, we finally calculate the overall node utilization score by Eq. 2.

$$
\begin{aligned}
M &= \{cpu, mem, disk, net\} \\
S_x &= \frac{T_x - S_{req\_x} - f * P_{req\_x}}{T_x} \qquad for\ x \in M \\
score_1 &= \frac{\sum_{x \in M} S_x}{|M|}
\end{aligned}
\tag{2}
$$

In addition to the overall node utilization score, we also calculate the balance degree between the resources. After calculating both scores, we ask the *exclusion detector* component if the current deployment request is possible.

The *topology listener* service detects changes in the node hierarchy. Each node needs to know its hierarchy for the FL or load detection. It is necessary to say that the topologies are our way of implementing container affinity and anti-affinity. Kubernetes introduces the concept of affinity when it must deploy containers with low latency. Similarly, Kubernetes uses the concept of anti-affinity when the containers shall not be close together. We implement the concept of anti-affinity in our architecture by deploying containers in different hierarchies. Similarly, we implement the concept of affinity in our architecture by deploying containers in the same region, as low latency and real-time communication are part of the properties of edge computing.

For the *monitoring platform*, we use a slightly modified version of the monitoring system of Le et al. [9]. Unfortunately, the collector node is a single point of failure (SPoF) in the network and if it fails, no monitoring results are sent to ONOS. To solve this issue, we modified the system so that every node is a collector and worker simultaneously. Our approach allows every node to send monitoring results to ONOS instead of just the collector system.

3 Evaluation

We evaluate our approach regarding CPU, memory, and disk usage on the edge nodes. Furthermore, we assess the agreement time, the load detection model, and the FL accuracy using a very simple target approximation, the identity function.

We ran all benchmarks in a KVM virtual machine with 28 virtual CPU cores from an AMD-5950x, 48 GB DDR4 RAM, and a 128 GB NVME SSD. Due to a local simulation, the loopback network speed only runs at 45.7 $^{Gbits}/_{sec}$ inside the virtual machine. Network activities of the host system shall not negatively impact the network speed inside the simulation due to a maximum available 89.5 $^{Gbits}/_{s}$ host network speed. In our simulation, two cores and 4 GB of RAM are assigned to each edge node. The disk usage of each host is limited to 5 GB.

For learning the global model, we collect all CPU and memory metrics with their timestamp, calculate the $score$ values and normalize the scores among all nodes at the given timestamps. We show the result in Fig. 3 where the blue dots are the $score$ values over time, the orange line is the approximated function, and the blue bar is the

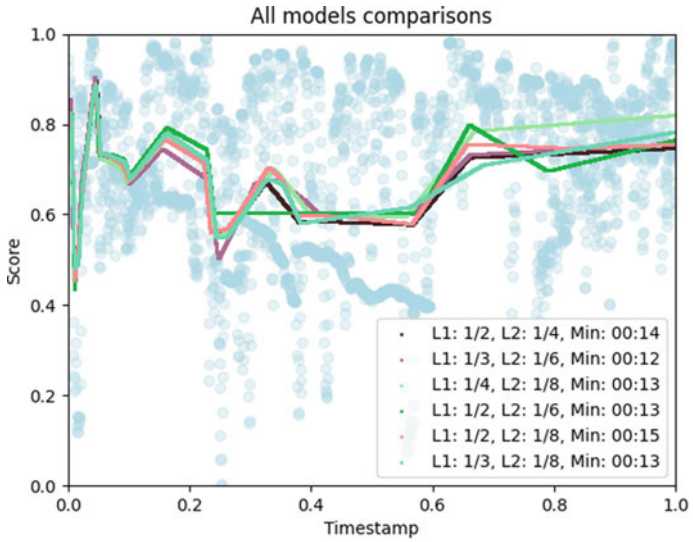

Fig. 3 Comparison of different approximations through the load detection function

lowest point. We provide the layer 1 and 2 node count and the calculated minimum value of this function approximation. We give the node count as a fraction, like 1/2 or 1/4. It means the following: We have set a fixed value of 800 for our trials. A value of 1 means that the number of hidden nodes in a layer is this fixed value. Hence, a value of 1/4 would mean that, given a value of 800, the given layer has 200 hidden nodes. We tested this with different amounts of fixed values to verify that our results matched with different layer count amounts. We use the eyeballing technique to assess this number of nodes as, due to the enormous amount of data points in the dataset, the accuracy for all scenarios was 0, and the loss was almost equally low.

We can see that the minimum load time is between 00:13 and 00:15 in this scenario and the difference between the configurations is mostly insignificant. Additionally, we tested the identical function approximation using a 3-layer neural network and did not see any significant changes in the function approximation.

Overall, we found out that the size of the layers does not make a significant difference in finding the minimum value, as the comparison image tells in Fig. 3, once there is a certain amount of nodes in a layer.

3.1 Federated Learning Accuracy

As the learning goal, we re-use the idea of an auto-encoder where the input data equals the output data. As input data, we have four random values between 0 and 100, which are represented by the radar chart's features. We choose a simple learning

Fig. 4 Federated machine learning feature importance

goal because the resource estimation is similarly simple with the additional scaling factor. It might be the case that, e.g., RAM usage of 2 might equal 300 MB of RAM, which is a scaling of 150. Obviously, in a real application scenario of our approach, the data will be much noisier, as some people might classify their application with RAM of 2, which gets different output values. Nevertheless, the auto-encoder and our resource usage scenario should be similar regarding learning difficulties.

In our benchmark scenario, we used {5, 10, 20, 35, 50, 75, 100} nodes, FL iterations of {1, 7, 15, 30}, and the hierarchy amount of {1, 10, 25}, where each node had data entries of {1, 7, 15}. Knowing that our benchmark scenarios do not necessarily reflect real datasets, as we assign the nodes randomly to the hierarchies and each node has the same amount of data, we still get an insight into the feature importance of each parameter. We have used three different classifiers for feature importance to understand which parameter has the most impact. We have used a random forest classifier [2], which is the left classifier, a decision tree regressor [3] in the middle, and a XGB classifier [5] on the right of Fig. 4.

We can see that the decision tree regressor and the XGB classifier calculate that the node data entries and the iterations are the most critical factors. The random forest classifier does not follow this pattern. We cannot explain why the random forest classifier estimates the node count as an essential factor. Eyeballing the benchmark data results, we also come to the same conclusion as the decision tree regressor and XGB classifier that the iteration count and dataset size per node are more significant factors than the number of nodes or hierarchies.

4 Conclusion and Future Work

Our architecture consists of three parts: The cloud layer, the fog layer, and the edge layer incorporate the MAPE-K architecture for autonomous computing. The cloud layers' intent is to analyze and detect events like high load and container failures, which is the A of MAPE-K. The fog layer's purpose is to handle these events, group nodes into hierarchies, and deploy new containers, the P and E of MAPE-K. The edge layer's ambition is to host the deployed apps and send monitoring events to the cloud, the M of MAPE-K.

The four goals of our research are to evaluate the MAPE-K approach for container orchestration, support dynamic event handling, support a high amount of nodes, and deploy containers smartly. We accomplish our first two goals through our cloud analysis layer. The application-provider given functions then handle these events to improve overall system performance. The third goal mainly involves the node scoring functionality. In our approach, each node scores itself in parallel, and the orchestrator picks a winner. For the fourth goal, we use FL to estimate the required container resources before the container deployment using a radar chart. Knowing the current node resource usage and the estimated resource usage of a new container, we can make smarter decisions. Additionally, we evaluate our agreement time and ML accuracy. From the agreement time, we recognized that node scoring, due to the parallelization, is fast, and the idea of distributed node scoring is feasible for real scenarios. For an approximation of the load of the edge nodes to detect moments of high and low resource utilization, we uncovered that more hidden layers with more nodes do not significantly change the approximated function given that a certain amount of hidden layer nodes exist. From the FL agreement, we revealed that mainly the number of iterations and the amount of data on each node are the driving factors.

In the future, our framework may include support for container relocation, which increases overall orchestration performance with several measures and resource usage. Secondly, the deployed applications could provide accessible optimization goals using an API to optimize resource usage and application performance, similar to DRAGON [4]. The system shall introduce constraints and optimization goals for the deployment to the system to, e.g., reduce overall network latency as the locality is an essential characteristic of edge computing. Thirdly, working more with background knowledge can improve our MAPE-K architecture. Similarly, our system must respect security and privacy issues before deployment in real environments. Lastly, we require more research on which analysis shall be moved to the fog layer to reduce the number of failure scenarios. Our current architecture only supports analysis steps in the cloud layer.

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Internet of Sensing Things-Based Machine Learning Approach to Predict Parkinson

Sohana Afroz, Tajim Md. Niamat Ullah Akhund, Tarikuzzaman Khan, Md. Umaid Hasan, Rashida Jesmin, and M. Mesbahuddin Sarker

Abstract With the help of the Internet of things, therapeutic science has progressed surprisingly. Lots of elderly individuals are affected by Parkinson's disease. This work proposed an Internet of sensing things-based system to collect data from Parkinson's affected people analyze the collected data in a cloud server with machine learning algorithms and predict the condition of the patient. Multiple types of sensors are used and tested. Micro-controllers are used to collect data from sensors and send them to a cloud server. Then, multiple machine learning algorithms are used to predict the patient's condition. Results between several methods are also compared.

Keywords Internet of things (IoT) · Parkinson prediction · Internet of sensing things (IoST) · Machine learning (ML) · Neurodegenerative disorder (NDD)

1 Introduction

Bangladesh is a very populous and developing country. Parkinson's illness is a neurodegenerative disease (NDD) influencing millions of individuals around the world. Support system for Parkinson affected people in Bangladesh is very rare. Exhaustion, shaking (upper and lower arms, as well as jaw shake), lack of concern, postural brokenness (sadness and disposition changes), dementia (misfortune of memory), and rest disarray all are classic Parkinson's infection indications.

S. Afroz · T. Md. N. U. Akhund (✉) · T. Khan · Md. U. Hasan
Department of Computer Science and Engineering, Daffodil International University, Dhaka, Bangladesh
e-mail: tajim.iitju@gmail.com

S. Afroz
e-mail: sohana15-2089@diu.edu.bd

R. Jesmin
Department of Zoology, Government Hajee Korop Ali Memorial College, Sirajganj, Bangladesh

M. M. Sarker
Institute of Information Technology, Jahangirnagar University, Dhaka, Bangladesh

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1.1 Contribution

This work's primary objective is to make a multi-functional, specialized apparatus that can monitor and predict Parkinson's illness with Internet of sensing things (IoST) and machine learning.

1.2 Background Study

Parkinson's is a neurodegenerative disease that affects millions of individuals worldwide [1]. Machine learning can make a good way to support these patients [2]. The paper [3] illustrates how an organization, characterized broadly as an organized collection of forms, conventions, and the concept of planning strategies to carry out particular exercises or unravel specific problems effectively applies to open well-being through different instruments, counting mechanical frameworks. The component or stuff of measuring and calculating brain well-being substance creates in internet-based design, and classification strategies are utilized to gather and analyze real-time information, agreeing to [4]. Agreeing to [5], guaranteeing the unwavering quality of collected information, like every solid report, may be a troublesome challenge in this application. Remote sensor systems are regularly created and outfitted with resource-controlled detecting gear for basic applications such as self-regulated independent cities, advanced, SDH, accuracy cultivating, and mechanical control frameworks, concurring to [6]. The creators of [7] discovered that by paying near consideration to the medical mixed media information classification modeling system, the clinical mixed media information classification quality may be progressed. [8], agreeing to the creator of this paper the framework recognizes markers and relegates a rest forecast, permitting us to compare the comes about of the dull-taken pointer. Agreeing with the creator of this paper [9], a show that's amazingly valuable for assessing enormous sums of information on cloud soil has been proposed. The huge machine information age, concurring to [10], produces noteworthy comes about through data-based well-being administration. Information source sensors for current information incorporate plenty of compelling trapezoids. Agreeing to [11], continuous consider papers are judged by patients and restorative benefit specialists in terms of the level of [12] reliability and pertinence in MH writing. The essential objective of the arranged design, agreeing to [13], is to help doctors in their objective administration of ordinary Parkinson's infection engine issues and change. A huge number of inhabitants are migrating these days, according to [14]. The foremost troublesome angle of city center flooding is the provision of therapeutic and instructive administrations. Huge information within the keen domestic, concurring to [15], can be utilized as a show for looking over human behavior propensities for learning and well-being applications. [16] indicates that three organized framework models have been created and tried: a solid conviction network, self-closing code gatherings, and complex uneasy systems. One of the cross-brain calculations, agreeing to the ponder paper [17], makes a progressive connection between huge information

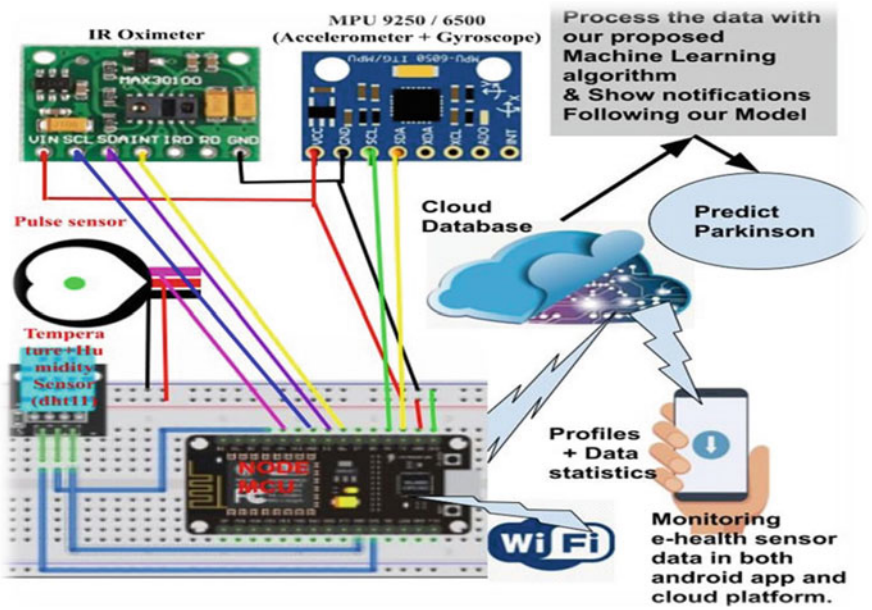

Fig. 1 Conceptual diagram of the system

and work blunder. Concurring to [18], Parkinson's is one of the foremost common illnesses, and their framework was extraordinary at diagnosing and evaluating the seriousness of PD. Alzheimer's affected people [19], disabled patients [20] can be helped with IoT. Restaurants [21] and numerous other divisions [22] are using IoT. Remote detecting makes a critical contrast in virus-affected individuals checking [23, 24] with secure way [25]. IoT-based systems have a great positive effects in horticulture [26], poultry cultivate and other farmings [27–29], crippled individuals administration [30], cultivating [31], nursing [32], infection influenced region checking [24, 33, 34], and in medical sectors [35, 36]. So, IoT can help Parkinson's affected people also.

2 Methodology

Figure 1 shows how the system is organized. The system's hardware architecture uses a node MCU ESP8266, MPU 9250 Accelerometer Gyroscope, and DHT11 sensor. Power source, wires, breadboard, and connectors are also used.

Our system's basic algorithm is as follows:

1. Power up the system.
2. Start connection between Wi-Fi router and Node MCU.

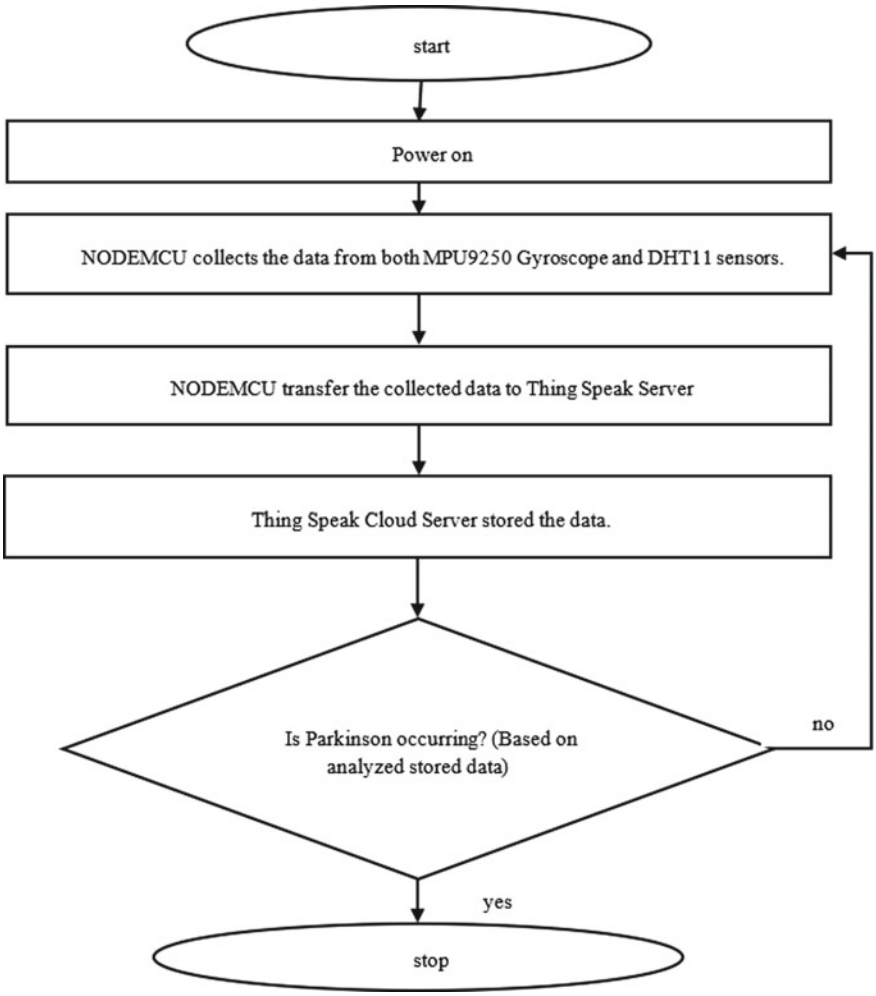

Fig. 2 Flowchart

3. Read data: temperature, humidity from DHT11; x, y, z axes acceleration and gyro value from MPU9250.
4. Send data to the cloud server via wifi from node mcu.
5. Save the data in server for monitoring and analysis.
6. Compare the analyzed data with ML algorithms, take decision and notify.
7. Go to step 2.

The system flowchart is as Fig. 2.

To train the machine learning model, dataset from Kaggle is used. Multiple algorithms are used to find the best result. Support vector machine (SVM), logistic regres-

sion, decision tree, and random forest are used. Then, the trained system is tested with the data collected with the resulting device of this work. There were 24 columns and 1000 rows in the dataset taken from Kaggle.

3 Results

The execution of the hardware prototype device is depicted in Fig. 3. An ESP8266 NODEMCU, a DHT11 temperature and humidity sensor, and an MPU 9250 accelerometer and gyroscope are the main instruments used in this project. The prototype is made as small as possible. It can be made smaller as a wearable device in future.

Temperature and humidity real-time data can be obtained in the ThingSpeak server (https://thingspeak.com/channels/1562218) like Fig. 4, and a CSV record can be downloaded from the ThingSpeak server.

The real-time value from the accelerometer and gyroscope can also be found from the cloud server like Fig. 5.

Figure 6 delineates the accuracy of sensor values. The bar chart delineates the exactness of our sensor's forecast in real-time information. To make a summary, select and report the most highlights of the data. The temperature is the foremost pressing issue. When measuring temperatures, it has a precision of around 99%. The humidity was measured with 95% precision. *X*, *Y*, *Z*-axes accelerometer and gyroscopes accuracy rate are also shown in Fig. 6.

The test assessment is portrayed in Fig. 7, how correctly the system predicted whether the patient has Parkinson's or not. By measuring model correctness, we

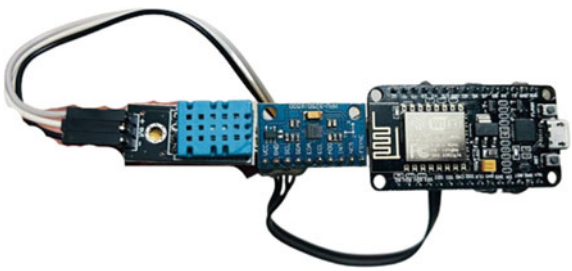

Fig. 3 Hardware prototype (one side)

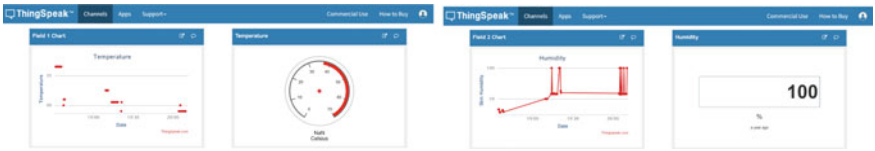

Fig. 4 Temperature and humidity value outputs in cloud

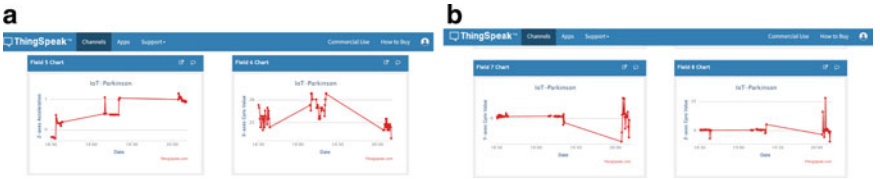

Fig. 5 **a** *Z*-axes acceleration and *X*-axes Gyro, **b** *Y*-axes and *Z*-axes Gyro

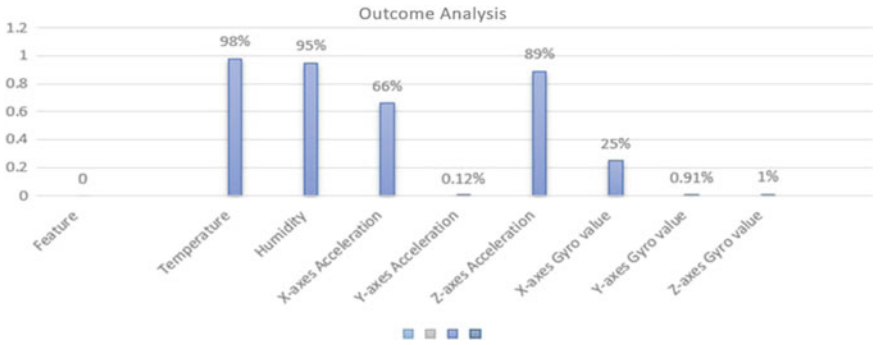

Fig. 6 Accuracy of measurement with sensors

compared various machine learning methods in this study, including the support vector machine (SVM), random forest, logistic regression, and decision tree implementation. The first one has an 89.74% accuracy according to the support vector machine algorithm. The second one has 87.17% accuracy according to the random forest algorithm. The third one has an accuracy rate of 82.05% according to the logistic regression technique. Finally, we used the decision tree technique to reach an accuracy of 79.48%.

The confusion matrix is mentioned in Table 1.

A perplexity grid is made for evaluating the accuracy of machine learning procedures. The following equations show how the accuracy percentages are calculated.

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{FN} + \text{TN} + \text{FP}} * 100\% \tag{1}$$

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}} * 100\% \tag{2}$$

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}} * 100\% \tag{3}$$

$$\text{FPR} = \frac{\text{FP}}{\text{TN} + \text{FP}} * 100\% \tag{4}$$

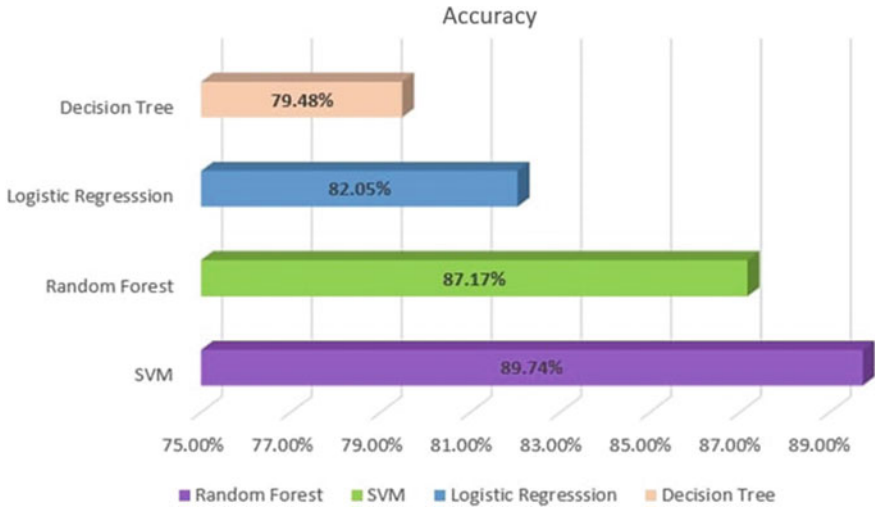

Fig. 7 Comparison of four classifiers accuracy

Table 1 Confusion matrix for each classifier

	True positive	False negative	False positive	True negative
Decision tree	4	4	4	27
Random forest	8	0	5	26
Logistic regression	5	3	4	27
Support vector machine (SVM)	5	3	1	30

$$\text{FNR} = \frac{\text{FN}}{\text{TP} + \text{FN}} * 100\% \tag{5}$$

The evaluated execution assessment measurements for each classifier are summarized in Table 2.

The sensitivity and specificity of four classifiers are compared in Fig. 8.

With the real-time data, we tested the trained system and compared the results of multiple algorithms to predict Parkinson's disease. Agreeing with Table 1, the decision tree had the most reduced precision 79.48% and 7.08 log loss. Random forest classifier had 87.17% precision and the highest 100% specificity. SVM shows the highest 89.74% accuracy. SVM also showed the highest sensitivity of 83.33%. Logistic regression has the highest 100% false positive ratio (FPR). SVM has the lowest false negative ratio (FNR) 16.66%. In the calculation of mean absolute error, SVM shows the lowest result 10.25%, and the decision tree shows the highest 20.51% error. SVM has the lowest root mean square error 32.02%. Every classifier has some

Table 2 Metrics of performance evaluation for four classifiers

Classifier	Accuracy (%)	Sensitivity (%)	Specificity (%)	FPR (%)	FNR (%)	Mean absolute error (%)	Root mean square error (%)	Log loss (%)
Decision tree	79.48	50	87.09	12.9	50	20.51	45.29	7.08
Random forest	87.17	61.54	100	00	38.46	12.82	35.80	4.43
Logistic regression	82.05	55.55	90	100	44.44	17.95	42.36	6.19
SVM	89.74	83.33	90.90	9.09	16.66	10.25	32.02	3.54

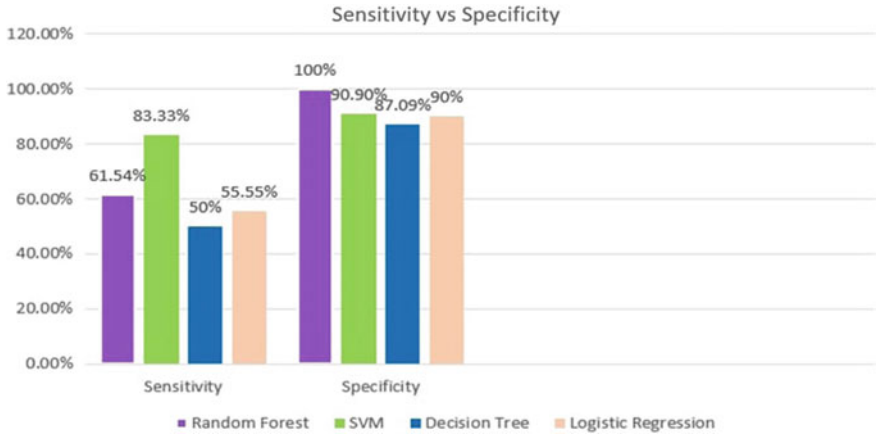

Fig. 8 Sensitivity and specificity of four classifiers are compared

log loss. The decision has the highest 7.08%, and SVM has the lowest 3.54% log loss. So, with the above discussion, we can declare SVM as a winner to predict Parkinson's with the resulting device of this work.

Last but not least, this system has attained the following qualities:

1. The IoT-based system successfully sends all the data to a cloud server and predicts Parkinson's sufferer's condition.
2. The device will keep track of a patient around-the-clock, every day of the week.
3. It helps lighten the workload for nurses.
4. It will make medical monitoring and diagnosis less expensive.

4 Conclusion

This work results in an Internet of sensing things (IoST)-based system to support Parkinson's affected people. The system was able to collect data, save them in a

cloud server then analyze them with multiple machine learning algorithms, and predict the condition of the patient. Multiple types of sensors and micro-controlling units (MCUs) are used to collect data, and the test results showed good output. Multiple machine learning algorithms with their results are also compared. Overall good results are found. In future, this real-time system integrated with a mobile app may help mankind a lot.

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Sorting of Similar Shaped Objects Using Object Detection Method

Naoya Wakabayashi and Hiromitsu Shimakawa

Abstract To detect only specific similar shaped objects with YOLO, the paper proposes a series of procedures as an automatic detection method. The method is applied to quality control of precious paint products. Paints are produced through the milling process of powders. Tiny powders randomly attach to larger powders, called asteroid powders. These are degrading the quality of the product. The asteroid powders should be detected automatically by other powders similar in shape to them. In the paper, various YOLO models which differ in size are constructed by expanding the number of evaluators and data. YOLO models output class names and coordinate information. It needs to be optimized to evaluate performance. The method optimized some information and evaluated the performance of the models through validation. The paper discusses the evaluation characteristics of the evaluator and the model. In addition, it provides feedback to the evaluator, making the prediction results visible and understandable to the evaluator.

Keywords Similar shaped object · Object detection · YOLO

1 Introduction

In recent years, a variety of paints have been developed in response to the diversification of color design. These paints used in a wide variety of products are fabricated through by milling process of powders. The quality of the paint depends on the degree of milling. It may degrade the product to which it is used.

N. Wakabayashi (✉) · H. Shimakawa
Ritsumeikan University, Kyoto, Japan
e-mail: wakaba.naoya@de.is.ritsumei.ac.jp

H. Shimakawa
e-mail: simakawa@de.is.ritsumei.ac.jp

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Due to the milling of powders process, different sizes of powders may randomly attach to each powder. The paper refers to powders attached to larger ones as asteroid powders. Asteroid powders are difficult to sufficiently mill. Since they have a significant impact on luminance, the content of asteroid powder determines the quality of the paint. Conventionally, skilled workers detect asteroid powders visually. It took an enormous amount of time. It is desired to develop an automatic detection system for the asteroid powders to improve productivity.

Wakabayashi and Shimakawa [1, 2] used an object detection method for this task to construct a detection model with constant performance. A previous study [1] has applied the 2 object detection methods, YOLO [3] and SSD [4] to the task. It reports YOLO is more suitable. Therefore, this study used YOLO method. A previous study [2] compared the performance of five different models constructed by changing the parameters of YOLO. These were evaluated using datasets obtained from one and three evaluators. It also focuses on image preprocessing and model construction. These are not indicated how feedback to the evaluator will be provided.

This paper evaluates various YOLO models, expanding the number of evaluators and data. The paper also shows the flow from the original data to the feedback to the evaluators.

2 Asteroid Powder

This study detects asteroid powders using an object detection method. An example of a set of powders is shown in Fig. 1, while an example of asteroid powders is shown in Fig. 2. Asteroid powders attach to larger ones of similar shape. Figure 2 is labeled by one evaluator. The discrimination varies with each evaluator.

Malik and Puzicha [5] have proposed a method to identify objects of similar shapes, solving for correspondences between points on the two shapes. The feature points of objects are used to identify similar shapes. The asteroid powders are similar in shape to the larger powders they attach. Since both have no difference when they are enlarged, feature points are useless for detection.

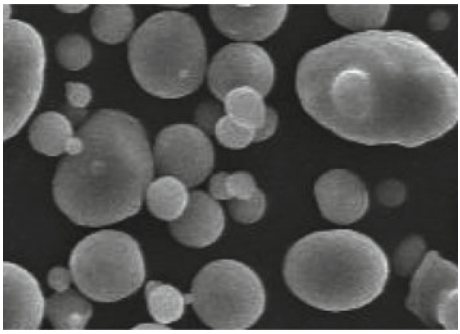


Fig. 1 Example of a set of asteroid powders

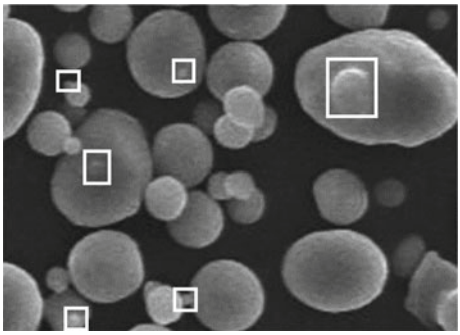


Fig. 2 Example of asteroid powders

Shechtman and Irani [6] proposed a method for finding similar shapes in videos and images. It is also possible to pay attention to small powders in the image. This is important because powders exist in a variety of sizes and shades. However, the method detects every powder of similar shapes. It likely fails to detect only attaching objects.

Few studies discriminate powders of similar shapes meeting specific conditions from others, as required in this task. This study examines various models with more data and evaluators to evaluate its performance.

3 Detection Flow

3.1 Method Outline

An outline of the diagram of this study is shown in Fig. 3.

The original micrograph is cut out into a square to be saved. For each image, every evaluator assigns a correct label to save it as a text file. Data are split for model building and performance evaluation. Training and validation data are used to construct YOLO models for every evaluator. Model performance is evaluated by comparing the model's predictions with the correct labels.

In this study, the results predicted by the YOLO model constructed from the acquired micrographs are feedback to the evaluator. Feedback to the evaluator is realized by displaying a composite of the predicted values with the image data.

3.2 Cutting Out the Image and Data Splitting

The method of cutting out the original micrographs and storing them with the correct labels is the same as in the previous study [1]. Figure 4 shows how to create a labeled dataset from the original image.

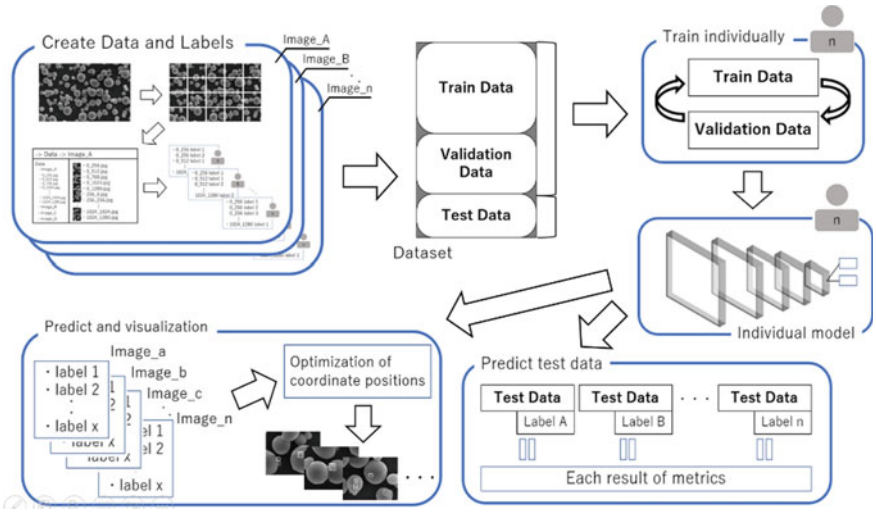
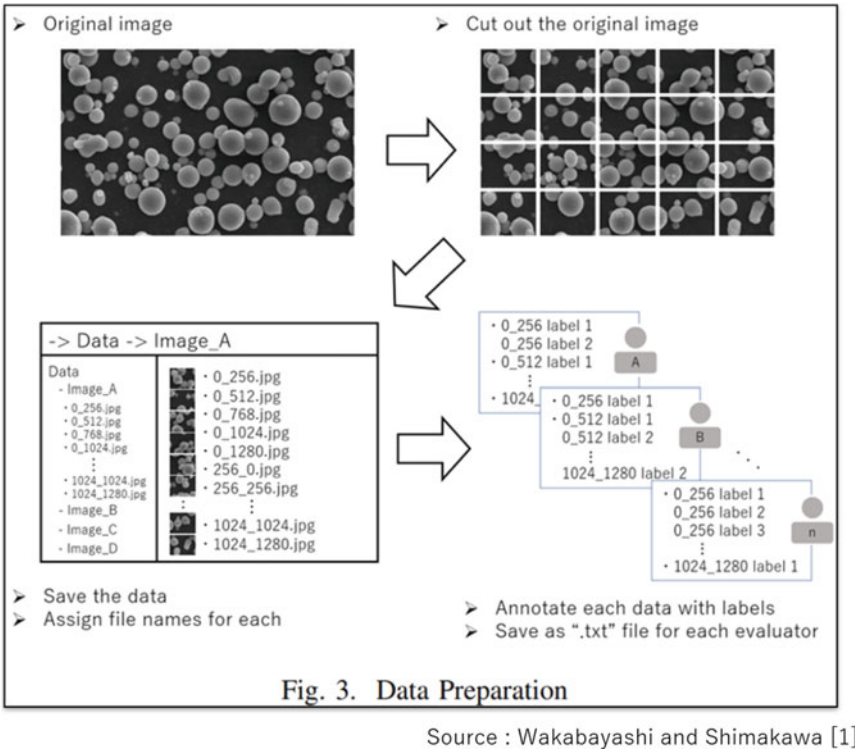


Fig. 3 Outline of the diagram



Source : Wakabayashi and Shimakawa [1]

Fig. 4 Create a labeled dataset from the original image

The original image taken by the microscope is cut out into squares of equal size. Each of them is stored with a unique number. The original images are cut out to avoid any situation where squares in the training data and validation data are included in the test data. Even if the micrographs are at different magnifications and sizes, it is not a problem because they are resized at the time of the training.

The evaluator assigns labels to all square images and saves them as a text file. This study used a tool called LabelImg [7]. If there are asteroid powders in the imported image, they can be marked with a rectangle. The coordinate positions of the rectangle are saved as a text file. Since different evaluators sort asteroid powders differently, all evaluators provide their own labels.

This study splits the dataset into training data, validation data, and test data so that constructed detection models are fairly assessed. It means, in data splitting, common cut-out images need to be assigned to every evaluator so that the performance of detection models can be assessed across evaluators. The number is randomly assigned to a cut-out image. The cut-out image files accompanied by text files are assigned commonly to individual evaluators. Due to the above procedure, the image data files are common with all evaluators, though labels to the images are different depending on the evaluators.

3.3 Constructing Individual Models

Each evaluator provides a different label for a cut-out image. It means an individual model is constructed to evaluate the performance.

A method for constructing individual models from a segmented dataset is shown in Fig. 5.

Models are constructed for individual evaluators using training data and validation data. The individual models predict the test data. The performance is assessed by comparing the predicted results with the correct labels assigned by the evaluators.

3.4 Feedbacks to Evaluators

Performance is assessed from the outputs of models. To determine whether a model is practical, it is necessary for evaluators to assess the content directly. The output results of the model need to be feedback to evaluators. To explain the feedback, this section shows how to visualize what the model predicts for the test data.

Figure 6 shows how the prediction results of constructed individual models are feedbacked to evaluators.

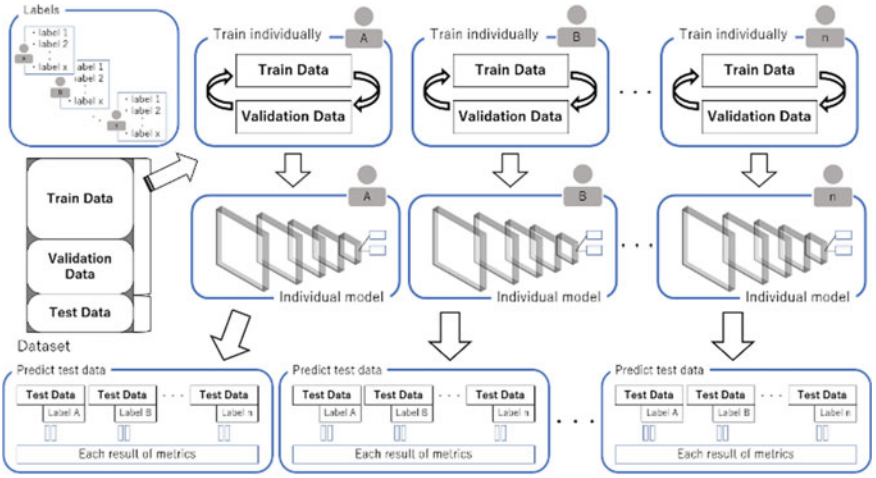


Fig. 5 Method for constructing individual models

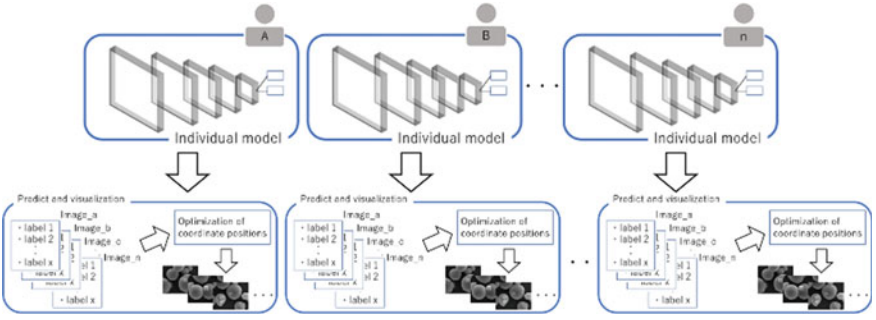


Fig. 6 Prediction results of constructed individual models

A predicted result of a model is represented with the class name, class probability, and coordinate information of a rectangle specifying a powder. They are contained in a text file. Out of the result, only the coordinate information is converted to the optimal value for visualization. The optimal value is the form that matches the argument of the function to draw the rectangle on the image.

The feedback method loads the image corresponding to the text file containing the coordinate information. It has a function to draw a rectangle using the ImageDraw module [8] in Python's PIL library. The method executes the function as many as the number of lines stored in the text file to draw all the rectangles. This process is performed on all images and feedback the results of the visualization using ImageDraw to the evaluator. Each evaluator performs the method to visualize and evaluate the performance of the model.

Table 1 Total number of labels for each evaluator's annotation

	Evaluator 1	Evaluator 2	Evaluator 3	Evaluator 4	Evaluator 5	Evaluator 6
Labels	84	82	69	32	51	33

4 Detection Environment

4.1 Data to Detect

This study detects asteroid powders using an object detection method. Since the correct labels differ for each evaluator, an individual model is constructed to evaluate performance.

The experiment in the paper uses 75 images created by cutting out two micrographs of different sizes. Six evaluators annotated all images with the tool and created a text file containing the labels.

The image data were split to evaluate the performance of the trained model. It consists of 40, 25, and 10 data of training data, validation data, and test data, respectively. The image files for all evaluators in each dataset are the same, but the correct labels are different.

The total number of labels for each evaluator's annotation of the 10 test data is shown in Table 1.

The values are different because the criteria are different among the evaluators. The difference between the maximum and minimum values is more than twice as large, and some evaluators may judge that there is no asteroid powder in the image. The experiment examines how accurately the trained individual model can detect them.

4.2 YOLO Models

Five different models with different numbers of YOLO layers and parameters were used in this verification. The performance of the five models constructed for each evaluator is compared. The model was built using GPUs at Google Colaboratory.

For reproducibility, used the YOLO package [9] which is available on GitHub. The version of YOLO is 5.0. The five models are referred to as n, s, m, l, and x, in ascending order starting with the smallest number of layers. The number of layers and parameters per model and the GFLOPs used are listed in Table 2. The GFLOPs used are large because the larger the model, the larger the memory requirement.

Some library versions were specified to avoid compatibility errors between published code and libraries. The versions of the libraries specified when training the model are listed in Table 3. Table 3 was prepared regarding the previous study [1].

Table 2 Number of layers and parameters per model and the GFLOPs

Model	Layers	Parameters	GFLOPs
n	213	1760518	4.1
s	213	7012822	15.8
m	290	20852934	47.9
l	367	46108278	107.6
x	444	86173414	203.8

Table 3 Versions of the libraries

Library	Version
Torch	1.10.0 + cu113
Torchvision	0.11.1 + cu113
Torchaudio	0.10.0 + cu113

4.3 Model Training and Evaluation

This section shows how to train and evaluate the YOLO model. Certain parameters were specified in the training. In the evaluation, three different values were calculated using the package.

The parameters specified for all models are listed in Table 4. Table 4 was prepared regarding the previous study [1] and adopted what was judged to be optimal in the preliminary experiments.

All annotations are resized to the same size even if they are annotated in different sizes. The number of epochs is 1000, but early stopping [10] was used to account for GPU usage. Training is terminated when the model has not been updated 100 times from the model with the smallest loss value. Initial weights for each model were taken from models that had already been trained with different data [9] to facilitate model convergence.

The performance of individual models was evaluated using three metrics commonly used in object detection methods. The first is precision which indicates the fraction of objects output by the model that is truly asteroid powders. The higher the value, the more likely the model output is a true asteroid powder. The second is recall which indicates the percentage of true asteroid powders that are correctly detected. The higher the value, the more asteroid powders in the image are detected. The third is the mAP which is the average of the APs in each class. AP refers to the

Table 4 Parameters

Image size	Train batch	Val batch	Epochs	Conf level	Early stopping
640	16	16	1000	0.25	100

lower area of the figure drawn by the precision–recall curve. The mAP and AP are the same means because this research is a binary classification.

The evaluation index was calculated using the mAP package [11]. The IoU threshold which indicates the overlap of banding boxes was set to the default value of 0.5. All text file names of ground truth and detection results must be compared match to use this package. If it is determined that there is no asteroid powder in the image, a text file is not created. The code to complement this is provided as an option in the tool. If one of them does not match, it is stored in a separate file, and the remaining one is used for evaluation. However, it cannot be properly evaluated if it is determined that there is no asteroid powder despite the presence of it, and when judged to be present despite the absence of asteroid powder. Therefore, an empty text file was created for those that did not match to make a proper determination.

5 Detection Results

5.1 Model Performance

This section presents the performance of each evaluator's models and provides an overall assessment of their contents. Table 5 shows the performance of each model constructed with the object detection method YOLO. Six evaluators constructed each and evaluated five different models. The epoch number and the value of the evaluation index are shown when a loss is the smallest, and early stopping is applied.

The number of epochs for all evaluators was less than 400. It is indicating that they converged relatively quickly. This task was easy to distinguish the powders themselves, and it is thought that characteristics of the attached features could be learned quickly.

Evaluator 3 had smaller values than the other evaluators, and Evaluator 6 had a relatively large variation in values. Evaluator 1 and Evaluator 2 which had a larger number of annotated pieces had less interchangeable precision and recall magnitudes. Precision is often higher, and this is due to its laxer criteria for asteroid powder compared to the other evaluators. On the other hand, Evaluator 4 which had fewer annotations has the precision, and recall values are swapped. Evaluator 3 and Evaluator 5 which have intermediate annotation numbers, precision, and recall are swapped before and after v5m. Therefore, as the model size increases, the models of evaluators with many annotations tend to have higher precision, while the models of evaluators with a small number of annotations tend to have higher recall.

Most of the evaluation indices are above 0.5 and with a few around 0.7. The region in which the object is located is important for this task. Therefore, it will not exceed 0.5 even if it is randomly selected. Therefore, a significant number of asteroid powders could be detected.

Table 5 Performance of each model constructed with the object detection method YOLO

	Model	Best epoch	Precision	Recall	mAP@0.5
Evaluator 1	n	230	0.68	0.58	0.67
	s	190	0.73	0.56	0.68
	m	138	0.79	0.58	0.67
	l	150	0.68	0.66	0.66
	x	176	0.75	0.60	0.66
Evaluator 2	n	389	0.75	0.68	0.67
	s	125	0.64	0.66	0.68
	m	121	0.74	0.66	0.67
	l	106	0.72	0.72	0.66
	x	105	0.64	0.71	0.70
Evaluator 3	n	189	0.57	0.57	0.53
	s	109	0.46	0.58	0.50
	m	184	0.67	0.52	0.54
	l	270	0.61	0.52	0.52
	x	166	0.69	0.58	0.57
Evaluator 4	n	258	0.59	0.72	0.69
	s	318	0.68	0.66	0.72
	m	164	0.59	0.75	0.67
	l	138	0.79	0.59	0.71
	x	302	0.59	0.75	0.70
Evaluator 5	n	166	0.68	0.71	0.69
	s	244	0.59	0.69	0.68
	m	127	0.63	0.67	0.67
	l	129	0.73	0.69	0.71
	x	105	0.73	0.63	0.68
Evaluator 6	n	202	0.42	0.82	0.55
	s	170	0.67	0.67	0.65
	m	158	0.56	0.58	0.56
	l	170	0.54	0.67	0.58
	x	210	0.51	0.79	0.62

This verification used 65 pieces of data for train and validation. Furthermore, increasing the number of images will allow the system to handle unexpectedly shaped asteroid powders, further increasing performance.

5.2 *Characteristics by Model Size*

This section suggests the differences in the values of each evaluation index due to differences in evaluators and models. All of evaluator and model precision in Fig. 7, recall in Fig. 8, and mAP in Fig. 9.

Precision has varied values depending on the size of model. The variation is particularly large for Evaluators 3, 4, and 6. This was due to the low number of annotations, which resulted in a higher precision. YOLO model v5s was low for Evaluator 3 and Evaluator 4, while it was high for Evaluator 6. YOLOv5n also

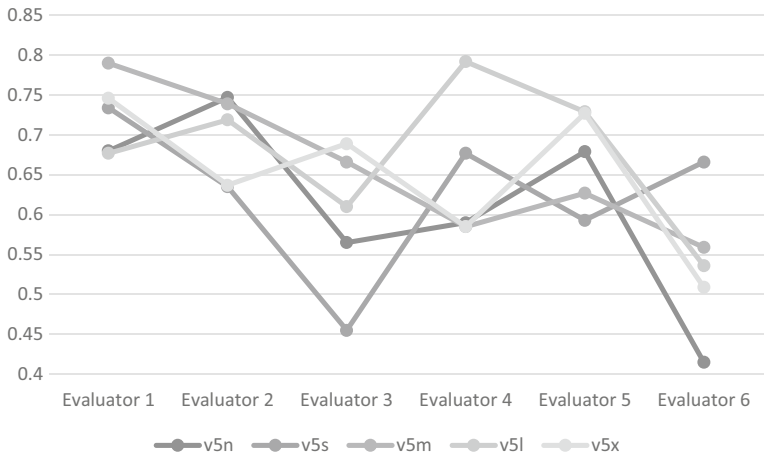


Fig. 7 All of evaluator and model precision

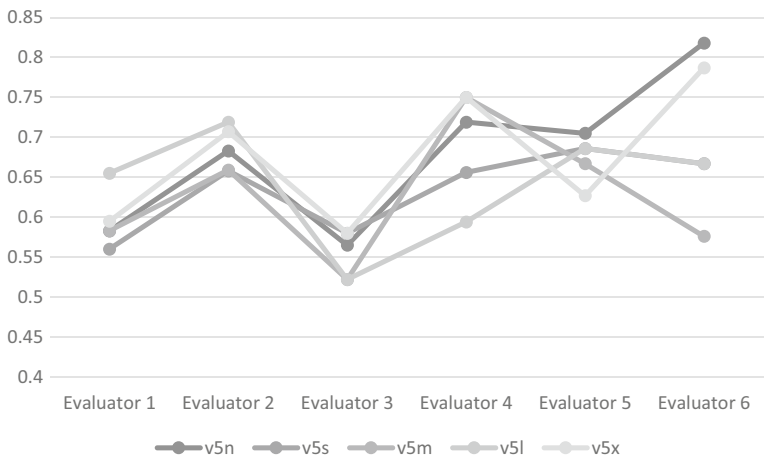


Fig. 8 All of evaluator and model recall

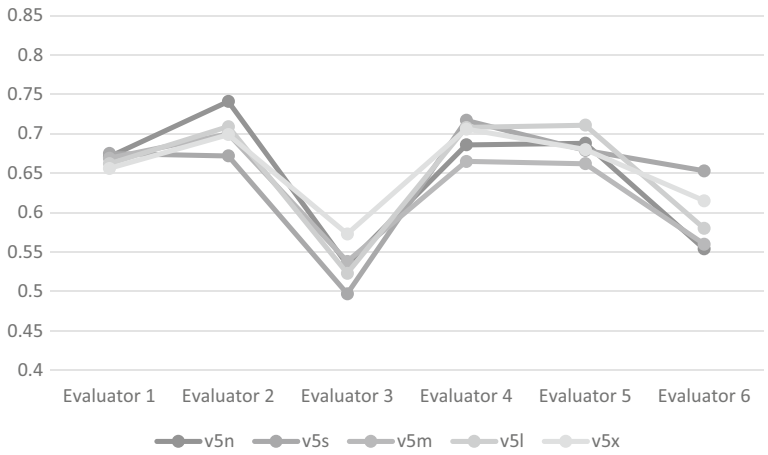


Fig. 9 All of evaluator and model mAP

remained low. On the other hand, YOLOv5m and YOLOv5l retain high values for all evaluators which have relatively large model sizes. The largest YOLOv5x has a large blur but rarely takes intermediate values. It is often with good or poor accuracy. Since each model size is convergent, there is a high likelihood that the variation among evaluators will increase as the model size decreases.

Table 5 shows that only Evaluator 4 and Evaluator 6 have a large variation in recall. Among the evaluators with high variability, the values of YOLOv5n and YOLOv5x are higher. These are those with the largest or smallest model size. The higher the output with asteroid powder, the higher the recall of the model with a smaller fit rate.

The mAPs of all evaluators have approximate values. It also has not changed significantly with model size. The mAP is calculated with emphasis on precision, to avoid all objects which are predicted as asteroid powders. The characteristics of precision and recall differed greatly from model to model. It is desirable to vary the parameters of the model depending on which evaluation index is more important.

6 Conclusion

This paper constructed various model sizes of YOLO for each evaluator to detect asteroid powders. As a result of the detection, a certain number of asteroid powders could be detected. Not only examine the characteristics of an individual model through performance indicators but also showed how to provide methods from preprocessing to feedback. In future, we will consider changing the model network structure and using new models. In addition, we will seek ways to improve the point where labels differ from individual to individual.

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A Two-Tape Design of Metamaterial Based on a Quasi-fractal Approach

Vadym Slyusar and Ihor Sliusar

Abstract Various options for the 3D design of a metamaterial cell based on two-ribbon split rings have been proposed and studied. When synthesizing the geometry of the outer tape, a quasi-fractal approach was used, which made it possible to form periodic sequences of depressions (slots) in its end surfaces. Their alternation from both ends of the tape was carried out synchronously or in a checkerboard pattern. In this case, the depth of all grooves could be fixed or changed according to a certain law. An Ansys HFSS electromagnetic simulator was used to study the properties of the proposed metamaterial cell designs. In the course of the research, the main attention was paid to determining the frequency ranges in which the dielectric permittivity and magnetic permeability take negative values (double-negative (DNG) zones). When a square conductor oriented perpendicular to the plane of the rings is included in the metacell, a relative bandwidth was achieved in the low-frequency zone, in which the condition of negative values of the dielectric permittivity and magnetic permeability is observed. The relative frequency band of the DNG zone in this case is 185.22%.

Keywords Ansoft HFSS · Quasi-fractal · Metamaterial · Refractive index · Relative permittivity and permeability · Split-ring resonator (SRR)

1 Introduction

The entry of humanity into the Internet of Things era has significantly expanded the range of tasks solved using wireless access technologies [1]. At the same time, taking into account the mobility of users of telecommunication services, preference

V. Slyusar (✉)
Central Research Institute of Armaments and Military Equipment of Armed Forces of Ukraine, Kyiv, Ukraine
e-mail: swadim@ukr.net

I. Sliusar
Poltava State Agrarian University, Poltava, Ukraine
e-mail: islyusar2007@ukr.net

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is given to compact solutions. Regardless of the frequency range used, the main ways to achieve miniaturization are, first of all, the use of electrically small antennas [2], as well as the use of metamaterials [3–8].

Since the elementary cells of a metamaterial in many cases have multi-component structures, the known set of approaches to the synthesis of such can be extended by passing to the 3D topology of their constituent elements [9–12].

2 The Aim of Research

The purpose of the report is to study the electromagnetic parameters of 3D SRR structures, in which the constituent elements are modeled on the basis of quasi-fractals.

3 The Main Results of the Study

The use of fractal solutions in radio engineering has been sufficiently tested and has proven itself on the positive side [13]. A similar approach can also be applied to the synthesis of metamaterial cells. In this work, the study of cells on a quasi-fractal basis was carried out in several stages. At the first of them, the object of analysis was two-ribbon split rings without a conductor, with end grooves in the outer tape. At the same time, the inner tape did not have such cutouts in its end surfaces. The grooves in the outer tape were obtained on the basis of the meander fractal initiator of the first iteration [1, 14]. The corresponding quasi-fractal technology used to synthesize the outer ring is based on the technique described in [15, 16]. The principle of groove formation is explained in detail in Fig. 1 [16].

It should be noted that double rings without a conductor make it possible to obtain zones of negative magnetic permeability that are broadband in frequency. This makes it possible to use them, for example, to form absorbers or magnetic metalenses.

The well-known Ansys HFSS simulator [17, 18] was used to study the electromagnetic properties of various options for the design of metamaterial cells. The 3D topology designer built into it made it possible to implement the configuration

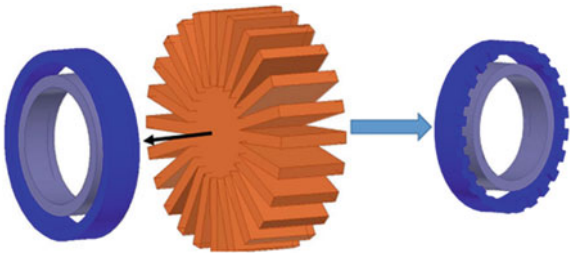

Fig. 1 Principle of formation of quasi-fractal grooves in the outer tape

shown in Fig. 1 method of forming end surfaces in the outer tape. The total number of grooves, similarly to [16], was set to 24, and they were located with a uniform step around the circumference with an angular interval of 15°.

To ensure the possibility of comparison with the previously obtained results, the geometric parameters of the metacell ribbon were set as follows: the thickness of the ribbons was 3 mm, the width was 9 mm, and the interval between the ribbons was equal to their thickness and was also 3 mm. The radius of the outer surface of the outer tape was 23.55 mm. The tapes were immersed in a vacuum.

Figure 2 shows a variant of the metacell design, in which the cuts in the tapes are located on the vertical *Z*-axis. The simulation results of this design (Fig. 3) indicate the existence of many frequency ranges in which the relative magnetic permeability is negative. At the same time, there are also so-called binegative zones, within which not only the magnetic but also the dielectric permittivity becomes negative ($\mathrm{Re}(\varepsilon) < 0$ and $\mathrm{Re}(\mu) < 0$). Since it is these zones that are of the greatest interest, let us analyze the effect of various parameters of the metacell geometry on them. The calculation of ε and μ values will use the special macros that are embedded in HFSS [12].

It should be noted that in the considered version of the outer tape, the depth of the grooves was constant along the entire length. At the same time, the grooves themselves from different ends of the outer tape were arranged in a checkerboard pattern. Next, we study the influence of the variable depth of the grooves, for example, when the cuts of the rings lie in the horizontal plane (Fig. 4), and the grooves on the end surfaces of the outer tape are symmetrical.

Efforts made to vary the design of the metacell made it possible to achieve the appearance of the DNG band in the range of 640–950 MHz (Fig. 5).

A variant of the horizontal arrangement of rings (Fig. 6) was also studied, which is a typical case in the formation of metalenses.

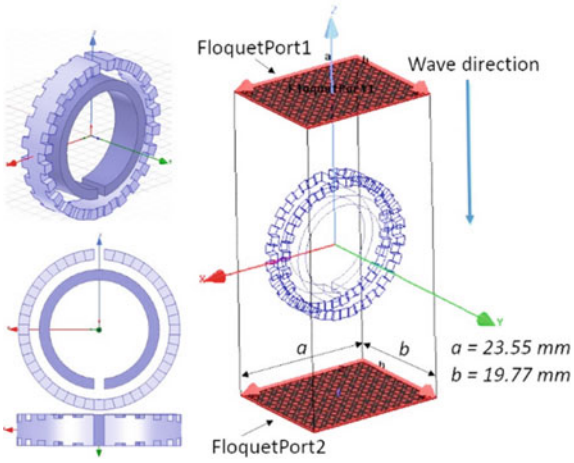

Fig. 2 Appearance of the 3D SRR model from different view angles

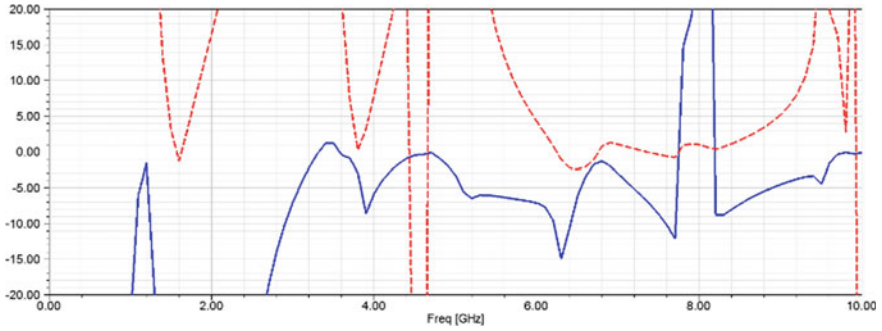

Fig. 3 Evaluation of the characteristics of the SRR model on Fig. 2, solid—Re(ε); dash—Re(μ)

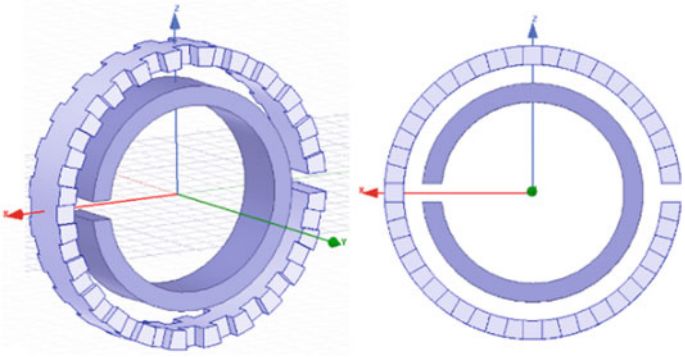

Fig. 4 Vertical orientation option of the SRR model on Fig. 2

At a variable depth of the grooves, the DNG section shifted to the regions of 7.0–7.7 and 7.9–9.25 GHz (Fig. 7), while the zone of negative magnetic permeability values covers a continuous region starting from about 5.3 GHz and beyond 10 GHz. The latter testifies to the prospects of using such structures for constructing magnetic metalenses, for example, for electron microscopes, naturally, provided that the sizes of metarings are scaled in accordance with a given wavelength.

At the end of the first stage of research, a variant of the ring structure with an external tape in the form of a meander was considered (Fig. 8) [15].

For this design, the area of negative permeability of interest is concentrated in the low-frequency range up to about 1.4 GHz (Fig. 9).

In the second stage of research, a transition was made to the combination of split rings and a straight conductor, traditional for metacells, taking into account 3D design. An example of this kind is shown in Fig. 10, while the slot in the outer ring is at the top of the Z-axis, and the center of the cross-section of the conductor is located at a distance of 4 mm from the center of symmetry of the rings. The grooves in the upper band varied in depth according to a sinusoidal law. Such a change in

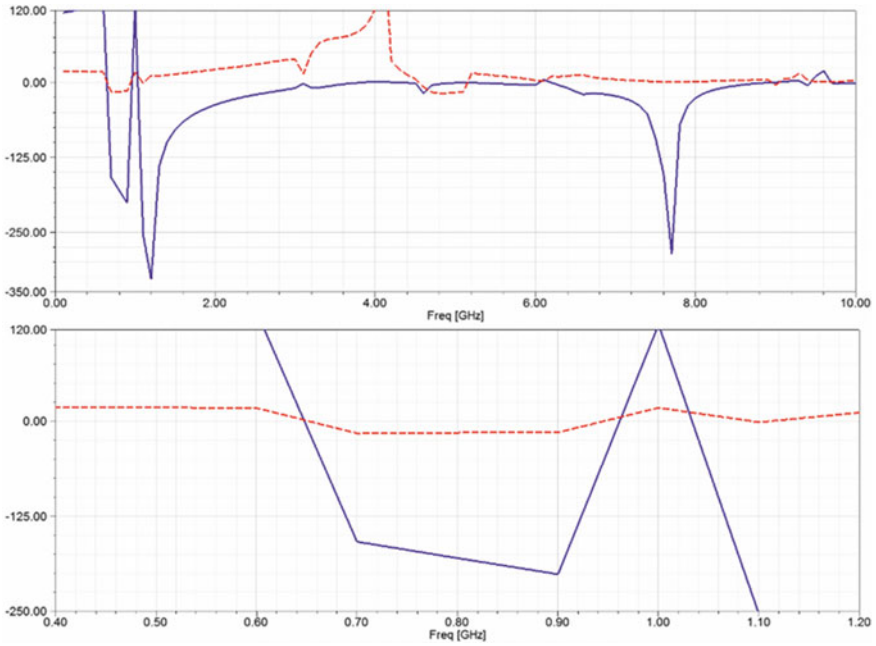

Fig. 5 Emergence of the DNG band in the range of 640–950 MHz, solid—Re(ε); dash—Re(μ)

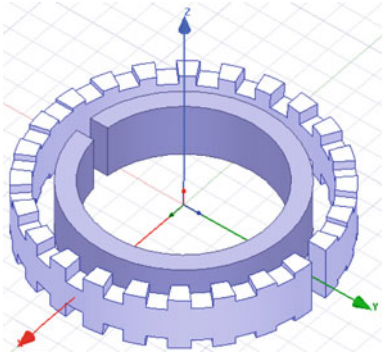

Fig. 6 Metacell with the horizontal orientation

the meander depth is an approximation of the second iteration of the meander-based quasi-fractal.

An important achievement of this design (Fig. 11) was the appearance of a low-frequency range with simultaneously negative values of permittivity and permeability in the region of frequencies from 100 to 336 MHz (100 MHz is the lower limit of calculations).

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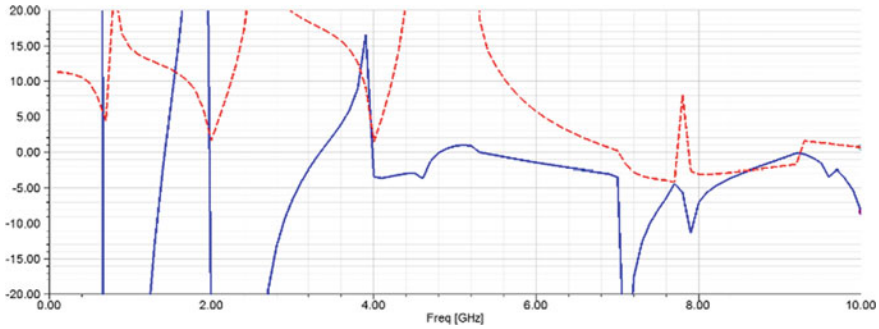

Fig. 7 DNG metacell properties; the solid line is Re(ε); the dashed line—Re(μ)

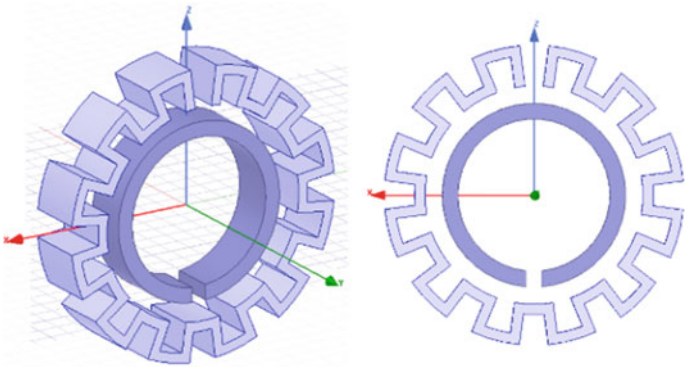

Fig. 8 Quasi-fractal SRR with an outer band in the form of a meander

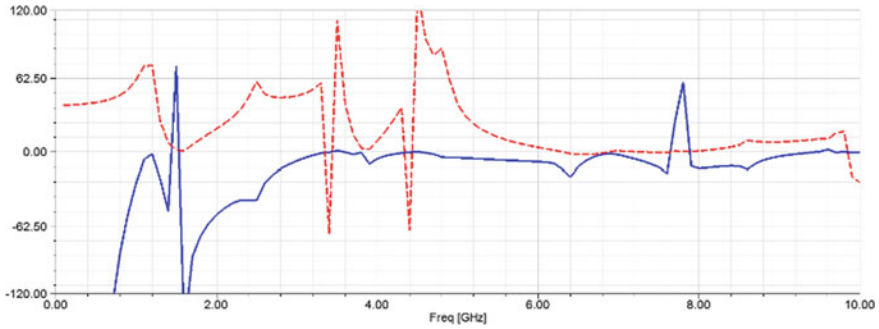

Fig. 9 DNG of the SRR in Fig. 8, solid—Re(ε); dash—Re(μ)

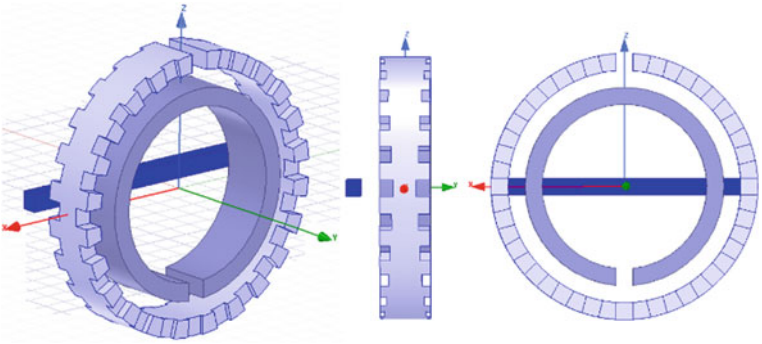

Fig. 10 Appearance of a 3D model of a metacell with a rectangular conductor

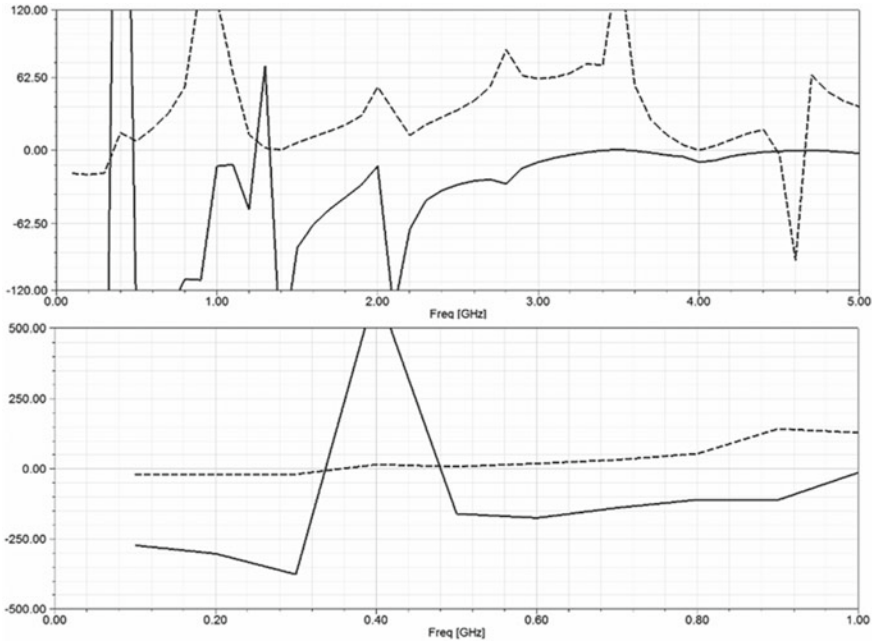

Fig. 11 DNG in the low-frequency region from 100 to 336 MHz, of the metacell in Fig. 10, solid—Re(ε); dash—Re(μ)

in the region of frequencies from 100 to 336 MHz (100 MHz is the lower limit of calculations).

The performed analysis confirmed the insignificance of the influence of the distance of the conductor from the surface of the rings on the width of the DNG range in the low-frequency region. In particular, an increase in this distance from 4 to 10 mm shifted the upper limit of the specified range to 342.6 MHz.

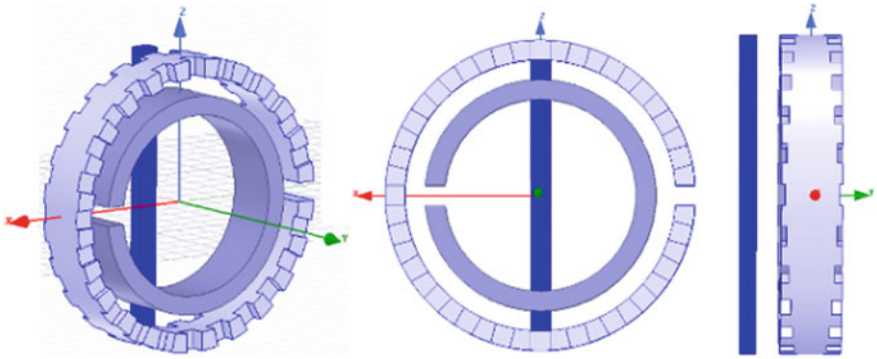

Fig. 12 Metacell vertical orientation option

A more significant result regarding the influence of the length of the low-frequency zone DNG made it possible to obtain an alternative variant of changing the design of the metacell, which consists of the vertical turn of the wire and the location of the cuts of the tapes in the horizontal plane (Fig. 12).

As can be seen from Fig. 13, the transition to a vertical wire extended the upper limit of the DNG zone in the low-frequency region to 647 MHz. At the same time, the second DNG zone was localized in the region of 4.65–5.15 GHz (Fig. 14).

Summarizing the results of the second stage, we can draw intermediate conclusions. In particular, in order for the DNG zone to be in the lower frequency region, it is necessary to place the cut in the outer tape at the top of the *Z*-axis or in the horizontal plane. The location of the cut in the outer ring on the *Z*-axis from below leads to the disappearance of DNG in the low-frequency region.

Since the vertical orientation of the conductor may have certain errors, it is of interest to study the influence of the angles of its deviation from the vertical axis. In particular, the limiting case of conductor deviation from the vertical by 45° was considered (Fig. 15). At the same time, the slots in the tapes were placed on the vertical axis.

The result of such manipulations was the narrowing of the band of the binegative zone to 340 MHz. The lion's share in such a deterioration in the properties of the cell was made not by the deflection of the conductor, but by the turn of the rings to align the slots with the vertical axis. Therefore, we can conclude that in order to maximize the expansion of the lower DNG strip in the case under consideration, it is necessary to place cuts in the ribbons in a horizontal plane. The deviation of the conductor from the vertical at an angle of up to 45° does not affect significantly (Fig. 16).

The next stage of the research consisted of the transition to a conductor located, similarly to [12], perpendicular to the plane of the rings (Fig. 17).

At the same time, the grooves in the uppercut tape at both ends had a variable depth and were located in a synchronous manner; that is, the grooves from opposite ends were opposite each other. An important nuance was also that the sections of the tapes lay in a horizontal plane.

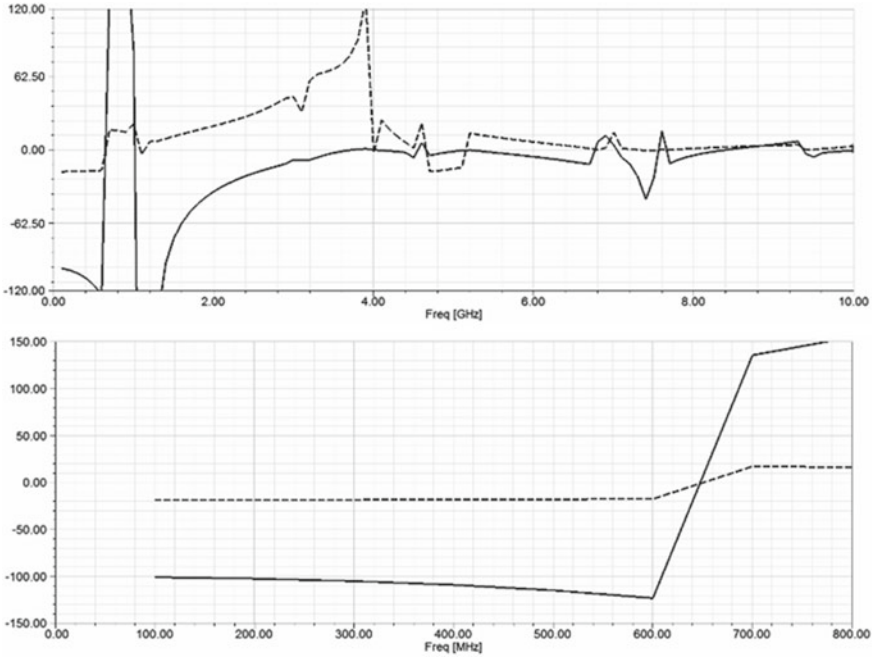

Fig. 13 DNG metacells in Fig. 12 and its band in the lower frequency region (100–647 MHz), solid—Re(ε); dash—Re(μ)

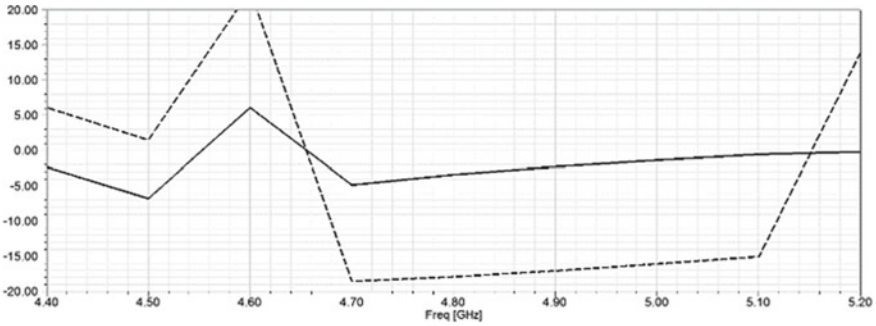

Fig. 14 Localization of DNG in the band of 4.65–5.15 GHz, solid—Re(ε); dash—Re(μ)

As a result of this modification of the metacell design, there was a significant expansion of the DNG bandwidth at lower frequencies, ranging from 25.02 MHz to about 652 MHz (Fig. 18). This corresponds to 185.22% when converted to a relative frequency value according to the fractional bandwidth formula [19–21]:

$$\delta F = \frac{2|f_1 - f_2|}{f_1 + f_2} \tag{1}$$

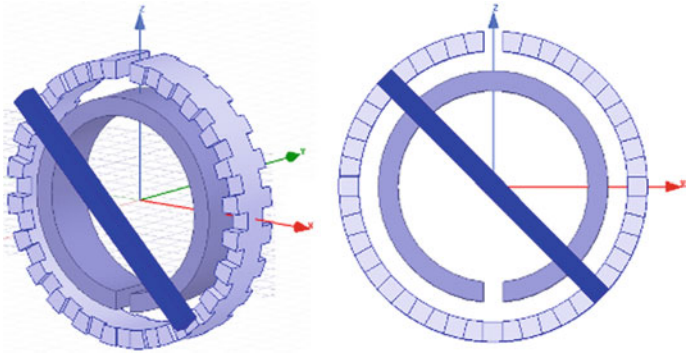

Fig. 15 Metacell with conductor rotated by 45°

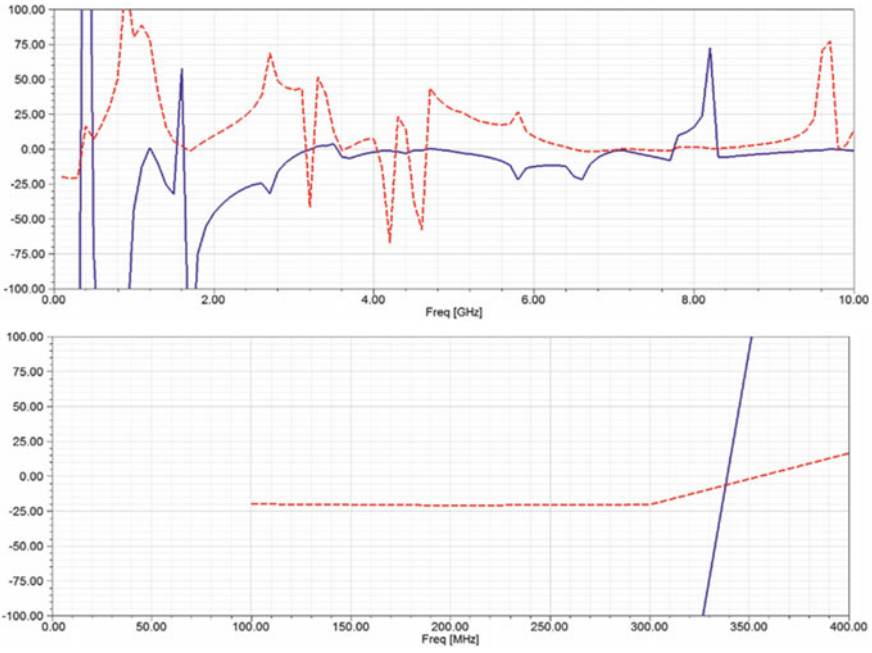

Fig. 16 DNG metacells in Fig. 15 and its low-frequency band, solid—Re(ε); dash—Re(μ)

where f_1 and f_2 are the values of the frequencies at which $\mathrm{Re}(\varepsilon) < 0$ and $\mathrm{Re}(\mu) < 0$.

There are also DNG bands in the ranges from 3.25 to 3.7 GHz and from 4.1 to 5.05 GHz (Fig. 19). Another of these zones is in the range of 8.25–8.75 GHz (Fig. 20).

Thus, the turn of the conductor perpendicular to the plane of the rings (top design), proposed in [12], is an effective solution that led to the expansion of the bandwidths in the corresponding DNG bands.

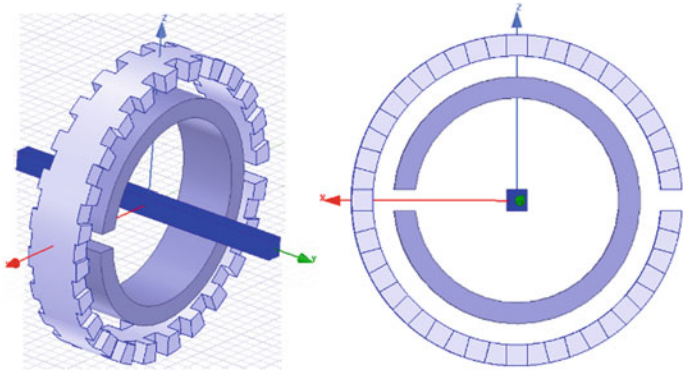

Fig. 17 Modification of a metacell with a rectangular conductor

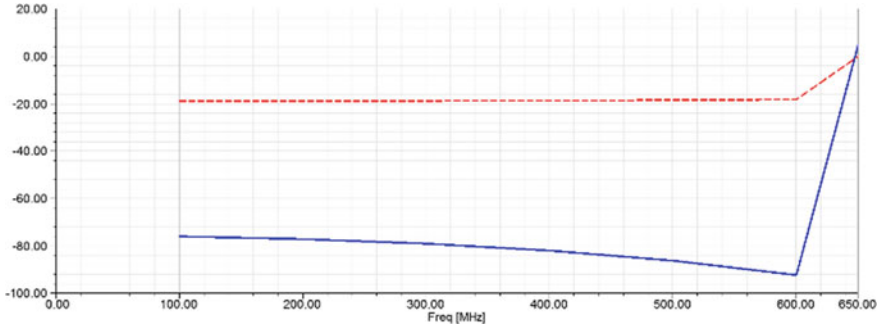

Fig. 18 Lower DNG zone metacell in Fig. 17, solid—Re(ε); dash—Re(μ)

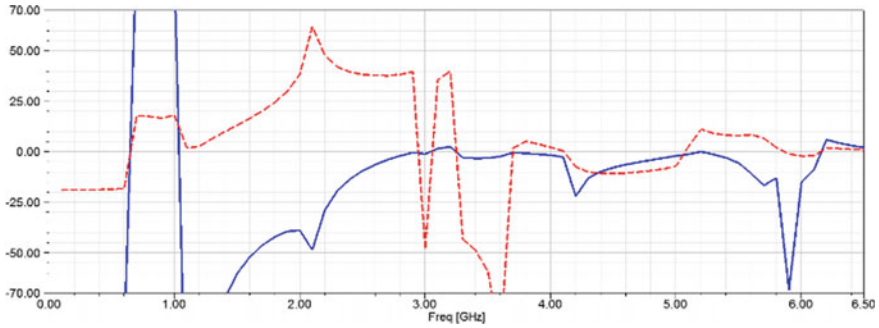

Fig. 19 Central DNG zone metacell in Fig. 17, solid—Re(ε); dash—Re(μ)

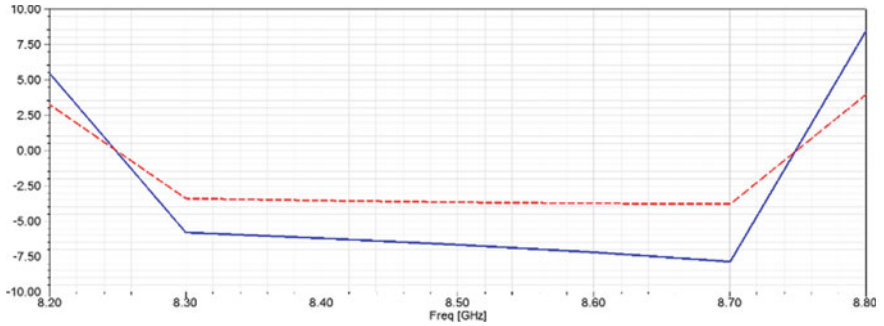

Fig. 20 Upper DNG zone metacell in Fig. 17, solid—Re(ε); dash—Re(μ)

As expected, with a vertical arrangement of the conductor and a horizontal arrangement of the rings (in the X_0Y plane, Fig. 21), similarly to Fig. 6, the DNG band disappears in the low-frequency region (Fig. 22).

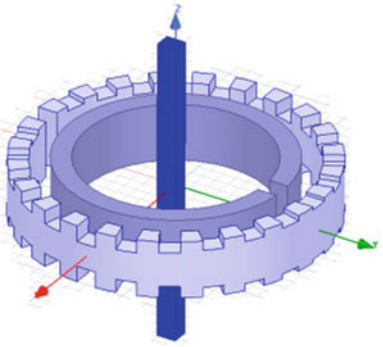

Fig. 21 Horizontal metacell orientation in Fig. 17

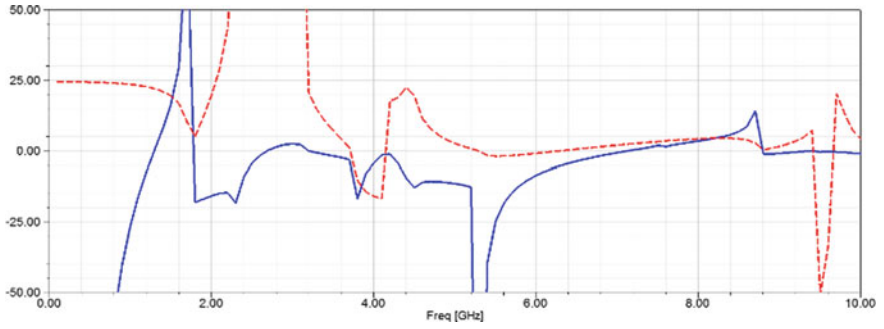

Fig. 22 Evaluation of the characteristics of the metacell model in Fig. 21, solid—Re(ε); dash—Re(μ)

However, in this case, if the conductor is placed horizontally, parallel to the plane of the rings, as shown in Fig. 23, then the specified low-frequency section is restored (Figs. 24 and 25). At the same time, its width becomes relatively smaller (0.1–0.44 GHz, Fig. 25). At the same time, the DNG bandwidth in the region of 7.05–7.75 GHz is 700 MHz (Fig. 26). If, however, the conductor is placed in the intra-annular space (Fig. 27), then regardless of its orientation relative to the cuts in the rings, the low-frequency range of the DNG disappears.

At the final stage of research, attention was paid to variants of the metacell design, with a conductor perpendicular to the plane of the rings and with cuts in the tapes located on the vertical axis (Figs. 28 and 29).

If we set the width of the cut equal to the width of the cross-section of the conductor (2.5 mm), then when the cuts are located on the *Z*-axis, the DNG region in the low-frequency region will disappear (Fig. 30). At the same time, the DNG region is preserved in the region of 4.8–6.35 GHz.

The deviation of the cut in the upper ring from the *Z*-axis in this case leads to the restoration and expansion of the band of the low-frequency section of the DNG as the cuts deviate from the vertical position.

The maximum strip in this design option is achieved when the cuts are located in a horizontal plane (deviation 90° from the *Z*-axis). At the same time, the presence

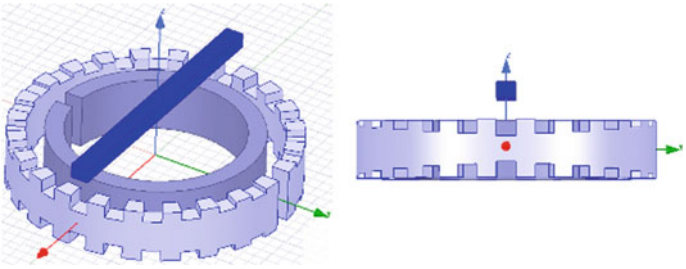

Fig. 23 Horizontal metacell orientation in Fig. 10

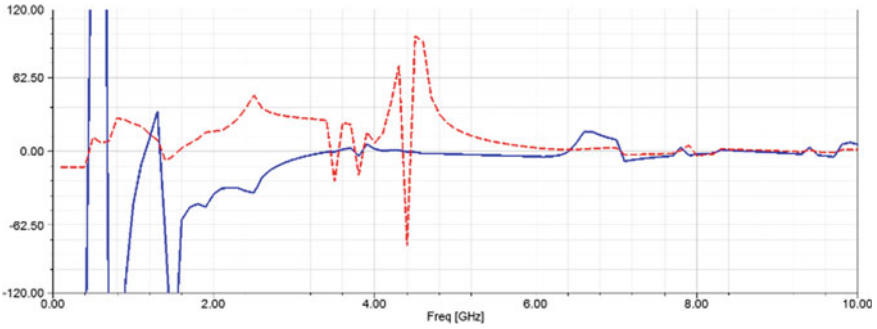

Fig. 24 DNG metacell in Fig. 23, solid—Re(ε); dash—Re(μ)

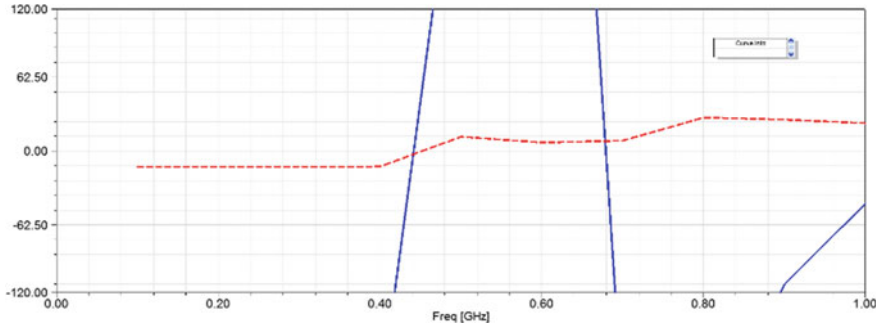

Fig. 25 Lower DNG zone (0.1–0.44 GHz) metacell in Fig. 23, solid—Re(ε); dash—Re(μ)

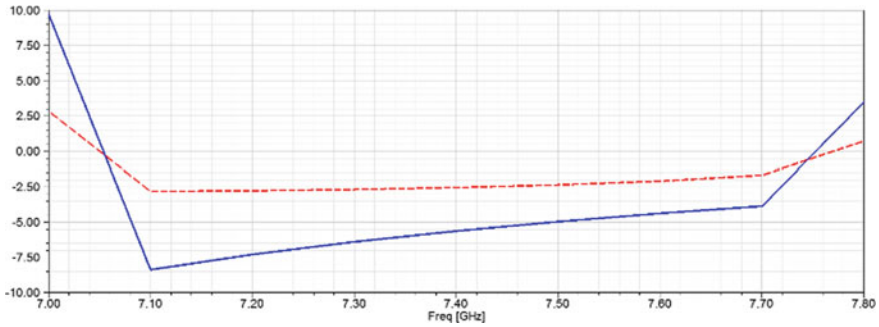

Fig. 26 Upper DNG zone metacell in Fig. 23, solid—Re(ε); dash—Re(μ)

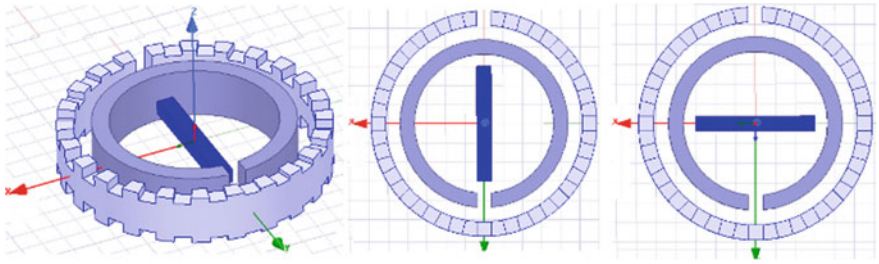

Fig. 27 Placement of the conductor in the annular space of the metacell

of a low-frequency DNG section at 45 and 90° angles of the cut from the *Z*-axis depends on the width of the cut in the ring.

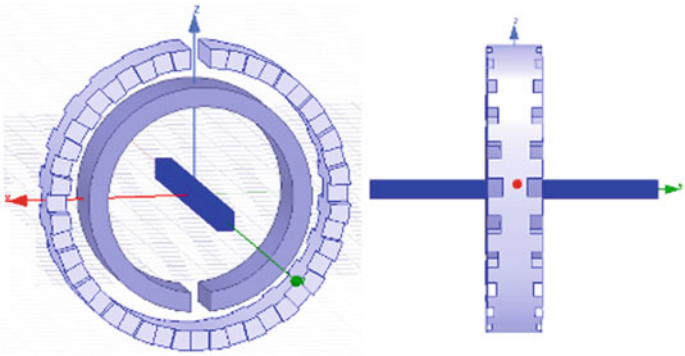

Fig. 28 Metacell layout with ring cuts along the vertical axis

4 Perspectives of Further Research

The presented results were achieved within the framework of the initial stage of generalization of the quasi-fractal approach for SRR synthesis.

Further research should be directed to studying the possibility of expanding the low-frequency zone and obtaining more broadband DNG solutions in other parts of the spectrum. In this regard, the use of sequences of grooves not only in the outer, but also in the inner tape, as well as the search for the optimal combination of their geometric shapes and parameters, deserves attention. In particular, of interest is the use of not only meander lines, but also other geometric figures as the initiator of quasi-fractals, and the study of the influence of dielectric fillers in the intercellular and intra-annular spaces. Further research, of course, will be aimed at preserving the properties of an elementary cell as much as possible in the environment of similar or other elementary cells in the composition of a multi-cell metamaterial. At the same time, not only the influence of the parameters of the relative position, but also the mutual orientation of the metacells in a space will be investigated.

5 Conclusions

The presented results testify to the efficiency of the quasi-fractal approach to the synthesis of metamaterial cells. Among the many variants of the studied SRR, the best solution in terms of the width of the frequency range, in which the condition of negative dielectric permittivity and magnetic permeability is observed, is the use of a conductor oriented perpendicular to the plane of the rings. In this case, the grooves on both ends of the outer tape had a variable depth and were arranged in a synchronous manner. An important nuance is also that the cuts of the tapes lie in a horizontal plane. The indicator of the relative frequency band of the DNG zone achieved in this case was 185.22%. In this sense, the use of a two-ribbon structure as the basis of

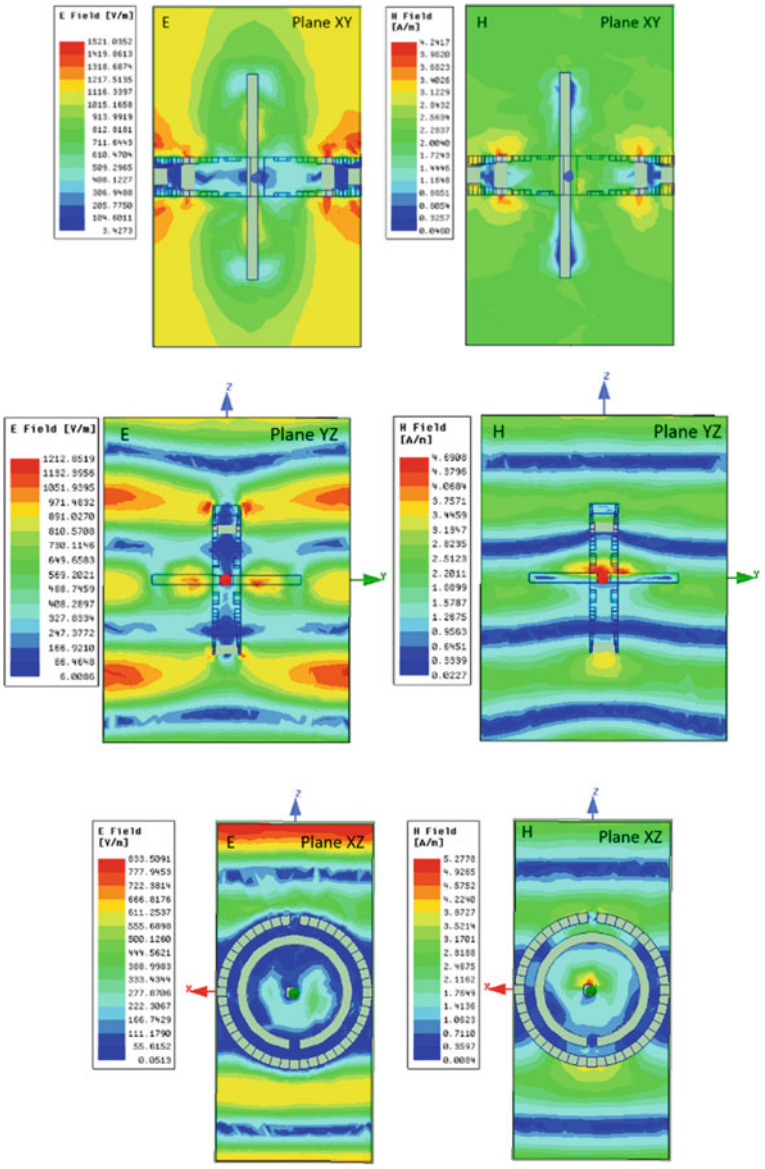

Fig. 29 Fields E and H of the metacell on Fig. 28

a metamaterial cell makes it possible to obtain a wider relative frequency band in comparison with the options for using them as an antenna (in [15], the same indicator did not exceed 132%).

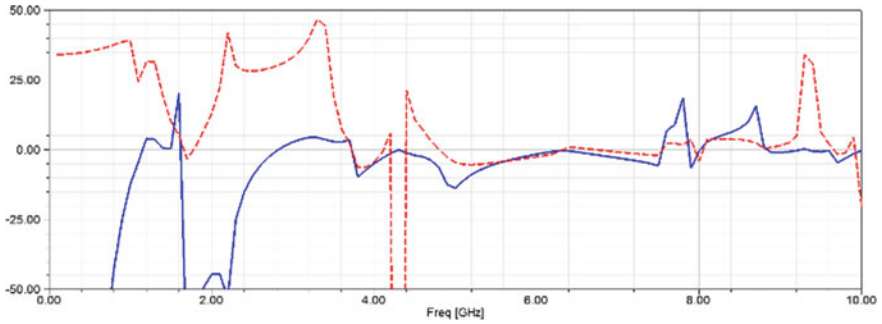

Fig. 30 DNG metacell in Fig. 28, solid—Re(ε); dash—Re(μ)

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Revisiting the Issue of Modelling Living Matter

Yaroslav Yurchyshyn and Vasyl Yurchyshyn

Abstract The modelling of living matter is an important issue for the scientific community, and we may soon see unexpected results in this field. This concerns us to a certain extent, and we would like to raise the issue of modelling living matter, and specifically our opinion on its possible model. We are not presenting the results of research and experiments. This is our view of this process and we would like to share our vision with the scientific community. For us, a living organism is a tool created to perform particular functions. We propose to treat the system of the living human body as a physical system using the existing scientific and technological developments of the IT industry. We lay out the opportunities for applying scientific and technical developments of physical systems in related medical systems. We discuss the opportunities for using the proposed model of a living human body to identify some diseases.

Keywords Physical model of the human body · Biological systems · Biological computer · Human memory · Diagnosis of diseases · Informational therapy and diagnostics · Informational medicine

1 Introduction

The modelling of living matter is of great importance not only for medical science, but also for the technical sciences, artificial intelligence, and many other scientific fields.

Y. Yurchyshyn · V. Yurchyshyn (✉)
Department of Computer Systems Software, Igor Sikorsky Kyiv Polytechnic Institute National Technical University of Ukraine, 37 Peremohy Avenue, Kyiv 03056, Ukraine
e-mail: vasil.yurchishin@gmail.com

Y. Yurchyshyn
e-mail: yaroslav.yurchishin@gmail.com

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We are sure that many scientists are interested in this, and that the field is set to throw up some big surprises. These issues are both extremely interesting and complex, as well as being understudied. Our attention is drawn to the general system of a living organism as a complex mechanism in which there are certain parallels and patterns with technological systems. At the same time, we believe that many technical developments can be used when modelling the general human system, assessing its physical condition, making more accurate diagnoses of diseases, and deviations from the generally accepted understanding of the physical state of the human body. Our ideas have not been published by other scientists.

We strongly believe that humans are not the kings of nature, but first and foremost a tool created to perform certain functions. Please be aware, however, that this is the opinion of technical scientists and not of medical specialists. In this case, we consider this issue not as a medical problem, but a physical problem, and that is how we believe it should be treated. We regard humans as biological computers. We do not question the knowledge in this field, but treat it as proven and irrefutable and something that we build on. For us, a living organism is a complex mechanism that is not easy to understand in its various manifestations, but modelling it using our knowledge of the characteristics of other complex mechanisms can help. We propose that the human body is treated as a complex and sophisticated computer system.

We do not present the results of experiments and studies for discussion.

We present our vision of this process for further discussion. We are keen to hear the opinions of other scientists. And in this regard, we would like to encourage others to take their own initiative in this field.

Our work is undoubtedly subject to debate.

The purpose of the article is to draw the attention of the scientific community to understanding humans as computer-like physical systems using the advancements in IT.

2 Medical Technical and Information Technologies

Technical progress (informatization, technologization, robotization, and intellectualization) has rapidly become an important part of our daily lives. The advancements in the field of artificial intelligence and robotics are impressive. And the medical industry has not remained on the sidelines. Modern scientific and technical advancements are helping in the fight against diseases that affect almost every part of the body. Information and technical solutions have been implemented in health care on a large and ever growing scale. Many well-known organizations are involved. Thousands of medical institutions are benefiting from these solutions.

But this article will not go into this in detail. In this article, we treat the system of a living organism as a physical system, and explore the model of how it functions in another way.

3 We Expound Our Concerns and Put Forward Proposals

We will not discuss the established models of the human body system in detail. They have been sufficiently well described, but we believe, as technical specialists, that they do not accurately reflect the actual state of this system [1].

Looking at the human body as a system, we see that it works on the same principle of a computer and has all its functional components: information input, storage, processing, information output, management system in the form of a software system. At the same time, it has additional control functions that modern computers do not yet have. This of course has long been known and worked on [2, 3]. We understand this, but we are talking about something different. We are talking here about the diagnosis of certain diseases and want this to enter the practical medical field.

Memory loss is a widespread problem experienced by elderly people, and it is considered a serious disease. While this fact is undeniable and is taken very seriously, we believe it is worth looking at this issue from a slightly different perspective. For this purpose, we will recount a real event that we directly witnessed.

A schoolboy is learning the poem Tatyana's Letter to Onegin from Pushkin's Eugene Onegin by heart. After reading the said poem aloud several times, the schoolboy tells his mother and his seventy-year-old grandfather that he is sick of it: he keeps reading it, but he cannot memorize it. In response to this, his grandfather recites the poem word for word from beginning to end. The boy is shocked: "Grandpa, you listened to the poem two or three times and can remember everything, while I have read it so many times and still can't memorize it…". The boy's mother reassures him: "It rhymes well, so it's easy to memorize". His grandfather then goes on to recite Lermontov's poems On the Death of a Poet and Mtsiri, to which his mother replies that while they don't rhyme as well, it still helps. The boy's grandfather then recites from memory Vladimir Mayakovsky's Poem about the Soviet Passport. His mum does not give up: "Well, it rhymes a bit too". But his grandfather also does not give up and recites from memory The Tale of Igor's Campaign, which he learned in grade 8 at school. The Tale of Igor's Campaign was written in the Old Slavic language, and for people today, it is completely incomprehensible. The boy's mother is now stumped, and she and her son fall silent in bewilderment.

The boy's grandfather is in his eighties, and he remembers everything he learned at school and college very well. Nowadays he is a lecturer at a higher educational institution, where he has to teach a variety of subjects. He has no problems preparing new lectures, but it is hard to memorize them so that he can read them in front of the students without the need to look at previously prepared notes. When he discusses these problems with his family members, they claim that he has a disease that needs to be treated. We don't believe that this is the case, because traditional treatment involves, as a rule, physical intervention in a living organism. In our case, intervention is also needed, but it can be purely informational and not related to known curative treatments or extrasensory healing of which little is known, because such treatments are still at the initial stage of understanding.

The boy's grandfather is also not in a hurry to see a doctor, because he thinks that he still can memorize information, but he needs more time to do it than when he was young. This process reminds him of writing down letters or figures on a blank sheet of paper with the sun's rays focused by a lens on a clear day at noon in mid-June, just as it was when he was young. And the same writing by focused moonlight on a moonlit night in his old age. The duration of the processes on a sunny day and a moonlit night, as well as the processes inherent to youth and old age, are incomparable in time, but in essence they are no different.

We also do not have a recipe for resolving this problem, but we would like to share our thoughts on this issue. For us, humans are, to a certain extent, tools created by someone to perform particular functions. Just as we have created cars and airplanes to move us and cargo around, so we were created to fulfil our inherent functions. We were created according to certain patterns. And we are trying to replicate this at another level.

For us, humans are clearly a kind biological computer, although it is difficult to make direct comparisons with a computer. Humans have lots of functions and features inherent to computers. On our own computer, we can send an unwanted document to the recycle bin, we can delete it completely from the computer so that it cannot be retrieved, but if necessary, an IT specialist can restore it. For us, it is indisputable that the human body is a biological computer. A computer is made up of software and hardware components. One of the most important of these components is the memory, whose main parameter is space. By filling the memory of a computer, you can increase its functionality, but when the memory full, no new information can be saved in the computer. It functions by the information saved on it. However, it is impossible to save new information on it as there is no free space. The computer does not have a disease, in this case it is its limitation.

There may also be diseases, such as the failure of certain memory cells or damage to certain areas of the memory medium. And in this case, the memory should be treated by, for example, replacing damaged cells or bypassing damaged areas of the medium. Replacing individual memory cells with recorded information with new free cells makes space for a certain amount of new information that previously could not be stored due to the lack of free memory space, but this is not due to any repairs, but due to a misunderstanding of what we actually do in this case. In practice, such replacements can be made for inanimate matter, but for living matter this is extremely undesirable.

So, this suggests that the loss of an elderly person's ability to memorize new information combined with the ability to remember well previously learned information may not be a manifestation of a disease affecting the memory, but a manifestation of the complete filling of its space. And here we need to look for ways to remove obsolete information in an informative way, rather than by replacing operable memory elements with recorded information with new memory elements into which the necessary new information can be saved. You can physically replace the memory in your phone if there is no place to save new contacts, but such a replacement is impossible in a living organism. It can be argued that at the moment the ways and methods of updating the informational component of the human body have not been well studied,

and we still have only an approximate idea of how human memory is organized, the working principle of human memory, and how information is written and read in the human memory.

What is memory in technical terms? It is primarily a regular structure that allows this structure to be broken in a particular way (and not in any way) with the subsequent restoration of the broken structure to its original undisturbed state. And writing to such a memory is a violation of the regular structure in accordance with the information being recorded, and reading is the process of detecting a disorder of the primary structure and fixing this disorder. A structure that allows its regularity to be broken in a given way with the detection of a breakdown of its regularity and the ability to fix the violation of its regularity and restore the broken structure to an intact state is memory with restoration. A structure that allows its regularity to be broken without restoring the original, undisturbed state of regularity is called permanent memory. For example, a CD. If it is possible to instantly restore the regularity of the structure at a random address, such memory is called random-access memory.

Memory issues as applied to the human body are being intensively researched and we are thrilled with the results, but we do have some questions. Which organ of the human body has a regular structure of the necessary space and at the same time can allow the necessary disturbance of its structure with the possibility of restoring the disturbances? The amount of information accumulated by humans is incredibly large, but the amount of regularity of the corresponding human organ should be even greater. In this regard, our attention was drawn to a relatively old, but extremely relevant publication for us by Mountcastle [4]. In their publication, Mountcastle emphasized that the cerebral cortex is very homogeneous in appearance and structure. Medical experts knew that the brain cortex is homogeneous, but they did not pay enough attention to it, because they were looking for heterogeneity. But Mountcastle paid attention to this and emphasized that the brain cortex is very homogeneous and very thin. And that is exactly what we are trying to ascertain. If this thin film creates our perception of the world and is our memory, then how can the writing-reading process be detected if studies have not yet found any manifestations of this? The intensive search for differences in the structure, which was performed by researchers over a long period of time, did not yield the desired results. Certain differences can be noticed, but they are clearly not characteristic of the writing-reading process.

As was indicated above, memory is a regular structure that allows its regularity to be disturbed in a certain way, with the subsequent restoration of the disturbed structure to its original, undisturbed state. And such heterogeneity can be multifaceted. Capturing energy by a spatially undisturbed structure is also creating heterogeneity, but such heterogeneity may be hidden from us if we do not know how to detect it. We believe that this process is hidden and, very likely, this is how our memory works. In our opinion, the rotating principle is suitable for this role. It can act as a good concealer. Something like the ferrite memory of computers from the 1960s and 1970s. To confirm or reject such a view, we could try to investigate the possibility of erasing the memory of some animals or simple living beings in an appropriate way. This can be done, for example, by the inertial method, but this is clearly a cruel method that cannot be applied in this case.

We suggest using a magnetic field for this. Not just a magnetic field per se. Many studies have been conducted on the impact and use of magnetic fields, including for the use of magnetic resonance therapy. In our opinion, this should be a changing rotational magnetic field with the possibility of changing its spatial orientation. The proposed study is quite complex and can be performed by highly qualified technical and medical specialists. In our opinion, such research should begin with an approximation of the processes of demagnetisation of the magnetic carrier by the magnetic field. These issues are highly complex, but without figuring them out it is difficult to imagine making significant progress in this regard. We think that the time has come for IT and medical specialists to sit down side by side, as it was at the dawn of the creation of modern computers, when computer engineers and programmers, who at those times were called mathematicians, worked side by side.

In addition, it is worth noting that the complexity of these issues is so significant that they lie beyond just the IT and medical industry. The most interesting discoveries in human informatization will be found at the intersection of many scientific disciplines and by the efforts of multidisciplinary specialists in various fields of knowledge.

By analysing the retrieval of long-unused information, we can treat the organization of human memory in accordance with the hierarchical principle. In our understanding, human memory is not holographic and is not based on wave principles. For us, it uses rotating principles, and the actions of the magnetic field during the erasing process should be directed at their elimination.

It should be emphasized that issues related to the informational system of the human body are complex, multifaceted, and poorly studied. Their solution lies at the intersection of many scientific disciplines, which requires the involvement of multidisciplinary specialists from many fields of knowledge.

4 Conclusions

1. The model of a living human is similar to the model of a modern computer.
2. Memory can be viewed as the most important functional component of the model of living matter.
3. As in the process of operating a computer, in the process of a human's life, memory is filled with information and eventually there is not enough space to record new information.
4. The amount of free computer memory decreases with time.
5. A computer with completely full memory may work well, but it is a limited device because it can no longer fully satisfy the needs of its user. It is not defective, but its functionality is limited.
6. Deleting outdated information does not repair a computer, but does lead to a change in the state of its individual functional component. At the same time, no physical functional component is replaced, but the states of certain components are changed.

7. The information in the computer's full memory can be updated by changing the informational component without any change to the hardware component.
8. With advancing age, humans lose the ability to memorize new information. This loss of ability increases with age.
9. Losing the ability with age to memorize new information may not always be a disease. With age, people may use up their available free memory.
10. A human's informational component can be updated in the same way as a computer's informational component, but this is not a cure in the conventional sense.
11. It is vital that we search for methods to update the informational component of living matter.
12. The search for methods to update the informational component of living matter should be carried out jointly by IT and medical specialists.
13. These studies should be conducted with the involvement of specialists from various fields of knowledge.

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FPGA Embedded Signal Conditioning System Based on Fuzzy Logic for Temperature Measurement

Luis Enrique Chinea-Mujica, Alejandro Espinosa-Calderón, Javier Diaz-Carmona, Alejandro Israel Barranco-Gutiérrez, Mario Alberto Mendoza-Bárcenas, and José Guadalupe Deanda-Rincón

Abstract Temperature is an important physical variable that is measured and controlled in many manufacturing stages in industrial processes. Commonly, a temperature measuring digital system requires additional signal conditioning circuitry, which represents a restriction for small area, weight, and power consumption applications. An FPGA embedded signal conditioning system based on fuzzy logic for temperature measurement is proposed in this paper. In this way external signal conditioning hardware is not needed for the temperature measurement. Particularly, a Takagi–Sugeno-Kang fuzzy inference system was employed. The temperature measurement system was implemented on a Spartan 6 FPGA using an LM35 temperature sensor. The sampled temperature value is real time monitored and displayed on a PC screen through RS-232 serial communication protocol. The measurement system using the proposed fuzzy logic signal conditioning was experimentally tested within a temperature values range, which was compared with the obtained values when it was not used. According to the statistical analysis of the obtained results, an average error reduction from 305.15% to 2% and a variance error reduction from 1851.3% up

L. E. Chinea-Mujica (✉) · J. Diaz-Carmona · A. I. Barranco-Gutiérrez
Tecnológico Nacional de México (TecNM), Celaya, México
e-mail: m2103054@itcelaya.edu.mx

J. Diaz-Carmona
e-mail: javier.diaz@itcelaya.edu.mx

A. I. Barranco-Gutiérrez
e-mail: israel.barranco@itcelaya.edu.mx

A. Espinosa-Calderón · J. G. Deanda-Rincón
Regional Center for Optimization and Development of Equipment (CRODE), Celaya, México
e-mail: alejandro.espinosa@crodecelaya.edu.mx

J. G. Deanda-Rincón
e-mail: guadalupe.deanda@crodecelaya.edu.mx

M. A. Mendoza-Bárcenas
Instituto Politécnico Nacional (IPN), México City, México
e-mail: mmendozab@ipn.mx

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to 2.64% were achieved. The described fuzzy logic system can be extended to conditioning other analog signals by just adjusting the membership functions coefficients, which is left as future work by the authors.

Keywords Fuzzy logic · FPGA · Instrumentation · Takagi–Sugeno-Kang

1 Introduction

Most of the measured physical variables in the industry are analog signals, which require signal conditioning due to the environmental noise corruption. This work is focused on proposing a digital embedded signal conditioning, particularly for temperature analog sensor signals since this variable is one of the most common and essential parameters in the industrial processing stages.

A signal conditioning is an important stage for signal noise reduction to achieve an accurate analog signal measurement. Some signal conditioning devices commercially available are (a) Texas Instruments PGAxxxEVM-034 family boards [1], external power supply from 10 up to 30 V, a current of 100 mA with a cost of $240 USD. (b) Jewell Instruments 84800 board [2], external power supply from 8 up to 18 V and a typical current of 8 mA. Dimensions of 63 × 63 × 16 mm and weight 21 gr. (c) Phoenix Contact 2810913 board [3], supply voltage from 18 V up to 30 V, maximum drawn current of 30 mA, dimensions: 114.5 × 99 × 17.5 mm and a price around 600 USD.

The above-mentioned devices require additional physical space, power consumption, and weight to the measurement system. These specifications are a restriction for applications like aerospace, submarines, autonomous vehicles, medical devices, and portable systems, among others.

Fuzzy logic systems are applied to control, decision-making, object detection, prediction, and monitoring variables, among others. Some recently reported projects based on fuzzy logic systems, particularly in temperature measuring applications, are described below.

Fuzzy logic controller systems have been proposed in diverse applications such as: detection, alarm systems and fire monitoring [4–6], smart water irrigation [7–11], ebb and hydroponic flow system [12], rainfall monitoring [13], tropical aquarium temperature controlling [14], smart pillow health sensing [15], greenhouses monitoring and controlling [16, 17], broiler chicken coop temperature monitoring [18], honey bee colony state detection [19], cavendish banana shelf life determination [20], and coffee roasting control [21].

The fuzzy logic is used in the above systems to control the process, and the inputs are analog signals sampled from environmental moisture, temperature, and humidity sensors. Particularly, the fuzzy logic system input is the measured temperature variable, which value is computed from the sensor analog signal processed through a Data Acquisition System (DAS). The conventional DAS stages for a digital signal processing system are shown in Fig. 1, where the sensor analog signal is conditioned

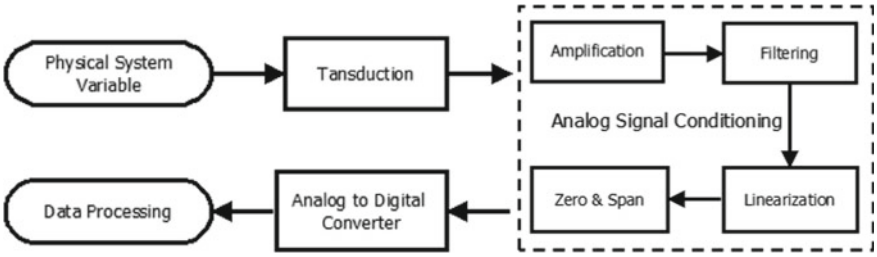

Fig. 1 General DAS for a digital signal processing system

by the analog amplification, filtering, linearization, and zero and span stages. The work described in this paper is focused on replacing the external circuitry implied in the analog signal conditioning by a proposed fuzzy logic FPGA embedded system, in this way external hardware is not required by the measurement system. Although the measured physical variable is temperature, the described design can be extended for measuring other variables.

The paper organization is as follows. The proposed system is described in the materials and methods section. The experimentally obtained results are presented in third section, and finally the discussion and conclusions are depicted in fourth section.

2 Materials and Methods

2.1 Materials

Sensor: the physical variable is the environment temperature measured through the analog LM35 sensor [22], which has a linear sensitivity of 10 mV/°C and a temperature range from − 55°C up to 150 °C. No external calibration or trim is required to provide accuracies of ± 1/4 °C at room temperature and ± 3/4 °C over the full temperature range.

Digital system: the proposed signal conditioning system was implemented on the FPGA Spartan6 XCLX16-CS324 available in the Digilent Nexys 3 board [23]. The system hardware design was developed in VHDL using ISE 14.7.

Analog Digital Converter (ADC): the temperature sensor signal is sampled and converted to digital by a PmodAD2 [24], which is a two-channel 12-bit ADC with a maximum simultaneously sampling frequency of one million samples per second for each channel.

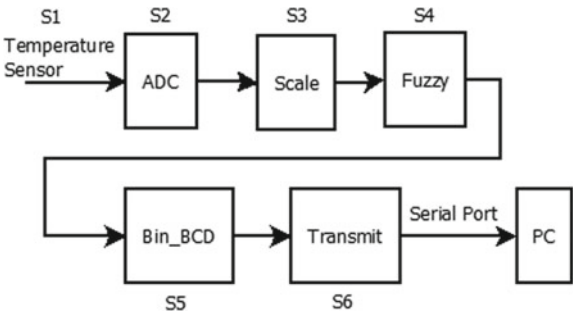

Fig. 2 Processing hardware stages of the temperature measurement system

A positive temperature range was considered in the system experimental testing. Hence, Zero and Span (Z&S) circuits were not required. Nevertheless, such circuits can be added if negative temperature values were measured [25–27].

2.2 Methodology

The processing hardware stages of the proposed temperature measurement system are shown in Fig. 2 and briefly described in the following:

S1: Temperature value is sensed as an analog signal.
S2: Temperature sensor analog signal is sampled and converted to digital.
S3: The digital signal is scaled.
S4: The analog signal conditioning is performed through the fuzzy logic stage.
S5: The temperature value is converted from binary to BCD.
S6: The resulted BCD value is transmitted to a personal computer through an asynchronous serial port (RS232).

Fuzzy System. The Fuzzy Inference System (FIS) aggregation method combines the output fuzzy sets into a single fuzzy set. Then, a final crisp output value is computed from the output fuzzy set through defuzzification methods [28]. However, defuzzification processes can be avoided if the Takagi–Sugeno-Kang (TSK) alternative method is used because no fuzzy set is obtained. The fuzzy system output is defined directly from an obtained set of linear functions [29].

The general TSK method block diagram of the fuzzy system is depicted in Fig. 3. Two values (Z_i, W_i) are generated by each rule. The rule Z_i output level can be a constant value or given by a linear combination of input values:

$$Z_i = a_i x + b_i y + c_i, \tag{1}$$

where x and y are the system inputs. The rule weights (W_i) are computed by:

$$W_i = \text{AndMethod}(F_1(x), F_2(x)), \tag{2}$$

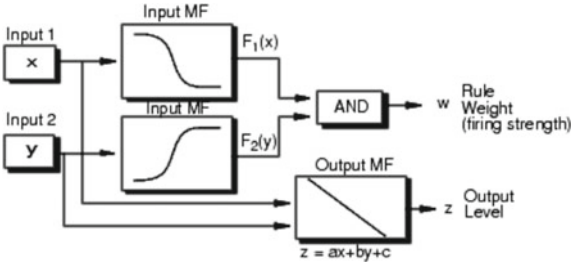

Fig. 3 TSK method block diagram

where $F_1(x)$ and $F_2(x)$ are the member functions for inputs *input 1* and *input 2*, respectively. The system output FO is the weighted average of all the rule results [30]:

$$FO = \frac{\sum_{i=1}^{N} Z_i W_i}{\sum_{i=1}^{N} W_i}. \tag{3}$$

The proposed fuzzy system was trained through two sample sets (theoretical and measured values) using Matlab *AnfisEdit* tool [31]. Once the fuzzy system is trained, the membership function graphs can be obtained by executing the Matlab *Fuzzy* tool as shown in Fig. 4, from which the coefficients ($a_{i,0}$ and $a_{i,1}$ for $1 \leq i \leq 3$) of the three membership functions are defined as:

$$MF1\begin{cases} 0; & x > 1701 \\ (-6.3052x)10^{-4} + 1.0725; & 115 \leq x \leq 1701 \end{cases} \tag{4}$$

$$MF2\begin{cases} (6.3052x)10^{-4} - 1.0725; & 115 \leq x \leq 1701 \\ (-6.3052x)10^{-4} + 2.0725; & 1701 < x \leq 3287 \end{cases} \tag{5}$$

$$MF3\begin{cases} 0; & x < 1701 \\ (6.3052x)10^{-4} - 1.0725; & 1701 \leq x \leq 3287 \end{cases} \tag{6}$$

Fuzzy System Hardware Design. The hardware block diagram of the fuzzy system first stage is shown in Fig. 5. Two finite state machines (FSMs) controlling the stage processes were designed. The computing of the membership function weights is controlled by the first FSM, whereas the process of the final system output is defined by the second one. The used data quantization format was signed fixed-point Q12,3.

The coefficient of the three defined membership functions are computed from the digital temperature input in U8, U9, and U10 blocks. The coefficients of each membership function to be sent one by one to U14 are selected by the multiplexers U11, U12, and U13. The membership function coefficients are selected by the multiplexer U14 block for next resolution stage. The polynomials are solved through an accumulated multiplications algorithm as:

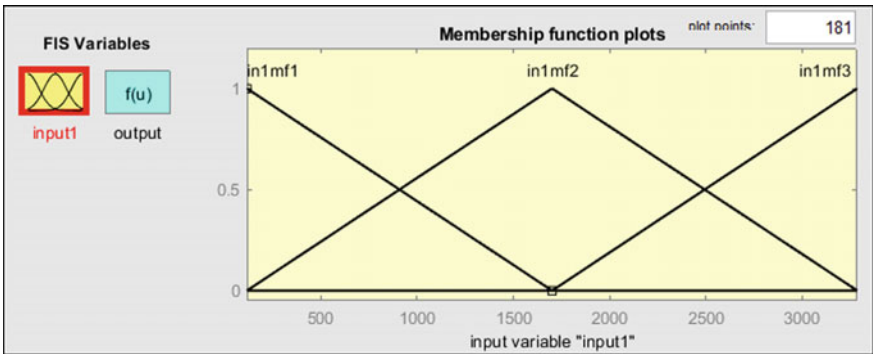

Fig. 4 Fuzzy system membership functions plots

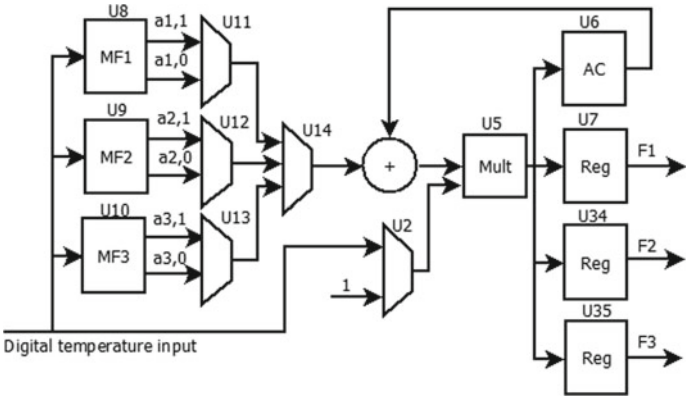

Fig. 5 Hardware block diagram of the fuzzy system first stage

$$F_i(x) = \left[\left(a_{i,1} + 0\right)x + a_{i,0}\right] * 1, \quad 1 \leq i \leq 3. \tag{7}$$

This algorithm is implemented using the accumulator register U6 and the multiplexer U2, which selects the input temperature or a constant value of one. The results of each polynomial are stored in the output resisters U7, U34, and U35. Hence, the three membership functions are solved through reusing same hardware blocks.

The hardware block diagram of the system output implementation, Eq. (3), is shown in Fig. 6. The weights (F1, F2, and F3) are multiplexed by U22, multiplied by the corresponding z_i value in U23, and the resulting value is stored in registers U36, U37, and U38. The three registers values are added in U25. Then, the system output is computed in U33 as the ratio between the U25 result and the addition of the three weights, which is concurrently computed in U26.

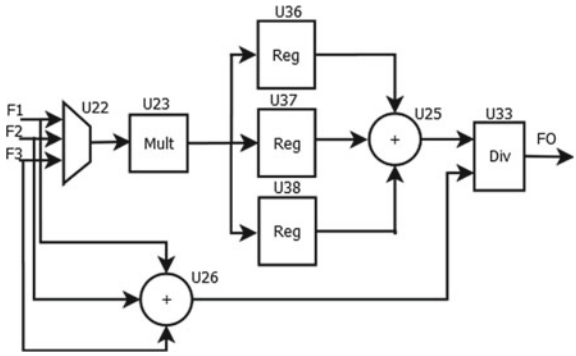

Fig. 6 Hardware block diagram of the system output

3 Results

Several experimental tests were carried out. The obtained results of the measured temperature values without signal conditioning system are depicted in Fig. 7 for one specific test within a controlled temperature range from 20 up to 40 °C. The shown theoretical temperature values are the ones directly obtained from the sensor output signal and the measured temperature values are the computed from the ADC value. As it was expected a significant temperature measurement error is observed due to the absence of a signal conditioning system. The sensor analog signal is highly corrupted by environmental noise mainly because its small value range (mV). The value trends of the measured and theoretical values are given, respectively, by the following regression third- and second-order regression polynomials:

$$y = -0.006x^3 + 0.2419x^2 + 0.3281x + 85.778 \tag{8}$$

$$y = -0.0318x^2 + 1.6032x + 15.543 \tag{9}$$

The experimental temperature measurement test was accomplished now including the implementation of the described fuzzy logic signal conditioning system. The experimental results set of the measured temperature values is presented in Fig. 8 within a controlled temperature range from 12 up to 37 °C. The value trends of the measured and theoretical values are given, respectively, by the following regression third-order regression polynomials:

$$y = 0.0005x^3 - 0.0304x^2 + 0.9399x + 12.867 \tag{10}$$

$$y = 0.0006x^3 - 0.0319x^2 + 0.9738x + 12.053 \tag{11}$$

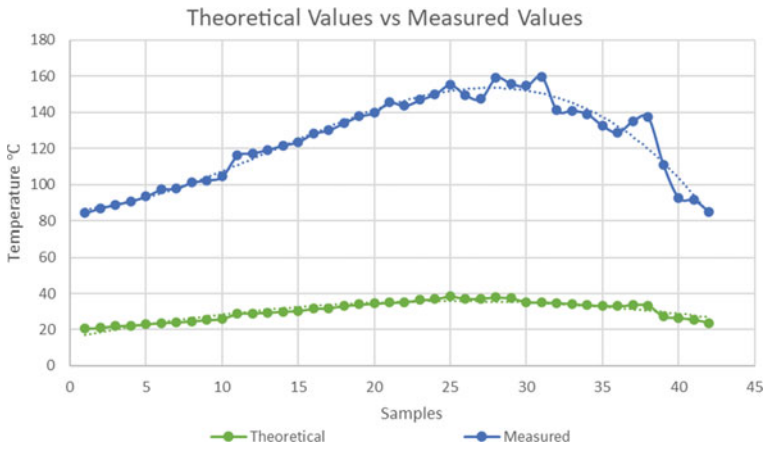

Fig. 7 Experimental results of temperature measurement without signal conditioning system

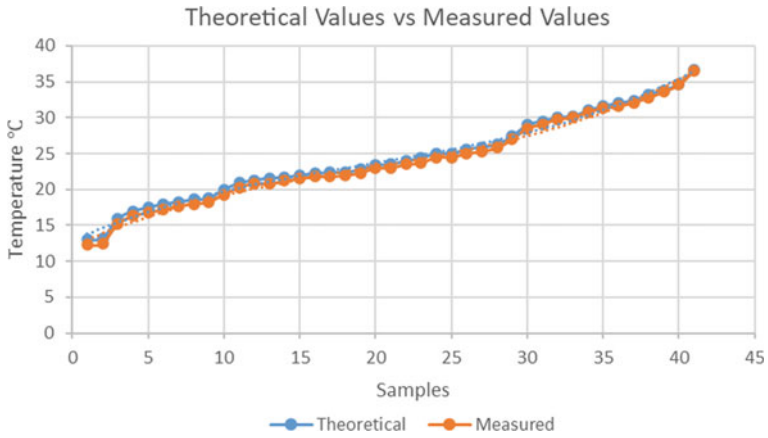

Fig. 8 Experimental results of temperature measurement with proposed conditioning system

A statistically comparison between the data sets of the theoretical and the measured values not using any signal conditioning system and using the described fuzzy logic one is shown in Table 1. The statistical analysis sample size was 42 elements. As it is quantitatively noted, a notably temperature measurement error reduction is achieved by using the proposed fuzzy logic signal conditioning. An error reduction relative to the mean value from 305.15 to 2% was achieved, and an error reduction relative to the variance value from 1851.3 to 2.64% were obtained.

Table 1 Statistically analysis of the theoretical and measured values for the cases without and with signal conditioning system

Without fuzzy system			
Characteristics	Theoretical values	Measured values	Relative error (%)
Average	30.66	124.22	305.15
Variance	29.18	569.39	1851.30
Correlation	0.979		
With fuzzy system			
Average	24.43	23.94	2.00
Variance	36.39	38.35	2.64
Correlation	0.999		

4 Conclusions

An FPGA embedded signal conditioning system based on fuzzy logic using Takagi–Sugeno-Kang fuzzy inference for temperature measurement is described in this paper. The temperature measurement was designed using VHDL and implemented on a Spartan 6 FPGA with an LM35 temperature sensor.

The measurement system using the proposed fuzzy logic signal conditioning was experimentally tested within controlled temperature values ranges, which was compared with the obtained values when it was not used. According to the statistical analysis of the obtained results, an average error reduction from 305.15 to 2% and a variance error reduction from 1851.3 up to 2.64% were achieved.

The obtained results show that an accurate temperature measurement can be performed without an external hardware system for the analog signal conditioning. This means that the proposed system is a full digital solution suitable for small physical space, low power consumption and weight applications.

The described fuzzy logic system can be extended to conditioning analog signals from other physical variable sensors just by adjusting the membership functions coefficients and that the dynamic voltage range of the analog to digital converter fulfills the sensor output analog voltage range, which is left as future work. Besides, the fuzzy algorithms could be implemented in other digital processing technologies.

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Adoption of AI Chatbots in Travel and Tourism Services

Sanjay V. Hanji, Nagaraj Navalgund, Sanjeev Ingalagi, Sumanth Desai, and Savita S. Hanji

Abstract AI chatbots are possessing significant importance due to the advent of emerging technologies, such as artificial intelligence. They are used in many industries to interact with customers, respond to frequently asked inquiries, and carry out specific duties for which they were designed. More AI enabled chatbots are being used in the tourism industry to provide better customer service to the travellers. In the literature review, researches relating to adoption of AI chatbots in tourism are scarce. The paper extends the UTAUT2 model and examines the aspects that impact consumer adoption of AI chatbots in the travel and tourism segment. We used a quantitative research approach and the data was collected through online surveys. A total of 466 responses were collected from frequent travellers. Partial least square approach was utilized to do the data analysis. The emanating outcome of this research study divulge the aspects of performance expectancy, effort expectancy, habit, personal innovativeness, and awareness of chatbot service optimistically influenced the behavioural intention to make use of AI chatbots for tourism services. Awareness of service also indirectly influenced intention to use through performance and effort expectancies. This paper offers unique insights for executives, practitioners, and employees at managerial level in the tourism sector, along with system designers and creators of AI chatbot technologies.

S. V. Hanji (✉) · S. S. Hanji
KLE Technological University, Dr. MSSCET, Belagavi, Karnataka, India
e-mail: sanjayhanji@klescet.ac.in

S. S. Hanji
e-mail: savitahanji@klescet.ac.in

N. Navalgund
KLE Technological University, Hubli, Karnataka, India
e-mail: nagaraj.n@kletech.ac.in

S. Ingalagi
KLS Gogte Institute of Technology, Belagavi, Karnataka, India
e-mail: ssingalagi@git.edu

S. Desai
KLS Institute of Management Education and Research, Belagavi, Karnataka, India
e-mail: sumanth@klsimer.edu

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1 Introduction

The tourism industry is undergoing a significant change due to novel technologies like robotics, artificial intelligence (AI), and chatbots [1, 2]. In addition to automating services and processes, AI-based systems are also being used to interact directly with customers at various points of contact [3]. Worldwide, the usage of AI chatbots in airports is expected to grow at 42% [4]. AI chatbot is an abbreviation for the use of an internal computer programme coupled with AI technology by a chat robot to create a conversation with humans [5]. Various devices can be used for accessing the chatbot interface, including Amazon Alexa, Siri and Google and as well as smartphones and computers. Using a chatbot involves either text input or vocal interaction. Intelligent backend systems facilitate chatbot interactions with users, facilitating the interaction process [6]. They provide the customers with human-like conversations as a result of AI and machine learning algorithms. The basic functions of sales, marketing, and customer service have indeed made these conversational technologies of chatbots and digital assistants increasingly popular. AI-based chatbots, in contrast to the earlier versions of simple response chatbots, are highly powerful and sophisticated, enhancing how people and technology interact [7].

A number of tourism and travel companies, including Expedia, Snap Travel, Mezi, and Hipmunk, are currently using chatbots to conduct operations [8]. In tourism sector, a chatbot is used to plan a trip, book a ticket, provide online customer support, and make recommendations and suggestions to customers about their trip. As tourism companies use chatbots to support customers 24/7, the same also increase revenues, improve engagement, generate leads automatically, reduce overhead costs, gain a competitive advantage, and save time; chatbots are helping them in providing the most optimum possible service to their customers [9]. A study reveals that consumers up to 44% are excited about using chatbots which are AI-driven as opposed to regular customer service agents [10].

In spite of having lot of researchers' interest in studying adoption of technology in various fields, travel and tourism have received less attention. Research on technology adoption in travel and tourism is still in its infancy, and studies that focus on exploring how tourism is changing, due to technological advancements such as AI and robotics, are scarce [2]. Especially, when it comes to AI chatbots adoption in travel and tourism there are very limited studies. These past studies are involved in examining the behaviours though different models, viz. Technology adoption model (TAM); e.g. [1], stimulus, organism, and response (S–O-R) model [11], unified theory of acceptance and use of technology model (UTAUT) [12].

TAM and UTAUT are the two models which are predominantly used in technology adoption studies. All variables which are measured using TAM [13] are captured in the modern UTAUT model [14] as UTAUT was developed as a results of detailed investigation and understanding of various models of acceptance like Theory of reasoned action (TRA), Theory of planned behaviour (TPB), TAM etc., [15]. Furthermore, UTAUT was revised to form UTAUT2. The initial four constructs of social influence, performance expectancy, effort expectancy, and facilitating conditions are shared by both UTAUT and UTAUT2 [14, 16]. Nevertheless, UTAUT 2 adds three more ones, namely habit, price value, and hedonic motivation for understanding how customers use technology. TAM and UTAUT have been the focus of adaption by many of the current studies to comprehend the acceptance of AI chatbots, however, only a fewer number of research studies have examined the adoption of AI chatbots in the tourism industry using the UTAUT2 model [17, 18]. Additionally, the significance of awareness of the service is overlooked by the research community which may have a considerable influence on behaviour intending to use chatbot technology [19]. It is significant to observe that the many of the research studies on chatbots have pointed towards technological facets and very few have looked at social science aspects of the solution which cannot be ignored.

In order to have technology-mediated interactions in tourism, there is an urgent need exists for research on AI chabot acceptance and adoption [1]. AI chabot adoption is one factor which could potentially affect the profitability of the travel and tourism companies. Understanding this would help companies in tourism industries to take major decision related to technology adoption. Knowing factors responsible for successful adoption of technology would also help software designers and developers in building right kind of technology which can be easily accepted and adopted in the markets. Studying AI chatbot adoption through the lens of extended UTAUT2 model will provide additional knowledge to the body of AI chatbots and tourism literatures.

Considering the above gap, the current study examines the factors that impact consumer adoption of AI chatbot in travel and tourism sector by extending the UTAUT2 model. Trust, personal innovativeness and awareness of service are additional variables which are studied along with the other variables of social influence, performance expectancy, effort expectancy and facilitating conditions, hedonic motivation and habit considered in UTAUT2 Model. The variable of price value has been omitted from the study because AI chatbots in tourism are free to use technologies.

Research presented in this paper offers unique insights for executives, practitioners, and employees at managerial level in the tourism sector, along with system designers and creators of AI enabled chatbot technologies.

The flow of the paper is arranged in this manner: the immediate succeeding section presents the theoretical framework and the hypothesis development. The third section is dedicated to the discussion of the research methodology, with the fourth section presenting the outcome (results). Fifth section throws light on discussions and conclusions are reported in the sixth section.

2 Theoretical Framework and Hypotheses Development

In this section, theoretical framework and hypotheses development is presented. Here the UTAUT model is extended with additional variables. Finally, the conceptual model is presented in the Fig. 1.

Generally it was believed that; customers exhibit greater motivation to adopt or accept the technology for enhancing user experience depends on the perceived benefits [20]. The expectation of performance, according to earlier studies in the literature, was one of the strong predictor of behavioural influence of AI chatbot usage in Air Travel services [18]. Melián-González et al. [17] discovered that there is a substantial influence of performance expectancy on acceptability and use of chatbots for tourism in particular. Hence the hypothesis was formulated by the researchers in the prevailing study. *Hypothesis H1: Performance expectancy (PE) has a positive and significant influence on behavioural intention of consumer to use AI chatbots for travel and tourism.*

The ease of technology usage makes the users more confident and hence boosts their confidence in using the technology. The prevailing studies on mobile support service [21], digital education [22], and banking [23] were successful in establishing the association between intention of user to use AI chatbots and expectancy of effort. If efforts to use the technology are less then there will be high chances of using those technologies. The hypothesis framed by the researchers is based on these arguments as mentioned above. *Hypothesis H2: Effort expectancy (EE) has a positive and significant influence on behavioural intention of consumer to use chatbots for tourism and travel.*

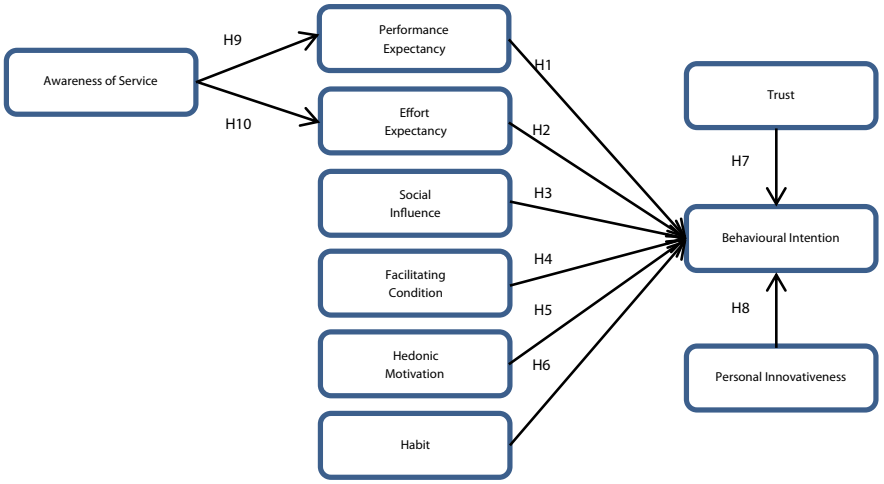

Fig. 1 Adapted extended UTAUT2 model

Enhance interaction has a huge influence on people's intention to embrace smart digital solution to overcome their challenges in swift time. To portray in nutshell, consumers always consider recommendations and information shared by the connected people as vital for chatbot/HCI usage [23]. Wang et al. [24] study reveals an important factor social influence as an influencer to use AI chatbots. The same is validated in travel and tourism sector by Trapero et al. [18]. In the backdrop of the above cited studies, the researchers postulated the hypothesis. *Hypothesis H3: Social Influence (SI) has a positive and significant influence on behavioural intention of consumer to use chatbots for travel and tourism.*

The "facilitating conditions" is designated as "user's perception of the resources and prevailing facilities available to exhibit the behaviour" [14]. The researches carried out by Alwahaishi and Snásel [25] and Akour and Dwairi [26], affirmed that intention to usage technology is influenced by the conditions that facilitate usage. Hence the hypothesis was set. *Hypothesis H4: Facilitating Conditions (FC) has a positive and significant influence on behavioural intention of consumer to use chatbots for travel and tourism.*

The motivation behind incorporating the hedonic motivation into human–computer interaction system is to give customers hassle free and timely solutions to enhance their usage experience with chatbots [20]. The researches carried by Gupta et al. [27], on touristic geolocation and [28], on online gaming have revealed that hedonistic intent factor plays a crucial role on the intention of the user to interact with chatbots. On the basis of the arguments mentioned herein, the hypothesis is framed as follows. *Hypothesis H5: Hedonic Motivation (HM) has a positive and significant influence on behavioural intention of consumer to use chatbots for travel and tourism.*

Habit is outcome of previous experience, if the experience was hassle free and positive customers tends to follow the pattern and develop it as a habit. The same holds good with chatbot case also [16]. Merhi et al. [29] study highlighted significance of habit to encourage people to use technologies. Melián-González et al. [17] in their work on travel and tourism established that habit positively influences chatbot usage behaviour. Hence the hypothesis was set. *Hypothesis H6: Habit (H) has a positive and significant influence on behavioural intention of consumer to use chatbots for travel and tourism.*

Another major role in HCI usage is played by the factor "trust" [30]. Trust helps to build the faith to use the technology and rely on the inputs provided by the machine [31]. To overcome risk and uncertainty in usage intention, trust plays an important role [32]. Kuberkar et al., Vimalkumar et al., Pitardi et al. [12, 33, 34] in their work on use of voice activated assistance (VA's) in transport service and retail service established that behavioural intention to use the technology was significantly influenced by trust. Therefore based on the above cited work the hypothesis was formed. *Hypothesis H7: Trust (T) has a positive and significant influence on behavioural intention of consumer to use chatbots for travel and tourism.*

Studies conducted by de Blanes Sebastián et al. [35] and Kasilingam [36] found that customer's personal innovativeness nature highly influenced customers' inherent behavioural intention to use AI chatbots. However, on the contrary, [37] in their

research found that personal innovativeness did not have much influence of AI chabot intention to use. The personal innovativeness trait of a person should ideally encourage him to use a specific technology and with this argument we frame our hypothesis: *Hypothesis H8: Personal innovativeness (PI) has a positive and significant influence on behavioural intention of consumer to use chatbots for travel and tourism.*

Intention to use the chatbots technology for the travel and tourism purpose significantly relies on awareness about the technologies among the users. Alt et al. [19] found in their research that awareness of service significantly impacts, a. performance expectancy which is perceived usefulness and b. effort expectancy of use which is perceived ease. The study undertaken by Sathye [38] found that awareness plays a central role to innovate and in using technologies. Similarly study undertaken by Pikkarainen [39] found that the amount of the information customers have on the chatbots positively influences adoption rate. Awareness play as a major driver which, influences ease of use and perceived usefulness [40]. On the arguments furnished herein, we formulated these hypotheses: *Hypothesis H9 and H10: Awareness of service (AWS) has a positive and significant influence on performance expectancy and effort expectancy of AI chatbots, respectively. Hypothesis H11 and H12: Awareness of service (AWS) has a positive significant indirect influence on behavioural intention of consumer to use chatbots through performance expectancy and effort expectancy, respectively.*

3 Research Methodology

For this particular research study we have utilized a quantitative methodology and a cross-sectional design. A systematic survey is created and its validity and reliability are examined. After assessing the instrument's reliability and validity with a pilot study, Google forms are employed to administer it across the population. The questionnaire had multiple choice-based questions linked to Likert scale, with the multiple choices ranged from "strongly agree" denoted as (1) to "strongly disagree" denoted as (5) on Likert scale on the consumers general behaviour towards usage of chatbots while booking online tours. We collected data from tourists in Indian subcontinent who booked and arranged tour and travel plans on their own. The aforementioned respondents were recruited from social networking cites such as Facebook and WhatsApp based on their interests in tours and travels. Random sampling method was adopted to reach out larger population across Indian subcontinent. The data was collected from 466 respondents over the period of three months. About 11 incomplete surveys were deleted form the survey.

Descriptive analysis of respondent's profile shows that there were about 266 responses 55% males and 45% of female completed the survey. It emerged that most of the aforementioned respondents fit in to age group (18–25) consisting of 55% and (25–34) consisting of 23%, respectively. About 10% of the aforementioned respondents belonged from the age group (35–44) and about 6% of aforementioned

respondents belonged from the age group (45–54), while the rest of 4% of aforementioned respondents belonged from the age group (≥ 55) years group. The majority of respondents were undergraduate students (44%) who used chatbots followed by job holders (33%), business (14%), and retired or household (8%). Authors examined education of the respondents consisting of post graduates (50%), followed by graduates (34%), PUC (10%), and SSLC or below (3%), where PUC is equivalent to 12th Grade and SSLC are equivalent to 10th Grade.

3.1 Measures

Based on the literature review, conceptual framework on AI chatbot usages by tourists was created and constructs were identified. The identified constructs recorded along with the literature sources that back them. The scales for this study were adopted from UTAUT-2 [16]. The model was extended with additional variables. These additional variables are key in predicting behaviour intention while "price value" variable (PV) was dropped because it is not relevant to the present research. Authors have adopted PLS-SEM for data analysis.

3.2 Dependent and Independent Variables

As shown in the Fig. 2, facilitating conditions (FC), hedonic motivation (HM), habit (H), social influence (SI), performance expectancy (PE), and effort expectancy (EE) are denoted as independent variables and measurement items are sourced from [16].

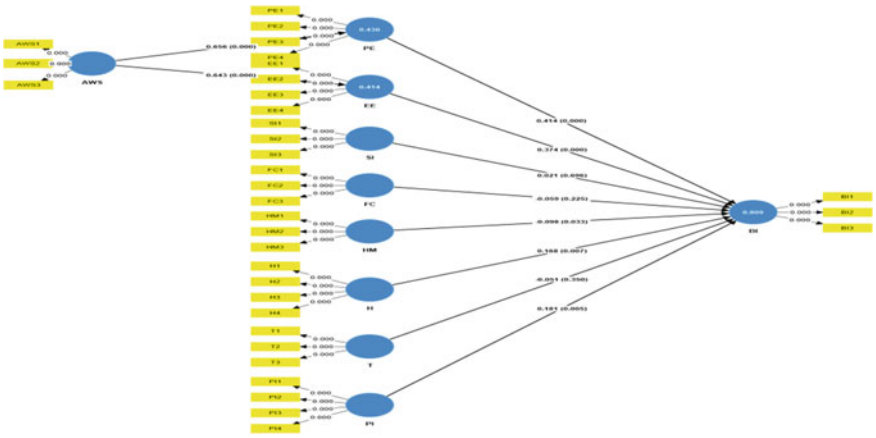

Fig. 2 Structural model

Further, trust (T) scale is sourced from [41]. Personal innovativeness (PI) measurement items are sourced from [42 to 43]. Awareness of service (AWS) items are sourced from [44 to 40]. Trust (T), personal innovativeness (PI), and awareness of service (AWS) are three additional independent variables included in the study. Measurement scales for the dependent variable, the same being behavioural intentions (BI) are sourced from [16].

4 Results

The approach used to analyse the data is partial least square (PLS) [45]. Smart-PLS Version 4 was used. Using a two-tailed technique using a bias-corrected, expedited bootstrap with no significant modifications, we bootstrapped 5000 samples.

4.1 Test of Reliability, Convergent Validity, and Discriminant Validity

The reliability of the measurement model was crucial pre condition before testing hypothesis. To ensure reliability, composite reliability along with Cronbach's alpha was used. As mentioned by [46], internal reliability can be understood by refereeing to the use of composite reliability values and the Cronbach's alpha, where they should exceed threshold value of 0.7 [47]. While composite reliability values and Cronbach's alpha, both exceeded the threshold, thereby proving internal consistency of the measurement model. The measure of convergent validity is average variance extracted (AVE) value. The most likely range of the AVE value is 0 to 1. For the convergent validity to be adequate the AVE value should exceed 0.50 [48]. According to Table 1, the AVE value varied between 0.641 and 0.782 which indicated satisfactory convergent validity. Using [48] criterion, discriminant validity, is satisfied [48]. As per the criteria (1) Every item loads most heavily on its related construct, and (2) the square root of every individual construct's AVE is greater than its correlation with alternative construct. The criteria's (1) and (2) of Fornell and Larcker's [48] requirements are met based on the data in Table 2.

4.2 Data Analysis

The output of PLS are summarized in Fig. 2 and Table 3. According to the immediate effects between all independent and dependent variables, Hypothesis H_1 is supported as performance expectancy (PE) has positive and significant influence on behavioural intention (BI) ($\beta = 0.414$, $t = 5.822$, $p < 0.001$). Similarly, Hypothesis H2, H6, and

Table 1 Reliability and convergent validity

Construct	Item	Factor loading	AVE	Composite reliability	Cronbach's alpha
Performance expectancy (PE)	PE1	0.743	0.685	0.851	0.845
	PE2	0.854			
	PE3	0.851			
	PE4	0.857			
Effort expectancy (EE)	EE1	0.754	0.654	0.825	0.823
	EE2	0.829			
	EE3	0.820			
	EE4	0.829			
Social influence (SI)	SI1	0.834	0.720	0.813	0.805
	SI2	0.883			
	SI3	0.827			
Facilitating conditions (FC)	FC1	0.811	0.667	0.751	0.750
	FC2	0.808			
	FC3	0.830			
Hedonic motivation (HM)	HM1	0.870	0.754	0.837	0.837
	HM2	0.870			
	HM3	0.865			
Habit (H)	H1	0.854	0.729	0.877	0.876
	H2	0.865			
	H3	0.863			
	H4	0.833			
Trust (T)	T1	0.822	0.721	0.809	0.807
	T2	0.864			
	T3	0.862			
Personal innovativeness (PI)	PI1	0.823	0.641	0.818	0.814
	PI2	0.798			
	PI3	0.789			
	PI4	0.793			
Awareness of service (AWS)	AWS1	0.873	0.782	0.861	0.860
	AWS2	0.898			
	AWS3	0.882			
Behavioural intention (BI)	BI1	0.795	0.690	0.778	0.775
	BI2	0.839			
	BI3	0.858			

Table 2 Discriminant validity

	AWS	BI	EE	FC	H	HM	PE	PI	SI	T
AWS	**0.884**									
BI	0.663	**0.831**								
EE	0.643	0.829	**0.809**							
FC	0.541	0.549	0.606	**0.817**						
H	0.725	0.731	0.691	0.587	**0.854**					
HM	0.577	0.608	0.669	0.6	0.702	**0.868**				
PE	0.656	0.854	0.815	0.596	0.71	0.642	**0.827**			
PI	0.671	0.751	0.694	0.613	0.758	0.701	0.753	**0.801**		
SI	0.672	0.657	0.645	0.599	0.772	0.601	0.653	0.673	**0.848**	
T	0.627	0.674	0.697	0.546	0.754	0.614	0.691	0.728	0.621	**0.849**

Bold values are the diagonal values i.e., square root values of AVE which are compared with other values in the matrix. If those values are greater than corresponding row and column values then discriminant validity is established for the data

H8 are supported as effort expectancy (EE) ($\beta = 0.374$, $t = 4.449$, $p < 0.001$), habit ($\beta = 0.168$, $t = 2.721$, $p < 0.01$) and personal innovativeness ($\beta = 0.181$, $t = 2.80$, $p \leq 0.01$) have positive and significant influence on behavioural intention (BI). Hypothesis H3, H4, and H7 are not supported as social influence (SI) ($\beta = 0.021$, $t = 0.390$, $p = 0.696$), facilitating conditions (FC) ($\beta = -0.059$, $t = 1.212$, $p = 0.225$) and trust ($\beta = -0.051$, $t = 0.934$, $p = 0.350$) have no significant influence on behavioural intention (BI). Hypothesis H5 is supported as hedonic motivation (HM) has significant but negative influence on behavioural intention (BI) ($\beta = -0.098$, $t = 2.138$, $p < 0.05$). Hypothesis H9 and H10 are reinforced as awareness of service (AWS) has positive and significant influence on performance expectancy (PE) ($\beta = 0.656$, $t = 14.984$, $p < 0.001$) and effort expectancy (EE) ($\beta = 0.643$, $t = 14.709$, $p < 0.001$) correspondingly. Hypothesis H11 and H12 are supported as awareness of service (AWS) has positive and significant indirect influence on behavioural intention (BI) through performance expectancy (PE) ($\beta = 0.272$, $t = 5.144$, $p < 0.001$) and effort expectancy (EE) ($\beta = 0.240$, $t = 4.214$, $p < 0.001$), respectively.

5 Discussion

To arrive at the solution to research question, the study conceptualized eleven hypotheses. The first research hypothesis H1 was accepted, where it was witnessed that the (PE) has a positive and significant influence on (BI) of consumers in utilizing chatbots for travel and tourism. This result conforms many studies in the past [17, 18, 20]. This result implies that traveller's perceptions performance and usefulness of AI chatbots will encourage them to adopt them for their tour and travel service planning and booking etc. The second hypothesis H2 was accepted, where it was observed

Table 3 Structural paths

Hypothesis number	Hypothesis relationship	Original sample	T statistics	*P* values	Hypothesis results
H1	PE → BI	0.414***	5.822	0.000	Supported
H2	EE → BI	0.374***	4.449	0.000	Supported
H3	SI → BI	0.021 ns	0.39	0.696	Not supported
H4	FC → BI	− 0.059 ns	1.212	0.225	Not supported
H5	HM → BI	− 0.098*	2.138	0.033	Supported
H6	H → BI	0.168**	2.721	0.007	Supported
H7	T → BI	− 0.051 ns	0.934	0.350	Not supported
H8	PI → BI	0.181**	2.8	0.005	Supported
H9	AWS → PE	0.656***	14.984	0.000	Supported
H10	AWS → EE	0.643***	14.709	0.000	Supported
H11	AWS → PE → BI	0.272***	5.144	0.000	Supported
H12	AWS → EE → BI	0.240***	4.214	0.000	Supported

*** Significant at $p \leq 0.001$ ** Significant at $p \leq 0.01$ * Significant at $p \leq 0.05$ ns Not Significant

that (EE) has a positive and significant influence on (BI). This outcome is convergent with [21–23]. This implies that if the usage is simple and easy to operate, majority of the customers' love to have chatbot experience in tourism service. Any technology for that matter, ease of use really motivates individuals to use that technology. The third hypothesis H3 was accepted, where it was found that (SI) has no significant influence on (BI). This outcome contradicts the previous studies [18, 23, 24]. This is a very interesting finding where behavioural intention to use AI chatbots is not affected by social influence. This implies that other opinions and encouragement will not drive consumers towards chabot usage in tourism. The fourth hypothesis H4 was accepted, where it was observed that (SI) has no significant influence on (BI). This result also refutes with the work carried out by previous studies [25, 26]. This implies that knowledge, necessary resources, and compatible technological devices does not encourage consumers' intention to use AI chats for tourism services. The fifth hypothesis H5 was accepted, where it was witnessed that (HM) has a significant but negative influence on (BI). This result also negates with the previous studies where hedonic motivation positively influence consumers' to use AI chatbots [20, 27, 28]. This implies that fun, happiness, joy, enjoyment, and playfulness of using AI chatbots not necessarily influence tourism consumers' to use AI chatbots. The sixth hypothesis H6 was accepted, where it was observed that (H) has a significant and positive influence on (BI). Previous studies support this result [17, 29]. This implies that habit and addition to technology has an influence on tourism consumers' to use AI chatbots. The seventh hypothesis H7 was not accepted, where it was found that (T) has a no significant influence on (BI). This result contradicts previous researches

[12, 32–34]. This is also a very interesting result as majority of previous studies supported the hypothesis. The results implies that trust in chatbots to be reliable in providing secure and quality service does not necessarily influence on tourism consumers' to use AI chatbots. The eight hypothesis H8 was accepted, where it was found that (PI) has a significant positive influence on (BI). This result is aligned with previous studies [35, 36] and contradictory with one of the past studies [37]. This implies that consumers who are keep exploring new ways plan and book their travels are more like to adopt AI chabots in tourism. The ninth hypothesis H9 was accepted, where it was evident that (AWS) has a significant positive influence on (BI). Previous studies support this result [38–40]. This implies that travel companies' constant communications and recommendations to their customers to use AI chatbots will help them in using chabots. The tenth hypothesis H10 and H11 were accepted, where it was found that awareness of service (AWS) has a positive significant indirect influence on behavioural intention (BI) of consumer to use chatbots through performance expectancy and effort expectancy, respectively. This result is supported by previous studies [18, 21, 23, 40]. This implies that travel companies' constant communications and recommendations to their customers will improve their perceptions about performance and ease of use which will in turn positively influence use AI chatbots.

5.1 Theoretical Implications

This research study has unique contribution to adoption of technology especially in travel and tourism services. Firstly, the utilization of unified theory and UTAUT2 model to understand AI chabot usage in tourism services [16, 49, 50] where there were very limited studies. Secondly, the study stretched the UTAUT2 model with surplus variables, viz. trust, personal innovativeness, and awareness of service, where the third variable was neglected in most of the previous studies. Last but not least, awareness of service was found to be indirectly influencing intention to use chatbots through performance expectancy and effort expectancy. All these results certainly add up new knowledge to the body of AI chatbots and tourism literatures.

5.2 Implications for Travel Companies and AI Chabot Developers

In the recent years, Instant messaging arenas like Facebook Messenger, Skype, Snapchat, and WhatsApp have experienced a substantial increase in communication and this may have implications for travel companies. It would be particularly beneficial for organizations in the segment of tourism to maximize the use of chatbots or chat robots in order to improve their existing services. This will reduce their

dependence on hiring more customer service agents and bring efficiency in their business. The present research also gives additional inputs to software designers and developers in addressing various issues related to our extended UTAUT2 model variables while developing artificially intelligent bots especially for tourism sector. They can focus on improving the chatbots' performance wise, their ease of use wise making their usage more fun and entertaining (hedonic wise). They need to develop bots which can habituate consumers' to use them again and again when need arises. Lastly, communicating and recommending customers to use chatbots for their travel purposes is utmost important in promoting their usage behaviour.

6 Conclusion

Our study started with a main research question of assessing the factors influencing the consumer adoption of AI chatbots in travel and tourism sector by extending the UTAUT2 model. This research question was further conceptualized into a theoretical model consisting of eleven hypotheses. Our investigation found that performance expectancy, effort expectancy, habit, personal innovativeness, and awareness of chatbot service positively influenced the behavioural intention to use AI chabots for tourism services. Hedonic motivation negatively influenced behaviour intention use AI chatbots. Awareness of service also indirectly influenced intention to use through performance expectancy and effort expectancy. The study presented unique contributions to theory and practitioners including tourism companies as well as software developers who build such technology. The study has some limitations. Firstly, we employed a cross-sectional design for the study whereas longitudinal studies would provide more detailed results. Secondly, we conducted the study for all types of AI Chabot services in tourism instead of studying some specific service chabots. Future studies can employ longitudinal research designs for addressing same research question. Adoption of more specific chatbot services can be services can be studied in tourism such as ticket booking service, travel planning, room service bots. More researches are warranted to enrich the body of AI chatbot and tourism literature.

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A New Concept of Data-Driven Education Based on Eduinformatics

Yasuo Nakata, Kenya Bannaka, Ikuhiro Noda, Katsuhiko Murakami, Yasuhiro Kozaki, Kenichiro Mitsunari, Masato Omori, and Kunihiko Takamatsu

Abstract There are two types of research after human genome sequencing; one is the hypothesis-driven approach and the other is the data-driven approach. This study investigates how do we deal with data-driven education in the big data era? After COVID-19, information and communication technology (ICT) and learning management system (LMS) have constructed big data of students. Eduinformatics (EI) is a new interdisciplinary field being proposed by the authors. We show two practices of data-driven education, which show that EI is the key concept in data-driven education. We suggest a new concept for data-driven education based on EI.

Keywords ICT · LMS · Data-driven education · Eduinformatics

1 Introduction

1.1 Hypothesis-Driven Approach and Data-Driven Approach

In the life science fields, the international human genome sequencing consortium reported initial sequencing and analysis of the human genome in 2001 [1] and finishing the euchromatic sequence of the human genome in 2004 [2]. This research

Y. Nakata (✉) · K. Bannaka · I. Noda · K. Mitsunari · M. Omori
Kobe Tokiwa University, Kobe 653-0838, Japan
e-mail: nakata0325@gmail.com

K. Murakami
University of Tokyo, Tokyo 108-0071, Japan

Y. Kozaki
Osaka Kyoiku University, Osaka 582-8582, Japan

K. Takamatsu
Tokyo Institute of Technology, Tokyo 152-8550, Japan

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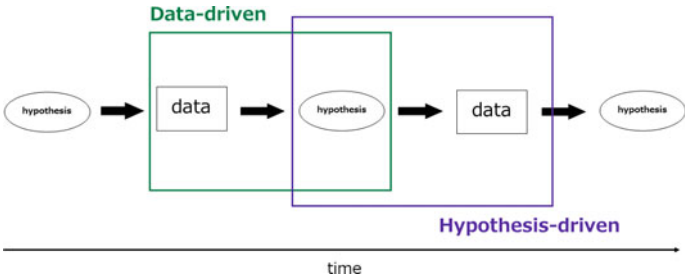

Fig. 1 Data-driven approach and hypothesis-driven approach from [4]

involves various research methods [3] since the human genome is about 3 billion base pairs; this means big data.

Before human genome sequencing research, researchers only used phenotype research by experiments, referred to hypothesis-driven research in life sciences (Fig. 1). Hypothesis-driven methods involve the development of a hypothesis and researchers perform experiments to confirm hypothesis or not. If the hypothesis is not confirmed, then researchers construct a new hypothesis and development a new experiment and the cycle continues (Fig. 1) [4].

Researchers had data on human genome sequences once the human genome sequence was established, which was completely opposite to the decision before. When researchers use the human genome sequence to construct hypotheses, it is called data-driven research (Fig. 1).

The hypothesis-driven approach and data-driven approach may look like to completely different methods; however, they are not. The hypothesis-driven approach develop new hypotheses based on data from experiments; thus, hypothesis-driven approach is not easily separated from the data-driven approach. Moreover, the hypothesis-driven and data-driven approach have a circular relationship (Fig. 2) [3, 4].

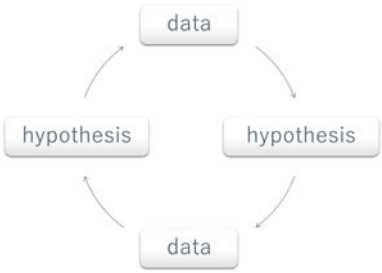

Fig. 2 Cycle of hypotheses and data from [4]

1.2 Data-Driven Education

The situation described above is also the same situation in the field of education. Information and communication technology (ICT) education is important to the younger generation because of rapidly evolving technology. There have been recent international conferences and congresses about ICT, one of them being ICICT2023 [5]. However, the coronavirus disease 2019 (COVID-19) has restricted our life style and transferred learning methods from physical to online [6], forcibly changing our learning methods.

A learning management system (LMS) is very useful when students study something online. Data increased with online learning than before COVID-19. This situation is very similar to the example discussed regarding the human genome sequencing 20 years ago. That is to say, the big data era in the education field is now. Therefore, data-driven education is in existence or will soon come.

1.3 Eduinformatics

We proposed a new interdisciplinary field called Eduinformatics (EI) in 2018 [7]. EI include both informatics and education. Education addresses new problems from the education field, and informatics provide new methods to improve problem-solving [8] (Fig. 3).

We presented our research results at the following conferences ICICT2021, ICICT2022, WS42021, and WS4 2022. Further, we presented this new idea using ICT with EI [9] at the ICICT2021, and the role of EI in the new ICT era [10] at WS4 2021. Moreover, we presented a novel idea of institutional research (IR), ICT and DX [11] at the ICICT2022 and their sustainability in WS4 2022 [12].

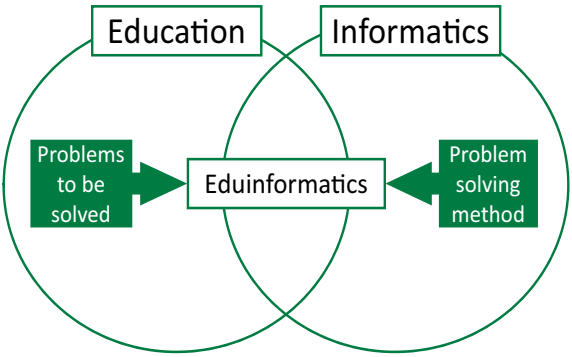

Fig. 3 Concept of Eduinformatics from [7]

1.4 Our Research Question

In this study, we investigate the following research question (RQ), "How to manage data-driven education in the big data era?" Fortunately, we have good examples of practice using Eduinformatics. We will understand that EI is the key concept of the answer of RQ. And finally, we suggest a new concept data-driven education based on EI.

2 Practical Examples for Data-Driven Education Based on Eduinformatics

In the last ten years, Japanese University have achieved first grade education. Kobe Tokiwa University in Japan started first grade education in 2017 because of higher education reform. All students in the first year of Kobe Tokiwa University have to take the first-year course. The course was called "Manaburu I and II"; "Manabu" means study in Japanese. We combine this study in Japanese and "able," which means possible. Therefore, "Manaburu" is a contracted word that means students will be able to study by themselves. The sample of students is about 400. In Manaburu I and II, 30 teachers are engaged in teaching students. This means that one teacher teaches 15 to 20 students. In Manaburu I and II, teachers pair up and the pair teach about 30–40 students in the same class. When we started Manaburu I and II in 2017, we actively LMS used and sharing tools, such as Microsoft OneDrive and Google drive to reduce the work time for teachers. We have reported about this process in 15 articles or proceeding papers regarding Manaburu I and II. Most of this research uses the data-driven approach. When students use the LMS, big data of LMS is constructed and when teachers evaluate students by competencies matrix, assessment of big data of students constructed.

First, we assess fairness of the students among teachers by statistical methods. Unfortunately, the first-year (2017) evaluation was not fair among teachers. We understand the result and can improve and report the unfairness among teachers using the grades of students in 2018. In 2017, teachers evaluated the grade of students using only a one-time report examination and combination of grade rubric with about 5–6 items.

When we analyze fairness among teachers using the grade of students, we cannot identify the unfairness among teachers. However, when we analyze fairness using detailed data (that means we analyzed the 5–6 items rubric and the report examination separately), we find that some teachers did not evaluate using rubric matrix correctly. To address this unfair evaluation, all teachers of Manabru I and II get together in a room both before and after Manabru I and II to discuss and reflect their classes and teaching methods. We can then confirm the fair evaluation among teachers [13]. When we reflect on this education research, we can say that this research is data-driven education based on EI.

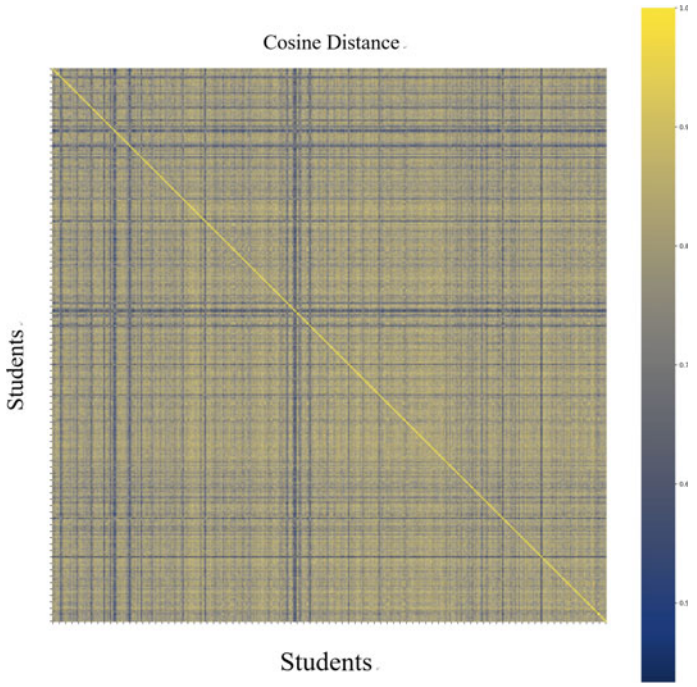

Fig. 4 Visualization similarity for report examination of students by heatmap from [15]

Further, we show another practice. We analyze similarity using students report examination by Doc2Vec [14] that is done by artificial intelligence (AI) or machine learning to visualize the similarity among students (Fig. 4) [15]. From this research, we identify students whose report examination is not like other students. This means that the students cannot write academic writing methods that was learned in Manaburu I and II. We must strongly identify and guide these students because they have the potential to get bad grades and leave university. When we reflect on this education research, we can say that this research is data-driven education based on EI.

3 Results and Discussions

We show the two practices of data-drive education based on EI. These practices both have the same situations. When we received the data of students through the LMS or sharing tools, we had not developed the hypothesis. Using this information, we constructed a hypothesis using the data-driven approach to education and propose the new concept of data-driven education based on EI (Fig. 5).

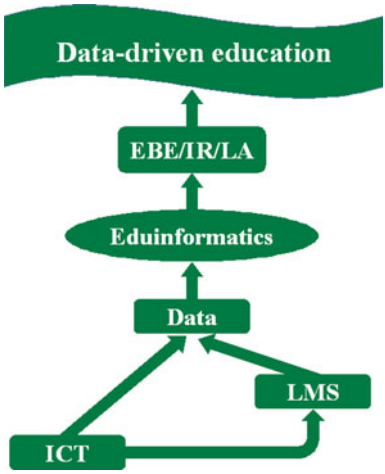

Fig. 5 Concept of data-driven education based on Eduinformatics

ICT together with a LMS constructs big data on students. We think that especially after COVID-19, teachers and students understand both the good and bad points of both onsite and online classes. It is important to combine onsite and online classes to get both benefits. In the new era of education, teachers will use these big data when teachers teaching students. Further EI will play a key role in evidence-based education (EBE), IR, or learning analytics (LA), which will become data-driven education.

4 Conclusion

In this study, we show two practices of data-driven education, ICT and LMS, constructed by big data. We also that EI is the key concept for the answer to the RQ. Finally, we suggest a new concept for data-driven education based on EI.

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Lightweight Network Architecture for Tethered Underwater Vehicles

Konstantin Chterev and Nikola Nikolov

Abstract A remotely controlled tethered underwater vehicle, or ROV for short, is an unmanned submersible which replaces manned submarines in any cases where the use of the latter is impractical. All modern ROVs use some form of networking to control the movement and obtain data from various sensors. As many of the ROV modules operate underwater, using off-the-shelf network equipment is problematic due to expensive shielding and specialised underwater cables. In this paper, a network architecture is proposed, which significantly reduces the ROV cost, complexity, and maintenance, while improving reliability at the same time. The architecture allows the underwater ROV modules to communicate with a novel lightweight protocol over a low wire count physical layer. The solution is implemented and tested in a commercial vehicle developed for Technical University-Varna, Bulgaria.

Keywords ROV · Networking · Underwater communication

The purpose of any inspection class ROV is the ability to manoeuvre underwater and provide video, telemetry, and other sensory data to the operator on the surface. All ROV systems consist of a remote control console (RCC), tether as a communication medium and the ROV itself, see Fig. 1. The ROV is a complex apparatus with many sensors and actuators, which, together with the RCC, form a communication network. This paper is focused on reviewing the existing network option for their usability in the ROV systems and ultimately developing a specialised network architecture suitable for the specific underwater requirements.

K. Chterev (✉)
Black Sea Research Fund,Varna, Bulgaria
e-mail: kc@bsrf.bg

N. Nikolov
Technical University,Varna, Bulgaria
e-mail: nn_nikolov@tu-varna.bg

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https://doi.org/10.1007/978-981-99-3236-8_59

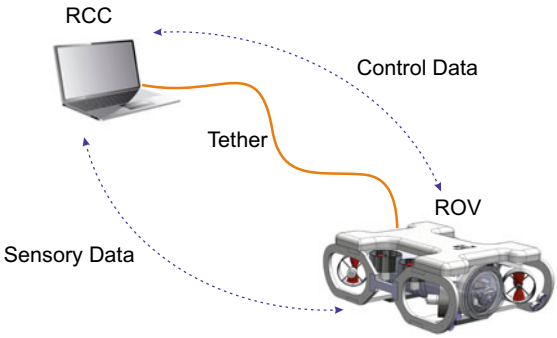


Fig. 1 ROV datastreams

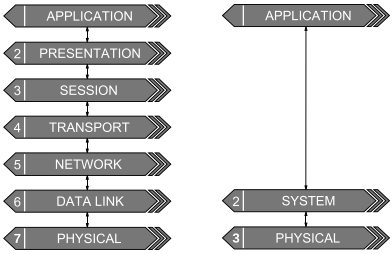


Fig. 2 Standard OSI model versus embedded

1 OSI and Embedded Networking Model

The seven-layer OSI model is developed for computer networks and gives a good abstraction of real-life interconnected systems. The model is described well in various sources [1, 2] and is not explained in detail here.

The vital difference between the computer networks and the ROV system is that the ROV contains several heterogeneous subsystems with different requirements for latency and throughput. Also, as many of the ROV modules are small embedded devices, the standard OSI model is cumbersome and unnecessary. In the embedded world, the network model is simplified to 3 layers only—application, system, and physical [3], see Fig. 2. The next section focuses on the overall network topology with the aim of selecting optimal architecture and physical layers.

2 Network Topology

The primary endpoints of the ROV system network are the RCC and the ROV components, see Fig. 3. The RCC is usually a simple ruggedised computer with a screen and a keyboard/joystick. The ROV, on the other hand, is a heterogeneous system with various components—Table 1. The two main communication requirements—throughput and latency, given for each endpoint, are high, medium, and low, qualitative properties derived from an evaluation performed in the next section.

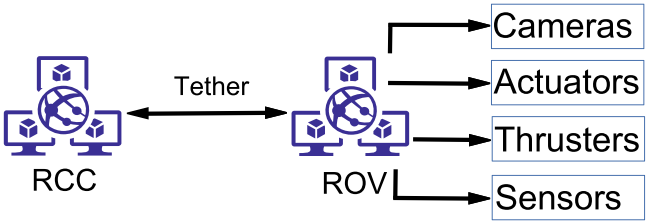
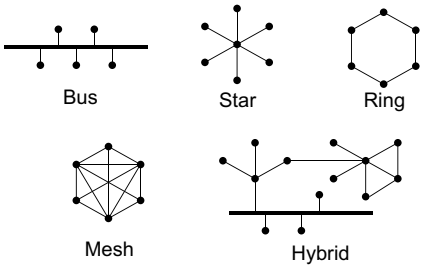


Fig. 3 ROV network main endpoints

Table 1 ROV system components and their network requirements

Component	Throughput	Latency
RCC	High	Medium
Cameras	High	Medium
Actuators	Low	Medium
Thruster controllers	Low	Low
Pressure, temperature, and other sensors	Low	Medium

Fig. 4 Most common network topologies



The most common physical network topologies are given in Fig. 4 [4]. It would be ideal if all the endpoints could be connected to a simple bus or star, low latency, high throughput network, but this comes with a high price and complexity.

It is strongly recommended that all the endpoints operating in the harsh, underwater environment have the absolute minimum physical wires and pin count connectors. Thus, it makes sense to group the components working underwater in a simpler and cheaper subnet, while the rest of the network could be based on standard, off-the-shelf equipment. From Table 1, all the modules, apart from the camera and the RCC, are suitable for such a low-speed subnet. This subnet can then be bridged to the high-performance network connected to the RCC, see Fig. 5.[1] In the next section, the network requirements for all the ROV system endpoints are evaluated, and a practical implementation of the ROV system networking solution is proposed.

[1] In this paper, the term "subnet" is used to describe a physical group of network endpoints, not to be confused with an IP subnet.

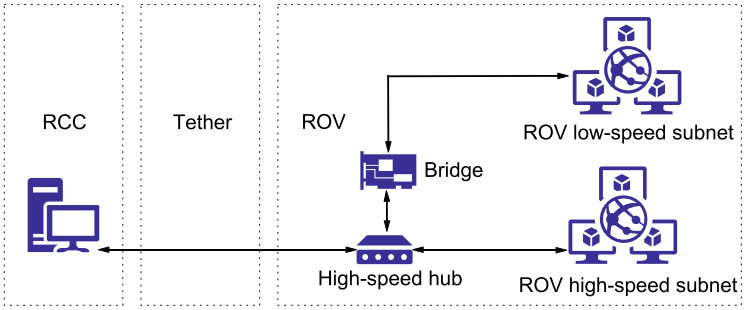


Fig. 5 High-performance network with a low-speed subnet

3 Network Requirements and Physical Layer Selection

3.1 Camera and RCC

The most demanding data stream is the video feed between the camera and the RCC. It requires a high throughput communication channel in order to accommodate at least the most popular HD1080p and recently 4K resolutions [5]. The throughput for transmitting HD1080p varies with the content and the compression used, but according to [6], the maximum throughput required is between 5 and 7 Mbps. The latency is not that critical but should be addressed as the video stream is the most important feedback for manoeuvring. The latency is not an issue if it is below 250–350 ms [7]. The final communication channel requirements for the video stream are

- Throughput >10 Mbps
- Latency <350 ms

Many communication networks cover these requirements, but the most popular physical channels in the industry are Ethernet and fibre optics [3]. While both cover the throughput and latency requirements, their use in the ROV is problematic. The Ethernet physical layer requires 2 twisted pair wires, which makes the tether expensive to make and also the Ethernet is reliable up to 100 m, while video stream must be carried by the tether, sometimes up to kilometres long. The fibre optics are better in terms of price and communication distance, but the underwater connectors are costly, and the fibre is practically unrepairable in a marine environment. A good solution for the ROV to RCC physical layer is power line communication (PLC) technology. Commercial devices branded HomePlug are available, and in essence, they provide Ethernet communication over two wires only, the same wires that carry the power to the ROV, see Fig. 6.

Many off-the-shelf IP cameras are available, already integrated with the most popular operating systems and browsers. This gives flexibility and platform independence to the PLC-over-tether solution.

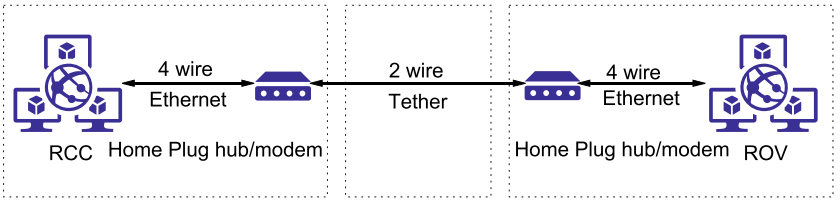


Fig. 6 Ethernet over HomePlug

Table 2 Serial protocols comparison

Protocol	Type	Pin count
RS232	Peer-to-peer	2
RS422	Multi-point	6
RS485	Multi-point	2
I2C	Master/multi-slave	2
SPI	Master/multi-slave	3 +
CAN	Multi-point	2
LIN	Master/multi-slave	1

3.2 Sensors, Controllers, and Actuators

Apart from the camera, all the other ROV components have similar communication requirements. From the list, the most critical component is the thruster electronic speed controller (ESC), which must react quickly enough to the control commands (low latency) so the remote control is comfortable for the operator. Similar to the camera latency, 200 ms between control commands is sufficient. The data packet between the RCC and the ESC is usually tiny. For example, the set point (requested motor speed) could be as short as a single byte. The same is valid for the sensors and the actuators. Few bytes are enough to transmit commands and receive telemetry and sensory data. Assuming that the ROV needs 8 ESCs and has 20 sensors providing 2 bytes of data each, the total data pack is less than 100 bytes. As per the latency requirements for less than 200 ms (1/5 s), the total throughput requirement comes to 500 Bps which is low:

- Throughput >500 Bps
- Latency <200 ms

With these loose requirements, many local bus standards such as RS485 and CAN can be used. A good comparison of the most popular local protocols is given in [8], with a summary presented in Table 2.

From the list, RS485, CAN, and LIN [9] look most suitable due to the low pin count. As local interconnect network (LIN) uses the least wires and is the simplest of all, it makes sense to be used for the low-speed ROV subnet.

LIN is well defined in ISO 17987 standard and will not be discussed in detail here. The physical interface is perfect as it uses just one wire bus, drastically reducing the wiring and the overall connector pin count. The data encoding and exchange are fairly simple too. It complies with most embedded universal asynchronous receiver transmitter (UARTs), making it easy to implement in any embedded platform. The LIN bus physical layer has many advantages for the ROV low throughput subnet such as flexibility and low cost, but the data link layer protocol is somehow cumbersome. Many features are not needed, while others are absent. The most problematic is the transferred data block size; it is up to 64 bits. This limits the slave endpoint response to only 8 bytes. Second, the master endpoint cannot send directly commands to the slave endpoints. In order to do so, a particular message is sent to the master itself, and the response from the master is the actual command data the slave endpoints receive. This creates unnecessary lag and makes maximum command data also 64 bits which is very limiting. Based loosely on the LIN concept, a half-duplex, single-master, and multiple-slaves novel lightweight protocol is developed and presented in the next section.

4 Lightweight Data Link Serial Protocol

The data link layer must provide the following services [10]:

- Framing
- Flow control
- Error detection
- Error correction
- Reliable delivery between endpoints
- Full/Half-duplex management.

Not all the services are always needed. In specific cases, additional services may be required. In the case of ROV control/telemetry subnet, some services are quite useful:

- Synchronous execution of all control commands
- Variable length command frames management
- Variable length data frames management
- Simple addition of new endpoints.

The full duplex is impossible over one wire physical interface, so half-duplex is the only choice. The flow control must be synchronous, controlled by the master. The final requirements for the new protocol are follows:

- Framing
- Synchronous flow control
- Error detection

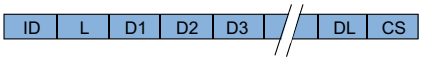


Fig. 7 Master broadcast frame

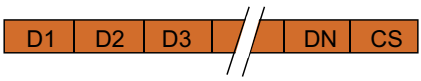


Fig. 8 Slave reply frame

- Reliable delivery between endpoints
- Half-duplex
- Synchronous execution of all control commands
- Variable length command frames management
- Variable length data frames management
- Simple addition of new endpoints.

The new data link protocol based on one wire LIN physical interface will be called local underwater network (LUN).

Framing

The framing is similar to the LIN one. There are 2 frame types: master broadcast frame **MBF** and slave reply frame **SRF**. The **MBF** consists of 4 fields, see Fig. 7

- **ID**—1 byte ID
- **L**—1 byte DATA length
- **D1, D2 ... DL**—L number of data bytes
- **CS**—1 byte check sum.

The **SRF** consists of 2 fields Fig. 8

- **D1, D2 ... DN**—N number of data bytes
- **CS**—1 byte checksum.

Flow control/half-duplex

The flow control is achieved by sending a broadcast message from the master at regular intervals—time slots—and receiving a reply from a single slave endpoint at the time. This makes the protocol synchronous and half-duplex. Care must be taken all the broadcast and the reply messages to fit in the time slot, otherwise, an non handled collision occurs, see Fig. 9. **MBF** is the master to slave endpoints broadcast frame, **SRF** is the slave endpoint response frame, and **IS** is the inter-frame space. From 3.2, the time slot is set to 200 ms. The endpoint synchronisation is achieved by **IS**, which must be long enough. The planned implementation uses the UART time-out feature, which resets the receive frame state machine of the slave endpoints.

Error detection

The error detection is achieved by checksums at the end of **MBF** and **SRF**. The checksum is calculated as an XOR over all frame bytes.

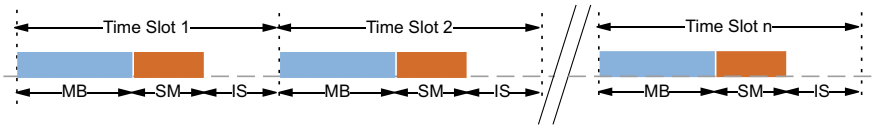


Fig. 9 Flow control timing diagram

Reliable delivery between endpoints
Usually, the reliability of a data link protocol is associated with error correction, frame acknowledgement, re-transmission, and similar techniques. Most hard-wired networks do not handle the reliability at this layer [11], and the same approach is adopted in LUN. Even though reliability is not handled here, the protocol allows the higher layers to do so. As any **MBF** is always followed by **SRF**, the **SRF** act also as an acknowledgement. If the **SRF** frame is not received or an error is detected, the master endpoint can then re-send the **MBF**.

Synchronous execution of all control commands
Any ROV needs at least three thrusters to manoeuvre. The camera usually has a tilt and pan servo motors. On the work class ROVs, one or more robotic arms must be precisely controlled. All these actions require precise and synchronous control. In a low-speed communication and a large number of endpoints, addressing the slave endpoints one by one takes time, and there is inevitably some delay between the first and the last endpoint commands. In order to eliminate this delay, the LUN allows all the devices to receive their command data simultaneously. This is achieved by the master endpoint sending the command data to all slave endpoints in a single **MBF**. All slave endpoints receive all command data simultaneously. This way, the servos and other control hardware execute the requested actions entirely in synch.

Variable length frames management
The **L** filed in **MBF** allows variable data filed length up to 256 bytes. As the master endpoint logic is fully aware of the slave endpoints response, the **SRF** can be of any length, provided it fits in the time slot window.

Simple addition of new endpoints
The frame format allows adding new slave endpoints without affecting the already existing ones. Adding additional slave endpoint requires modifying the master endpoint application software. The slave endpoints software, though, if correctly configured, does not need this. More details are presented in the next subsection, which gives an overview of the application layer of LUN.

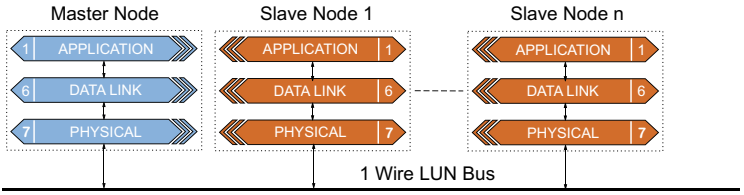


Fig. 10 3 layer LUN bus architecture

Fig. 11 LUN ID byte

MSB							LSB
C	ID6	ID5	ID4	ID3	ID2	ID1	ID0

5 Application Layer Serial Protocol

The 7 layer ISO model is often too complicated and unsuitable for small embedded networks. In the embedded world, usually, only 3 layers are used—application, system, and physical [12]; see Fig. 10.

The data link protocol is implemented in the system software layer, while the application layer takes care of the business logic. The application protocol is designed as follows:

Master broadcast frame MBF The control data in Fig. 1 consists of **MBF**s. As described in the previous subsection, the **MBF** starts with an **ID** field. This field consists of 2 parts, 7 bit slave endpoint address, and 1 bit configuration shown in Fig. 11.

Each slave endpoint has a unique address from 0 to 0x7F (0 to 127). Thus, up to 127 slave devices can be attached to the LUN bus. The 7 bit address defines which slave endpoint must reply after the **MBF**. The address "0" is reserved and not used, so the **MBF** frame has no reply if the **ID** = 0. The slave endpoint IDs must start from address "1".

- **ID** = 0—reserved
- **ID** = 1–127—slave endpoint address

The configuration bit **C**, which is the MSB, defines the modes of operation:

- **C** = 0—operation mode **OM**
- **C** = 1—configuration mode **CM**

In **OM**, slave endpoint expects a command to execute in the **DATA** field of the **MB** frame (see below). In the **CM**, the **DATA** field contains slave device configuration parameters.

The **L** field is a single byte, presenting the number of the following **DATA** bytes. Up to 255 **DATA** bytes can follow. **L** = 0 is reserved for requesting the slave endpoint to reply without execution of any commands. In **OM**, the slave endpoint replies with a status, in **CM** with the current configuration data.

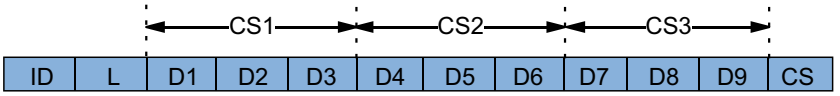


Fig. 12 LUN command data slots

- **C** = 0—operation mode **OM**

– **L** = 0—no command to execute; the slave endpoint replies with status only
– **L** > 0—in **DATA** field - command to execute, the slave endpoint replies with status also

- **C** = 1—configuration mode **CM**

– **L** = 0—no configuration sent, the slave endpoint replies with the current configuration only
– **L** > 01—configuration sent in the **DATA** field, the slave endpoint replies with the current configuration also

DATA bytes. Depending on the mode **OM** or **CM**, the **DATA** bytes can be either a command set or a configuration data. In the **CM**, the **DATA** bytes are destined to one slave endpoint only, with an address matching the **ID** field. The rest of the endpoints must ignore this frame. As the configuration varies between the slave endpoints, no standard format is possible. In **OM**, the **DATA** field contains the command set, which is broadcast to all slave endpoints. The addressing, i.e. which part of the **DATA** is intended to which slave endpoint, is achieved by splitting the **DATA** field into command slots **CS**. The position of the slot corresponds to the slave endpoint address, i.e. the data in the 3-rd slot is intended for a slave endpoint with address 3. The command slots can be any number of bytes, provided the total does not exceed 255. For the purpose of visualisation, 3 slave endpoints and 3 byte slots are chosen in Fig. 12.

The slave endpoints must calculate and extract from the corresponding slot the command data intended for them only. The only knowledge the slave endpoint needs is it's own address (**ID**) and the slot size. The equation for extracting the appropriate command bytes from the received frame is

$$\mathrm{sb} = \mathrm{ID} \times \mathrm{ss} + 2 \tag{1}$$

sb is the start byte of corresponding ID slave endpoint slot. The slave endpoint must read the next ss (slot size) bytes. This way, adding a new slave endpoint in the system is a simple 2 step process:

- The **MBF** is extended with another command slot
- The new slave endpoint address (**ID**) is the last **ID** + 1

Slave reply frame **SRF** The sensory data in Fig. 1 consists of **SRF**s. As described in the previous subsection, the **SRF** consists of 2 fields only data and checksum. The data filed is a sequence of arbitrary bytes which value depend on the slave endpoint function. Depending on the mode set by the **C** bit in the **MBF**, the data bytes are either status or configuration:

- **C** = 0—operation mode. The **SRF** returns the slave endpoint status. This could be a temperature reading, motor RPM, etc.
- **C** = 1—configuration mode. The **SRF** returns the current slave endpoint configuration. E.g. PID controller parameters.

6 Lightweight Underwater Network Architecture (LUNA)

The full ROV system network model is defined by putting together all the network components described in Sect. 3, see Fig. 13. In essence, this is the network from Fig. 5 with appropriate physical interfaces assigned to the endpoints. The HomePlug and the LAN to LUN bridge are dual interface network devices, bridging physically incompatible networks. The LUN protocol serves the low-speed subnet on the ROV. The master endpoint of the LUN can be anywhere, on the RCC or the ROV, depending on the requirements.

The proposed LUNA has several advantages over the trivial networks for ROV use:

- High flexibility
- Parallel high-speed and low-speed networks
- Low cost
- Low wire count
- Low connector pins count
- Easy adding new endpoints
- Easy programming
- Ability to use off-the-shelf hardware components.

7 Current Status and Future Work

The LUNA project started in 2016 to address the problem with the ROV systems high cost of ownership, which makes them unobtainable for small research groups and institutions. Two prototypes were built by 2020 as proof of a concept. The networking proved very reliable and the HomePlug technology allowed transmitting 1080p HD video stream over 750 m of a standard power cable. The low-speed network latency was tested by professional ROV operators, who confirmed no issue with the control.

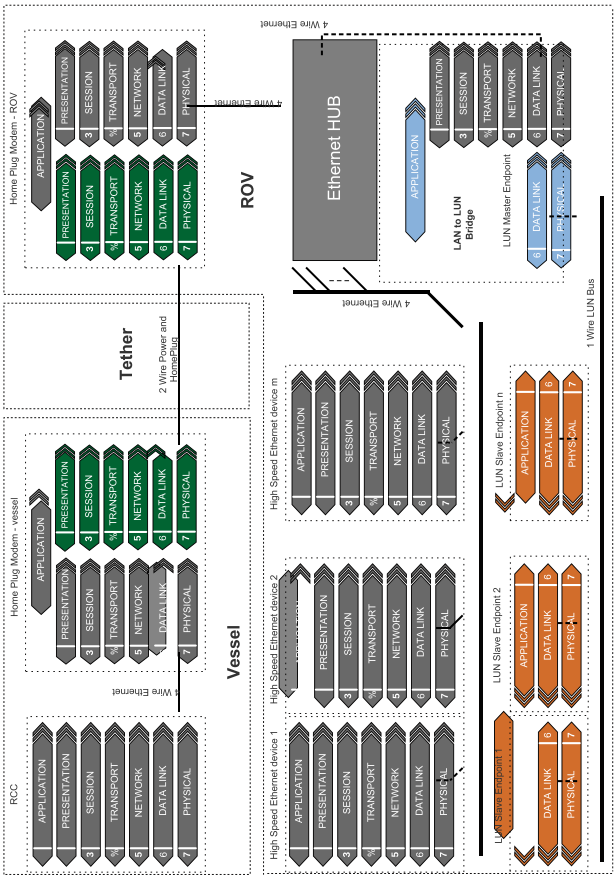

RCC
Vessel
ROV
Tether
2 Wire Power and HomePlug
4 Wire Ethernet
Home Plug Modem - vessel
Home Plug Modem - ROV
Ethernet HUB
LAN to LUN Bridge
LUN Master Endpoint
High Speed Ethernet device 1
High Speed Ethernet device 2
High Speed Ethernet device m
LUN Slave Endpoint 1
LUN Slave Endpoint 2
LUN Slave Endpoint n
1 Wire LUN Bus
APPLICATION
PRESENTATION
SESSION
TRANSPORT
NETWORK
DATA LINK
PHYSICAL

Fig. 13 LUNA

This encouraged a team of engineers and scientists, and in 2021, two commercial vehicles were ordered and built with a third-party company for a scientific project at the Technical University, Varna, Bulgaria. One limitation of the proposed architecture is the number of network endpoints. The thrusters and servos are above 12, the time slot must increase, which will also increase the latency. Most of the commercial ROVs have less than 8 thrusters/actuators, though, so this is not critical. The technique time complexity is low, and small embedded microcontrollers, NXP LPC1115 Cortex M0, are used for the low-speed subnet. This further reduces the cost of the solution. One improvement is planned for the next release of LUNA, replacing all the high throughput components in the ROV, like cameras, with HomePlug-enabled devices. This way, all physical interfaces will be either 1-wire LUN bus or 2-wire HomePlug, reducing further wiring and underwater connectors pin count.

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Multi-task and Multi-team Work Order Scheduling Using Non-dominated Sorting Genetic Algorithm II

Triet Le, Hai Vu, Phu Nguyen, Duong Nguyen, Thien Pham, and Tho Quan

Abstract Work orders in the maintenance field and in general resource-constrained problems have integrated multi-objective scheduling in order to produce an efficient job routine. One of the current drawbacks of today's scheduling apparatuses often introduces conflicting schema and illogical arrangements. In this research, non-dominated sorting genetic algorithm version II (NSGA-II) is proposed for work order scheduling applications, using a set of five-step genetic-oriented workflow. The set includes data (chromosome) representation, high-fitness parents selection, adjusted binary crossover, mutation, and survival selection. NSGA-II is investigated in conjunction with multi-team and multi-task directives or MT^2WOS-NSGA-II. The scheduling results show noteworthy improvements compared to traditional NSGA-II with binary n-crossover, having minimum timing and resource constraints violation, and reducing execution hours by approximately 300 units.

Keywords Evolutionary computation · Work order scheduling · Hybrid multi-predictive modeling · Multi-objective optimization · Non-dominated sorting genetic algorithm

T. Le (✉) · H. Vu · P. Nguyen · D. Nguyen · T. Pham · T. Quan
Faculty of Computer Science and Engineering, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam
e-mail: hai.vu.tharios19@hcmut.edu.vn

P. Nguyen
e-mail: phu.nguyen7122002hp@hcmut.edu.vn

D. Nguyen
e-mail: nhduong.sdh21@hcmut.edu.vn

T. Pham
e-mail: pcthien.sdh20@hcmut.edu.vn

T. Quan
e-mail: qttho@hcmut.edu.vn

Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam
e-mail: triet.lecsk20@hcmut.edu.vn

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1 Introduction

1.1 Problem Statement

Job scheduling is one of many optimization frameworks in the field of computer science. Scheduling a set of jobs requires the output to be both feasible and in logical ordering to ensure all available resources are utilized [1]. Work orders perform on a similar setup akin to job scheduling methodology. However, their strict timing, concurrency, and multi-tasking aspects enforce work routines to be flexible in adjusting its rhythm depending on round-the-clock resources. This research paper proposes *non-dominated sorting genetic algorithm—version 2*, or NSGA-II, to address the issue of multi-task, multi-team scheduling, and optimizing for work orders.

Multi-objective scheduling and optimization for work orders have been studied extensively over numerous scientific research. However, they are cumbersome to apply and require extensive external resources, which can further complicate the ongoing directive. This exact motivation pushes the discovery for newer, better, cheaper, and resource-compliant methods for the mission, enabling a vast application of scheduling paradigm with ease of managing.

Section 1 explains preliminaries of multi-task, multi-team scheduling, as well as its objectives and mathematical approaches. Section 2 briefly walks through foundational works previously attempted for multi-objective-oriented scheduling. Section 3 describes the main method of NSGA-II frameworks, providing enhanced customization toward scheduling optimization. Section 4 provides experimental results, both statically and graphically. Section 5 concludes this paper and its future remarks toward a better multi-scheduling directive.

1.2 Problem Definition

This paper focuses on data-driven approach for task scheduling. Hence, the data collection methods and the techniques of embedding them in the algorithm play an important role. It is preferable to view the technique taxonomy under the lenses of strategic scheduling. NSGA-II operates on a hybrid strategy, combining both static and heuristic methods, while negating job characteristics. Figure 1 represents the scope for solving multi-task, multi-team scheduling problem.

1.3 Dataset Key Features

Due to the complex nature of multi-objective optimization, curated and feature-relevant data is required for proper scheduling. In this paper, the applied data is a composite of predominant features, which are copulated into an ordered string. The representation is shown in Table 1 and reproduced into an output set of logical ordering.

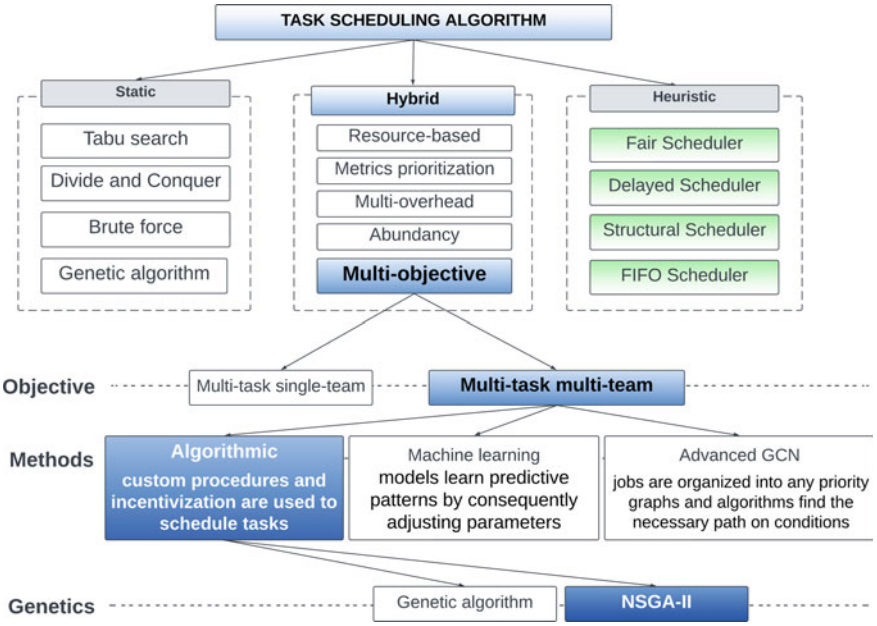

Fig. 1 Taxonomy tree for multi-task, multi-team-oriented scheduling [2]

Table 1 Data features and their corresponding description

Features	Description
Team	The team consists of maintenance workers belong to a specific location of interest, and each is assigned to a task
Targstartdate, targcompdate	Any assigned task has a starting time and an ending time requirement
Estdur	Estimated duration, in hour, of a given task
Siteid	The location assigned to a task
Resource	The maximum number of personnel per team allotted for each location

1.4 Objectives

Set attributes—Given the specified inputs and outputs, the scheduling framework in the context of this research is summarized into a set of requirements in Table 2. Furthermore, define the following notations:

$$f_{\text{actual}}(t_i) \rightarrow D \qquad f_{\text{pred}}(t_i) \rightarrow D \tag{1}$$

$$\text{and} \quad g_{\text{actual}}(t_i) \rightarrow D \qquad g_{\text{pred}}(t_i) \rightarrow D \tag{2}$$

Table 2 Set definitions and their description and mappings

Set	Element	Range	Set mapping	Description
T	t_i	$i \in \mathbb{N}$		Set of tasks
E	e_i	$i \in \mathbb{N}$	$f_{\text{dur}}(T) \rightarrow E$	Set of time intervals
τ	τ_j	$j \in \mathbb{N}$	$f_{\text{team}}(T) \rightarrow \tau$	Set of teams
S	s_k	$k \in \mathbb{N}$	$f_{\text{loc}}(T) \rightarrow S$	Set of workplaces
D	d_t	$t \in \mathbb{N}$		Set of date during the scheduling process
P	p_m^{ijkt}	$m \in \mathbb{N}$	$f_{\text{per}}(T, \tau, S, D) \rightarrow P$	Set of work personnel with t_i, τ_j, s_k, and d_t formal quadruplets
R	r_n^{jkt}	$n \in \mathbb{N}$	$f_{\text{res}}(\tau, S, D) \rightarrow R$	Set of available resources with τ_j, s_k, and d_t formal triplets
Z	z_c^{it}	$c \in \mathbb{N}$	$f_{\text{plt}}(T, D) \rightarrow Z$	Set of work personnel with no reference to their location and team

as the functions for determining actual and predicted output of the starting time and ending time for task t_i, respectively. With:

$$\lambda_i = (f_{\text{actual}}(t_i), g_{\text{actual}}(t_i)) \in \lambda \tag{3}$$

$$\theta_i = (f_{\text{pred}}(t_i), g_{\text{pred}}(t_i)) \in \theta \tag{4}$$

λ is the set containing the actual starting and ending date of task t_i, while θ is the set containing the predicted counterparts.

Optimization targets—Allot the maximum number of working people per day and not exceeding the provided resources.

$$\text{Maximize} \quad \chi = \sum_{i=1}^{|T|} \sum_{t=1}^{|D|} \sum_{r=1}^{|Z|} z_r^{it} \tag{5}$$

$$\begin{aligned} \text{subject to} \quad & \chi \leq |R|\,, \\ \text{where} \quad & R = \left\{ r_n^{jkt} \mid (j,k,t) \in \tau \cup S \cup D; n \in \mathbb{N} \right\} \end{aligned}$$

Hard constraints—All of the conditions below must satisfiy; they include:

- The starting time and completion time of task t_i must be in the accepted time allotment δ. In mathematical terms:

$$|\lambda - \theta| \in \delta \tag{6}$$

- Number of workers must not exceed provided resources, or $\chi \leq |R|$.

Soft constraints—The conditions below can or cannot satisfy; they include:

- Minimum total execution time, of which SCHEDSTARTDATE variable reaches minimum value.

2 Related Works

Brute force algorithm—Brute forcing is one of many efficient ways to find the optimal solution by selecting the best candidate from resulting sets. Its derived variation uses the branch and bound method to narrow down *current best* values while discarding outliers. Although this can reduce the number of iterations, in the worst case, it still carries complexity of branch and bound due to extensive iteration through the search space [3].

Divide-and-conquer algorithm—The breakdown of the large problem into smaller problems can be attributed to a priority-based schema, in which urgent task will be divided further down the hierarchy, before moving to the next lower priorities. The results are complied up the division tree to get the desired output.

Heuristic algorithm—Scheduling problems that apply heuristic method are lower cost of computing than other conventional methods. Its output solution might not be the most optimal; however, it is the best approximation [4, 5]. Heuristic state space bears resemblance to an ordered tree structure, and a function must be defined to evaluate the goodness of a scheduled day, such as increasing or decreasing the number of workers on the scheduled day.

3 MT^{2}WOS-NSGA-II

3.1 Operators of Genetic Algorithm

Genetic algorithm is a set of algorithms inspired by the natural evolution process [6], and they operate on the fitness levels of genomes [7]. Using the collection alone for multi-objective optimization is in a difficult realm because not all objective functions are independent [8, 9]. In some cases, the increment of one objective function will lead to deterioration of the others. NSGA-II solves this problem by extending the definition of dominance relationship between sets of solutions [10, 11].

3.2 Preliminaries

The NSGA-II Framework—The steps of NSGA-II are outlined in Algorithm 1 where similar procedures of regular genetic algorithm are repeated. The expansion allows for off-springs generation Q_t to be categorized into multiple Pareto fronts instead of being randomly chosen. Individuals whose distance are closest from the optimal front, after performing crowded tournament selection paradigm, are transferred to the next generation $t + 1$.

Algorithm 1 NSGA-II Framework

1: Create initial population $P^0 = \{P_1, \ldots, P_n\}$
2: $t = 0$
3: **while** ¬StopCondition() **do**
4: $Q_t \leftarrow$ crossover(P^0)
5: $Q_t \leftarrow$ mutate(Q_t); $|Q_t| = |P_t| = N$
6: $R_t = P_t \cup Q_t$
7: $F \leftarrow$ NonDominatedSorting(P)
8: **for** $i* \leftarrow 1$ to n **do**
9: **if** $\sum_{i \leftarrow 0}^{i^*-1} |F_i| \leq N$ $\&\& \sum_{i=0}^{i^*} |F_i| \geq N$ **then**
10: break;
11: **end if**
12: **end for**
13: $F \leftarrow$ CrowdingDistanceSorting(F_{i*})
14: M_t: member with highest crowding distance in F_{i*}
15: $|M_t| \leftarrow N - \sum_{i=0}^{i^*-1} |F_i|$
16: $P_{t+1} \leftarrow (\cup_{i=1}^{i=i^*-1}) \cup M_t$
17: **end while**

Algorithm 2 shows the sorting algorithm using elitist strategy in NSGA-II to create sets of Pareto frontiers. For each frontier, each pair of solution is compared with their dominance attribute using crowd distancing method. If a point P_i dominates a point P_j, P_j is added to the set SD; otherwise, count the points NC of which P_i was dominated. The most dominant solutions are put into the first frontier F_1, then according to the order of dominance between the neighboring individuals, assign them to the remaining frontier ranks F_2 to F_n.

Chromosome representation—The representation for the the problem is compiled into a cohesive chromosome string with its components as follow:

- **WONUM**: Task ID number.
- **TARSD**: Main starting date.
- **TARED**: Main ending date.
- **SHIFT**: Predicted starting shift.
- **RAND_DATE**: Predicted starting date.
- **TEAM_ASSIGN**: Predicted assigned team.
- **NUM_PEOPLE**: Predicted number of workers.

Crossover—In this paper, *simulated binary crossover* is applied for simulating the operation of the single-point crossover operator on binary strings [12]:

Algorithm 2 Elitist non-dominated sorting (ENDS)

Require: $P = \{P_1, P_2 \ldots, P_n\}$: set of individuals
Ensure: $F = \{F_1, F_2, \ldots, F_n\}$: set of ranks

procedure ENDSFUNC(P)
  for $i \leftarrow 1$ to N **do**
    $NC(P_i) \leftarrow 0$
    $SD(P_i) \leftarrow \emptyset$
  end for
  for $i \leftarrow 1$ to N **do**
    for $j \leftarrow 1$ to N **do**
      if $P_i \preceq P_j$ **then**
        $SD(P_i) \leftarrow SD(P_i) \cup P_j$
      else if $P_i \succeq P_j$ **then**
        $NC(P_i) \leftarrow NC(P_i) + 1$
      end if
    end for
  if $NC(P_i) = 0$ **then**
    $F_1 \leftarrow F_1 \cup P_i$
  end if
  end for
  $k \leftarrow 1$
  while $F_i \neq \emptyset$ **do**
    $F_{k+1} \leftarrow \emptyset$
    for all $p \in F_k$ **do**
      for all $q \in SD_p$ **do**
        $NC(q) \leftarrow NC(q) - 1$
        if $NC(q) = 0$ **then**
          $F_{k+1} \leftarrow F_{k+1} \cup q$
        end if
      end for
    end for
    $k \leftarrow k + 1$
  end while
end procedure

1. Genarating a random number u between 0 and 1
2. Calculating parameter β

$$\beta = (2u)^{\frac{1}{n_c+1}} \quad (\text{if } u \leq 0.5)$$

$$\beta = \left[\frac{1}{2(1-u)}\right]^{\frac{1}{n_c+1}} \quad (\text{otherwise})$$

3. Calculating children x_1^{new} and x_2^{new}

$$x_1^{\text{new}} = 0.5 \times [(1+\beta)x_1 + (1-\beta)x_2]$$
$$x_2^{\text{new}} = 0.5 \times [(1-\beta)x_1 + (1+\beta)x_2]$$

The non-negative real number n_c is the distribution index. A large value increases the likelihood of producing near parent solutions, whereas the opposite permits the selection of distant answers as child solutions.

Mutation—Polynomial mutation is used for this specific purpose, which is proposed by Deb and Argawal in 1999 [12]. The alteration strategy superimposes a user-defined index parameter. For a solution p, a mutation p' is generated with u randomly set between 0 and 1:

$$p' = p + \theta_L(p - a) \quad (\text{if u} \leq 0.5)$$
$$p' = p + \theta_R(b - p) \quad (\text{otherwise})$$

Parameters θ_L and θ_R are calculated by:

$$\theta_L = \left\lfloor (2u)^{\frac{1}{n_m+1}} \right\rfloor - 1 \quad (\text{if u} \leq 0.5)$$

$$\theta_R = 1 - (2-2u)^{\frac{1}{n_m+1}} \quad (\text{otherwise})$$

where n_m is the user-defined index parameter

4 Experiment Results

In this section, all aforementioned techniques to perform multi-objective scheduling using NSGA-II workflow are applied for a work order dataset. Based on conducted experiments, both qualitative and quantitative factors are analyzed. The performance of NSGA-II and traditional genetic algorithm flow is compared.

4.1 Experiment Setup

Listed parameters—Table 3 shows the environment configuration for the conducted experiment.
Output requirements—Below are the verification criteria for the experiment session using the 4-tuple output (out_1, out_2, out_3, out_4)

- *Output 1*: the number of jobs that violate deadline constraints.
- *Output 2*: the number of shifts whose total number of workers exceeds the provided resources, preferrable minimal value.
- *Output 3*: total execution time of each task.
- *Output 4*: timeline of the scheduling process.

4.2 Statistical Scheduling Results

NSGA-II with adjusted crossover—The algorithm is executed for at most 2750 iterations, and Fig. 2 describes these scheduling results. For the first output parameter,

Table 3 Environment configuration for the experiment

Experimental parameters	Execution/evaluation method
Predicted objectives	SHIFT: Predicted starting shift
	RAND_DATE: Predicted starting date
	TEAM_ASSIGN: Predicted assigned team
	NUM_PEOPLE: Predicted number of workers
Length of tasks	2116
Population size	20
Chromosome representation	NSGA-II Adjusted: Decimal string
	NSGA-II Binary: Bit string
Crossover operation	NSGA-II Adjusted: Simulated binary crossover
	NSGA-II Binary: n-point crossover
Mutation operation	NSGA-II Adjusted: Polynomial mutation
	NSGA-II Binary: Bit-flipping
Total EPOCHs	1, 50, 100, 200, 500, 1000, 1500, 2000

the number of deadline violations approaches 0 in fewer than 100 runs, showing effective assignments. The second output witnesses an overall downtrend as more iterations are followed. Similar cases are seen for the third and fourth outputs, except the timelines in the latter fixed its value at 61 days.

NSGA-II with binary n-crossover—All outputs in Fig. 2 experience delayed downtrend than its adjusted counterpart. The marginal decrease rate for every output is insignificant for every 100 EPOCHs, despite operating on a similar timeline with adjusted NSGA-II.

4.3 Graphical Scheduling Results

All scheduled tasks are presented in Gantt charts format to dissect how each NSGA-II algorithm performs with respect to the number of overlaps. Let $J_i(\alpha, \beta)$ describe a job whose identifying tuple i, α, and β defines specific job attributes, with α number of people and β time duration for the task to finish. The first 15 jobs from each approach of NSGA-II are shown for the following sections.

NSGA-II with adjusted crossover—Fig. 3 enlisted the tasks the algorithm has arranged into a cohesive 31-day timetable. No tasks are seen to try to overhead one another. This seemingly connected behavior ensures tasks are done efficiently with minimum resources spent on each workforce.

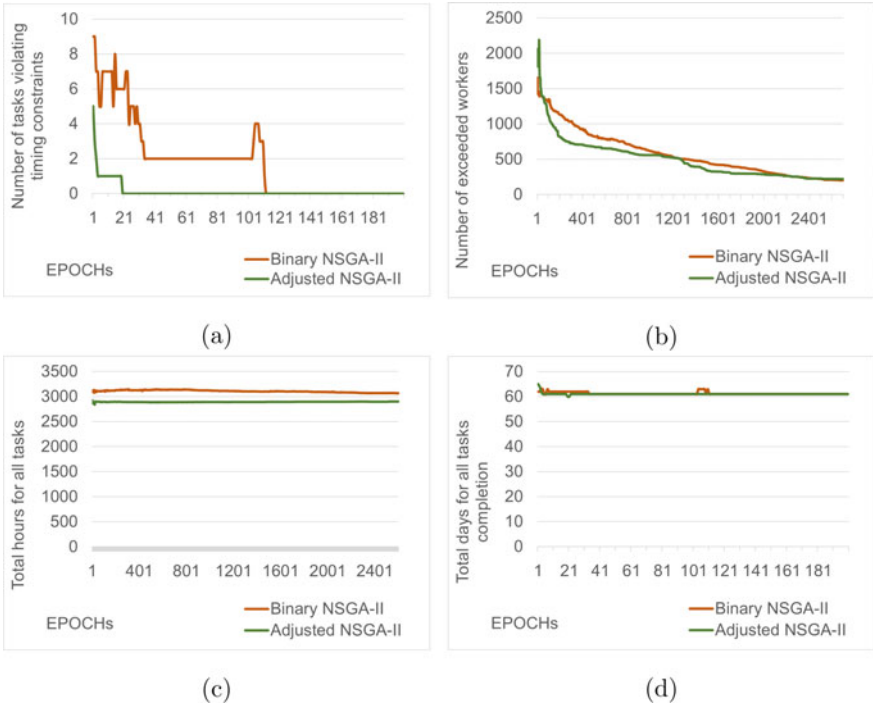

Fig. 2 Line plot for all outputs comparison with adjusted NSGA-II and binary n-crossover NSGA-II. **a** Output 1. **b** Output 2. **c** Output 3. **d** Output 4

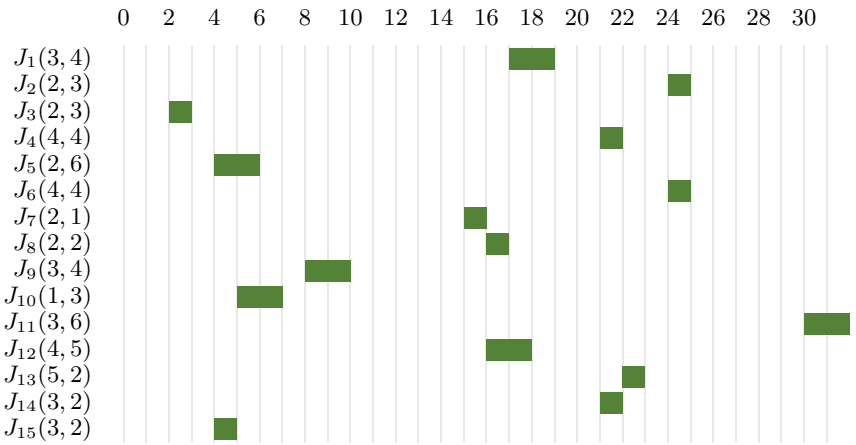

Fig. 3 Gantt schedule for the first 15 jobs using adjusted NSGA-II

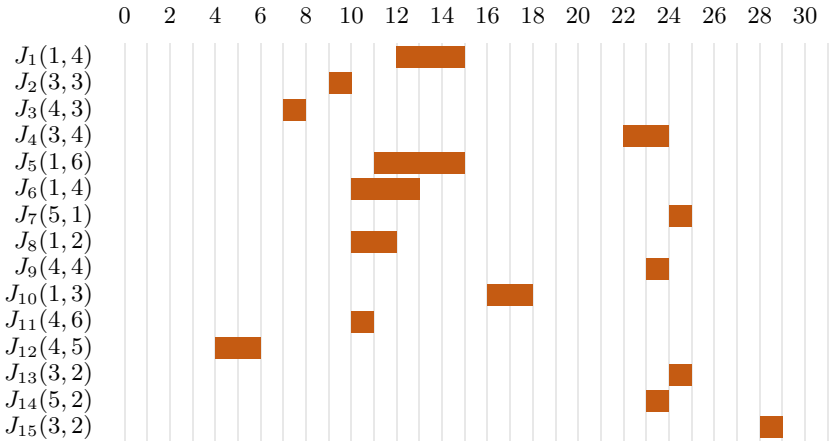

Fig. 4 Gantt schedule for the first 15 jobs using binary n-crossover NSGA-II

NSGA-II with binary n-crossover—Fig. 4 performs arrangement similarly to its adjusted variant. However, overlapping is more prominent, and tasks can be observed trying to overhead each other during a single day. At the same time, multiple tasks are allowed to start at same day, mixing with a lower and higher number of α workers, resources are consumed dramatically, and efficiency are below acceptable range.

5 Conclusion

This paper has introduced NSGA-II, its techniques on the foundation of genetic algorithms to empower multi-task, multi-team scheduling-related challenges, requiring speed, accuracy, and efficiency. A deep understanding about real work order data enables us to select useful corpus to optimize our model. Different outputs to evaluate the scheduling strategy have been enlisted, taking inspiration from comprehensive discussion to find suitable evaluation technique and greater adaptability. The research has focused on three focal points (1) introduced different organization to solve task scheduling problem by using NSGA-II algorithms, (2) applied NSGA-II algorithm in the provided set of data to solve key problems, and (3) combined multiple algorithms for each part of our research.

Throughout the research progress, several shortcomings are present. The paper emphasizes on the original take of NSGA-II with extended customization for job scheduling with minimal consideration to its variants, such as steady-state, parallel, random, or adaptive NSGA-II and future versions. Furthermore, due to hardware limitations, the experiment quickly runs into threshold boundary with high-value configurable parameters. These factors do not affect the foundational results of this paper, only to serve as future extensions and assist in comparison.

In light to address the challenges and extend the impacts of this research, future scheduling frameworks with comparable or greater performance shall be investigated, along with different customization of NSGA-II methodologies, advanced crossover, mutation, and selection techniques. On top of it, more curated features are introduced, allowing for vast population diversity, better determination of performance metrics, and the overall scheduling apparatus.

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Knowledge Graphs for News Recommendation in a Local News Organization

Kunitoshi Igarashi, Israel Mendonça, and Masayoshi Aritsugi

Abstract In this paper, we investigate the efficacy of using knowledge graphs for news recommendation. Small institutions usually do not have the required amount of data needed to build robust recommender systems. Knowledge graphs allow us to recommend news, based on their content, with small amount of data. The graph can be created using related data and calibrated to use domain-specific data. Despite gaining popularity recently, the problem of how to construct knowledge graphs has not been adequately addressed. In this work, we consider the effects of using sentences extracted from the titles and the bodies of news in different languages. Our test case is focused on news data provided by a local news organization in Japan. We develop an effective knowledge graph construction method for the available data that is used by a recommender systems. We evaluate the effectiveness of this system by predicting the clicks of users.

Keywords Knowledge graph construction · Text mining · Personalized news recommendation

1 Introduction

Recommender systems have been a flagship example on how big data has been employed to improve user's experience when browsing. Despite solutions not being new, there are still many hurdles when small organizations try to implement of-the-shelf solutions into their datasets. Cold-start is a potential problem when the amount

K. Igarashi (✉) · I. Mendonça · M. Aritsugi
Kumamoto University, Kumamoto 860-8555, Japan
e-mail: igarashi@dbms.cs.kumamoto-u.ac.jp

I. Mendonça
e-mail: israel@cs.kumamoto-u.ac.jp

M. Aritsugi
e-mail: aritsugi@cs.kumamoto-u.ac.jp

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of data available to recommender systems is not sufficient for it to draw inferences. It is one of the most common problems for small organizations with limited amount of data.

One of the main users of recommender systems is online news publishers. Such entities provide convenient news services timely to users. In Japan, it is common to have local news organizations that report daily on local activities and events. There are many of those in Japan, and most of them provide niche information to its readers. One of the required services by users to these organizations is the personalized recommendation of news [7]. However, as the information is regional, it is hard to use a generic system to recommend news effectively. In this paper, we build a recommender system for the Kumamoto NichiNichi Shimbun,[1] a local news organization in Japan. We explore how can local data offered by the organization can be used to recommend articles that can be of the interest of users.

As mentioned before, the target news articles of this paper are in silos at local news organization. When comparing to big news distributing platforms such as Microsoft News, [2] the task of modeling good semantic information for recommendation is strictly harder due to the cold-start problem. There have been studies of using knowledge graph embeddings to overcome this problem. Reference [5] proposes a deep knowledge-aware network (DKN) for news recommendation. We borrow the DKN framework and attempt to develop appropriate knowledge graph construction.

DKN works by exploiting the entities contained in the titles of news. This is due to mainly the processing time it would require to process the body of the articles as well. However, when the data is not as large and the body of the news can be processed in a reasonable amount of time, the following question arises naturally: For small datasets, can using the body of text, which trades-off processing time for increased richness of information, achieve better recommendations when compared to systems that uses the titles only?

As shown in this paper, we argue that just blindingly adding information and expanding the search space does not automatically translate to an increment in performance. We explore this phenomena and present a method that takes advantage of the richness of information contained on both: the title and the body of news to generate high quality recommendations. Also, we investigate variants of the knowledge graph construction and how it impacts performance.

The rest of this paper is organized as follows: Section 2 mentions related work. Section 3 describes three variations of knowledge graph construction we investigate in this paper. Section 4 reports and discusses results of experiments. Finally, Sect. 5 concludes this paper.

[1] https://kumanichi.com/.

[2] https://microsoftnews.msn.com.

2 Related Work

News recommendation has been studied recently in both academia and industry, e.g., [4, 6]. In contrast to most of the recent studies that have to consider treating a huge amount of news and users, the target of this study is about online news services by a local news organization, in which news and users are supposed to be relatively more specialized and their numbers smaller, compared to big news distributing platforms. As described in [7], there are mainly two things to model in news recommendation: news modeling and user modeling. We focus on news modeling in this paper.

As one of the characteristics of news offered by a local news organization is that the number and range of news are limited, and thus it tends to be hard to model news appropriately. In this paper, we borrow the deep knowledge-aware network (DKN) proposed by [5] and construct the network with using news offered by the local news organization. We investigate into construction and usage of the knowledge graph.

3 Knowledge Graph Construction

In this section, we explain how we created the knowledge graph to make recommendations. Our methodology is based on DKN [5], where the graph is constructed by using information extracted from the title of news. We then borrow ideas from recent studies, e.g., [3, 6] in which they state that in addition to the title, the body of the news can be used effectively. We create two variations of such graphs: One focused on the English language and uses features that are common for the language, and another one focus on the Japanese language (Fig. 1).

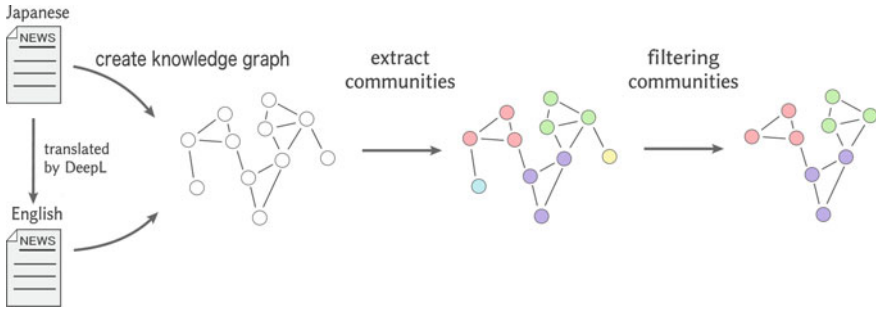

Fig. 1 Workflow

3.1 Language-Based Knowledge Graphs

Different languages have different characteristics, which makes them require different types of processing. As the news we are treating (offered by Kumamoto NIchiNichi Shimbun) are written in Japanese, it is natural to construct a knowledge graph using text processing techniques to Japanese. However, most of the research regarding knowledge graph uses English, and there may be some benefits that will be lost when using only Japanese. For this purpose, we decided to test the differences in performance of using each language to build recommender systems.

Our inspiration comes from the machine translation field for multiple languages, in which sometimes a pivot language is used to treat the target language [2]. Thankfully, English is a global language, and there are many useful tools for treating it, including machine translation tools. We used a translation tool to convert our corpus from Japanese to English.

As we mentioned before, there are differences when treating each language. In the next two sub-sections, we will detail how we created the nodes and edges that compounds the knowledge graphs for each language.

English-Based Knowledge Graph Creation The first part of our work focuses on creating the knowledge graph using English. To do so, we first translated news written in Japanese into in English using DeepL translation.[3] Every sentence was then processed to create triples. Each triple is composed by a *subject*, an *object*, and a *verb*. Our text processing procedure looks for these elements. The extracted *subject* and *object* are supposed to be related entities and the *verb* to be the indicator of the relation, and thus, we set the *subject* and *object* as nodes and *verb* as edge. For cases in which either the *subject* or *object* could not be extracted (and consequently a triple would not be created), we create a placeholder node so that the information of the entity is not lost. Figure 2 illustrates the normal process in which the entities are all extracted.

Japanese-based Knowledge Graph Creation For the Japanese language, we initially used the same process as the English language one, however, the results were much worst, and no proper recommendation could be made. The main cause of the problem is due to the number of extracted entities that was too small when compared to English. This made the algorithm having difficulties identifying points of interest and making meaningful connections between the news.

We then moved to a different approach for constructing the graph specifically for Japanese language: We decided to make us of all entities, and nouns extracted from a sentence; Then, we connect each of them with an extracted verb from the sentence in the graph. We used GiNZA[4] for the extraction. We set the entities as nodes and the relations. Additionally, it is possible for one sentence to generate more than one triple. Similarly to English, if enough nodes could not be extracted (and consequently

[3] https://www.deepl.com/translator.

[4] https://megagon.ai/ginza/.

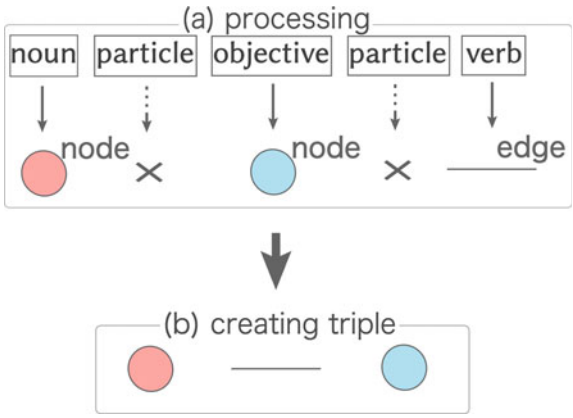

Fig. 2 Triple creation process for English Language: First, we do part-of-speech tagging to identify the node candidates; then, we extract the subject and object of the phrase; finally, the verb is used to create an edge between them

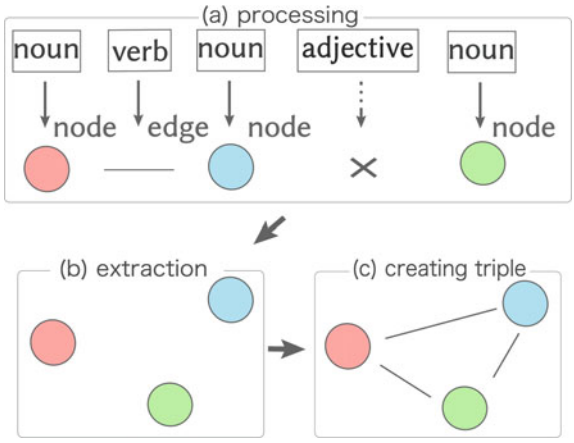

Fig. 3 Triples creation in Japanese. Differently from the English processing, we use all the entities from the sentence, and multiple triples can be created from just one sentence

a triple would not be created), we create a placeholder node so that the information of the entity is not lost. Figure 3 illustrates the normal process in which the entities are all extracted.

3.2 Communities

One of the problems of creating too many triples is that the graph becomes too dense and noisy. This cause many news, which are not likely lined, to be recommended because there are many unimportant entities in their relationship. To mitigate this proble, we take account of communities at the graph construction time; we used the Louvain method [1] to try to separate the nodes into regions of interest and then use it to make recommendations. For recommending, we analyze the news read by the

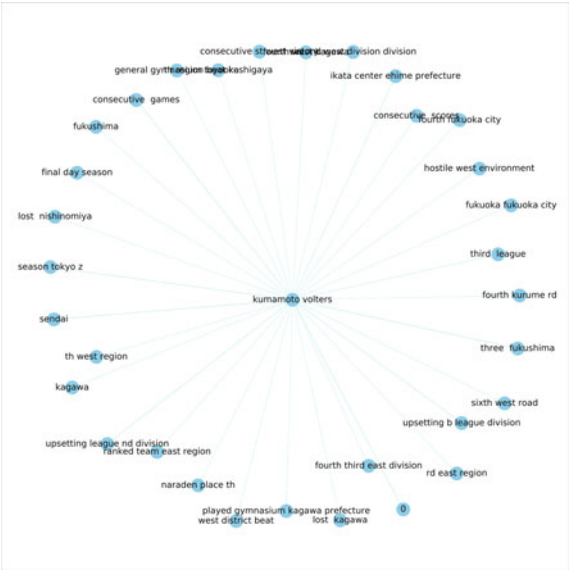

Fig. 4 Subgraph example

user and extract the entities from it. We then remove the entities that did not included in the extracted communities, thereby refining the knowledge graph. We examine the effectiveness of this refinement in the experiments in the next section.

3.3 Subgraphs

A news article is expressed as a subgraph in the knowledge graph constructed in Sect. 3.1, and the subgraph is then used for recommendation generation. In this section, we will give an example how we construct the subgraphs: Given a news article entitled "Kumamoto Volters lose for the first time in three games", an entity, "kumamoto volters", is extracted. We then extract the entity from the knowledge graph and finally construct a subgraph, as shown in Fig. 4 where labels of edges are omitted. Such subgraph can allow us to generate recommendation of not only news directly relating to the entity but also those relating to the entity through entities of the subgraph, thereby reducing the effect of the relatively small number of news articles a local news organization would have.

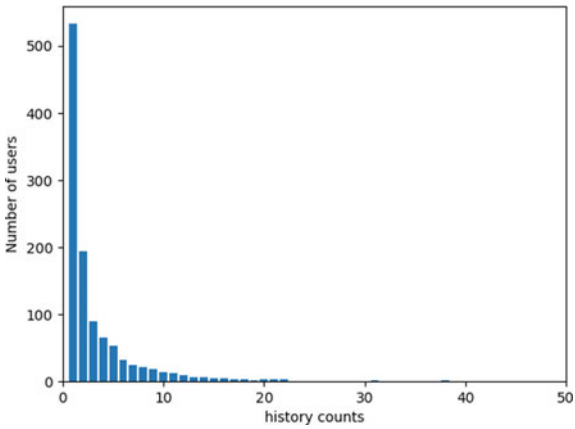

Fig. 5 History counts distribution

4 Experiments

In this section, we detail our experiments. Section 4.1 explains the settings used for the experiments, and Sect. 4.2 discusses the initial results of the usage of the created knowledge graphs.

4.1 Settings

The dataset used to create the knowledge graph consists of news published in a period of time of three months between August and October of 2021. For the recommendation, we used monthly access logs of November and December of the same year. The access logs include IDs of 1359 users and information regarding URLs that the users accessed. Similarly to [5], we used $\frac{20}{21}$ access logs for training and the rest for testing where we evaluate AUC of click rate prediction.

Figure 5 shows the distribution of user histories used in this study. We observed that the majority of users had very few entries, i.e., the number of access to news was small. To examine how such small numbers of logs affected to the results, we performed experiments of data with excluding users whose history counts were equal to or less than 0, 1, 2, and 3. Note that the case of 0 was the case of using the whole logs, that is, no user exclusion. The numbers of log data of the 0, 1, 2, and 3 cases were 8974, 7957, 7159, and 6600, respectively.

Table 1 AUCs when applying knowledge graphs in Japanese and English

	History counts			
	0	1	2	3
JP-title	0.57	0.55	0.54	0.52
JP-full	0.55	0.55	0.55	0.51
EN-title	0.59	0.59	0.57	0.56
EN-full	0.57	0.57	0.59	0.57

Table 2 Statistics of knowledge graphs in English and Japanese

	# entities	# triples
Japanese	59,332	798,005
English	94,671	113,065

Table 3 Average numbers of triples in a subgraph

	# triples
JP-title	39,931
JP-full	143,382
EN-title	93
EN-full	305

4.2 Results

Knowledge Graphs in English and Japanese In this section, we compare the results of the recommender system using knowledge graphs in English and in Japanese. Table 1 shows AUCs obtained by using knowledge graphs constructed from titles only (TITLE) or titles and bodies (FULL) in Japanese and English with varying history counts of excluded users from 0 to 3 cases. Note that in the following, EN-TITLE corresponds to the original DKN [5].

When the trained data includes logs of users with low history counts, knowledge graphs constructed with titles only gave higher AUCs than those with titles and bodies. The number of entities was about one or two in graphs with titles only, while that was about more than five in graphs with titles and bodies. Comparing the tables, we observe that knowledge graphs in English gave higher AUCs than those in Japanese. This may indicate that translating in high resource languages could improve the quality of knowledge graphs. As shown in Table 2, the knowledge graph in Japanese was much more complex when compared to the one in English. Also, Table 3 shows average numbers of triples in a subgraph. We therefore expect that a complex knowledge graph in the way of construction would have worse AUC.

Knowledge Graphs with/without Communities One of the reasons why a complex knowledge graph could not give good results is that it would have not so important relations between entities. To remove unimportant relations from knowledge graphs,

Table 4 Knowledge graphs in Japanese and English with/without communities

		# communities	# triples	# entities
Japanese	Without communities	641	798,005	59,332
	With communities	91	553,971	58,033
English	Without communities	23,822	113,065	94,671
	With communities	1305	55,197	43,993

Table 5 Average numbers of triples in a subgraph

	# triples
JP-title	16,416
JP-full	66,865
EN-title	48
EN-full	200

Table 6 AUCs when applying knowledge graphs with communities in Japanese and English

	History counts			
	0	1	2	3
JP-title	0.57	0.55	0.54	0.52
JP-full	0.58	0.56	0.54	0.52
EN-title	0.59	0.59	0.56	0.56
EN-full	0.59	0.59	0.55	0.51

we introduce the concept of community in the knowledge graph construction; communities are extracted by the Louvain method [1] from a knowledge graph and then entities which are not included in the communities are excluded from the graph. Table 4 shows statistics of knowledge graphs in Japanese and English with/without communities. Table 5 shows average numbers of triples in a subgraph with communities. We observe that the numbers of entities and triples in the graphs and the average numbers of triples in a subgraph were reduced by taking account of communities in the construction.

The results of AUCs of using knowledge graphs in Japanes and English with communities are reported in Table 6. Comparing Table 1 with Table 6, we observe that communities have the ability to improve AUCs in both Japanese and English, especially when using not only titles but also bodies in constructing knowledge graphs.

Processing Times In the case of this study, all original news were written in Japanese; it takes time to translate if we want to treat them in another language, such as English. For example, it took about four hours to translate 452 news of Kumamoto NichiNichi Shimbun in English in a batch manner using DeepL on our machine. Note that the batch processing was for the sake of experiments, and in the real life, the system

would only need to translate one news for recommendation. This would drastically reduce the translation time.

Another cost to be taken into account is for executing preprocessing on news, such as parsing news and extracting entities from them. The necessary times depend on characteristics of languages and tools for them. For example, it took about one second for the processing of the news in English, while it took about 20 min in Japanese.

5 Conclusions

We investigated construction of knowledge graphs used for news recommendation in a local news organization where the numbers of news and active users are relatively small. The experimental results showed that by exploiting the concept of communities a knowledge graph constructed with the whole data of news in a high resource language could allow us to generate good news recommendation. According to this, small news organizations can provide better recommendation based on knowledge graphs with communities.

Recently, our system has been employed the news site of Kumamoto NichiNichi Shimbun in practice, and we have begun collecting and analyzing user behaviour with/without our system. We intend to further improve the performance of knowledge graphs based on the results. Also, we have to improve our system to be able to recommend to new users. The current system cannot recommend to new users because it needs history to create subgraphs of news.

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Hospital Funding System by Crowdfunding Website

Firman Pribadi, Arni Surwanti, Aldi Abilawa, Agus Samsudin, and Wen Chung Shih

Abstract The purpose of this survey research is to find out how far the hospital leadership knows about the crowdfunding platform all this time. Then, the next goal is to find out how much respondents are interested in getting involved in a crowdfunding platform if the Muhammadiyah organization sets a crowdfunding platform as a funding source for its health services. Because actually, Muhammadiyah has a vital funding source but not and wholly organized. Therefore, a great system is required to maintain the Muhammadiyah organization's goals. This study is a survey research with questionnaires that were distributed online to hospital leaders in Indonesia through the forms of closed and open questions. The data collection technique that we did was using a questionnaire that we distributed via google form. The results of the study show that some of the directors already understand crowdfunding and have been in touch with crowdfunding. Furthermore, the directors are willing to use crowdfunding as a source of funding for their hospital investment if Muhammadiyah establishes a crowdfunding platform. The result of this research is opinions and real conditions faced by the leader of hospitals related to hospital funding. On the other hand, the novelty of this study is the author knows an understanding of the leader hospitals related to funding through crowdfunding in Indonesia. The majority of the leader of the hospital don't know about crowdfunding as their counterparts in other countries who are familiar with crowdfunding.

Keywords ICT · Crowdfunding · Start-up · Survey · Muhammadiyah

F. Pribadi (✉) · A. Surwanti · A. Abilawa · A. Samsudin
Universitas Muhammadiyah Yogyakarta, Kasihan, Indonesia
e-mail: firmanpribadi@umy.ac.id

W. C. Shih
Asia University, Taichung City, Taiwan
e-mail: wjshih@gm.asia.edu.tw

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1 Introduction

The Indonesian healthcare industry is growing rapidly. Health care is a very capital-intensive business and access to source of financing, which is essential to keep operational activities.

Some hospitals are able to generate a sufficient cash flow amount from their operational revenues. On the other hand, for the small-revenue hospital that cannot cover its development plan or operational activities, access to capital becomes more important. Their competitiveness will depend on funding resources with low costs.

Based on that description, there is an apparent problem faced by hospital in accessing the fund. Because the current source fund is expensive and limited. In accordance with the development of ICT, currently there are many technology-based crowdfunding platforms. This research is interesting to find out how far the knowledge of these hospital executives toward crowdfunding or technology-based crowdfunding platforms and whether in the future this crowdfunding can be a source of funding for hospitals in their health services. Moreover, this research has aim to see whether the establishment of crowdfunding by Muhammadiyah as the largest religious organization in Indonesia will be responded well by hospital leadership.

2 Literature Review

Health care is a very capital-intensive business. The hospital must master the ability to find source of financing and support it for its survival. At this point, access to external capital is more important than ever. The problem is that currently, access to debt funding sources or other investment funding sources is not many and still expensive.

Sussman and Jordahl provide seven strategies to raise funds/money for hospitals. Crowdfunding has emerged as an alternative source of project-type finance for various groups [1]. Initially, agency mainly used crowdfunding to fund artists from different sectors places [2]. The formulation of multiple Internet crowdfunding platforms in the music sector (e.g., ArtistShare, SellaBand). Crowdfunding is perceived as a plan to reduce the funding gap at the initial stage of a new business (early-stage gap) [3].

Financing from venture capitalists and banks is usually merely available in the later development phase [4, 5]. Early in the life cycle phase of a company (the pre-seed / seed stage), financing is usually provided by the owner, friends, and family and, if possible, from business angels. If these funds are insufficient, the business suffers from a funding gap [6]. This spot has been exacerbated by the financial market crisis [7, 8, 9].

Moritz and Block present an overview of crowdfunding academic research for all types of crowdfunding. First, crowdfunding literature with a focus on capital seekers [10]. Crowdfunding literature that focuses on capital seekers pays close attention to crowdfunding motivations, determinants of success, and the legal limitations of equity-based crowdfunding. Several researchers related to capital seekers are, Agrawal et al. about; the importance of geographical proximity between entrepreneurs and providers of capital [2]; Belleflamme et al. about the importance of geographical proximity between entrepreneurs and providers of capital [11]; Belleflamme et al. Motivation for entrepreneurs and the importance of business types for successful funding [12]; Belleflamme et al. Crowdfunding vs. traditional sources of financing; price discrimination possibilities; type of company (profit vs. non-profit); and many other researchers from 2010 to 2014 [13].

Second, crowdfunding literature with a focus on providers of capital. The behavior of capital providers is critical to crowdfunding accomplishment. Scientific research mainly focuses on the motives of capital providers can be seen in the following studies: Ahlers found the identification of signals that facilitate investment decisions [14]; Allison discovered the importance of intrinsic and extrinsic cues in entrepreneurial narratives in the microcredit market [15]; behavioral analysis promised crowd investors and recommendation strategy development, and many other researchers related to the focus of providing capital.

Third, crowdfunding literature with a focus on mediators A platform, a mediator on the transaction, crowdfunding involvement offers many advantages for the fund seeker and provider. Besides the process standard, the platform also acts as an information gate, communication, and execution. Through that, we could decrease the asymmetry of information and the risks involved in party participation [16, 17].

Furthermore, the platform could strengthen the market participants' trust [18]. The business's current model is different from the existing crowdfunding platform [19]. Business research on which model is the most suitable for successful crowdfunding remains scarce. Moritz and Block research reveals that research priorities in the academic literature are the motive for participating in the crowdfunding market for capital seekers and providers of capital are the primary educational interest [10]. Below is the research roadmap for lecturers, sub-clusters, and university research clusters.

The development of ICT has pushed the crowdfunding system into a technology-based platform. Kang and Kim research focuses on the survival and evolution of individual participants in the socio-technical ecosystem of a crowdfunding platform [20]. Empirical results show that the quality of intra-role and inter-role exchanges determine their influence on funding success. Kumar showed the ten best crowdfunding websites for raising funding in 2022 [21]. From Kumar's writing, we can see the websites of the ten crowdfunding platforms along with the amount of fees charged by each crowdfunding platform.

3 Research Method

This research is qualitative in the form of survey research which is used to obtain data that occurred in the past or present, about the beliefs, opinions, characteristics, behaviors, with hospital executive respondents. Our data collection technique was done by using a questionnaire that we distributed through the google form. The questionnaire was distributed for approximately 3 weeks with open-ended and closed-ended questions.

4 Results

4.1 Description of Research Subjects and Objects

The data of this study were obtained by distributing online questionnaires to all respondents who work in hospitals.

4.2 Results and Discussion

a. Characteristics of Respondents

The characteristics of the respondents observed in this study were gender, age, length of work, and, position at work. The complete respondent characteristic data can be seen as follows.

(1) Characteristics Based on Age

Table 1 shows the percentage of characteristics respondents based on the gender. The highest percentage of the gender is woman of 52%, and the percentage of man is 44.8%.

(2) Characteristics Based on Age

Table 2 shows the percentage of characteristics respondents based on the age. The highest percentage of age is 31–40 years about 32.1% (43), then followed by age

Table 1 Characteristics of respondents by gender

Gender	Frequency	Percentage (%)
Man	60	44.8
Woman	74	55.2
Amount	134	100

Source Primary Data 2021

41–50 years about 28.4% (38), age 50–60 years about 20.1% (27), age 21–30 years about 17.2% (23), and the last one is age 61–70 years about 2.2% (3).

(3) Characteristics based on Length of Work

Table 3 indicates the rate of leader's length of work. The highest experience of work from the leader is 11 years and over about 39.5% (53), followed by 2–5 years experience about 34.3% (46), 6–10 years experience about 18% (24), under 2 years about 6.7% (9), and the last one is without explanation about 1.5% (2).

(4) Characteristics Based on Position

Judging from Table 4, the most position of this research is work as a hospital director about 40% (53) and then followed by heads of division about 28.3% (38), general practitioners about 12.7% (17), medical specialist 6% (8), employee about 6% (8), dentist 3% (4), nurse 2% (3), and empty 2% (3). The majority in this study were leaders who worked as doctors.

(5) Knowledge about Crowdfunding

Regarding the first question, "Do you know what Crowdfunding is?" As many as 52% respondents answered No, I am new to crowdfunding after reading the explanation above, and 38% respondents answered Yes, I have heard about crowdfunding from

Table 2 Characteristics of respondents by age

Age	Frequency	Percentage
21–30 Years	23	17.2
31–40 Years	43	32.1
41–50 Years	38	28.4
51–60 Years	27	20.1
61–70 Years	3	2.2
Amount	134	100

Source 2021 primary data

Table 3 Characteristics of respondents based on length of work

Length of work	Frequency	Percentage
Under 2 years	9	6.7
2–5 Years	46	34.3
6–10 Years	24	18
11 years and over	53	39.5
Without explanation	2	1.5
Amount	134	100

Source 2021 primary data

Table 4 Characteristics by position

Profession	Frequency	Percentage
Medical specialist	8	6
General practitioners	17	12.7
Dentist	4	3
Nurse	3	2
Employee	8	6
Hospital directors	53	40
Head of field/division	38	28.3
Empty	3	2
Amount	134	100

Source 2021 primary data

other people's explanations or other media such as the Internet, but have never been in touch and as many as 10% respondents answered Yes, I ever/currently using a crowdfunding platform in Indonesia.

(6) Crowdfunding Platforms that Ever Used

Next, the question "If you have used/currently used a crowdfunding platform in Indonesia, state the name of the crowdfunding platform that has been/is currently being used" respondents who have used a crowdfunding platform answered as Table 5.

The most well-known crowdfunding platform and currently used by the respondents is Kitabisa.com 6 respondents, followed by LazisMU 5 respondents, and ACT 2 respondents.

(7) Role of Respondents in Crowdfunding Platform

Third, the question "What is your role if you have been involved with this crowdfunding?" as many as 34% respondents as seekers of funds, as many as 20% respondents as providers of funds and as many as 46% respondents as seekers and providers of funds.

(8) Current Source of Hospital Operational Funding and Investment

Then to "Where are the sources of funding for your current hospital investment project?" respondents answered that the source of project funding came from as Table 6.

Table 5 Crowdfunding platform

No	Platform	Respondent
1	Kitabisa.com	6
2	LazisMU	5
3	ACT	2

Table 6 Source of hospital operational funding and investment

No	Source	Respondent
1	Bank	26
2	Hospital profit	22
3	Foundations	14
4	Government	12
5	Independent source	11
6	Regional revenue and expenditure budget	7
7	State budget	6
8	Social security agency of health (BPJS)	5
9	Universitas Muhammadiyah Yogyakarta	4
10	Company profits	4
11	Grants	4
12	Internal source	4
13	Clinics	3
14	Loans	3
15	Public service agency	3
16	Other sources	49

* *Other Sources* LazisMU 2 respondents, Ministry of Health 1 respondents, Subsidies 1 respondents, CSR 1 respondents, and the last is Investor 1 respondents

Table 6 shows about the source of Hospital Operational Funding and Investment. There are 20 sources of Hospital Operational Funding and Investment that answered by the respondents. These are Bank 26 respondents, Hospital Operations 22 respondents, Foundation 14 respondents, Government 12 respondents, independent source 11 respondents, and other sources.

(9) Desire to be Involved in Crowdfunding Muhammadiyah

Then for "If Muhammadiyah established this crowdfunding, would you be willing to be involved?" as many as 73% respondents answered Yes and as many as 27% respondents answered No.

Next to "If Muhammadiyah established this crowdfunding, would you prefer to use this Muhammadiyah crowdfunding fund or would you prefer to borrow from a bank? Could be with reasons why choose one of them." A total of 10% respondents chose a bank, 1% respondent chose both, 6% respondents could not choose, while 83% respondents chose crowdfunding Muhammadiyah for reasons of procedures and systems and in the future it will be simpler and easier in terms of applying for funds, based on sharia

(10) To Desired form of Crowdfunding

Finally, for "If Muhammadiyah makes a crowdfunding funding system, what form of crowdfunding do you want?" as many as 42.50% respondents answered based

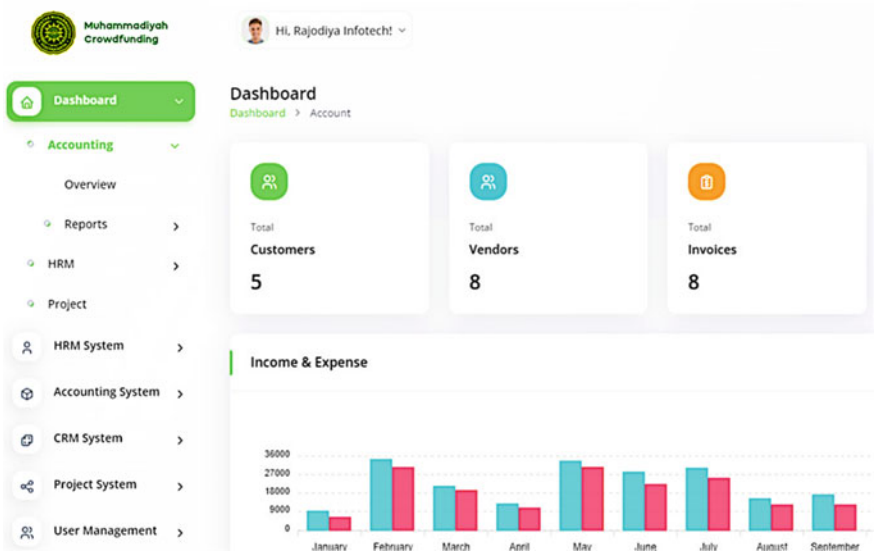

Fig. 1 Summary of all accounting report

on equity/shares, as many as 42.30% respondents answered based on donations (example of waqf), as many as 8.20% respondents answered based on debt as, as many as 7% respondents answered based on combined donations, debt, and share.

(11) Website Platform Crowdfunding Muhammadiyah

Following are some parts of the Muhammadiyah crowdfunding website that prepared. Accounting: All items in the accounting menu are summaries of various accounting data reports from various activities related to finance. This menu is used specifically to view various summary accounting reports, without providing input or editing data. The data presented are in the form of statistical tables and diagrams that make it easier for users to see important patterns in their finances. A summary of all accounting report features, such as a summary of total customers, income, expenses, total billed refunds, total clients, last received income, cash flow, and others (Fig. 1).

5 Discussion

The majority of respondents in this survey research are hospital leaders to find out how far the health services in Indonesia are familiar with crowdfunding as a source of funding for health services. Many studies show that crowdfunding-based funding has actually been carried out in other countries, especially in some developed countries.

The results of this study indicate that the majority do not know what crowdfunding and only 10% of respondents have ever used a crowdfunding platform. Respondents using crowdfunding act as fundraisers, givers, and or as both of them.

From 10% of respondents or as many as 13 people who have used the crowdfunding platform, 6 people use the kitabisa.com platform, and 5 people use LazisMU. It is interesting to note that the second largest crowdfunding platform ever used by respondents is LazisMU, where LazisMU is part of the Muhammadiyah organization whose establishment is for charity.

The majority of respondents or about 46% are fund seekers, and only 20% are funders. So far, the majority of hospital funding sources have come from the banking system, hospital operating income, government, and foundations. If the Muhammadiyah organization established crowdfunding, the majority of respondents, 83%, answered that they were willing to be involved in it. Also, if the Muhammadiyah organization established crowdfunding, 42% of respondents answered that the desired form of crowdfunding was based on equity, 40% answered that it was based on donations, and 8.2% was based on debt securities.

The interesting thing from the results of this research is that the majority of respondents are willing to use the crowdfunding platform founded by Muhammadiyah. It is possible that the majority of respondents understand the role of Muhammadiyah organizations in the health sector, where the role of Muhammadiyah organizations in Indonesia is greatest in education and health. Many schools, universities, and hospitals under the Muhammadiyah organization have experienced rapid progress in Indonesia recently due to the long journey of this organization in Indonesia which began before the Indonesian independence period. Because of this, this success has become the basis for the Indonesian people to trust this organization in managing their funds both for the social sector and even the possibility to enter the business sector in the future.

6 Conclusion

From the results of this survey, it appears that the majority of respondents who come from hospital leaders are not familiar with crowdfunding as a source of funding for health services. The interesting thing in this study is that the majority of respondents are willing to be involved in the Muhammadiyah crowdfunding platform if the Muhammadiyah organization forms a crowdfunding platform. The crowdfunding platform is beneficial for Muhammadiyah for the development of da'wah in the health sector because all this time many hospitals in the Muhammadiyah environment are still experiencing difficulties in funding sources for their health services. This happens because health services are expensive, and the current sources of funding are expensive and high risk. Therefore, it is important for Muhammadiyah to find alternative sources of funding that are low cost with low risk.

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Improvıng Maternal Health Servıces in Remote Rural Areas: Through the Use of Geographıc Informatıon System Technology

Arlina Dewi, Supriyatiningsih, Sri Sundari, and Nursetiawan

Abstract Indonesia's high Maternal Mortality Rate (MMR) and İnfant Mortality Rate (IMR) are major health concerns. In Indonesia's 2020, MMR was 199/100,000 live births, exceeding the 2015–2030 global target of 70/100,000. Geographic Information Systems (GISs) maternal and infant health are useful in mapping and evaluating pregnant women's locations to determine health facility access. This study aimed to describe the use of GIS to map pregnant women, risky pregnant women, and the distance to the nearest health facility in a remote rural Indonesian area. The study used descriptive quantitative surveying. This study focused on rural pregnant women in Bulukumba, South Sulawesi. The sampling method used the total population. This study uses ArcGIS to find coordinates points using latitude and longitude points. Descriptive analysis to be used maps pregnant women's risk of accessing health facilities. Results this research, using GIS to map pregnant women, especially high-risk ones, to shelters and health facilities found 47.7% have a risk of pregnancy, 34.9% get to the hospital in 50–60 min, and 1.1% above 60 min. GIS mapping in rural pregnant women can monitor high-risk pregnancies, but it must be enhanced continuously. GIS in health, especially for mothers and children, can help the government present health equality policies by estimating distance and time to access health facilities, especially in specific geographic locations, with decreased MMR and improving maternal and child health.

A. Dewi (✉)
Master of Hospital Administration, Faculty of Post Graduate Program, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia
e-mail: arlinadewi@umy.ac.id

Supriyatiningsih
Obstetrics and Gynecology, Faculty of Medicine and Health Sciences, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

S. Sundari
School of Medicine, Faculty of Medicine and Health Sciences, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Nursetiawan
Civil Engineering, Faculty of Engineering, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

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1 Introduction

High MMR and IMR are major health issues in Indonesia. MMR and IMR are indicators of a nation's health, not just health programs but the degree of public health [1]. MMR prevalence in Indonesia reached 199/100,000 live births in 2021 [2], far from the 2015–2030 global MMR target of 70/100,000 live births [3]. Comorbidities during pregnancy, such as cancer, kidney, heart, tuberculosis, or other diseases, are 40.8% of causes of MMR, followed by bleeding (30.3%), hypertension (27.1%), and infection (7.3%) [4]. MMR increases due to delays in seeking care, getting to facilities, and receiving quality care [5], so indirectly, pregnant women die as a occurs of limited access to health facilities [6]. Pregnant women with poor geographical access to health facilities prefer not to have examinations and give birth at home without a health worker, which makes delivery unsafe [7], because the distance between the house and the health facility is more than 5 km [7].

Early pregnancy complications diagnosis and treatment can prevent maternal death during pregnancy to puerperium [8]. Preventing pregnancy complications requires early risk factor identification. The government has established Birth Waiting Homes (RTK) completed health workers and collaborated with village midwives, cadres, and traditional birth attendants to improve health, especially for pregnant women. A government policy must call for a fair increase in maternal and infant health related to the distribution of people who have difficulty reaching health facilities [9] so a clear mapping of pregnant women is needed to make it easier to determine the distance to health facilities [10] and to aid decision-making [11].

GIS supports the health sector due to rapid information technology development. Grimshaw defines GIS as data input, storage, retrieval, mapping, and analysis for decision-making [12]. The purpose of this study was to describe how a GIS was used to map the location of pregnant women, pregnant women at risk, and the distance to the nearest health facility in one of Indonesia's most remote rural areas.

2 Methods of Research

The quantitative descriptive method was used for the research. This study was conducted in Bulukumba, South Sulawesi, with the target population consisting of all pregnant women who were in the Bontobangun and Kajang Health Centers. The total population technique was used in this study to match the data of 280 pregnant women at the Bontobangun Pukesmas and 163 pregnant women in Kajang. A questionnaire was given to each pregnant woman, and the data was processed for each completed questionnaire. This study used GPS to determine pregnant women's latitude and longitude points and a GIS survey questionnaire to collect data on their

health and travel time to Community Health Center and hospitals. Ten community midwives from each Community Health Center were trained to use GPS on mobile phones (if the signal is good) or GPS machines to collect GPS data and questionnaires (if the signal is not good). The descriptive analysis method was used in this study to describe the mapping of the position of pregnant women at risk and not at risk in accessing health facilities in Bulukumba, South Sulawesi.

3 Result

Based on Table 1 shows that most of the respondents aged between 20 and 35 years were 324 respondents (73.5), parity 1 was 170 respondents (38.5), second trimester gestational age (15–28 weeks) was 214 respondents (48.5). Regular ANC visits according to gestational age were 356 respondents (80.7), respondents knew their blood type as many as 229 respondents (67.8), and most respondents had not provided donors as many as 320 respondents (72.6). A total of 437 (99.1) respondents did not have danger signs. The majority of respondents (98.6 or 435 respondents) did not have barriers to health facilities, as many as 435 respondents (98.6). Travel time for respondents to Community Health Center 5′–15′ was 292 respondents (66.2), travel time to hospital 30′–45′ was 213 respondents (48.3), and 50′–60′ was 154 respondents (34.9). There are 248 health conditions (47.7) for respondents with health risks and 272 health conditions (52.3) for non-risk respondents.

Table 2 shows that most respondents make regular ANC visits according to gestational age with a travel time of 5′–20′ to the Health Center for 237 (53.7), and 20′–35′ for 119 (27), while 55 respondents based on gestational age who make irregular ANC visits require a 5′–20′ travel time (12.5) (Table 3).

Table 4 shows that 205 respondents (39.4) reported no health issues. Still, some respondents said that the health conditions of pregnancy with chronic diseases (e.g., diabetes, heart failure, kidney failure, Hb anemia 10.5) in 79 respondents (15.2), left arm circumference 23.5 cm in 72 respondents (13.8), pregnant with 4th child or more in 47 respondents (9.0), pregnant with 4th child or more (7.9).

According to table 5, the Bontobangun Health Center is close to three other auxiliary Health Centers in terms of time and distance: Herlang Health Center (8′/6.8 km), Tanete Bulukumba Health Center (11′/7.6 km), and Salasae Health Center (15′/7.7 km), whereas the Kajang Health Center is close to the Lembanna Health Center (12′/8.3 km) and Herlang Health Center (15′/9.1 km).

4 Discussion

The results of study, 356 respondents (80.7) had frequent Antenatal Care (ANC) visits according to their gestational age, and 437 respondents (99.1) did not exhibit pregnancy risk indicators. Pregnancies with 4 or more children, too close spacing,

Table 1 Frequency distribution of pregnant women's characteristics at the bontobangun and kajang health centers

No	Characteristics of respondents	Bontobangun Health Centers ($n = 286$)		Kajang Health Centers ($n = 155$)		Total (%)	
1	*Age of pregnant woman*						
	< 20 and > 35 years old	73	(25.5)	44	(28.4)	117	(26.5)
	20–35 years old	213	(74.5)	111	(71.6)	324	(73.5)
2	*Paritas*						
	1	110	(38.5)	60	(38.7)	170	(38.5)
	2	92	(32.2)	55	(35.5)	147	(33.3)
	3	43	(15)	19	(12.3)	62	(14.1)
	> 3	41	(14.3)	21	(13.5)	62	(14.1)
3	*Gestational age*						
	Trimester I	41	(14.3)	30	(19.4)	71	(16.1)
	Trimester II	145	(50.7)	69	(44.5)	214	(48.5)
	Trimester III	100	(35)	56	(36.1)	156	(35.4)
4	*ANC visit*						
	UK regulated	243	(85.3)	113	(72.9)	356	(80.7)
	Irregular for UK	43	(15.1)	42	(27.1)	85	(19.3)
5	*Blood type of pregnant women*						
	Know	167	(58.4)	132	(85.2)	229	(67.8)
	Don't know	119	(41.6)	23	(14.8)	142	(32.2)
6	*Donor*						
	Available donors	62	(21.7)	59	(38.1)	121	(27.4)
	No donors available	224	(78.3)	96	(61.9)	320	(72.6)
7	*Danger signs of pregnant women*						
	Available danger signs	4	(1.4)	0	(0)	4	(0.9)
	No danger signs available	282	(98.6)	155	(100)	437	(99.1)
8	*Barriers to health facilities*						
	There are obstacles	6	(2.1)	0	(0)	6	(1.4)
	No obstacles	280	(97.9)	155	(100)	435	(98.6)
9	*Travel time to health center*						
	5′–15′	178	(62.2)	114	(73.5)	292	(66.2)
	20′–30′	108	(37.8)	41	(26.5)	149	(33.8)

(continued)

Table 1 (continued)

No	Characteristics of respondents	Bontobangun Health Centers ($n = 286$)		Kajang Health Centers ($n = 155$)		Total (%)	
	> 35′	0	(0)	0	(0)	0	(0)
10	*Travel time to hospital*						
	10′–25′	69	(24.1)	0	(0)	69	(15.7)
	30′–45′	141	(49.3)	72	(46.5)	213	(48.3)
	50′–60′	76	(26.6)	78	(50.3)	154	(34.9)
	> 60′	0	(0)	5	(3.2)	5	(1.1)
11	*Health risks of pregnant women*						
	There is a risk	143	(43.2)	105	(55.6)	248	(47.7)
	No risk	188	(56.8)	84	(44.4)	272	(52.3)

Table 2 Distribution of frequency of reported travel time for ANC visits according to gestational age of pregnant women at the bontobangun and Kajang Health Center

Characteristics of respondents	Bontobangun Health Centers ($n = 286$)		Kajang Health Centers ($n = 155$)		Total (%)	
Travel time for an ANC visit						
Regular						
5′– < 20′	157	(54.9)	80	(51.6)	237	(53.7)
20′–35′	86	(30.1)	33	(21.3)	119	(27)
Irregular						
5′– < 20′	21	(7.3)	34	(21.9)	55	(12.5)
20′–35′	22	(7.7)	8	(5.2)	30	(6.8)

Table 3 Estimated frequency distribution of distances to the Bontobangun and Kajang Health Center distances

Characteristics of respondents	Bontobangun Health Centers ($n = 286$)		Kajang Health Centers ($n = 155$)		Total (%)	
Distance to health facility						
0–2 km	34	(11.9)	63	(40.6)	97	(22)
2–5 km	106	(37.1)	82	(52.9)	188	(42.6)
5–10 km	146	(51)	10	(6.5)	156	(35.4)

chronic disorders including anemia, and Chronic Energy Deficiency (CED) with a left arm circumference of 23.5 cm are still health risks in pregnancy. Increased MMR is caused by several risk factors, including: pregnant women < 20 years old have a 4 times greater risk, parity pregnant women > 3 have a 1.1 times greater risk, late ANC

Table 4 Frequency distribution of health conditions for pregnant women at Bontobangun and Kajang Health Center in 2019

Characteristics	Bontobangun Health Centers		Kajang Health Centers		Total (%)	
Condition of pregnant women						
1. Pregnancy with a history of caesarean section	4	(1.2)	2	(1.1)	6	(1.2)
2. Babies in the womb of twins	0	(0)	1	(0.5)	1	(0.2)
3. Haven't taken iron tablets yet	4	(1.2)	4	(2.1)	8	(1.5)
4. Have never given birth to a baby weighing more than 2.5 kg	1	(0.3)	1	(0.5)	2	(0.4)
5. Have never given birth to a full-term baby	1	(0.3)	0	(0)	1	(0.2)
6. With diseases in the female organs (uterine tumors, venereal diseases)	2	(0.6)	0	(0)	2	(0.4)
7. Pregnant with 4th child or more	39	(11.8)	8	(4.2)	47	(9.0)
8. The distance between previous pregnancies was less than 1.5 years or more than 5 years	27	(8.2)	14	(7.4)	41	(7.9)
9. Pregnancy with chronic disease (e.g., diabetes, heart failure, kidney failure, anemia Hb < 10.5)	24	(7.3)	55	(29.1)	79	(15.2)
10. Weight gain < 1 kg/month	5	(1.5)	14	(7.4)	19	(3.7)
11. Mother's emotional condition (irritability, feeling tired easily, worrying about physical changes)	9	(2.7)	9	(4.8)	18	(3.5)
12. The duration of pregnancy is more than 9 months	10	(3.0)	0	(0)	10	(1.9)
13. Left upper arm circumference is less than 23.5 cm	46	(13.9)	26	(13.8)	72	(13.8)
14. Blood pressure > 140 mmHg/ 90 mmHg	2	(0.6)	0	(0)	2	(0.4)
15. Body height < 145 cm	5	(1.5)	2	(1.1)	7	(1.3)
16. There are no health conditions as above	152	(45.9)	53	(28)	205	(39.4)

examinations have a 3.1 times greater risk, and not carrying out an examination has an 8.1 times greater risk of increasing the death and morbidity of pregnant women [17].

The first and most important global health priority is improving maternal health [18]. WHO recommends pregnant women to have at least four ANC exams at health facilities to identify pregnancy complications, administer Fe tablets, get tetanus shots, and screen for infections [19]. Carroli et al. found that the ANC examination can

Table 5 distribution of time frequency and distance to the nearest health centers to Bontobangun and Kajang Health Centers viewed from google maps

Nearest health centers		Time (minute)	Distance (km)
Bontobangun Health Centers			
1	Herlang Health Centers	8′	6.8
2	Tanete Bulukumba Health Centers	11′	7.6
3	Salasae Health Centers	15′	7.7
Kajang Health Centers			
1	Lembanna Health Centers	12′	8.3
2	Herlang Health Centers	15′	9.1

reduce MMR and pregnancy comorbidities by identifying risk factors and morbidity during pregnancy, preventing, early detection, and timely treatment [20]. Yasuoka et al. found that pregnant women with secondary education or higher, awareness of ANC's importance, mother's knowledge of health workers' recommended ANC frequency, and distance to health facilities all contributed to regular ANC visits [21].

Regular ANC examination based on gestational age, safe delivery by skilled health workers, and postnatal care can reduce MMR and improve the health of mothers and babies in low and middle-income developing countries [22]. According to WHO, poverty, distance to health facilities, a lack of health information, especially about pregnancy, inadequate health services, and cultural practices influence pregnant women's refusal to undergo examinations during pregnancy and childbirth [23]. Hirosa et al., explain pregnant women delay checking into health facilities for decision-making, transportation, and infectious diseases, which are 4.9 times, 2.1 times, and 2.6 times riskier than mothers giving birth with bleeding [24]. Pregnant women who reside 10–14.9 km from a health center are 68% less likely to have ANC examinations, and 79% fewer if they live above 15 km [21]. To overcome these barriers, it is important to choose the suitable health system [23]. Institute of Medicine and Committee On Quality of Health Care in America (2000) stated that one of the six goals of quality health services is equality in providing health care both in terms of geographic location [25].

Salehi and Ahmadian explained that an effective health system has a strong monitoring system that considers the needs of vulnerable groups and quickly identifies progress or problems [18]. GIS is the latest health technology to improve better health care [26]. GIS accurately measures distances accurately and cheaply. GIS is best for analyzing health facility access in remote areas with geographical barriers [21]. Juarez et al., say GIS in health can support complex interaction analysis of health outcomes, health disparities, environmental mapping, and health information to visualize regional public health patterns [27, 28].

GIS helps to evaluate geographic accessibility to health facilities, detect distance and time constraints to health facility access and informs effort to enhance access [29]. It is also used to map health facilities and estimate the distance and travel time for patients with obstetric risk using a travel model to reality so that represent access

to health facilities [30, 31]. Fradelos et al. added that GIS helps monitor, manage, and analyze diseases. A map showing health information linked to environmental, health, and social factors, thus can help health workers understand, monitor, and prevent disease [26]. GIS can help health workers work more efficiently by remotely monitoring health and easily identifying problems and differences in access to health facilities [26] and identify high-priority healthcare areas [18]. GIS can clearly and specifically describe the location of an area with the actual location of health facilities, allowing for fast access [26].

Access to health facilities is the foundation of the quality of health services [29] as measured by five factors: affordability, availability, accessibility, accommodation, and acceptance. Accessibility refers to geographical conditions that make it physically easy for patients to reach the location of the health facility, both in terms of distance and travel time [32-34]. The WHO recommends evaluating an area's geographical accessibility based on travel time rather than distance traveled [36]. When compared to the distance to health facilities, this is due to geographic and transportation differences. Masoodi and Rahimzadeh say the time calculation method uses the shortest path and travel time to provide more patient location and health facility availability information [37].

This study found that 292 respondents (66.2%) reported travel time to Community Health Center 5′–15′ and 213 respondents (21.3%) to hospitals 30′–45′ (48.3). Pregnant women who made regular ANC visits reported a travel time of 5′–20′ to the health center for 237 respondents (53.7) and irregular visits with 5′–20′. (12.5). Radcliff et al. found that patients in remote areas affect travel time to health facilities with $p = 0.001$, making it short trips easier for them to visit the public health center or hospital [29]. Furthermore, patients with limited mobility are more likely to seek health care at the nearest facility [33]. The patient's travel time from home to the health facility can be estimated using GIS. The findings revealed a strong relationship ($r = 0.856$) between the estimated time using GIS and the patient's reported time, so the estimated time was longer than the reported time because most patients rounded their travel time to be 5′ or 10′ closer to real-time [31].

This results show that 35.4% of pregnant women travel 5–10 km to the hospital. According to Cambodian study, travel distance is a hurdle for patients to access health facilities. Thus distance measurements must be precise to assess trip time, especially in distant places with specific geographic locations. Pregnant women must detour through forests, rivers, and other topographical obstacles [21]. Radcliff et al., research, the distance traveled by patients in remote areas affects access to health facilities, so long distances to health facilities become a travel burden for patients and their families [29].

Another factor considered to increase regular ANC visits and the use of maternal and child health facilities is the long-distance [21]. In addition, patients should be interviewed individually and in groups about the barriers and facilities needed to improve access to health facilities [38]. Health policy and decision-making can do it using GIS [18]. Masoodi and Rahimzadeh stated that GIS data made it easier for planning to find out which cities had or did not have access to health facilities according to travel time, providing complete information regarding the position of

patients with health facilities based on time and making it to determine the best place to build new health facilities [37]. Furthermore, GIS results for adding new health facilities, particularly in areas requiring longer access in terms of time or distance to the nearest health facility [33].

Contrary to Salehi and Ahmadian, building new health facilities to reduce MMR can be cost-ineffective and increase the government's burden, so effective interventions, such as developing small, low-cost health centers in the regions with trained staff to accompany, and monitor pregnant women, are needed [18]. To help pregnant women get to healthcare, policymakers must rebuild roads and boost public transit. Following the Bulukumba South Sulawesi government's strategy, village midwives, cadres, and traditional healers have collaborated to promote pregnant women's health, and Birth Waiting Homes (RTK) for isolated regions with provide health professionals with delivery help [2] with a distance of more than 10 km from a health facility [39]. Maximize health facility access for pregnant women and their families to reduce morbidity and mortality, especially for mothers and children. Pregnant women can use the nearest health facilities to the Bontobangun and Kajang Health Centers (Table 5) in 8–15 min.

5 Conclusion

GIS in health, especially for mothers and children, helps visualize the condition of pregnant women by taking into account the distance and estimated time to access health facilities, especially in certain geographic locations, so that assisting the government in making decisions and policies for equal public access to health to MMR and improve maternal and child health. However, this study has limitation, as it was only conducted at two Community Health Centers in one district, hence this study only provided an overview of GIS usage in one district.

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The Effect of Online Video in Improving Maternal Nutritional Behavior and Nutritional Status of Stunted Under Five

Titih Huriah, Nurjannah, and Yoyok Bekti Prasetyo

Abstract One of the causes of high stunting in toddlers is mothers' poor behavior in providing toddler nutrition. Health education through online media about stunting is one way to influence mothers' behaviors in preventing stunting. The online video was chosen based on the characteristics of the participants, geographical conditions, and the COVID-19 pandemic. The aim of this study is to determine the impact of educational videos on maternal nutritional behavior and the nutritional status of stunted children. In this study, we employed a quasi-experimental pretest-posttest control group design. The study was conducted in December 2020–February 2021 in the Gondomanan and Umbulharjo Health Cent Yogyakarta. The sample was 26 respondents, divided into the intervention group and the control group with simple random sampling, and each group had 13 respondents. The intervention group was given an education from two videos about nutrition in children and stunting. The data is analyzed using the *Wilcoxon and Mann–Whitney* tests. Health education using online video can increase maternal nutritional knowledge, attitudes, and behaviors with *p values* of 0.003, 0.000, and 0.023, respectively, while the nutritional status of stunted children, there is no difference with *a p* value of 0.626. Online video education can improve aspects of knowledge, attitudes, and nutritional behaviors of mothers but cannot improve the nutritional status of stunted children.

Keywords Online video · Stunting · Nutritional behavior · Nutritional status

T. Huriah (✉)
Community Nursing Department, Master of Nursing, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia
e-mail: titih.huriah@umy.ac.id

Nurjannah
Community Nursing Department, Stikes Mitra Adiguna Palembang, Palembang, Indonesia

Y. B. Prasetyo
Community Nursing Department, School of Nursing, Universitas Muhammadiyah Malang, Malang, Indonesia

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1 Introduction

Children under five are one of the vulnerable groups that should be considered and are in the most crucial developmental phase of life [1]. This phase is the initial foundation in determining the quality of life and is referred to as the "golden period". The World Bank states that the period of the first 1000 days of life, starting from conception until the child is two years old, is the most important and critical period in improving cognitive and physical development [2].

Globally, some countries are still faced with a double burden of malnutrition, where one of the nutritional problems is stunting [3]. Stunting is the most common symptom of malnutrition when children have a low height for their age [4]. Stunting causes 14% of child mortality and affects one-third of children under five in developing countries [5]. Stunting can result in short-term and long-term cognitive impairment and academic performance deficits [6].

Stunting affected 21.9% or 149 million children under five globally in 2018. The sub-territory of the United Nations consists of; 81.7 million in Asia, 58.8 million in Africa, 4.8 million in Latin America and the Caribbean, and 0.5 million in Oceania [7]. The global prevalence of stunting in 2019 was 21.4% in children under five in developing countries, while the majority of stunting in Tanzania, a developed country in Eastern Africa, was 34% [4].

The World Health Organization (WHO) stated that Indonesia is the third country with the highest stunting prevalence in the South-East Asia Regional (SEAR) region, with an average of 36.4% in 2005–2017, compared to 50.2% in Timor Leste and 38.4% in India [8]. Very short and short prevalence in 2018 was 11.55% and 19.3% [9]. The prevalence of stunting toddlers in 2018 in Yogyakarta was 12.37%, which decreased to 13.86% in 2017. The prevalence of children under five is lowest in the Bantul region at 9.75%, and the highest in Gunung Kidul Regency is 18.47% [10]. The prevalence of stunting toddlers in Yogyakarta City Regency has decreased, but not significantly compared to 2018, which was 12.82%, while in 2019, it was 11.3%.

The Indonesian government has implemented strategies for addressing stunting, including nutritionally sensitive and specific interventions. Handling stunting is a national priority program that must be included in the Government's Work Plan (RKP). Targets and indicators of stunting reduction are significant to be carried out with a multi-sectoral approach through sustainable programs both in the form of local, central, and regional communities and at the national level [11].

Specific nutritional interventions prevent and reduce dietary problems that are given directly, especially in the first 1000 days of life. Meanwhile, sensitive nutrition interventions mitigate dietary issues that are given indirectly and carried out in various non-health development activities [12]. The health sector only contributed 30%, while the non-health sector contributed 70% to overcoming nutritional problems [13]. Care Settings nutrition consists of 3 components, including (1) Hospital, which refers to care for inpatients, (2) Outpatient, which carried out by patients who still need treatment but do not require hospitalization; and (3) Community, this treatment is carried out outside the hospital and can involve people in the institution [14].

The selection of online media is based on the characteristics of the participants, geographical conditions and the number of desired targets; then, one of the media can use audio-visual. Audio-visual media is considered more attractive than other media because it combines audio, visual, and animation so that the message recipient will understand more quickly and not feel bored when receiving health education [15]. Based on the description above, researchers are interested in researching stunting toddlers and finding out whether online videos are compelling if used as an educational medium to improve nutritional behavior and nutritional status for stunted children.

2 Materials and Methods

The type of this research is a Quasi Experiment with a pre-test–post-test with the control group design. This study was carried out for one month at the Gondomanan and Umbulharjo Health Center in Yogyakarta City. The research sample was 26 stunted children, divided into two the intervention group and the control group with simple random sampling, and each group had 13 respondents. The inclusion criteria in this study were mothers who had children aged 6–59 months with stunting, had a smartphone at home and could follow the intervention to the end. The exclusion criteria in this study were children under five who experienced physical disabilities, family who had changed their homes.

Several methods are used to create an online video: (a) determining the audience, (b) developing a concept based on the purpose of the health education material, such as the concept of children, nutrition in children, definition of stunting, signs of stunting symptoms in children, factors that influence stunting, and efforts to overcome stunting, (c) The process of recording sound with a smartphone and preparing illustrations such as pictures, animation, and text, (d) After the videos and illustrations have been combined, the editing process is carried out using Adobe Photoshop, Adobe Illustrator, and Adobe Audition. The video education is divided into two parts: nutrition and toddlers and stunting, with each audio-visual lasting between 4–5 min.

Researchers assessed the nutritional status of children assisted by cadres or mothers by measuring body length or height. After that, this study's intervention and control groups were given pre-tests regarding maternal nutrition behavior. The intervention group was assigned video-based education related to nutrition in children and stunting. In contrast, the control group was not given intervention and a post-test after providing education to the intervention group. Mothers of stunted children given online video health education using stunting prevention educational media. The content is divided into two videos: children nutrition and stunting. The online video is sent to mothers with children under the age of five via cell phone, and health education is provided every two weeks with different materials for one month. Follow-ups are done every 3–4 days via chat on the WhatsApp. The data is analyzed using the *Wilcoxon and Mann–Whitney* tests.

The research has been approved by the Health Research Ethics Committee (KEPK) of Aisyiyah University Yogyakarta with the number: 1737/KEP-UNISA/XII/2020.

3 Results

Table 1 show the frequency distribution based on the characteristics of stunting toddler respondents (age, sex, and exclusive breastfeeding) and maternal respondents' characteristics (age, mother's age at childbirth, maternal BMI, last education, occupation, parental income, and antenatal care history). Table 1 shows that based on chi-square test analysis, there is no difference in both toddler and maternal characteristics in the control and intervention group with a *p* value more than 0.05.

Table 2 shows height characteristics and age of toddlers with the highest mean values in the post-test intervention group of 80.65 cm and 28.38 months, respectively.

Table 3 shows the pre-test scores in the categories of knowledge, attitudes, and behaviors, most of whom have sufficient knowledge and attitudes, both in the intervention and control groups. Meanwhile, in the knowledge category, the pre-test value appears to differ between the intervention and control groups. The post-test value showed different types of knowledge, attitudes, and behaviors, whereas in the intervention group, there was an increase in categories. In contrast, in the control group, there was no difference. There was no difference in types in the intervention group and the control group in the nutritional status variable.

Table 4 shows significant increase in pre-test and post-test scores in the knowledge and attitudes in the intervention and control groups. In contrast, the aspects of maternal behavior commitment and nutritional status of toddlers based on *the Z-score* in the two groups did not significantly differ in values in the pre-test and post-test interventions. Statistical analysis with Wilcoxon Test show *P* Value < 0.05 for knowledge and attitude in intervention group, which means that knowledge and attitudes improve after watching an online video. The *p* value for behavior, on the other hand, is greater than 0.05, which means that behavior doesn't change after watching an online video. With a *p* value greater than 0.05, the Wilcoxon test results in the control group revealed no differences in knowledge, attitudes, or behavior.

The following result of the analysis is to look at the difference value between the control and intervention groups. The pre-test results with Mann Whitney showed no difference in each variable with a *p* value of > 0.05, so the researcher analyzed the difference in the post-test value. Table 5 shows the effect of intervention administration on improving aspects of knowledge, attitudes, and nutritional behaviors of stunting toddler mothers. In contrast, in the nutritional status of stunted toddlers, there is no difference between the intervention and control groups.

Based on Table 5, the knowledge and behavior variables have *an effect size* value of more than 0.2 and less than 0.8 with an average category. In contrast, the results in the action variable *have an effect size* value below 0 and 0.2 with a low category.

Table 1 Characteristics of respondents ($n = 26$)

Variable	Intervention group ($n = 13$)	Control group ($n = 13$)	P value*
	n (%)	n (%)	
Toddler Age	6 (46.2)	7 (53.8)	0.695
• 6–24 months	7 (53.8)	6 (46.2)	
• > 24 months			
Gender	7 (53.8)	6 (46.2)	0.695
• Male	6 (46.2)	7 (53.8)	
• Female			
Exclusive Breastfeeding	11 (84.6)	9 (69.2)	0.352
• Exclusive	2 (15.4)	4 (30.8)	
• Not exclusive			
Mother's Age	1 (7.7)	1 (7.7)	0.215
• ≤ 20 years	1 (7.7)	4 (30.8)	
• 21–30 years	10 (76.9)	5 (38.5)	
• 31–40 years	1 (7.7)	3 (23.1)	
• > 40 years			
Mother's Age During Childbirth	2 (15.4)	2 (15.4)	0.783
• ≤ 20 years	4 (30.8)	4 (30.8)	
• 21–30 years	7 (53.8)	6 (46.2)	
• 31–40 years	–	1 (7.7)	
• > 40 years			
BMI Mother	–	–	0.129
• Less	3 (23.1)	8 (61.5)	
• Normal	7 (53.8)	4 (30.8)	
• Overweight	3 (23.1)	1 (7.7)	
• Obese			
Maternal Education	1 (7.7)	1 (7.7)	0.887
• Elementary school	4 (30.8)	3 (23.1)	
• Junior high school	6 (46.2)	6 (46.2)	
• Senior high school	–	1 (7.7)	
• Diploma	2 (15.4)	2 (15.4)	
• College			
Mom's Job	11 (84.6)	9 (69.2)	0.352
• Housewives	2 (15.4)	4 (30.8)	
• Private			
Parents' Income	6 (46.2)	3 (23.1)	0.447
• < Minimum wage	4 (30.8)	5 (38.5)	
• Minimum wage	3 (23.1)	5 (38.5)	
• > Minimum wage			
History of Antenatal Care	2 (15.4)	3 (23.1)	0.619
• Less than four times	11 (84.6)	10 (76.9)	
• Four times or more			

* p value < 0.05 based on chi-square test

Source Primary data, 2021

Table 2 Characteristics of respondents based on length/height and age of children with stunting ($n = 26$)

Research variable	Intervention group ($n = 13$)				Control group ($n = 13$)			
	Pre-test		Post-test		Pre-test		Post-test	
	Min–Max	Mean ± SD	Min–Max	Mean ± SD	Min–Max	Mean ± SD	Min–Max	Mean ± SD
Height (cm)	63–95	79.39 ± 10.61	65–96	80.65 ± 10.55	62–95	77.70 ± 10.78	64–97	78.98 ± 1061
Age (month)	8–54	27.38 ± 15.19	9–55	28.38 ± 15.19	8–51	25.92 ± 15.34	9–52	26.92 ± 15.34

Source Primary data, 2021

Table 3 Effect of online video on mothers behavior and toddlers nutritional status in intervention and control group ($n = 26$)

Research variables	Intervention group ($n = 13$)		P value*	Control group ($n = 13$)		P value*
	Pre-test (n, %)	Post-test (n, %)		Pre-test (n, %)	Post-test (n, %)	
Knowledge • Good • Enough • Less	2 (15.4) 7 (53.8) 4 (30.8)	11 (84.6) 2 (15.4) –	**0.002***	2 (15.4) 7 (53.8) 4 (30.8)	3 (23.1) 6 (46.2) 4 (30.8)	0.564
Attitude • Good • Enough • Less	4 (30.8) 6 (46.2) 3 (23.1)	10 (76.9) 3 (23.1) –	**0.007***	2 (15.4) 8 (61.5) 3 (23.1)	1 (7.7) 9 (69.2) 3 (23.1)	0.317
Behavior • Good • Enough • Less	7 (53.8) 5 (38.5) 1 (7.7)	9 (69.2) 4 (30.8) –	0.083	4 (30.8) 5 (38.5) 4 (30.8)	4 (30.8) 5 (38.5) 4 (30.8)	0.655
Nutritional Status (*Length/height-for-age*) • Very Short • Short	2 (15.4) 11 (84.6)	2 (15.4) 11 (84.6)	1.000	3 (23.1) 10 (76.9)	3 (23.1) 10 (76.9)	1.000

* p value < 0.05 based on Wilcoxon test
Source Primary data, 2021

4 Discussion

The results showed that providing education using online videos can offer changes in the level of knowledge of stunted mothers related to nutrition and stunting in the work area of the Gondomanan Health Center. This study supports research conducted by [16] states that health education provided through video can increase knowledge faster than verbal education and can provide patient satisfaction. Another benefit of video-based education is that patients can rewatch the video at specific intervals.

Audio-visual media in the form of online video used for education has advantages, one of which is that it is easier for someone to accept because they can combine the senses of sight and hear simultaneously [17]. The provision of audio-visual media education proves it is very effective because mothers can continue to repeat and re-understand what has been explained or conveyed [18].

The need for information and opportunities obtained by mothers can increase after mothers access knowledge from online sources so that health-related education can be carried out quickly and precisely [19]. Other studies explained that mothers with higher education are sometimes less likely to apply the knowledge they have gained regarding the fulfillment of nutritious food intake. On the contrary, poorly

Table 4 Effect of online video on mothers behavior and nutritional status among intervention and control groups ($n = 26$)

Research variables	Pre-test ($n = 13$)		P value*	Post-test ($n = 13$)		P value*
	Intervention (n, %)	Control (n, %)		Intervention (n, %)	Control (n, %)	
Knowledge • Good • Enough • Less	2 (15.4) 7 (53.8) 4 (30.8)	2 (15.4) 7 (53.8) 4 (30.8)	1.000	11 (84.6) 2 (15.4) –	3 (23.1) 6 (46.2) 4 (30.8)	**0.003***
Attitude • Good • Enough • Less	4 (30.8) 6 (46.2) 3 (23.1)	2 (15.4) 8 (61.5) 3 (23.1)	0.571	10 (76.9) 3 (23.1) –	1 (7.7) 9 (69.2) 3 (23.1)	**0.000***
Behavior • Good • Enough • Less	7 (53.8) 5 (38.5) 1 (7.7)	4 (30.8) 5 (38.5) 4 (30.8)	0.136	9 (69.2) 4 (30.8) –	4 (30.8) 5 (38.5) 4 (30.8)	**0.023***
Nutritional Status (*Length/height-for-age*) • Very short • Short	2 (15.4) 11 (84.6)	3 (23.1) 10 (76.9)	0.626	2 (15.4) 11 (84.6)	3 (23.1) 10 (76.9)	0.626

* p value < 0.05 based on Mann–Whitney test
Source Primary data, 2021

Table 5 *Effect size* calculation results of online video

Variable	The average score in the intervention group	The average score in the control group	*SD*	*d*	Category
Knowledge	0.50	0.05	0.67	0.68	Average
Attitude	0.51	0.02	0.64	0.77	Average
Behavior	0.5003	0.0482	0.83	– 0.54	Low

* *Effect size* based on Cohen's Formula

educated mothers are more feasible to seek information about nutritional food intake for toddlers [20].

The results showed that providing education using online videos can change the level of knowledge of stunting toddler mothers. Knowledge will affect the attitudes mothers. Previous research [21] states that insufficient maternal knowledge can cause the formation of negative attitudes toward stunting prevention efforts. In line, a study conducted by [22] noted that health education using videos has proven effective in improving the knowledge and attitudes of toddler mothers. Maternal nutritional

knowledge can influence the mother's attitude and behavior toward selecting foodstuffs and affect the family's nutritional status. A person in determining attitudes is controlled by the knowledge he has gained [23]. Family knowledge level affects family attitudes and behaviors regarding health status [24].

The prevalence factor of stunting can be significantly reduced when families adopt attitudes related to washing hands before eating. According to this study, children as young as 12 years old crawl and stand frequently exposed to the environment, such as putting contaminated objects into their mouths. So that some children experience stunting caused by chronic diarrhea, recurrent infection and not getting the proper treatment for the first two years (< 24 months) in the process of growth and development [4]. The study's results prove that knowledge and improved attitudes can change the behavior of stunting toddler mothers in the work area of the Gondomanan Health Center. In line with the study's results [25] the knowledge mothers possess about mothers changes behaviors and dietary habits in the family.

Parents, especially mothers, are responsible for healthy feeding behaviors for children under five. Some mothers of toddlers assume that formula feeding can replace breast milk, even though mothers know breast milk provides many benefits for the growth and development of toddlers. Behavioral-based nutrition education interventions for children resulted in a substantial increase in maternal involvement in physical activity, providing fruits, vegetables, and fulfilling animal proteins as a promoter for child growth, but significantly did not affect the increase in child height. The results showed that although mothers' knowledge, attitudes, and behaviors increased, there was no difference in the nutritional status because children under five sometimes prefer snacks outside to consuming nutritious food. Other causes were the time length of the intervention was too short, the duration of stunting experienced by toddlers, so it will be difficult to change the nutritional status in one month, and the measurements made by cadres may be invalid. However, these results are inversely proportional to the studies carried out by [25] that there is a significant relationship between the knowledge of toddler mothers and the *High For Age* (HAZ) index.

Maternal knowledge, attitudes, and behaviors impact children's health. The effect of exclusive breastfeeding is enormous on the nutritional status of children, so the *World Health Organization* (WHO) recommends the implementation of increasing breastfeeding for the first six months, which is one of the efforts to achieve the WHO Global Nutrition Target 2025 related to reducing the prevalence of stunting in toddlers [21]. Nutritional problems can occur due to ignorance or lack of information related to correct and appropriate nutrition [20].

The nutrition status of mothers under five has an essential role in the fetus growth, the healthy baby and the development of toddlers' long-term life. The family's economic situation, family income, and parents' education level are indirect factors that can be attributed to the prevalence of stunting. Families who are not low incomes will find it easier to access information and health services so that it will not cause nutritional problems in children. Fulfillment of children's dietary needs is carried out by exclusive breastfeeding for the first six months, without adding extra food. Working mothers with their abilities can better meet the nutritional needs of children

but are limited in terms of meeting dietary needs directly in children, so working mothers have an essential role in caring for children.

Maternal nutrition is essential and must be provided optimally, even before conception, so that the growth of the fetus in the womb can develop properly. Insufficient allocation of costs in meeting inappropriate needs and resources in the family can lead to poor health and suboptimal nutritional status the family determines the child's health status based on treatment related to meeting the child's dietary needs in daily life [23].

5 Conclusions

Developing an educational model using online videos for mothers of stunted children is considered adequate. The results showed that education with videos influenced healthy behavior in aspects of knowledge, attitudes, and behavior. However, there was no improvement in the nutritional status of stunting toddlers. This result is because the stunting condition experienced by toddlers has been long enough, making it difficult to change the nutritional status of toddlers within one month. For further research, it can provide longer intervention with more respondents so that can improve research results.

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Vision-Based Warning System for Maintenance Personnel at Short-Term Roadworks Site

Xiao Ni, Walpola Layantha Perera, Carsten Kühnel, and Christian Vollrath

Abstract This paper proposes a vision-based warning system for the maintenance personnel working at short-term roadworks sites. Traditional solutions use passive protection, like setting up traffic cones and safety beacons. However, such methods cannot function as physical safety barriers to separate working areas from used lanes. In contrast, the proposed system provides active protection, leveraging acoustic and visual warning signals to help road workers be cautious of approaching vehicles before they pass the working area. For the reduction of too many warnings to relieve a disturbance of road workers, a traffic flow check algorithm is implemented, by which about 80% of the useless notices can be filtered. The evaluations are conducted in laboratory conditions and the real world, proving the applicability and reliability of the system.

Keywords Computer vision · Traffic safety

1 Introduction

The safety of road workers has been a well-known object of traffic research and development projects in Europe in recent years. As a result, guidelines for human behavior, roadworks site setups, and technical solutions were developed and implemented [1–3]. However, almost all of these guidelines deal with the improvement of the safety of road workers at long-term and short-term construction sites. Despite addressing principle requirements to improve safety, especially for vehicles driving in the direction of short-term roadworks sites, maintenance workers' safety within the area of the short-term roadworks sites (STRWS) itself did not attract much attention. When the maintenance workers are working, sometimes they cannot sense the surroundings explicitly. Moreover, the maintenance vehicles in the front can obscure

X. Ni (✉) · W. L. Perera · C. Kühnel · C. Vollrath
University of Applied Sciences, Altonaer Straße 25, 99085 Erfurt, Germany
e-mail: xiao.ni@fh-erfurt.de

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the view of the road workers, and they cannot see the traffic behind them. Furthermore, the maintenance workers have to use ear protectors because they use machines at work that can produce loud noises. Nevertheless, that also has the disadvantage that they cannot use their hearing senses to identify the vehicles' coming.

In many European countries, the short-term roadworks sites are separated from lanes with free-flowing traffic only by mobile warning signs such as traffic cones and safety beacons. Protection by passive protective devices is impossible due to the bad benefit–cost ratio so that no physical barriers can hold back vehicles in case of an accident. As a result, personnel in STRWS are generally exposed to higher risks. Therefore, the German Federal Ministry of Labour and Social Affairs implemented a guideline to lower the risk of accidents in short-term roadwork sites. However, hands-on experience shows that this is difficult to observe for maintenance workers at the lower tier network, as there are many situations in which they do not even set up any warning signs for time-saving (Fig. 1).

The solution proposed in the paper addresses this problem by detecting the approaching vehicle from both front and rear directions based on computer vision and triggering a warning signal to alert the maintenance personnel. For that aim, the recent groundbreaking deep learning-based object detection is to be utilized for detecting approaching vehicles on the road in both directions. Furthermore, the system can track such vehicles and record their trajectories. After vehicles are tracked, the traffic flow check algorithm is utilized to filter unnecessary warnings.

Fig. 1 Short-term roadworks site

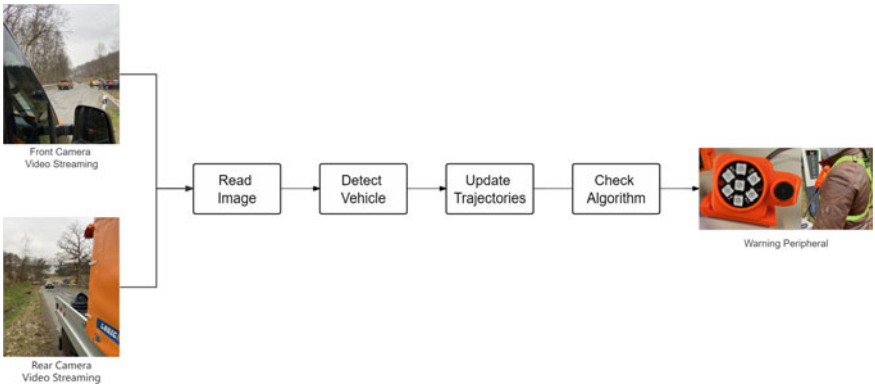

Fig. 2 Workflow of the vision-based warning system

There are two inputs to the system. One is a video streaming of a front-mounted conventional RGB camera, and another is a video streaming of a rear-mounted conventional RGB camera. With these two cameras, we can observe both directions of the roadworks site. The whole workflow is composed of three main steps: (1) detecting vehicles, (2) tracking vehicles, and (3) checking traffic flow (see Fig. 2).

2 Related Works

2.1 Vehicle Detection

Vehicle detection is a considerably mature and proven technology that is crucial for the whole system. Traditionally, it was done by using the sliding window method with traditional machine learning classifiers [4, 5]. However, these methods require much feature engineering work and cannot achieve satisfactory accuracy. In recent decades, due to the groundbreaking improvements in deep learning, modern detectors are mainly composed of the convolutional neural network (CNN) [6–8]. CNN has a similar property to the traditional fully connected network but considerably reduces the amount of the neural network's parameter by sharing weights, which means that the same set of weights are used for multiple regions of the input image. This allows CNN to be much more robust and reduces the risk of overfitting. Such CNN-based detectors require large-scale datasets to train their neural network and can achieve a better generalization capability. The working conditions of maintenance being outdoors and constantly varying from one country road to another can present challenges for vehicle detection. The different backgrounds, such as dense forest and mountain bodies, can make it difficult for a detector to identify vehicles accurately, as the background can obscure them. Similarly, open fields can present a different set of challenges, such as glare from the sun. These varying conditions require a robust

and highly reliable detector that can handle such variations and still maintain a high level of accuracy. This is one of the reasons why CNN-based detectors are preferred for this application, as they have better generalization capabilities and can handle a wide range of conditions. CNNs have a high requirement of computing resources to get a fast inference speed, so in the project, we equipped the vehicle computer with GPU, which can accelerate the neural network's inference.

There are also two main branches of modern detectors. The first is R-CNNs based on the regional proposal, and the inference process consists of two stages [6, 9, 10]. The other is a one-shot method, which operates the feature extraction and object localization at the same time [7, 8, 11]. The one-shot methods have a relatively lower accuracy but much less inference time. Since it is a real-time application with a high running time requirement, a type one-shot detector is to be used in the project.

2.2 Multiple Object Tracking

In recent years, multiple object tracking (MOT) has gained increasing attention, and there are still many challenging tasks like severe object occlusion and abrupt appearance changes [12]. MOT is a technique used to find out multiple objects in single frames and calculate the trajectory of each object across continuous frames. According to the criterion of the initialization method, MOT can be categorized into two main categories: detection-based tracking (DBT) [13, 14] and detection-free tracking (DFT) [15, 16]. DFT has a manually defined and fixed number of objects, so it cannot handle the new appearance and disappearance of objects and is inappropriate for our application. In contrast, DBT uses detectors to discover new objects without number limitations, and disappearing objects are abandoned automatically.

MOT can also be grouped into offline tracking [14, 17] and online tracking [18]. Offline methods utilize batches of frames or the entire image sequence to process the data. Nevertheless, our real-time application requires low inference time so that online methods would be more appropriate. We can predict the object's current state solely based on the observations from the past up to the current frame.

3 Vision-Based Warning System

The basic concept of the whole warning system is to alert the maintenance workers of the coming vehicles from both directions when they might be unaware of the possible danger. Figure 3 displays the overview of the use case scene of the warning system. When the vehicle approaches the short-term roadworks site, the vision system detects it and decides if it is worth warning. Then, it sends a warning trigger to the warning peripherals to alert the road maintenance workers.

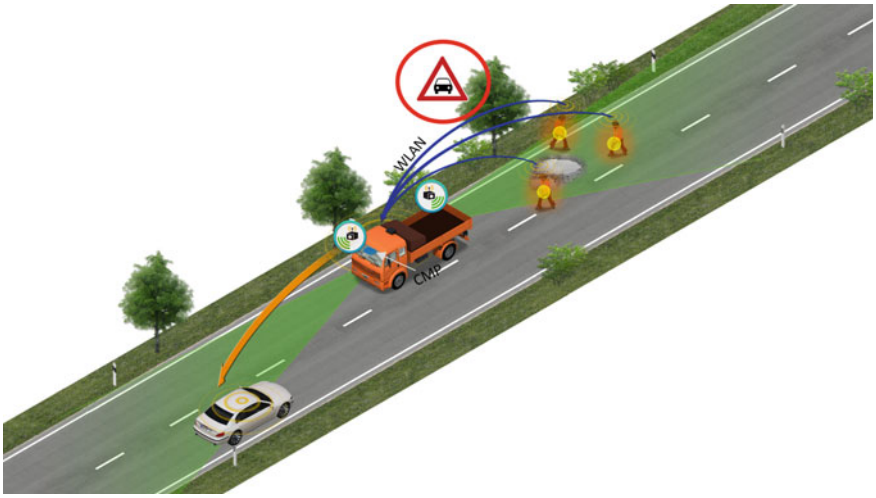

Fig. 3 Overview of the use case scene of the vision-based warning system. *Source* CAR 2 CAR Communication Consortium

The components of the system will include two traditional RGB cameras mounted on the maintenance vehicle and a computer (CMP) with the graphic processing unit GeForce GTX 1080 Ti for computer vision purposes. The vehicle computer can be operated directly using a 12 V power supply from the vehicle's electrical system, which means that it can be operated directly in the vehicle without the need for major structural modifications. All the vehicle computer requires is an adequately protected and suitably dimensioned connection to the vehicle's electrical system. The operating system is Linux-based and thus offers a good platform for vision-based applications.

The peripheral components of the system are warning signal devices worn by road maintenance workers, which receive the warning triggering signal from the vehicle computer through a wireless local area network (WLAN). The component can be attached to a chest strap to improve wearing comfort (Fig. 4). The acoustic signal is implemented by a piezo buzzer, as in smoke alarms. The reason for this choice is that the frequency of the hearing protector does not filter these frequencies strongly in the buzzer range, and the signals can be accordingly easily perceived by the road workers. The acoustic signal generator, in combination with the visual warning lights, is attached to the chest strap. The software components of the system are installed in the vehicle computer, and the description of the corresponding components is structured into the following three parts: (1) the description of the proposed detector, (2) the detection-based tracking system in more detail. (3) The last section then explains the traffic flow check algorithm.

Fig. 4 Warning signal device. *Source* htw saar—ITS Research Group (FGVT)

3.1 Approaching Vehicle Detection

In the first step, the approaching vehicles should be detected in each frame of both camera streams. Here, YOLOv4 is selected to perform the detection, which is a one-shot detector and provides a suitable trade-off between inference time and accuracy. In the following, the training phase of YOLO will be described.

There are three classes in our application to be categorized. They are trucks, vehicles, and pedestrians. We used the pre-trained weights from the original author[1] and applied the transfer learning concept. The transfer learning concept means the knowledge that the neural network has learned from a previous task could be applied to the current task [19]. Transfer learning can dramatically reduce the time required to train neural networks from scratch, and the model can yet perform similarly. Here, we fine-tuned the neural network with our dataset to adapt the neural network to our application.

In the project, a dataset was created based on the videos taken from actual maintenance environments. The dataset contains 1200 images with annotations. The project team members manually performed the labeling task for the dataset. Moreover, the dataset was randomly split into three sets (training/development/test), where the allocation percentage of these three sets follows the rule of thumb (60/20/20).

Since there was only a relatively small training set, only the output layer and the weights feeding into that layer were deleted. Then, a new output layer was created with the output tensor shape $N \times N \times [3 \times (4 + 1 + 3)]$. $N \times N$ represents the number of grid cells, and 3 is the number of anchor boxes. The bounding box of each anchor box is defined by (c_n^i, w_n^i, h_n^i), $n \in [1, N \times N \times 3]$, where $c_n^i = \left(x_n^i, y_n^i\right)$ represents the center, w_n^i the width and h_n^i the height of the corresponding box. i implies the frame index. 1 Objectness C_n^i denotes the probability that an object belonging to any class in the training set exists in the bounding box. 3 class confidence scores $P_n^{i(j)}\left(C_n^i\right)$, $j \in [1, 3]$ are the conditional probability, i.e., probability of class x given an object exists in this box. The products of the Objectness and the class confidence scores specify the probability that the bounding box contains a specific object type.

The weights of the output layer were randomly initialized. Only the weights of the last two layers were optimized, and other layers of the neural network were fixed because of the lack of a large-scale training dataset and the corresponding overfitting concern. The learning rate was set to 0.001, ten times lower than the regular learning rate. The neural network was trained for 20 epochs.

3.2 Detection-Based Tracking

The visual appearance of approaching vehicles can vary greatly due to the outdoor environment in which maintenance workers operate. Factors such as weather conditions, sunlight intensity, and light reflection can greatly impact imaging conditions and lead to significant differences in appearance over time and location. For this reason, not the visual appearance model but only the motion model is applied to relate the detections to the trajectories, similar to [20].

[1] https://github.com/AlexeyAB/darknet.

Kalman filter is applied to estimate the states of each approaching vehicle from a series of uncertain measurements. Here es is assumed that the approaching vehicle travels at a constant velocity since the vehicle's acceleration is not that high, and the interval between image frames is sufficiently small. Our test also proves that using higher-order motion assumption-based model did not lead to more accurate predictions of the vehicles' locations. Therefore, the Kalman filter model is employed with the assumption of constant velocity to increase computational efficiency. The Euclidean distance $\left\|\hat{c}_k^i - c_{n2}^i\right\|$ is defined as the cost of detection being assigned to a trajectory t_k, where $\hat{c}_k^i = F\left(c_k^{i-1}, v_k^{i-1}\right)$ is the filter's state estimation of the trajectory at the frame i. Here, c_k^{i-1} is the location of the kth vehicles at the previous frame $i-1$, v_k^{i-1} the velocity, and F the state transition function. After calculating the matching cost, the Hungarian algorithm is employed to find the best match between detections and trajectories [17, 21]. Therefore, the trajectory of the k th vehicles is updated with $t_k^i = t_k^{i-1} \cup c_n^i$ in case new detection c_n^i is assigned to the trajectory t_k^{i-1}. Then, the filter's state is updated with the new observation.

When new detections cannot be assigned to existing trajectories, they are used to initialize new, suspended trajectories. These suspended trajectories are set as active only if detections could be assigned to them in the subsequent frames. They will be terminated if the suspended trajectories cannot match any detections for several consecutive frames.

3.3 Traffic Flow Check Algorithm

Every time a vehicle is tracked with the help of the detection-based tracking system, the maintenance workers will be not only acoustically but also visually warned. However, in one peak hour, hundreds of vehicles approach the roadworks site, and for each vehicle, the warning device is triggered once, and the road worker is alerted. That means the road workers should be warned hundreds of times in one hour. Apparently, it is not an appropriate solution for road workers. Road workers cannot endure being constantly distracted from their work by such warnings, and such notices can even cause light and sound contamination to them. To overcome these issues, we also developed a traffic flow check algorithm to filter such identification signals from the tracking system.

Algorithm 1 Traffic Flow Check Algorithm

```
Begin
    T_duration := 10
      Set t_start as the current timestamp
      While True
          If a new vehicle is identified Then
              Set t_end as the current timestamp
              t_diff = t_end − t_start
              If t_diff > τ_headway Then
                  Trigger Warning
              End If
              Set t_start as the current timestamp
          End If
      End While
End
```

The warning system aims to alert the maintenance workers of the coming vehicles when they might be unaware of the possible danger. When a car approaches and the system alerts the road workers, they will already prepare and start observing the road condition. At that time, another vehicle is driving to the roadworks site. There is no need to alert the road workers again because they have already been on guard for the passing cars. The traffic flow will also keep the road workers paying attention to the road condition. It is necessary to alert the road workers of the newly emerging vehicle only if there are no vehicles on the road and the road workers relax their attention.

The traffic flow check algorithm uses a while loop to monitor the signal from the tracking system. The tracking system will signal the check algorithm when it identifies a new vehicle. After receiving the signal, the check algorithm will check whether the elapsed time from the last signal to this one t_{diff} exceeds the pre-defined time headway τ_{headway}. If true, the check algorithm will eventually trigger a warning alerting road workers. If false, the start time t_{start} will be reset to the current timestamp, and the timing process will restart. In the initialization phase, t_{start} will be set to the timestamp at that moment. With the algorithm, we can ensure that the check algorithm can trigger a warning only if there is no traffic on the country road for 10 s since the last vehicle. The setting of the T_{duration} as 10 s is the trade-off between convenience and safety. Despite necessary warnings, the road workers should be minimally disturbed. Empirical evidence shows that maintenance workers can maintain the warning-caused attention for about 10 s.

4 Evaluation

4.1 Detector Performance

Both accuracy and the inference time of the underlying detectors are key performance indicators for the whole system. The detector should accurately identify the objects at a high frame rate. A high frame rate means that the elapsed time between frames is short; therefore, the locations change between frames is small, which ensures reliable matching between detections and trajectories. The detector will be evaluated by the test set of the application-specific dataset, which covers a diverse collection of images taken in different weather and sunlight conditions by the two cameras, which are mounted on the vehicle. Therefore, the evaluation with this test set can demonstrate how well the detector can perform in actual working environments. The average precision of the detector can reach 96.2%, while the runtime can still be restricted to 26.9 ms, which equals 37.2 frames per second (FPS). The frequency of the image input of cameras is 30 FPS, which is lower than the processing speed of the detector. That means the detector can be applied to the real-time application in combination with the two cameras. The bottleneck lays not on the detector but the sensor now.

4.2 Real-World Test

The system's effectiveness is not only in laboratory conditions but also in the real world evaluated. For example, we installed the whole system in a maintenance vehicle, and two road workers wore the corresponding warning peripherals. During the testing days, the road workers solely did the regular work, like cleaning potholes, inserting asphalt, and compressing.

Throughout the long-term study, we recorded (1) the timestamps of warning the road workers and (2) the timestamps of the vehicles which caused the corresponding warning passing the roadworks site. Then, the time difference between both timestamps is to be calculated, and the number of time differences that belong to the fixed range is to be counted.

Figure 5 demonstrates the whole system's performance: How many seconds before the approaching vehicles pass the construction site can the detector recognize the vehicle and alert the road workers by the visual and acoustic signals of the warning device? The pre-warning duration represents the remaining response time for the road works and is crucial to the performance of our application. From the figure, we can see that our system can reliably report the warning 3–7 s before the approaching vehicle passes the roadworks site, which allows the road worker to have adequate time to prepare for the potential dangers. We performed a manual analysis for the cases where the time differences were only equal to about 1–2 s. Such cases happened when the roadworks site was in the middle of the curve of some country road. The

camera's view will be blocked by trees or mountain bodies so that it cannot detect the approaching vehicle earlier. Nevertheless, this scenario itself is even more dangerous without our warning system. With the help of the front camera on the car and the vehicle recognition system, we can win up to 2 s for the road workers to prepare, which significantly improves the safety of maintenance work in this dangerous scenario.

In addition, Fig. 5 can present the influence of the implementation of the traffic flow check algorithm. From the graph, we can count the number of alerts received by the road worker in one day in the condition with or without the check algorithm. The road workers receive 1308 warnings in one day, on average 164 warnings per hour without the check algorithm. In peak hours, the road worker can receive even about 32 warnings per minute, which is unacceptable for the road workers. When implementing the check algorithm, the warning times are filtered to one-fifth of the original times, only 316 times. Especially in peak hours, the check algorithm makes a big difference. The received warning times are restricted to only about one warning per minute when the traffic flow is very dense because the vehicles that follow the

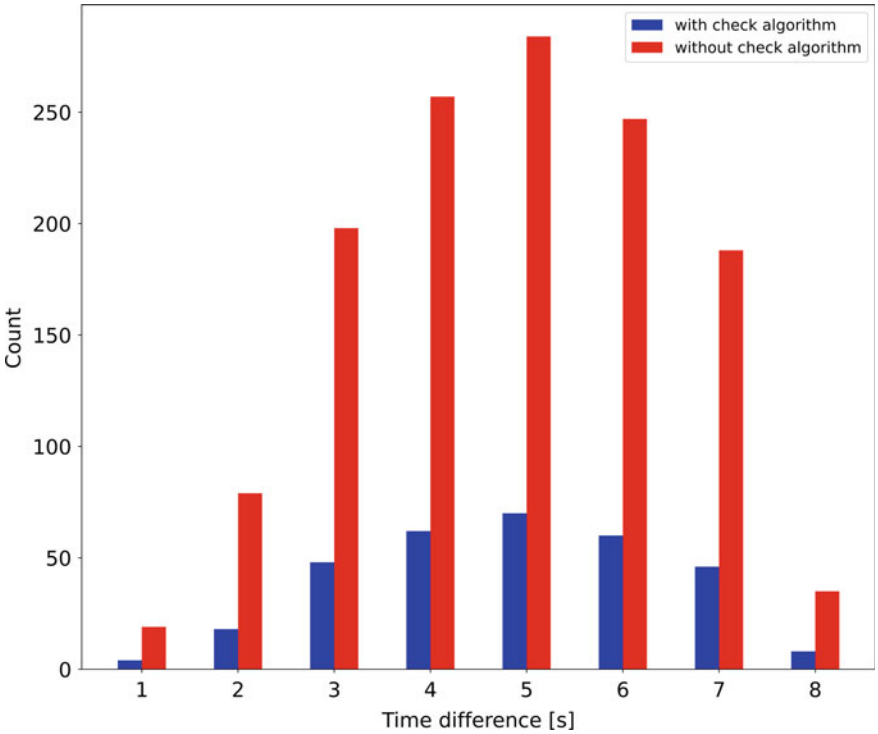

Fig. 5 Time difference between warning of the road workers and vehicles passing the construction site and the count of the warnings in one day

first approaching vehicles are very close. The time headway between those vehicles is usually lower than τ_{interval} (10 s) and will trigger no warnings. In such a situation, the road workers are aware of the existence of such approaching vehicles, so there is no need to remind them repeatedly.

On the one hand, the system can help road workers detect approaching vehicles when they focus on work and are not so sensitive to the environment; on the other hand, it can give warning to the road workers in advance when approaching vehicles are still obscured by the maintenance vehicle, which results in that the road workers cannot detect such vehicles in time. The latter is extremely dangerous and can be thoroughly solved by the vision-based warning system.

5 Conclusion

The safety of road maintenance workers on STRWS is critical, mainly because there are no physical safety barriers separating working areas and used lanes. Instead, only traffic cones and safety beacons separate the roadworks site and the traffic lane. The approach proposed in this paper, which consists of a detector, tracking, check algorithm, and warning device, aim to improve the safety of maintenance workers in STRWS with active protection. The evaluations demonstrate that the implemented system can reliably detect the approaching vehicle and decide intelligently whether the warning device should alert the road workers or not. With two cameras in both the front and rear of the construction vehicle, both sides of the country road will be under observation. The developed traffic flow algorithm can efficiently reduce the warning times so that the road workers are not too often disturbed and receive just necessary warnings. Furthermore, the warning device can send both visual and acoustic signals. The acoustic signal is implemented by a piezo buzzer, whose frequency will not be significantly filtered by the hearing protector that the road worker wears during the work to filter the noise from the roads.

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Video Game in Unity for the Learning Process in the Mathematics Course in Children

Carbajal Montalban Walter Piero and Michael Cabanillas-Carbonell

Abstract Education has become not so different in the course of the years using blackboards and a teacher explaining different knowledge, in output to it the use of technology has become a great ally of education, achieving important benefits for the student, especially in the learning process. Video games are being used by several teachers and students for didactic learning remotely and/or face-to-face. This article shows the development and influence of a video game that serves as a learning enhancement of the mathematics course in first-grade elementary school students. The Scrum methodology is used during the development process of the video game, the research design is experimental because the corresponding pre-test and post-test are performed on a single group of students a total of 40, obtaining a final result in the increase of the student's concentration time indicator by 40.30%, and in the following indicator of academic results, an increase of 35.73% was obtained and finally in the satisfaction degree indicator an increase of 17.14%, giving in conclusion that the video game helps them to improve their learning.

Keywords Video game · Learning · Elementary education · Scrum methodology

1 Introduction

Nowadays, we live in a world of great changes, which is witnessing innovations practically every day. This situation involves all aspects of our lives, and the world of education is no exception [1]. As stated by [2], the traditional way of teaching mathematics to today's children no longer has the same effect as it had on the children of past generations, because nowadays different things attract children's attention, such as information technology, which can act as a distractor if they do not use it correctly. We find the fact that there are teachers who lack knowledge of information technology (IT), some of them are not willing to learn to use technological tools for

C. M. W. Piero (✉) · M. Cabanillas-Carbonell
Universidad Privada del Norte, Lima, Perú
e-mail: n00209050@upn.pe

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the teaching process, and however, it is known that the number of young teachers who are willing to work with technologies and seek to innovate teaching to capture the children's attention is increasing.

Techniques to capture the attention of students and reach the different learning styles. Although, indeed, technology is not the same for everyone because certain parts of the world are more advanced in technology than others, such as China and the USA. The fact that ICTs are not widely used in education in Latin America, which is a considerable difference from first-world countries, what is sought is to universalize access to the digital world with what is available, and it is education that should take charge of leading this change [3].

Therefore, the study of the impact of video games is a topic of special interest, not only from the perspective of consumers, production companies, and public administrations but also because video games are a socializing agent that has a great influence on the cultural values that our children and adolescents are acquiring. It is essential to emphasize that video games influence the part of the population that consumes them, so studies are being carried out on the cognitive implications of video games and how they influence education [4, 5].

Education has been the same for decades, and over the years, it has not been so different, having a folder, a teacher, notebooks, pens, and the possibility of improving a book for learning. Nowadays, children grow up with technology in the palm of their hands, and their way of doing things is very different from those who were not born in the technological era, so children with technology at hand need to know different learning methods and techniques to attract their interest.

One of the ways to establish improvements in the educational world is through the use of technological tools [6, 7]; for that reason, a video game has been developed and implemented in which children can interact and learn in a didactic way the basic concepts of mathematics since they are first-year elementary school students. What we want to achieve in this research is to provide a technological proposal, which will help improve student learning in the mathematics course, showing a significant increase in (the three KPIs).

2 Bibliographic Study

Teaching in schools has long been based on the traditional teacher-blackboard-student elements, thus having to learn in a rigid way and without the use of technology. Nowadays, much educational software facilitates our learning in an efficient and self-taught way. As [8] says, teachers should be trained in how to use ICTs for student-centered learning; i.e., they should model the use of ICTs so that the child can recognize problem situations, analyze them, solve them, and present the results, and all this using ICTs.

According to the publication made in 2013 [9], any computer program whose structural and functional characteristics support the process of teaching, learning, and administration. A more restricted concept defines it as learning material specially

designed to be used with a computer in the teaching and learning processes. On the other hand, [10] says that: educational software is a computer application, supported by a well-defined pedagogical strategy, that directly supports the teaching–learning process, constituting an effective instrument for the educational development of the man of the new century.

3 Methodology

Both Scrum methodology and XP methodology have an agile approach, and both are governed by the fact that work should be done incrementally. Both methodologies emphasize the importance of team autonomy, transparent communication, and prioritization [11].

3.1 Comparison of Agile Methodologies

In this research, we are working with the Scrum methodology, since after comparing both methodologies (Table 1), it was concluded that Scrum is flexible for the team and quick to adapt.

Table 1 Comparison of agile methodologies

	Scrum methodology	XP methodology
Definition	The Scrum methodology is a management framework for incremental product development using one or more cross-functional, self-organizing teams. It provides a structure of roles, meetings, rules, and artifacts. Teams are responsible for creating and adapting their processes within this framework [12]. The objective of this methodology is to maximize the return on investment for the business. It is based on the initial creation of the most valuable functions for the customer and the principles of continuous testing	Extreme programming, or extreme programming, is a software development discipline based on agile methods, which evidence principles such as incremental development, active customer participation, focus on people rather than processes as the main element, and acceptance of change and simplicity. The fundamental work was published by Kent Beck in 1999 and took the name Extreme Programming because of the recognized practices in software development and customer involvement at extreme levels [13]
Elements	Exploration, initialization, sprint planning, development, sprint review	Planning, design, coding, testing
Roles	Product owner, Scrum manager, Scrum team, stakeholders, users	Programmer, client, tester, tracker

3.2 Research Design and Type

According to its approach, this research is considered quantitative, because through measurement procedures, we will focus on the study and analysis of the problem. To carry out experiments and obtain contrasted explanations based on the hypotheses proposed [14]. The present research is of pre-experimental design with pre-test and post-test design, since this design is for a single group. This research is considered applied since it will be possible to achieve the proposed objectives, thus allowing us to provide solutions to different problems, offering elements such as software or decision-making.

3.3 Population and Sample

According to Ref. [15], the population, for educational research, is the set of elements about which it is of interest to obtain conclusions or make inferences for decision-making. For the present investigation, there will be 40 students in the mathematics course of the first year of primary school "Fe y Alegría N° 8°", located in the city of Lima, in the district of Comas.

The sample is a subset of the population to which we have access and must be representative of it because the pertinent measurements are made on it [15]. For the present investigation, the sample will be made up of 37 students identified in the population.

3.4 Data Collection Instruments

In this research, we used surveys to measure the degree of satisfaction, also observation to examine the student's concentration time when using the software, and finally, a test to measure the degree of capture or academic surrender. After applying the instruments, we organized the information and used SPSS software version 28.0 to analyze it.

3.5 Methodology Development

Sprint 1. We proceeded to visualize the game options or categories (addition, subtraction, multiplication, division) (see Fig. 1e). This being the core of the video game, we proceeded immediately to make visible each game option as mentioned above: addition (see Fig. 1b), subtraction (see Fig. 1c), multiplication (see Fig. 1d), and division (see Fig. 1e).

Fig. 1 Developed sprint 1 interfaces

Sprint 2. For the theme of the actions, a green color will be added in case the selected answer is correct and a red color in case it is incorrect (see Fig. 2a, b). Also, the main menu (see Fig. 2c) and the interaction of the lives (see Fig. 2d) have been incorporated.

Fig. 2 Developed sprint 2 interfaces

Sprint 3. To make the game a little more interesting, the game will show the accumulated points (see Fig. 3a) and the option in case you have passed the whole game (see Fig. 3b).

Sprint 4. We proceeded to develop the "lost" interface (See Fig. 4a), also in case the user needs to interrupt the activity, we developed the "pause" interface (Fig. 4b) where the user has the option to restart the game (Fig. 4c), to re-select the category (Fig. 4d) and to return to the main menu (Fig. 4e), and finally, we placed background music automatically at all times to make the environment more user-friendly.

Fig. 3 Developed sprint 3 interfaces

Fig. 4 Interfaces desarrolladas del sprint 4

4 Results and Discussion

4.1 Descriptive Analysis

Indicator 1—Student Concentration Time: Fig. 5 shows the results obtained from the experimental group concerning the pre-test and post-test, and it is observed that the level of interest of the students increases by 40.30% over the interest they have during the development of the mathematics course.

Indicator 2—Academic Results: Fig. 6 shows the results obtained by the experimental group concerning the pre-test and post-test, and it is observed that the academic results have increased by 35.73%.

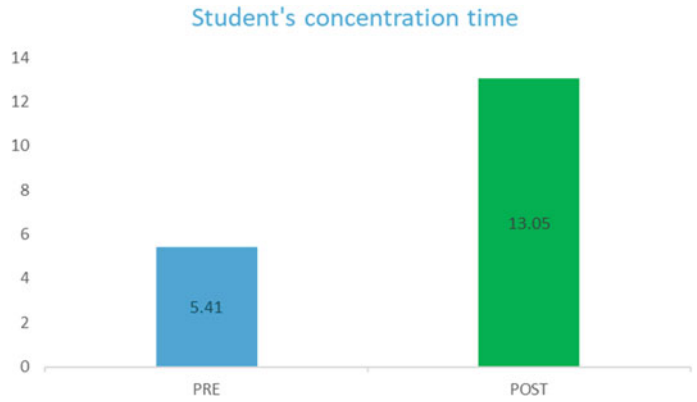

Fig. 5 Pre-test and post-test of student concentration time

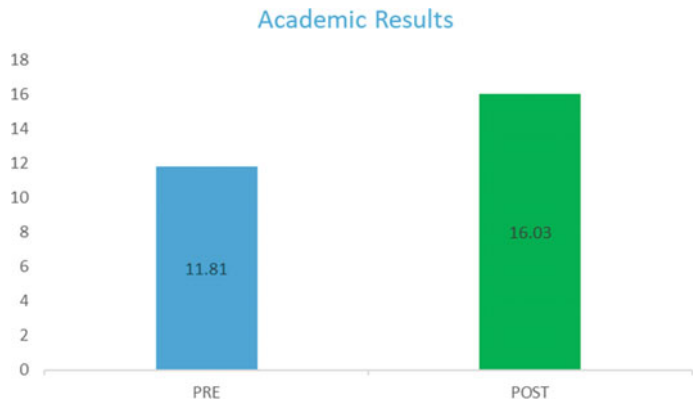

Fig. 6 Pre-test and post-test of academic results

Fig. 7 Pre-test and post-test of student satisfaction degree

Indicator 3—Degree of satisfaction of the students: Fig. 7 shows the results obtained from the experimental group concerning the pre-test and post-test, and it is observed that the degree of satisfaction has increased on the part of the students.

5 Conclusions

In this research article, we have presented a review of research on the benefits of the use of ICT in children's learning, concluding that these contribute greatly to their academic performance, self-learning, and creativity, in addition to increasing their enthusiasm for the courses encouraging research and wanting to support and teach their peers.

In this article, a video game was developed with Unity and Visual Studio Code as a tool to improve learning in the mathematics course for elementary school students, providing additional didactic information along with questionnaires to measure the progress of their knowledge.

It has been observed that the use of video games significantly improves learning in mathematics courses due to an increase of 35.73% in their grades as shown in Fig. 6, and the concentration time and enthusiasm for learning are higher by 40.30% as shown in Fig. 5. The results showed that the proposed video game has succeeded in promoting self-learning, didactic learning, research, and fellowship. It is recommended for future research to develop much more didactic and much more complete video games for the other areas.

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Evaluation of Intrinsic Explainable Reinforcement Learning in Remote Electrical Tilt Optimization

Franco Ruggeri, Ahmad Terra, Rafia Inam, and Karl H. Johansson

Abstract This paper empirically evaluates two intrinsic Explainable Reinforcement Learning (XRL) algorithms on the Remote Electrical Tilt (RET) optimization problem. In RET optimization, where the electrical downtilt of the antennas in a cellular network is controlled to optimize coverage and capacity, explanations are necessary to understand the reasons behind a specific adjustment. First, we formulate the RET problem in the reinforcement learning (RL) framework and describe how we apply Decomposed Reward Deep Q Network (drDQN) and Linear ModelU-Tree (LMUT), which are two state-of-the-art XRL algorithms. Then, we train and test such agents in a realistic simulated network. Our results highlight both advantages and disadvantages of the algorithms. DrDQN provides intuitive contrastive local explanations for the agent's decisions to adjust the downtilt of an antenna, while achieving the same performance as the original DQN algorithm. LMUT reaches high performance while employing a fully transparent linear model capable of generating both local and global explanations. On the other hand, drDQN adds a constraint on the reward design that might be problematic for the specification of the objective, whereas LMUT could generate misleading global feature importance and needs additional developments to provide more user-interpretable local explanations.

Keywords Explainable reinforcement learning · Reinforcement learning · Artificial intelligence · Remote electrical tilt optimization · Cellular networks

F. Ruggeri · A. Terra · R. Inam
Ericsson Research, Stockholm, Sweden
e-mail: ahmad.terra@ericsson.com; terra@kth.se

R. Inam
e-mail: rafia.inam@ericsson.com; raina@kth.se

F. Ruggeri (✉) · A. Terra · R. Inam · K. H. Johansson
KTH Royal Institute of Technology, Stockholm, Sweden
e-mail: franco.ruggeri@ericsson.com; fruggeri@kth.se

K. H. Johansson
e-mail: kallej@kth.se

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1 Introduction

In the last two decades, reinforcement learning (RL) has received considerable attention from the telecommunication domain due to its outstanding performance in many applications. Traditional rule-based techniques have been outperformed by RL algorithms in a variety of complex telecommunication use cases, such as edge computing [1], radio resource management [2, 3], and Remote Electrical Tilt (RET) optimization [4–7]. In the RET use case, RL can be used to control the electrical downtilt of multiple antennas in a cellular network in order to optimize specific key performance indicators (KPIs).

Despite the superior performance, state-of-the-art RL algorithms lack explainability and transparency [8, 9], i.e., it is often hard for humans to understand why an RL agent makes a specific decision. This lack of explainability can hinder the adoption of RL for industrial domains [10–12], as users are less likely to use an application that they do not trust, and black-box models may raise ethical issues. In the RET use case, the decision of an RL agent to adjust the downtilt of an antenna influences the experienced communication bandwidth of some users. Therefore, it is desirable to understand the reason behind each decision. Recently, researchers have focused on the development of Explainable Reinforcement Learning (XRL) methods to enhance RL explainability [8, 9]. Such methods inspect different parts of the RL framework—namely agent's model, rewards, and environment state—to extract explanations and provide additional insights to the system designer.

The main motivation for this paper is that most XRL methods have not been extensively evaluated in real-world applications, including the telecommunication domain. XRL is, indeed, still a research area in its infancy. A search of the literature has revealed only few studies that have applied XRL to real-world problems [13–16], and many promising XRL methods have not been covered by such studies. Due to this scarcity of results, it is unclear which method best suits a particular problem and what advantages and disadvantages each method provides. There is a need for systematic comparisons of XRL methods that can provide guidelines for the application of XRL.

The purpose of this paper is to empirically evaluate on the RET optimization problem two promising XRL algorithms: drDQN [17] and LMUT [18]. For doing so, we first formulate the RET optimization problem as an RL problem suitable to apply both drDQN and LMUT and describe how to apply them to such a problem. In particular, we consider a simplified use case where only one of the antennas needs to be controlled, which allows checking the explanations provided by the two XRL methods. Second, we evaluate drDQN and LMUT in a simulated radio access network (RAN). Since these two XRL algorithms are intrinsic, i.e., they modify existing RL algorithms to make them more transparent and provide explanations by showing their internal mechanism, the performance may be degraded compared to the original RL algorithm. Thus, the evaluation considers both performance and explainability. The results are discussed thoroughly to highlight the advantages and disadvantages of drDQN and LMUT.

Contributions: The main contributions of this paper are: (i) to present, to the best of our knowledge, the first study that empirically compares drDQN and LMUT on the RET use case; (ii) to formulate the RET optimization problem as an RL problem suitable to apply drDQN and LMUT, as well as to benchmark other XRL methods in the future; and (iii) to present qualitative results of the explanations achievable using drDQN and LMUT in the RET use case.

Outline: Section 2 presents the related work. Section 3 formulates the RET optimization problem as an RL problem suitable to apply the selected XRL methods. Section 4 briefly describes drDQN and LMUT with focus on how to apply them to the RET problem. Section 5 discusses the simulation setup and the results of the simulations. Section 6 summarizes our findings and the ideas for future work.

2 Related Work

The relevant literature for this paper comprises two research areas: RL in RET optimization and XRL. Previous studies have found that RL approaches can outperform traditional rule-based policies hand-crafted by domain experts in the RET use case [4–6]. In particular, Vannella et al. [5] demonstrated how safe RL can outperform rule-based policies in terms of both performance and safety by training the agent offline on real network data collected under the rule-based policy. In [6], Vannella et al. showed that an off-policy contextual bandit algorithm consistently outperforms the rule-based policy in RAN simulations. Buenestado et al. [4] found that RL can tune several parameters of the antenna, among which the downtilt, more efficiently than traditional algorithms.

The literature on XRL has developed several promising methods. According to [8, 9], these methods can be classified into post-hoc and intrinsic methods. Whereas post-hoc methods rely on an auxiliary model to extract explanations from the complex agent, intrinsic (or transparent) methods are RL algorithms that provide explanations by design. Another criterion is given by the scope of the explanation: A global explanation summarizes the general behavior of the agent, while a local explanation refers to a specific agent's decision. Among the intrinsic methods, Liu et al. [18] proposed LMUT as a transparent model to learn mimicking a black-box agent. LMUT is a combination of regression trees and linear regressions. It can provide both global and local explanations. Juozapaitis et al. [17] modified existing RL algorithms by decomposing the reward into a sum of reward components and, consequently, decomposed the agent's model to learn separate value functions while still optimizing the total reward. This idea, known as reward decomposition, was applied, for example, to DQN [19] to generate drDQN, which is capable of providing contrastive explanations with lightweight post-processing consisting of differences of Q-components. Starting from drDQN, Terra et al. [16] combined the reward decomposition idea with SHAP [20], an established feature attribution method from Explainable AI (XAI), to find correlations between inputs and outputs of the Q network. The new method, called Both Ends Explanations for Reinforcement Learning (BEERL), was imple-

mented on the RET use case. Regarding post-hoc methods, Hayes and Shah [21] devised an algorithm-agnostic framework to summarize the agent's policy (i.e., state-to-action mappings) in natural language by using user-interpretable communicable predicates. Van der Waa et al. [22] modified the idea in [21] to explain actions in terms of expected consequences, rather than correlations between state and action, through user-interpretable outcomes describing rewards. More specifically, they proposed to compute the expected outcomes of an action by simulating future steps through a learned model of the environment. Greydanus et al. [23], instead, considered agents learning directly from raw images, in which case the XRL methods mentioned so far can hardly be successful. The authors used perturbation-based saliency maps to highlight pixels with a high impact on the action selection. Iucci et al. [13] applied [17, 21] to a human–robot collaboration scenario and showed how having both local and global explanations can help to have a complete overview of the agent's behavior.

The existing literature on RL in RET optimization focuses on performance but neglects explainability. An exception is [16], which applied XRL to the RET use case. Inspired by it, we design the reward as a linear combination of KPIs in order to apply drDQN. However, while [16] focuses on developing a new XRL method and implementing it on the RET problem, our work aims to *assess and compare* two existing XRL algorithms, drDQN [17] and LMUT [18], to find their advantages and drawbacks. To be able to assess explanations, we consider a RET problem where only one antenna is controlled. This simple setup serves as a benchmark for XRL and can be used in future work to evaluate other XRL methods. Among the available XRL methods, we decided to restrict the work to *intrinsic* XRL, as it does not suffer from potential inaccuracies of the auxiliary model present in post-hoc methods. Furthermore, to the best of our knowledge, no previous study has applied LMUT to a telecommunication problem.

3 RET Optimization

In this section, we describe in detail the RET use case, including the explainability aspects we seek in this work, and formulate it as an RL problem suitable to apply the selected XRL methods.

3.1 System Model

We consider a geographical area where B BSs and U UEs are deployed. Each BS is equipped with A_b directional antennas. Thus, the set of antennas $\mathcal{A}$ in the cellular network has cardinality $|\mathcal{A}| = B \cdot A_b$. Figure 1 shows an example with $B = 2$, $A_b = 3$ (three-sectorial BSs), and cells with hexagonal shape. Given a fixed electrical downtilt of the antennas $a_2, ..., a_{|\mathcal{A}|} \in \mathcal{A}$, the problem is to control the electrical downtilt θ of the remaining antenna $a_1 \in \mathcal{A}$, denoted as a hereafter, in order to

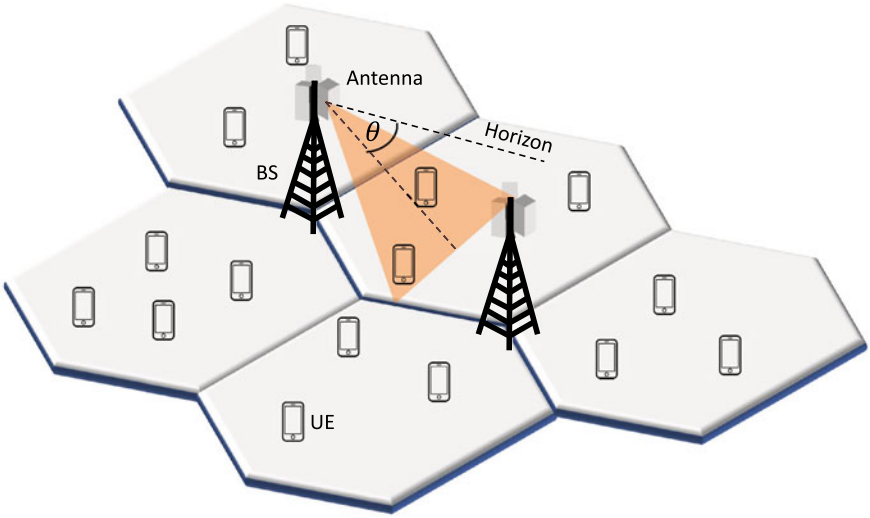


Fig. 1 Abstract representation of the RET optimization problem. There are two BSs, each equipped with 3 directional antennas. The downtilt θ of one antenna needs to be adjusted to optimize coverage and capacity. The downtilt of the other antennas is fixed

optimize certain KPIs. The downtilt is defined as the inclination angle of the main lobe of the antenna radiation pattern with respect to its horizontal plane [5] (see Fig. 1).

Two important KPIs for mobile network operators are coverage and capacity, which are conceptually defined as follows. Coverage refers to the area from which a UE can access the cellular network, while capacity refers to the amount of traffic the cellular network can handle simultaneously. Inspired by [16], we use reference signal received power (RSRP) and signal-to-interference-plus-noise ratio (SINR)[1] to represent coverage and capacity, respectively. RSRP can be used to assess whether a coordinate in the area of interest is covered by the network, as it considers a reference signal from the antenna that has not been optimized for a specific UE. In contrast, the amount of traffic the network can handle strongly depend on the number of errors and retransmissions and, consequently, on the SINR to each UE. Note that more sophisticated ways to model coverage and capacity have been proposed (e.g., [6, 7]), but are out of the scope of this work.

Explainability is important in the RET use case and represents the focus of this work. When an RL agent adjusts the downtilt θ of the antenna, the performance may degrade for some users and increase for others. Specifically, higher values of the downtilt θ reduce the area covered by the antenna, with the risk of leaving a certain area without coverage, but increase the capacity in the covered area due to a stronger signal. In contrast, smaller values of θ result in a larger area covered

[1] In this work, SINR refers to the SINR in the data plane.

but lower capacity due to a weaker signal. Essentially, the problem implies a multi-objective optimization of coverage and capacity with a clear trade-off determined by the downtilt. For these reasons, it is crucial to explain the RL agent's tilt decisions. The specific kind of explanation depends on the XRL method and will be described in Sect. 4. For example, a local explanation might highlight which KPI has the most significant impact on an agent's decision.

Before formulating the RET use case as an RL problem, it is worth mentioning why RL is suitable to solve this problem. A cellular network is a dynamical system with intricate dynamics that are difficult to model analytically and accurately. There are plenty of factors to take into account, such as propagation loss of the signal along with fading and shadowing, antenna model, UE mobility, and the BS selection procedure (also known as cell association). To exemplify, when θ decreases (i.e., the signal beam turns up), some UEs previously served by antenna a might be reassigned to another antenna that can serve them better. Such a complexity of the system dynamics is the primary motivation for using model-free RL.

3.2 RL Problem Formulation

Before applying the XRL algorithms, we need to model the RET optimization problem as an RL problem. We assume a quasi-stationary scenario where the UEs are static for a certain period. Under this assumption, the KPIs vary only if θ varies, i.e., they are functions of θ. We define the average RSRP and SINR per UE as:

$$\overline{\text{RSRP}}(\theta) = \frac{1}{U} \sum_{i=1}^{U} \text{RSRP}_i(\theta) \tag{1}$$

$$\overline{\text{SINR}}(\theta) = \frac{1}{U} \sum_{i=1}^{U} \text{SINR}_i(\theta) \tag{2}$$

where RSRP_i and SINR_i are the RSRP and SINR measured by the UE i in dBm and dB, respectively. In the following, we use min-max normalized versions fulfilling $\text{RSRP} \in [-1, 1]$ and $\text{SINR} \in [-1, 1]$. The objective is to find the optimal downtilt maximizing a linear combination of average RSRP and SINR:

$$\begin{aligned} \underset{\theta}{\text{maximize}} \quad & \text{RSRP}(\theta) + w \cdot \text{SINR}(\theta) \\ \text{subject to} \quad & \theta_{\min} \leq \theta \leq \theta_{\max} s \end{aligned} \tag{3}$$

where $\theta_{\min}$ and θ_{max} are preconfigured by domain experts according to safety regulations and specifications of the antenna. The weight w controls the relative importance of RSRP and SINR and is set according to the requirements of the network. This optimization problem can be formulated in the RL frame-

work by defining state space $\mathcal{S}$, action space $\mathcal{A}$, and reward function r. Let $s' = (\text{RSRP}', \text{linear combination of average}', \theta') \in \mathcal{S}$ be the system state after an action:

$$\mathcal{S} = \{(\text{RSRP}, \text{SINR}, \theta) \mid (\text{RSRP}, \text{SINR}) \in [-1, 1]^2, \theta \in [0°, 15°]\} \tag{4}$$

$$\mathcal{A} = \{+\delta, 0, -\delta\}, \ \delta \in \mathbb{R} \tag{5}$$

$$r(s, a, s') = r(s') = \text{RSRP} + w \cdot \text{SINR}, \ \forall s' \in \mathcal{S} \tag{6}$$

The state includes the normalized versions of RSRP and SINR, and the downtilt θ measured in degrees. The action space contains the three actions corresponding to downtilting (i.e., increasing θ by δ degrees), keeping the same downtilt, and uptilting (i.e., decreasing θ by δ degrees). The reward received for an action depends only on the system state $s' \in \mathcal{S}$ after applying the action. Since the state transitions are deterministic under the assumption of static scenario, the reward $r(s, a)$ associated with an action $a \in \mathcal{A}$ in the state $s \in \mathcal{S}$ is also deterministic. Nevertheless, state transitions and rewards are unknown.

4 XRL Algorithms

In this section, we present the selected XRL algorithms, focusing on their application to the RET optimization problem. We discuss only the relevant aspects necessary for the evaluation.

4.1 DrDQN

DrDQN [17] is an intrinsic XRL algorithm that modifies the structure of DQN in order to provide local explanations. Its main idea is to decompose the reward, which normally is a single scalar value, into a vector of semantically meaningful reward components. Equation (4), the reward decomposition for our problem is as follows:

$$r(s, a, s') = r(s') = r_{\text{rsrp}}(s') + r_{\text{sinr}}(s'), \ \forall s' \in \mathcal{S} \tag{7}$$

$$r_{\text{rsrp}}(s') = \text{RSRP}' \tag{8}$$

$$r_{\text{sinr}}(s') = w \cdot \text{SINR}' \tag{9}$$

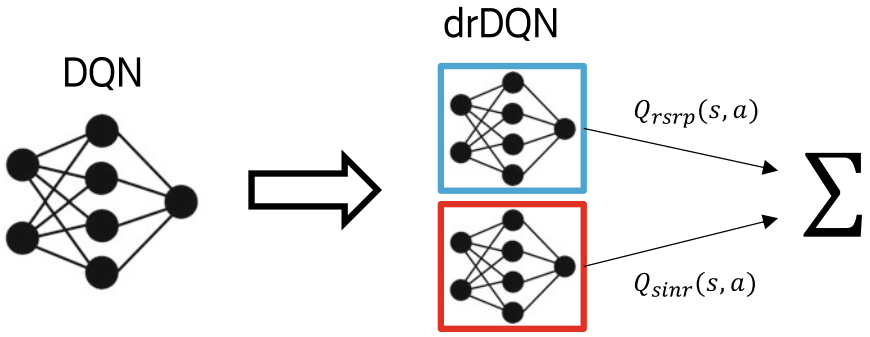


Fig. 2 Structure of drDQN derived from DQN for the RET optimization problem

This reward decomposition is then incorporated into the drDQN model by using one separate DNNs for each reward component (differently from DQN, which uses a single DNN). Therefore, in our problem, the structure of drDQN consists of two DNNs, as depicted in Fig. 2. The output of the drDQN model is a Q-vector:

$$\mathbf{Q}(s,a) = [Q_{\text{rsrp}}(s,a),\, Q_{\text{sinr}}(s,a)]^T \tag{10}$$

where Q_{rsrp} and Q_{sinr} are the Q-components corresponding to the reward components r_{rsrp} and r_{sinr}. The drDQN agent can be trained in the same way as any other RL algorithm by directly interacting with the system. Like the original DQN, drDQN's objective is to learn the Q-function, with the only difference that the Q-function is a sum of Q-components:

$$Q(s,a) = Q_{\text{rsrp}}(s,a) + Q_{\text{sinr}}(s,a) \tag{11}$$

By exploiting such a decomposed structure, the agent can provide contrastive explanations by calculating the Reward Difference Explanation (RDX) as follows:

$$\begin{aligned}\Delta(s,a_1,a_2) &= [\Delta_{\text{rsrp}}(s,a_1,a_2),\, \Delta_{\text{sinr}}(s,a_1,a_2)]^T \\ &= [Q_{\text{rsrp}}(s,a_1) - Q_{\text{rsrp}}(s,a_2),\, Q_{\text{sinr}}(s,a_1) - Q_{\text{sinr}}(s,a_2)]^T \\ &= \mathbf{Q}(s,a_1) - \mathbf{Q}(s,a_2)\end{aligned} \tag{12}$$

where positive and negative components of indicate advantages and disadvantages of action a_1 compared to action a_2. For example, $\Delta_{\text{rsrp}} > 0$ means that, according to the agent's model, selecting a_1 instead of a_2 benefits the RSRP (or, more specifically, leads to a higher expected discounted r_{rsrp}).

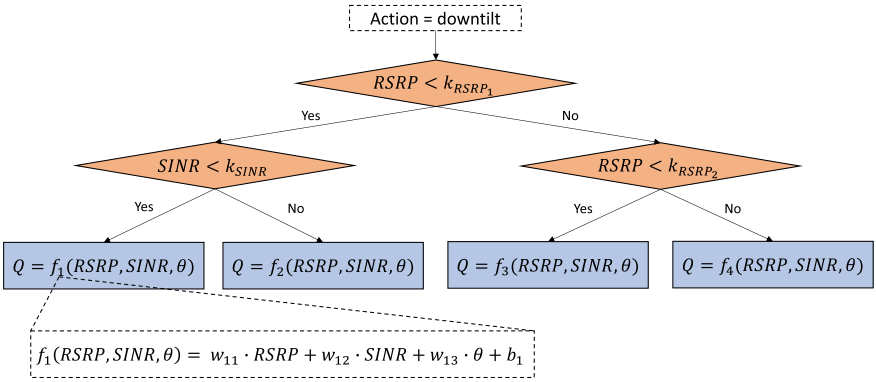


Fig. 3 Example of LMUT for the RET use case. Only the linear tree corresponding to the downtilt action is shown

4.2 LMUT

LMUT [18] is an intrinsic XRL method that approximates a black-box model—in our case DQN—with a transparent model in order to provide both global and local explanations. The transparent model, made of $|\mathcal{A}|$ (i.e., number of actions) linear trees,[2] is trained in a supervised manner to predict the Q-values produced by DQN. Thus, we train three linear trees corresponding to *downtilting*, *keeping the same tilt*, and *uptilting*. An example of possible LMUT for the RET problem is illustrated in Fig. 3. The training algorithm incrementally (episode by episode, online learning) adds a binary split over a feature every time the model cannot fit the data accurately enough (threshold of Mean Squared Error (MSE)). When a split happens, a leaf becomes a splitting node, and its linear regression is no longer updated. In order to support online learning, the linear regression is trained with SGD.

LMUT selects the best feature and value for a split according to the criterion of maximum variance reduction of Q-values. In [18], the variance reduction is calculated by considering only the child node with minimum variance, which encourages always splitting on the smallest or greatest value of a feature (left or right child node with one instance and zero variance). The consequence is an unbalanced tree that grows only on one side (left or right) and inevitably becomes large and hard to interpret. We modified this calculation to a weighted sum of the variances in the child nodes, with the weight of each child proportional to the number of instances falling into it. This modification keeps the model small and easy to investigate for explainability, as illustrated in Sect. 5.

Local explanations LMUT generates local explanations via rule extraction. When the lmut agent has to select an action in a state $s \in \mathcal{S}$, the Q-value $Q(s, a)$ of each

[2] A linear tree is an extension of a regression tree where each leaf contains a linear regression instead of a scalar value [18]. It provides more expressiveness than standard regression trees while maintaining transparency.

action $a \in \mathcal{A}$ is calculated by using a linear regression in a leaf. Therefore, it is possible to extract rules $A \implies B$, where A is the logical conjunction of the splits from the root to the leaf, and B is the linear regression in the leaf. For example, in the RET problem, a rule can be as follows:

$$\text{RSRP} \in (k_{\min}, k_{\max}) \implies Q(s, a_1) = w_0 + w_1 \cdot \text{RSRP} + w_2 \cdot \text{SINR} + w_3 \cdot \theta$$

where $k_{\min}$ and $k_{\max}$ are constants, and w_i are the weights of the triggered linear regression.

Global explanations LMUT provides also a global explanation via feature importance. Let $\mathcal{N}_f$ be the set of splitting nodes in the linear trees using feature f (e.g.,RSRP) to split. The global feature importance of f is defined as:

$$\phi(f) = \sum_{n \in \mathcal{N}_s(f)} \phi_n(f) \tag{13}$$

That is, the sum over the feature importance for each splitting node $n \in \mathcal{N}_f$. The feature importance for a single splitting node $n \in \mathcal{N}_f$ is computed as:

$$\phi_n(f) = \left(1 + \frac{|w_{n,f}|^2}{\sum_{j=1}^{F} |w_{n,j}|^2}\right) \cdot \left(\text{var}_n - \sum_{c=1}^{C} \frac{I_c}{\sum_{i=1}^{C} I_i} \cdot \text{var}_c\right), \forall n \in \mathcal{F}_s \tag{14}$$

where F is the number of features, C is the number of child nodes, and var_i and I_i are the variance and the number of Q-values $Q(s, a)$ stored in node i. The feature importance contains two contributions from the linear regression and the variance reduction. Both contributions come from the splitting nodes.

5 Evaluation

In this section, we describe the simulation setup and present our simulations' results. After that, we discuss the advantages and disadvantages of the evaluated XRL algorithms.

5.1 Simulation Setup

We simulated the scenario depicted in Fig. 4 (based on Fig. 1) by using a high-fidelity RAN simulator employing state-of-the-art models. The scenario consists of a sectorized LTE cellular network containing 2 BSs, each with 3 directional antennas, and 1000 UEs whose position was sampled from a uniform random distribution. The geographical area is a square of 16 000 m^2 divided into squared bins of 1 m^2, which

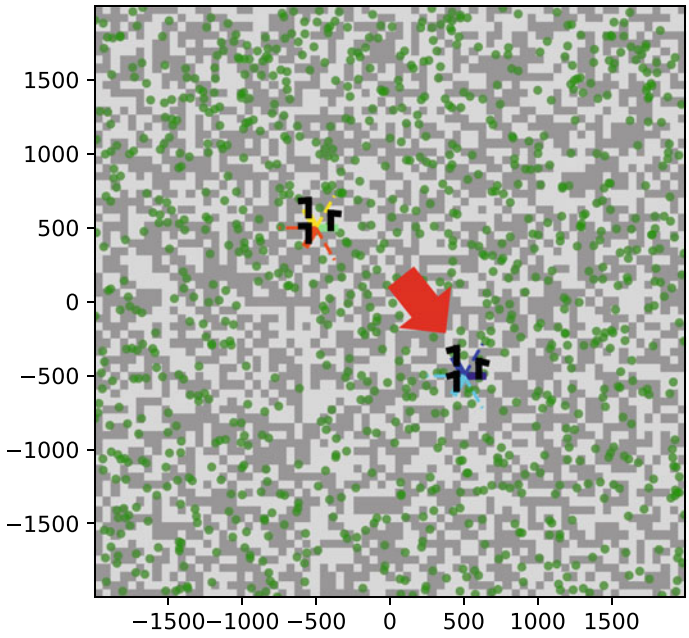


Fig. 4 Simulated scenario. The map is divided in indoor and outdoor bins, colored in dark and light gray, respectively. UEs are represented as green dots, while antennas are drawn in black. The antenna under control is pointed by a red arrow

are randomly classified as indoor or outdoor with the same probability. The downtilt θ of the controlled antenna can vary in the range $[0°, 15°]$ with adjustments of $1°$. In contrast, the downtilt of the other antennas is fixed to random values sampled from a uniform distribution in $[0°, 15°]$. According to the assumption mentioned in Sect. 3, the scenario is static except for the downtilt of the controlled antenna. All the relevant parameters of the simulation are reported in Table 1.

With this setup, the downtilt θ of the controlled antenna can assume 16 different values. Consequently, there are 16 distinct states. Figure 5 shows rewards and reward components obtained by analyzing the 16 possible configurations with the simulator. Observing the reward curve, we can understand that the optimal policy consists of reaching $\theta = 8°$ in the minimum number of actions and then staying at $\theta = 8°$ for the rest of the time. It is also worth mentioning that, for each episode, we reset θ randomly among the 16 possible discrete configurations.

5.2 Performance

We started by training a DQN agent employing a DNN with two 128-neuron hidden layers. All the relevant hyperparameters are reported in Table 2. The drDQN agent, instead, comprises two DNNs, each with the same hyperparameters from Table 2

Table 1 Parameters of the simulated scenario.

Parameter	Value
Map size	16,000 m^2
Number of BSs (B)	2
Inter-site distance	$\approx$ 1414 m
Number of antennas per BS (A_b)	3
Range of downtilt ($\theta_{\min}$, $\theta_{\max}$)	[0°, 15°]
Variation of downtilt per action (δ)	1°
Downlink maximum power	40 W
Antenna model on BS	hv 742,215 fitted
Number of UEs (U)	1000
Antenna type on UEs	Isotropic
Propagation model	Okumura–Hata
Fraction of indoor/outdoor	0.5
Radio technology	LTE
Optimization weight (w)	1

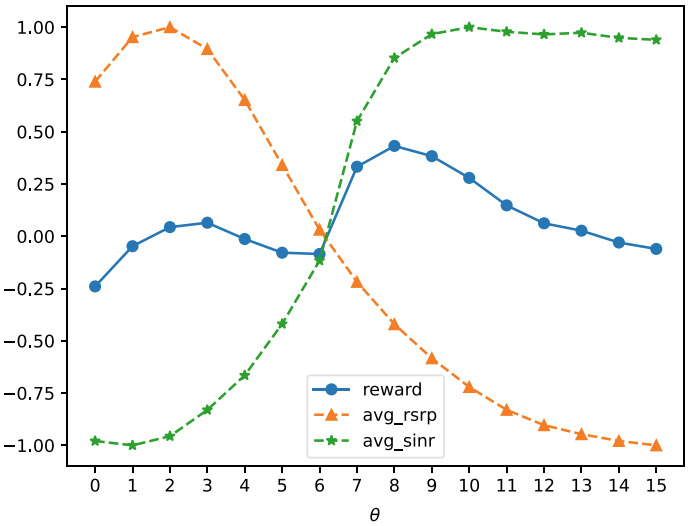


Fig. 5 Rewards and reward components for varying downtilt θ in the simulated scenario

and receiving the same input features (i.e., the complete system state). The learning curves, shown in Fig. 6, indicate that drDQN and DQN agents converged with a similar trend. With the optimal DQN agent available, we continued by training LMUT. After some tuning, we ended up with the hyperparameters in Table 3. Then, we evaluated the fidelity of LMUT with respect to DQN using root mean squared error (RMSE), mean absolute error (MAE), accuracy, and confusion matrix. Whereas

Table 2 Hyperparameter to train DQN and drDQN

Hyperparameter	Value
Optimizer	Adam
Learning rate	0.001
Num. hidden layers	2
Num. neurons per layer	128
Activation function	tanh
Num. steps per episode	20
Exploration strategy	ϵ-greedy

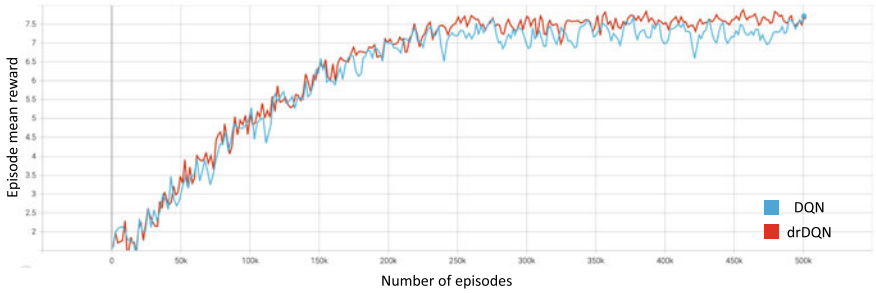


Fig. 6 Learning curves of DQN and drDQN

Table 3 Hyperparameters to train LMUT

Hyperparameter	Value
Min. MSE to split	0.01
Min. instances to split	50
Min. instances per child	10
Min. variance reduction	0.01
Max. tree depth	50
Optimizer (linear regression)	Adam

RMSE and MAE measure the difference of the Q-values provided by LMUT with respect to the targets from DQN (regression problem), accuracy and confusion matrix measure the difference between LMUT and DQN in selecting the action (which can also be seen as a classification problem where the ground truth is the action selected by DQN). As shown in Table 4, both RMSE and MAE are small, meaning that LMUT can approximate the DQN model precisely. From Fig. 7, we can observe that LMUT managed to fit the action selection of the DQN agent perfectly. Furthermore, this fit was achieved with only a few binary splits, which allows inspecting the model directly as a white box, as depicted in Fig. 8. Such a small model was expected, given the small state space.

Table 4 Fidelity of LMUT with respect to DQN

Metric	Value
RMSE	0.01
MAE	0.01
Accuracy	1.0
Balanced accuracy	1.0

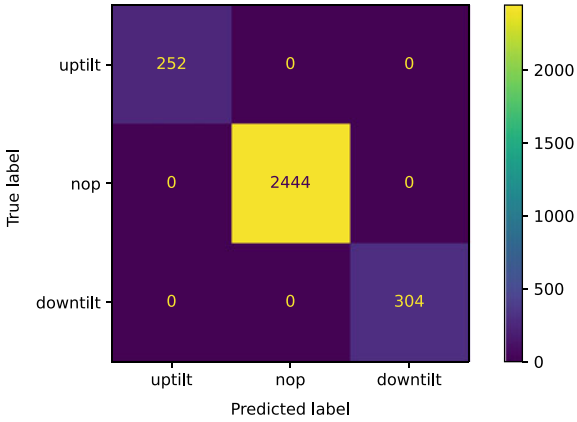
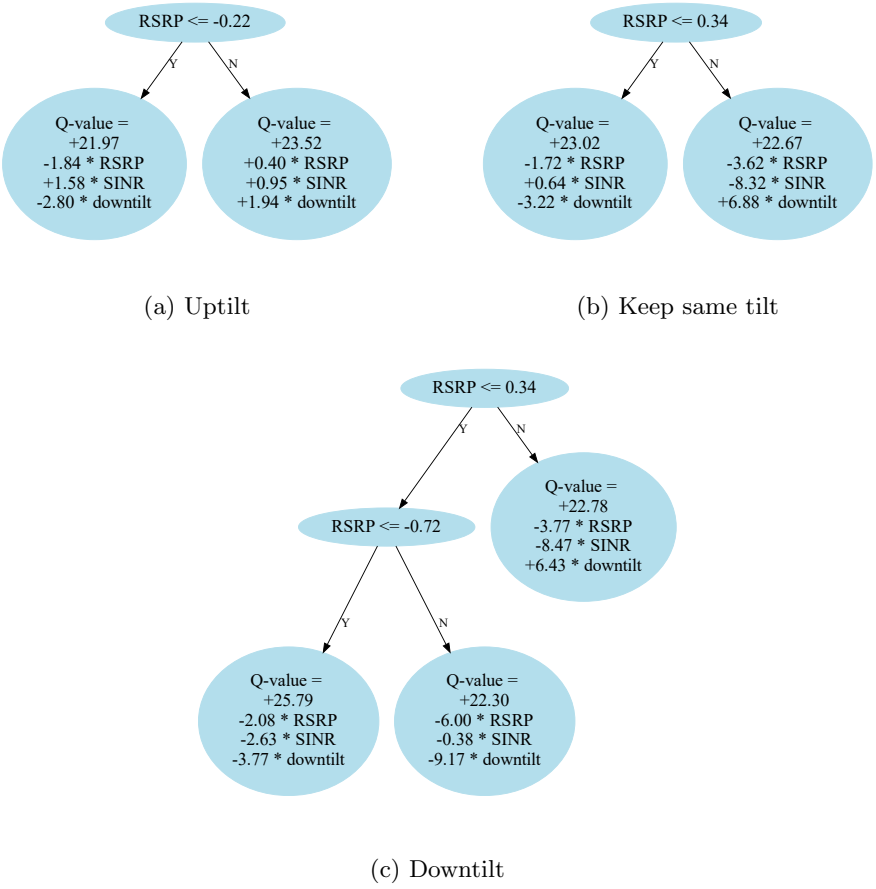


Fig. 7 Confusion matrix of LMUT with respect to DQN

The performance of the trained agents is quantified by the episode mean reward during the evaluation phase. As reported in Table 5, both drDQN and LMUT perform optimally like DQN. Considering the duration of an episode (Table 1) and the reward at the optimal downtilt (Fig. 5), it is evident that all three algorithms found the optimal policy. These results help prove the correctness of the implementation, especially in preparation for the explainability evaluation. However, it is worth pointing out that this paper focuses on the explainability aspects of these algorithms rather than their performance. Such satisfactory results in terms of performance were expected, considering the small state space.

5.3 Explainability

Once the drDQN and LMUT agents were adequately trained, we evaluated their explanations. As described in Sect. 4, drDQN can explain its action selection by providing contrastive explanations through RDX. Figure 9 shows two of such local explanations. In particular, from Fig. 9c, we can understand why the drDQN agent prefers to downtilt instead of uptilting when $\theta = 2°$. According to the agent's explanation, downtilting outperforms uptilting in terms of expected r_{sinr} but not expected r_{rsrp}, and the agent prefers this action because the benefit is greater than the loss. This explanation can be confirmed by checking Fig. 5. Considering the initial state with



(a) Uptilt

(b) Keep same tilt

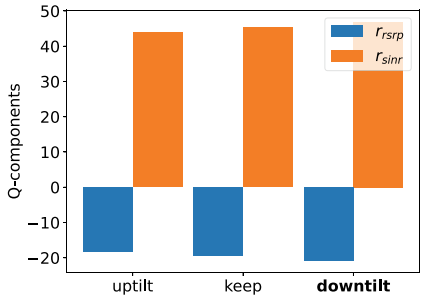
(c) Downtilt

Fig. 8 LMUT structure after training. There is one linear tree for each action

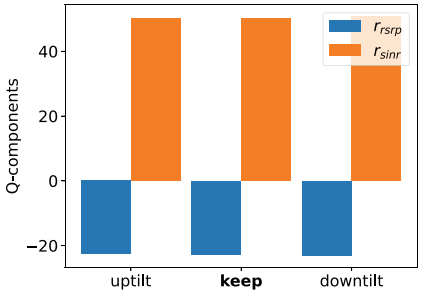
Table 5 Performance of DQN, drDQN, and LMUT

Algorithm	Episode mean reward
DQN	7.74
drDQN	7.74
LMUT	7.74

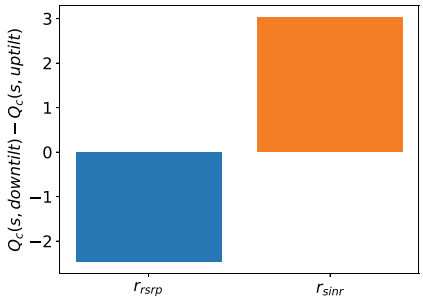
$\theta = 2°$, we can observe that downtilting and then following the optimal policy collects a higher r_{sinr} but a lower r_{rsrp}, in comparison with uptilting. We also know that downtilting is optimal because it proceeds toward the optimal configuration ($\theta = 8°$). Similarly, in Fig. 9d, we can understand why drDQN decides to keep the same downtilt in $\theta = 8°$. The agent believes that this action, compared to downtilting, leads to a better overall reward thanks to a higher r_{rsrp}, despite the cost in terms of r_{sinr}. Once again, we can verify that the agent's belief is correct by looking at Fig. 5 (Table 6).



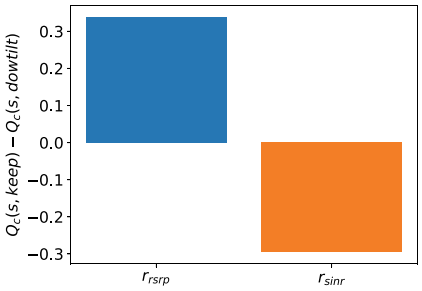
(a) Q-components when $\theta = 2$. The *downtilt* action is selected.



(b) Q-components when $\theta = 8$. The *keep* action is selected.



(c) RDX showing the advantage of *downtilting* over *uptilting* when $\theta = 2$.



(d) RDX showing the advantage of *keeping the same tilt* over *downtilting* when $\theta = 8$.

Fig. 9 Local explanations generated by drDQN for two different states ($\theta = 2$ and $\theta = 8$), including Q-components (**a**, **b**) and RDX (**c**, **d**)

Table 6 Global explanation via feature importance generated by LMUT

Feature	Importance
RSRP	0.82
SINR	0.00
θ	0.00

LMUT can generate both global and local explanations, as explained in Sect. 4. Table 7 presents two local explanations for the same cases considered before for drDQN. It is worth highlighting that the rules for the Q-value computation can be directly identified from the LMUT model in Fig. 8, but extracting and listing them is convenient, especially when dealing with a larger model. When $\theta = 2°$, the best action is to downtilt, which is optimal, as already argued for drDQN. The triggered rule in this situation is:

$$\text{RSRP} \in (0.34, +\infty) \implies Q = +22.78 - 3.77 \cdot \text{RSRP} - 8.47 \cdot \text{SINR} + 6.43 \cdot \theta \tag{15}$$

Table 7 Local explanations via rule extraction generated by LMUT for two different states ($\theta = 2°$ and $\theta = 8°$). The normalized version of θ is denoted by $\overline{\theta}$

State	RSRP $= 1.00$ SINR $= -0.96$ $\theta = 2$ ($\overline{\theta} = -0.73$)	RSRP $= -0.42$ SINR $= 0.85$ $\theta = 8$ ($\overline{\theta} = 0.07$)
Uptilt rule	RSRP $\in (-0.22, +\infty)$ $\Downarrow$ $Q = 0.40 \cdot \text{RSRP} + 0.95 \cdot \text{SINR}$ $+1.94 \cdot \overline{\theta} + 23.52 = 21.59$	RSRP $\in (-\infty, -0.22)$ $\Downarrow$ $Q = -1.84 \cdot \text{RSRP} + 1.58 \cdot \text{SINR}$ $-2.80 \cdot \overline{\theta} + 21.97 = 23.89$
Keep rule	RSRP $\in (0.34, +\infty)$ $\Downarrow$ $Q = -3.62 \cdot \text{RSRP} - 8.32 \cdot \text{SINR}$ $+6.88 \cdot \overline{\theta} + 22.67 = 22.01$	RSRP $\in (-\infty, 0.34)$ $\Downarrow$ $Q = -1.72 \cdot \text{RSRP} + 0.64 \cdot \text{SINR}$ $-3.22 \cdot \overline{\theta} + 23.02 =$ **24.07**
Downtilt rule	RSRP $\in (0.34, +\infty)$ $\Downarrow$ $Q = -3.77 \cdot \text{RSRP} - 8.47 \cdot \text{SINR}$ $+6.43 \cdot \overline{\theta} + 22.78 =$ **22.39**	RSRP $\in (-0.72, 0.34)$ $\Downarrow$ $Q = -6.00 \cdot \text{RSRP} - 0.38 \cdot \text{SINR}$ $-9.17 \cdot \overline{\theta} + 22.30 = 23.86$
Best action	Downtilt	Keep

Linear regression models are transparent by design, as their weights indicate the relative contribution of each input feature to the output. Thus, we can observe that when RSRP $\in (0.34, +\infty)$, the largest impact is caused by the current SINR value. Similarly, when $\theta = 8°$, the best action is to keep the same downtilt (which is, again, optimal), and the greatest contribution comes from θ.

The global explanation provided by LMUT, which indicates the overall importance of RSRP, SINR, and θ on the LMUT agent's decision-making, is shown in Table 6. Surprisingly, the explanation contains a null value for SINR and θ that, in light of the model in Fig. 8, is fallacious. These features, in fact, have a non-negligible impact on the Q-function through the linear regression on the leaf nodes. The root of the problem is that Eqs. (13) and (14) considers only the splitting nodes in the regression trees and neglects the leaf nodes altogether.

5.4 Discussion

We now critically discuss the results presented in the previous section to generalize and draw conclusions. We found that both drDQN and LMUT achieve optimal performance in the considered RET scenario. Despite this finding, we warn that LMUT might lose performance compared to deep RL algorithms in more complex RET scenarios with a larger state space (e.g., multiple antennas to control), since linear trees are less expressive than DNNs. In contrast, drDQN is expected to always keep the same performance as the state-of-the-art DQN, due to its design and convergence proof.

Both XRL algorithms have additional requirements compared to standard RL. drDQN adds a constraint to the reward design, as the reward needs to be a sum of reward components. We argue that this requirement is the most critical drawback of drDQN and limits the specification of the optimization objective in the RET use case. Such a constraint has indeed affected our problem formulation in Sect. 3 and prevented us from considering different reward designs. In contrast, LMUT requires a high-performing RL agent that provides targets for supervised learning not only for the initial training but also to keep learning while interacting with the environment. As a consequence, this RL agent should use an off-policy algorithm to keep learning from experiences generated by LMUT and providing updated targets for the online training of LMUT.

In terms of model complexity, while drDQN needs to specify the DNN structure before training, LMUT adapts to the problem and grows its structure as little as possible to fit the data. In our RET scenario, LMUT fit the data with a small model, which was easy to inspect directly. In addition, drDQN still employs black-box DNNs, whereas LMUT is fully transparent with only linear models.

The types of local explanations provided by the two XRL algorithms are very different. drDQN can compare two actions by looking at the composition of future expected rewards (i.e., Q-values). In the RET use case with only three actions (uptilt, downtilt, and keep the same tilt), we argue that contrastive explanations are very user-interpretable, as they concisely answer questions in the form of "why did you decide to downtilt instead of uptilting?." On the contrary, LMUT cannot provide contrastive explanations. Extracted rules make how the Q-value is computed transparent but do not provide a direct comparison with other actions. From a rule head, a more desirable explanation would be to understand in which sub-range the agent prefers the selected action and what happens outside that sub-range. Furthermore, the idea of reward decomposition from drDQN might be integrated into LMUT to enhance its explainability.

Differently from drDQN, LMUT can also provide a global explanation. However, we showed that this global explanation could be very misleading. The computation completely neglects the linear regressions at the leaf nodes, which contribute to the Q-value computation. Modifying this computation is necessary to make the global explanation more reliable.

6 Conclusions

In this paper, we empirically evaluated two intrinsic XRL algorithms, drDQN and LMUT, in the RET optimization problem. In terms of explainability, we conclude that drDQN can provide intuitive contrastive local explanations which fit perfectly the RET problem. In contrast, even employing a fully transparent model, we found that LMUT needs further research on the extracted explanations, which are less interpretable than drDQN's. Surprisingly, we identified an issue in the global explanation of LMUT, which neglects the critical contribution of leaf nodes. In terms of

performance, our results indicate that both drDQN and LMUT can perform well in the presented RET use case, with performance similar to DQN. However, further experiments are needed to test LMUT's performance with larger state spaces.

Future research directions are as follows. The explainability of LMUT might be improved by fixing the computation of the global explanation and by developing more intuitive contrastive explanations extracted from the transparent model. drDQN might be extended to support more general functions than simple sums. Finally, the complexity of the RET scenario might also be increased.

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Deep Learning at Behavioral Analysis of Analog Amplifiers with Negative Feedback

Malinka Ivanova

Abstract In the paper an approach for behavioral analysis of analog amplifiers with negative feedback is presented. It can be in support of an engineer analyst, speeding the analytical process, reducing operational efforts and shortening the path from research laboratory to manufacturing. Behavioral analysis treats the amplifiers and feedback blocks as "black boxes" and do not interested in their internal structure and occurred electrical processes. The connections among high level amplifier building blocks and their main parameters are studied trough utilization of artificial neural networks to predict the number of stages, feedback availability and feedback type in a two-step analytical process. The performance of the created predictive models is evaluated and the obtained errors are small.

Keywords Behavioral predictive analysis · Deep learning · Analog amplifiers · Negative feedback · Automation

1 Introduction

Analysis of electronic circuits could be done at different levels and different domains and it depends on what kind of understanding the engineer analyst wish to receive. Studying the circuits' functionality and investigating the properties lead to outlining their applications for one or another purposes.

Behavioral analysis sees the electronic circuits as "black boxes", without caring about their internal structure and what kind electrical processes occur inside. More important is the functional behavior of circuits at given input signals and obtained output reaction or at given environmental conditions. Predicting the building blocks of circuits according to predefined user specification is also very useful in an analytical process. The circuit behavior is described through high level mathematical equations, so called transfer functions, ignoring the detailed mathematical expressions,

M. Ivanova (✉)
Technical University of Sofia, Sofia, Bulgaria
e-mail: m_ivanova@tu-sofia.bg

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which reveal the specifics of low level electrical processes. Knowing the specificity of behavioral analysis, a wide variety of predictive models could be created and in this way the behavior of a given circuit could be predicted. Predictive analytics is always in support of decision making and is related to automation of analytical tasks. It can reduce analyst' effort, increase his/her productivity and decrease needed time from investigation to manufacturing.

Behavior examination could be based on various analysis like symbolic and semisymbolic [1], asymptotic [2], worst-case [3], etc. Recently, artificial intelligence and machine learning capabilities for circuit analysis are also explored [4, 5]. It is proved that they can propose suitable techniques for analysis of specific circuit behavior as well as of complex and dynamic systems' behavior, implemented according to the principles of analog electronics, which is harder in comparison to digital electronics.

The most common utilized analog circuits are amplifiers, which very often are realized with local/global negative feedbacks. The negative feedback is applied in order to change or improve some amplifier parameters and characteristics.

The aim of the paper is to present an approach for predictive behavioral analysis of analog amplifiers with and without negative feedback through usage of a deep learning algorithm.

2 Analog Amplifiers and Negative Feedback

The term feedback is defined as a channel, through which a part or the whole output signal is returned to the circuit input. The feedback is realized through a block with passive/active components and its behavior is described through transmission factor β [6–9].

An amplifier circuit without feedback is characterized with some main parameters: input resistance r_{in}, output resistance r_{out}, voltage gain A_V, and current gain A_I. They could be changed/improved when a local/global feedback is added as they get new values: r_{inF}, r_{outF}, A_{VF}, A_{IF}. The feedback is negative when the polarities (phases) of the signal from the feedback block v_β / i_β and the input signal v_i / i_i are opposite, then the amplitude of the input (or output v_o / i_o) signal decreases. A local feedback spans a single stage while a global feedback spans more than one stage or the whole amplifier.

Depending on the ways of connecting the amplifier and feedback blocks, four types of negative feedback are defined: series current feedback, series voltage feedback, parallel current feedback, and parallel voltage feedback (Fig. 1).

- The series current feedback (SCF) reduces the voltage gain, increases the input and output resistances. The current gain is not changed. This feedback stabilizes the output current.

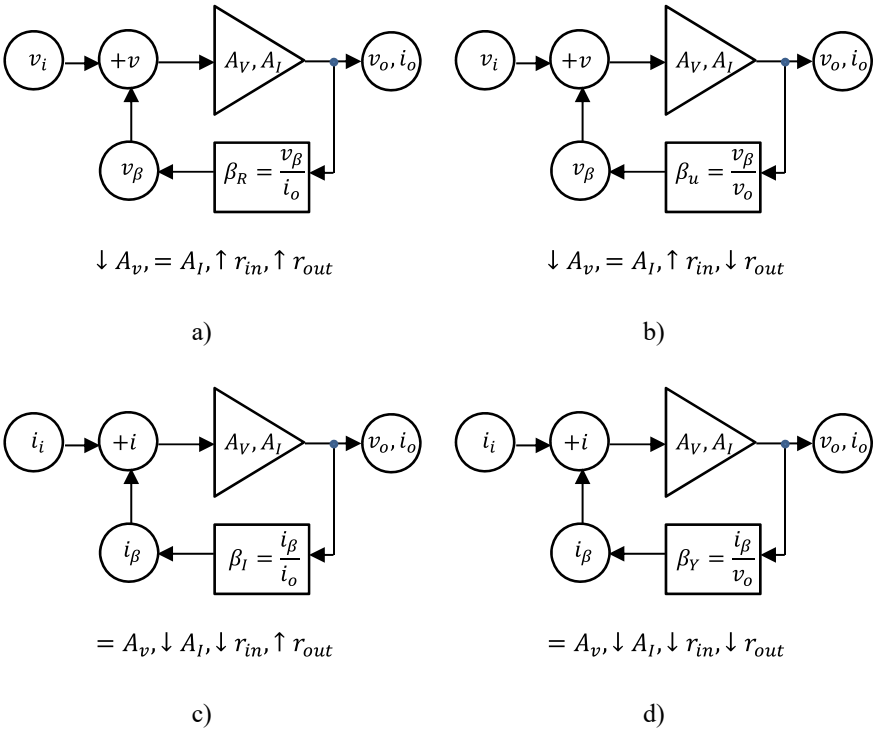


Fig. 1 Negative feedback types: **a** series current feedback; **b** series voltage feedback; **c** parallel current feedback; **d** parallel voltage feedback

- The series voltage feedback (SVF) decreases the voltage gain, increases the input resistance, and decreases the output resistance. The current gain is not changed. This feedback stabilizes the output voltage.
- The parallel current feedback (PCF) reduces the current gain, reduces the input resistance, and increases the output resistance. This feedback stabilizes the output current.
- The parallel voltage feedback (PVF) reduces the input and output resistances, and the current gain. The voltage gain is not changed. It stabilizes the output voltage.

Figures 2, 3 and 4 presents different configurations of amplifiers with and without feedback at high level. The amplifiers are realized through one, two, or three stages with/without local/global feedback/s as some three stage circuits with a global feedback are not presented. In the current work, these amplifier configurations are bases for further investigation and behavioral analysis through applying a deep learning algorithm.

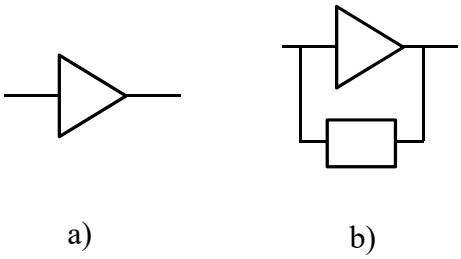


Fig. 2 Single stage amplifiers: **a** without feedback; **b** with feedback

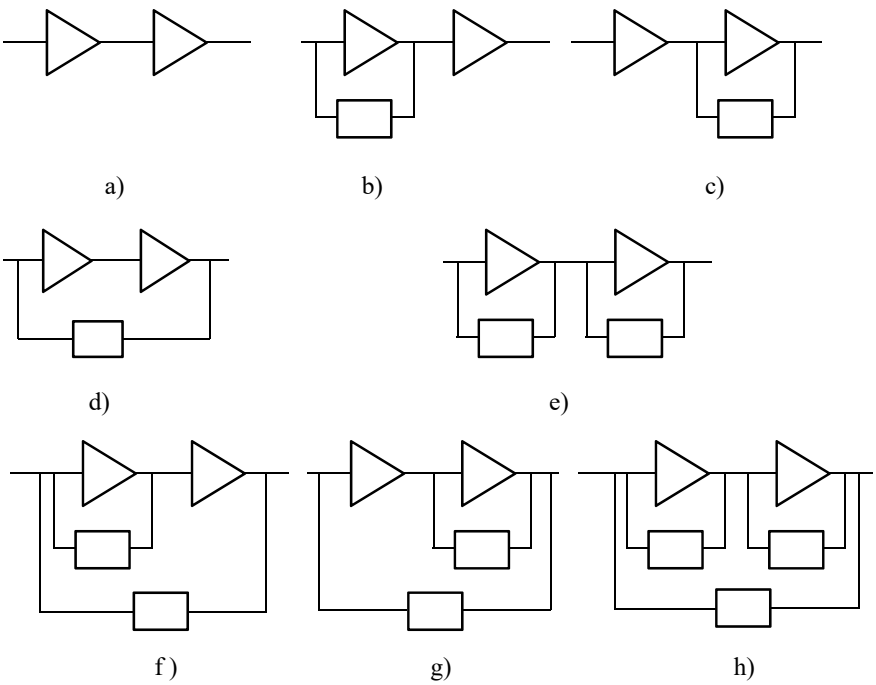


Fig. 3 Two stage amplifiers without/with local or global feedback/s: **a** without a feedback; **b** with a local feedback on the first stage; **c** with a local feedback on the second stage; **d** with a global feedback on the first and second stage; **e** with local feedbacks on the first and second stage; **f** with a local feedback on the first stage and a global feedback; **g** with a local feedback on the second stage and a global feedback; **h** with a local feedback on the first and second stage and a global feedback

3 Proposed Method

The proposed method gives possibilities for conductance of predictive behavioral analysis considering the presented configurations of analog amplifiers with and without negative feedbacks (Figs. 2, 3 and 4). The method is based on two steps: at the first step the number of stages and availability of feedback/s are predicted and at the second stage is pointed out the feedback's type. For this purpose, an

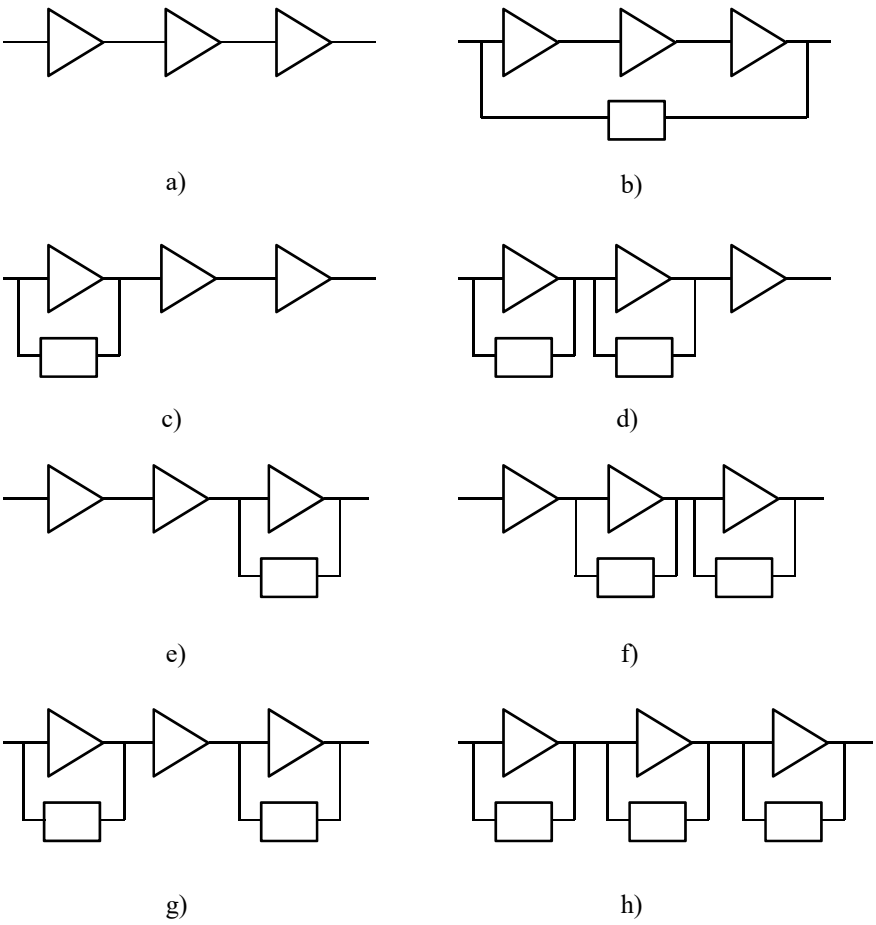


Fig. 4 Three stage amplifiers: **a** without a feedback; **b** with a global feedback; **c** with a local feedback on the first stage; **d** with local feedbacks on the first and second stages; **e** with a local feedback on the third stage; **f** with local feedbacks on the second and third stages; **g** with local feedbacks on the first and third stages; **h** with local feedbacks on the first, second, and third stages

initial matrix is constructed (Fig. 5), which generalize the possible configurations of one/two/three stage amplifiers with/without negative feedback/s. The amplifiers and the blocks for negative feedback are presented as "black boxes" as each block is placed between two matrix points. The points in the matrix are numbered and used to identify a connection or absence of it. For example, according to configuration from Fig. 3b, the important points for predictive behavioral analysis are: 1, 2, 3, 5, 6, because the first amplifier stage is placed between points 1 and 2, the second amplifier stage between points 2 and 3, the feedback block is placed between points 5 and 6. This initial statement is utilized for construction of datasets (Table 1) with information regarding the connection between matrix points and also taking into

account the possibility for changes the main amplifier parameters (D- the parameter value decreases after realization of a feedback, I—increases, E—equal, e.g., there is not changes).

The constructed first Artificial Neural Network (ANN), shown on Fig. 6, predicts the number of stages (SN) and availability or not of a feedback (F/NF) as the inputs are considered the connections between two matrix points. ANN consists with input layer, two hidden layers and output layer.

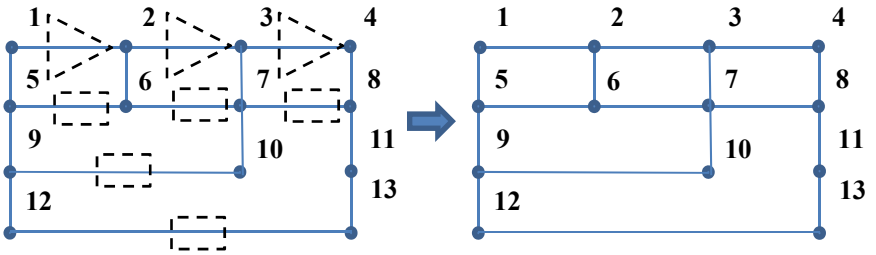


Fig. 5 Initial matrix

Table 1 Initial dataset

12	23	34	15	–	LF/GF	$A_{V(F)}$	$A_{I(F)}$	$r_{in(F)}$	$r_{out(F)}$	SN	F/NF	FType
Yes	No	No	No	–	NA	E	E	E	E	One	NF	NA
Yes	No	No	Yes	–	GF	D	E	I	I	One	F	SCF
Yes	Yes	No	No	–	NA	E	E	E	E	Two	NF	NA
Yes	Yes	No	Yes	–	LF	D	E	I	I	Two	F	SCF
–	–	–	–	–	–	–	–	–	–	–	–	–

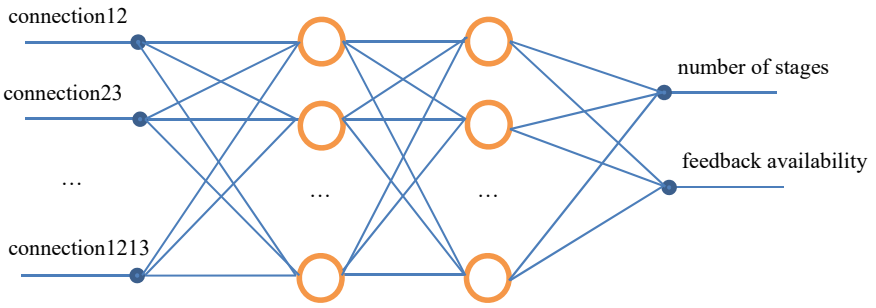


Fig. 6 The constructed ANN with two outputs: number of stages and feedback availability

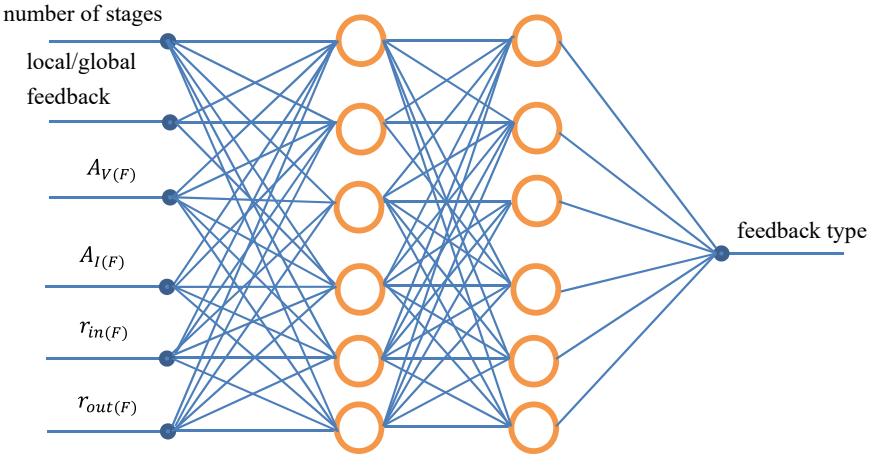


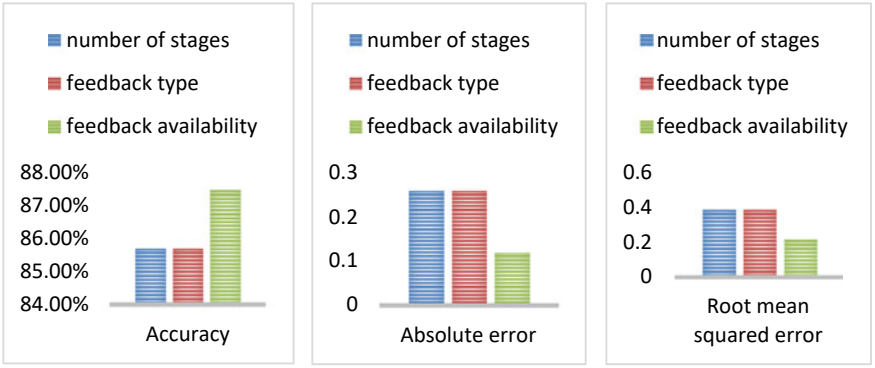
Fig. 7 The constructed ANN with an output: feedback type

The second ANN (Fig. 7) predicts the type of the negative feedback, which could be: series current feedback, series voltage feedback, parallel current feedback, and parallel voltage feedback. The ANN input is presented through six variables: number of amplifier stages, availability of a feedback/s, the main parameters when the amplifier possesses or not feedback/s $r_{\text{in(F)}}$, $r_{\text{out(F)}}$, $A_{\text{V(F)}}$, $A_{\text{I(F)}}$.

4 Experimentation and Results

The experimentation regarding the ANNs performance is conducted in the environment of RapidMiner Studio. The constructed ANNs possess better accuracy when the number of neurons in the hidden layers are respectively 15 and 20. The activation function is rectifier. 70% of the datasets are used for learning and 30% for testing. The predictions of the number of stages and feedback type are characterized with 85.71% accuracy and the prediction of the feedback availability with 87.50% accuracy. Absolute errors and root mean squared errors are very small. A comparison regarding the performance of the created predictive models is shown on Fig. 8.

Experimentation is also conducted with bigger number of neurons in the hidden layers (50 neurons for each layer) as well as with other supervised machine learning algorithms like: Decision Tree and Random Forest, which are used for solving classification tasks. The highest obtained accuracy 96.67% is achieved at application of deep learning and Random Forest algorithms. The errors are as follows: absolute error: 0.1279 and root mean squared error: 0.1900 (Fig. 9).



a) Accuracy b) Absolute error c) Root mean squared error

Fig. 8 Comparison of models' performance when ANNs are with two hidden layers and with 15 and 20 neurons, respectively

a) Accuracy b) Absolute error c) Root mean squared error

Fig. 9 Comparison the performance of the used classifiers

5 Conclusion

The paper presents an approach for behavioral analysis of analog amplifiers without or with negative local/global feedback/s, which is based on utilization of ANNs. It is proven that the high performance of the constructed ANNs models is achieved when ANNs are with two hidden layers and with 50 neurons in each layer. The results among three different classifiers: deep learning, Decision Tree, and Random Forest are compared as the best accuracy 96.67% is obtained at application of deep learning and Random Forest algorithm.

The method is proposed to support the decision making process of an engineer analyst and to facilitate the high level behavior analysis of electronic circuits. Such approach is suitable for automation of some analytical engineering tasks and also for integrating in contemporary CAD software tools.

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Web System Managed by Adults with Down Syndrome for Inventory Management in the Skyline Company

Carla Soley Ramírez and Michael Cabanillas-Carbonell

Abstract This research deals with the analysis, design, development, and implementation of a web system managed by adults with Down syndrome for inventory management in the Skyline company, where the type of research is applied with a quantitative approach, with an experimental design. Likewise, the methodology used for the development and implementation is Scrum, as it is the one that is most in line with what was presented and the requirement of the system allowing one to understand and simplify the steps, the programming language is PHP, MySQL database engine and IBM SPSS Statistics software are used to evaluate the statistical results, and Figma was used for the software design. In addition, to meet the objective, 3 indicators were used: rotation, percentage of inventory without rotation, and duration with a population of 37 products, 35 products, and 37 products, respectively. When carrying out the pre- and posttest, favorable results were obtained and then passed to the contrast of hypotheses, and the 3 hypotheses are approved where it indicates that the system favors inventory management in the Skyline company. Finally, it is concluded that the implementation of the system meets the objectives set with results that significantly benefit the company and to the inclusion of people with Down syndrome.

Keywords Web system · Inventory management · Down syndrome

1 Introduction

At the global level, the processes to reactivate the economy are being resumed after 2 years of the coronavirus pandemic (COVID-19) outbreak caused by the SARS-CoV-2 virus in 2020. Now most companies in the world are updating and improving

C. S. Ramírez · M. Cabanillas-Carbonell (✉)
Universidad Privada del Norte, Lima, Perú
e-mail: mcabanillas@ieee.org

C. S. Ramírez
e-mail: n00209782@upn.pe

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their service performance to be competitive, which is why they also focus on the management of their inventories, which aims to ensure availability in a timely manner, in desired conditions, and in the corresponding place of everything that is used, among them is raw materials, materials in process, finished products, and inputs. This management is a transversal activity to the supply chain that allows a high level of service and avoids the increase of administrative costs for this, and strategies are implemented to achieve better management [1].

Just as companies try to improve to give competition, they must also focus on labor inclusion which is an issue that is left aside globally and does not provide opportunities to people with different abilities despite the existence of inclusion laws. People with these disabilities are classified into 9 groups, one of them is a mental disability, comprising the population of the below-average ability of those with their age, level of education, and socio-cultural level, and this group is composed of 3 subgroups: 310 Intellectual Disability, 320 Behavioral Disabilities, and 399 Disabilities Insufficient, expresses [2].

In subgroup 310 Intellectual Disability, there is Down syndrome which is a genetic disorder also called Trisomy 21. The severity of their abilities varies between each person such as their facial features and learning disabilities (most are mild to moderate, helped through early intervention and special education). It is one of the most common malformations, affecting about 1 in 800 babies. There is no cure, but there are treatments and/or programs that can help them develop and reach their potential from childhood so that in the lives of adults, they can take care of themselves, doing household chores also get to have a common job to be independent and improve their quality of life, according to research [3].

In countries of America, it is sought to include people with different abilities in a job to break the inequality gap representing an advance in organizations by demonstrating the commitment to incorporate personnel in the conditions of low competence. When selecting personnel with a disability condition, Corporate Social Responsibility Evidence Corporate Social Responsibility encouraging their competitors to also make this type of hiring for the benefits of this and change the quality of life of people. However, the labor inclusion of people with disabilities continues to show itself with great difficulty to insert themselves in the market given the logic of competition and limited access to jobs [4].

At the national level, companies have problems of inefficiency in inventory management and lose profitability in their supply chain, the level of customer service, the constant turnover of staff, among others [5].

In addition, in Peruvian companies, the lack of management in inventory management is evident, causing economic losses and delays with the service times offered to customers, since many do not have an orderly or organized warehouse not allowing to know what is available at that time, they also do not keep their check-in and check-out up to date. In the same way, it does not have an established process, nor do they use technology to help them have better control, it is only done empirically as inputs arrive, and consequently, there are numerous drawbacks [6].

Also, in Peru reports the head of INEI [7] that in its last report in the country, 10.3% of the population has a disability, and their employment status in people over 14 years of age is 43% in the 2019 surveys.

And the National Council for the Integration of Persons with Disabilities (CONADIS) reports that the National Registry of Persons with Disabilities (RNPCD). From its operation to 2021, it has registered 330 thousand 689 people with disabilities, of which 19 thousand 849 were diagnosed with Down syndrome, representing 6.0% of the total enrolled, but due to the global pandemic caused by COVID-19, there were few registrations in 2020, and in 2021, it presented a recovery. Also, according to the age group, there is a concentration of enrollees from 6 to 29 years old; otherwise, in lower concentration in children under 6 years and over 60 years. In Metropolitan Lima, it concentrates 34.8 of the total registered [8].

2 Bibliographic Study

Web System: As defined [9] that a web application is a computer program that runs on a remote server and access requires Internet through a web browser. In addition, it is interactive where it depends on the colors and the design of the interfaces. For development, it is necessarily to have knowledge of a programming language such as: HTML, JAVA, or PHP. Inventory management: It is one of the basic activities of the Operations Management of any organization. To be able to perform, there are different systems to be used depending on multiple factors such as: decision making, demand, inventory costs, or supply time, among others [10].

3 Methodology

For the development of this research work, the investigation of existing agile methodologies was carried out and for the choice considers the amount of information that is used, knowledge of each methodology, adaptation, and flexibility for implementation.

3.1 Comparison of Agile Methodologies

For the result of Table 1, the agile methodology used is Scrum by higher score in the comparison of the 4 criteria, and for this, it is necessary to work in a team with the client divided into sprints [11].

Table 1 Comparison of methodologies

Methodology/criteria	Information management	Knowledge	Adaptation	Flexibility	Points
RUP	4	4	4	4	16
XP	4	3	4	5	16
Scrum	5	5	5	4	19
KANBAN	4	3	4	3	14

Table 2 Population and sample

Population	Sample	Indicators	Time
37 products	35 products	Inventory rotation	1 month
33 products	31 products	Percentage of inventory without rotation	1 month
37 products	35 products	Inventory duration	1 month

3.2 Research Design and Type

The present work of scientific research belongs by its purpose to the applied level because according to [12] the contribution of scientific theories must be counted, where it has a quantitative approach with explanatory scope because it is sequential and evidentiary in all stages, supported by [13]. It belongs to the experimental design, from which it is divided, and it is determined that it is of pre-experimental design by the effect of a cause that is manipulated as is the case in the pre- and posttest.

3.3 Population and Sample

According to [14], it explains that population is the set of all the elements that belong to the spatial field where the research work is developed, and sample indicates that it is a representative part or fragment of the population for the present research based on what is mentioned about the 3 indicators (Table 2).

3.4 Data Collection Instruments

The present research work used the instrument of observation structured by the sequence of steps to follow (inventory management) and estimation scales (Table of Methodologies); it also makes use of unstructured observation by the notes with information obtained from the company which is used in written records in the observation and collection sheets [15]. Finally, SSPS software is used for data analysis.

3.5 Methodology Development

Sprint 1. For the implementation of the system, the first step is database modeling that helps define and structure information (see Fig. 1a). The login interface is designed and implemented where the username and password are necessary (see Fig. 1b). In addition, we proceed with the creation of users with detailed information (see Fig. 1c).

Sprint 2. The general configuration of the system is carried out where the menu, search, and filters sections of the processes are (see Fig. 2a). The product section is developed with its detailed information: status, weight, measurement, description of reception and photograph of the same (see Fig. 2b). The image shows the catalog of all the products added with their respective photograph and with the search bar (see Fig. 2c). The status labels of the products are configured which are: draft, standby, prepared, and done (see Fig. 2).

Sprint 3. We proceed with the registration of income of the product: sale price, category, and status (see Fig. 3a). Inventory income is recorded: weight, volume, and date of entry (see Fig. 3b). The frequent customer is registered with mail and phone (see Fig. 3c).

Sprint 4. The type of operation is configured, reservation method, and the tab is saved and closed (see Fig. 4a). The final report of the products sold is shown to which customer and with departure date, detail of each product, and respective quantity (see Fig. 4b). At the end, the Kardex is obtained in PDF format, with the logo of the company and in a detailed format with relevant information (see Fig. 4c).

4 Results and Discussion

4.1 Descriptive Analysis

Indicator 1—Inventory rotation. As detailed in Fig. 5, where the results of the inventory rotation indicator are shown, where the average of the pre- and posttest is compared: in the first the value is 1.11, and in the second it is 3.22. It is visualized that there was an increase of 190.09%.

Indicator 2—Percentage of inventory without rotation. As detailed in Fig. 6, where the results of the percentage of inventory without rotation indicator are shown, where the average of the pre- and posttest is compared: in the first the value is 3.41, and in the second it is 1.06. It is visualized that there was an increase of 3.11%.

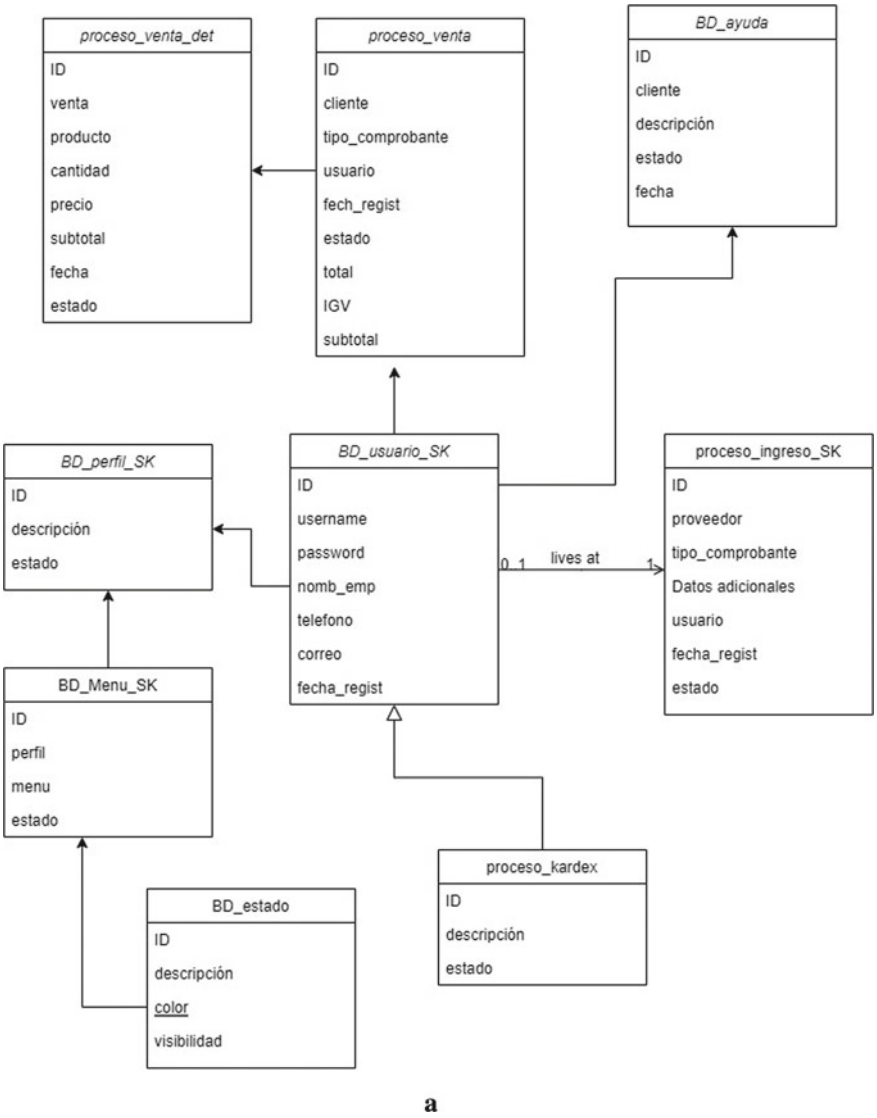
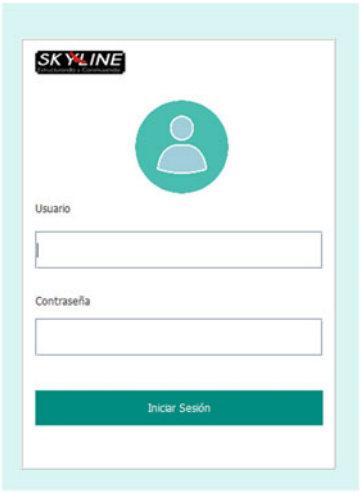


Fig. 1 Interfaces developed in Sprint 1

Indicator 3—Inventory duration. As detailed in Fig. 7, where the results of the inventory duration indicator are shown, where the average of the pre- and posttest is compared: in the first the value is 1.02, and in the second it is 3.54. It is visualized that there was an increase of 274.06%.



b

c

Fig. 1 (continued)

5 Conclusions

We hope that it will be of great help to small and medium-sized companies in the clothing sales sector, to obtain knowledge as well as a guide for the implementation and start-up of an ERP system, and free software, and obtain benefits without making a costly investment.

In the present research that is focused on the implementation of a web system managed by adults with Down syndrome for inventory management in the Skyline company, where 3 indicators were used, and the following conclusions are obtained.

First, the inventory turnover rate obtains an increase of 190.09% of the result in the pretest 1.11 and in the posttest 3.22, affirming the hypothesis.

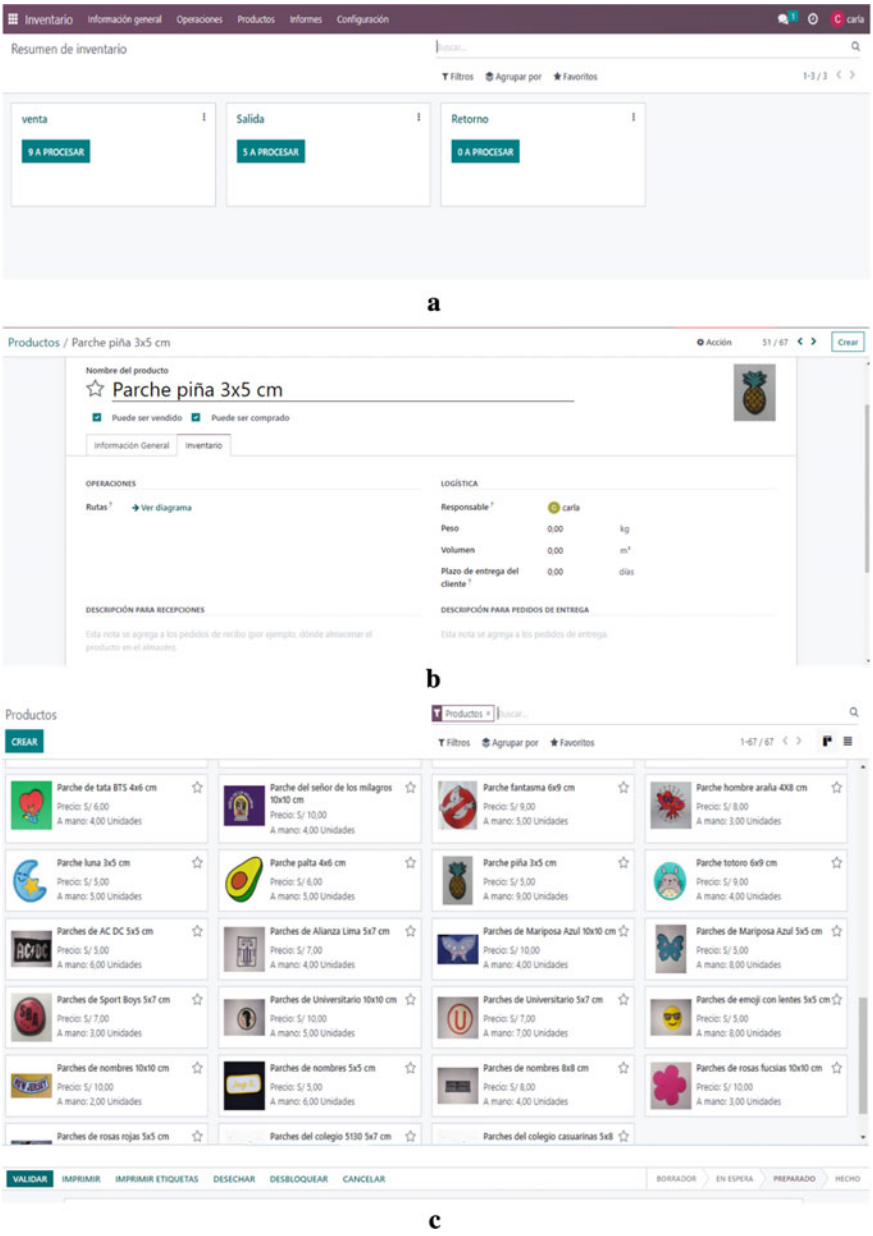


Fig. 2 Interfaces developed in Sprint 2

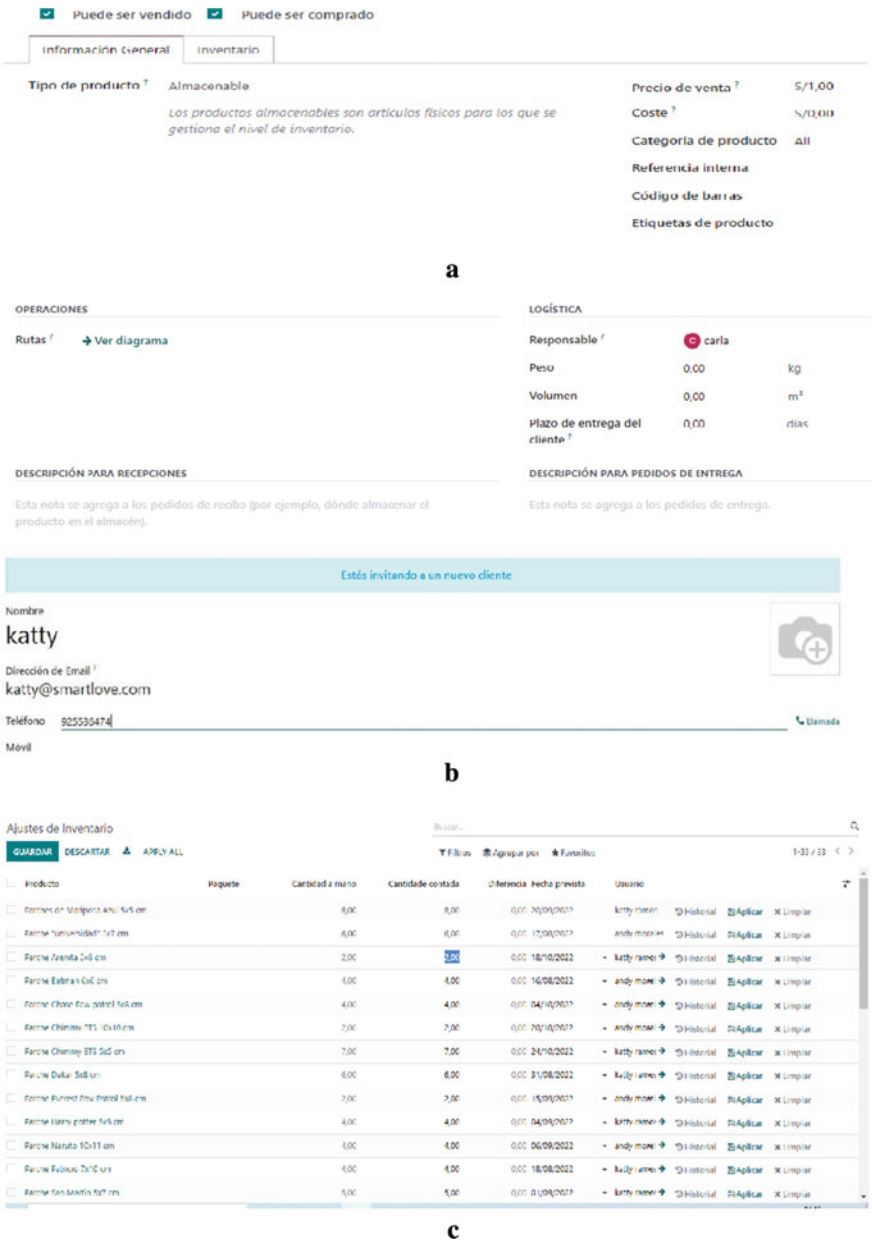


Fig. 3 Interfaces developed in Sprint 3

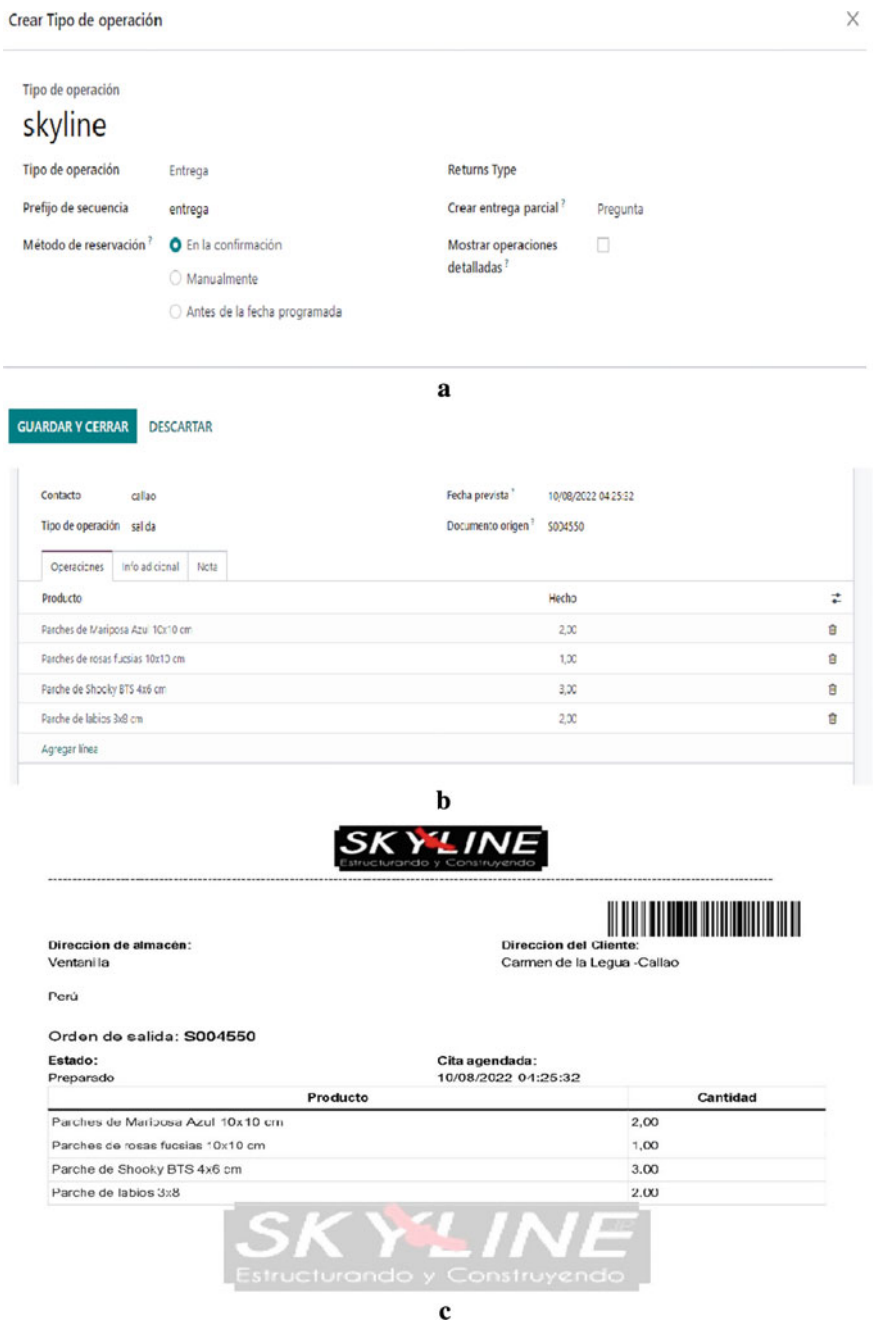


Fig. 4 Interfaces developed in Sprint 4

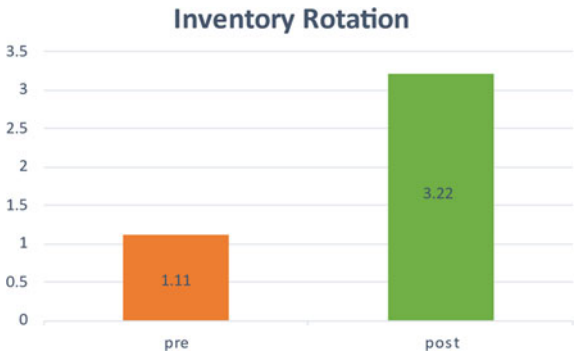


Fig. 5 Average pretest and posttest of the inventory rotation indicator

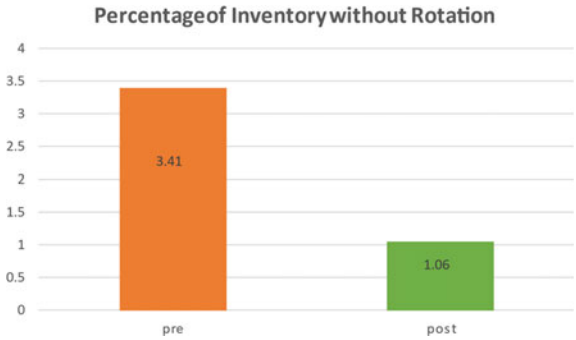


Fig. 6 Average of pretest and posttest indicator percentage of inventory without rotation

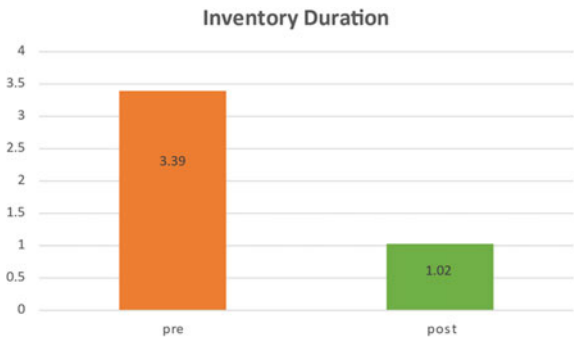


Fig. 7 Average pretest and posttest of the inventory duration indicator

The implementation of a web system influences the rotation for inventory management, managed by adults with Down syndrome in the Skyline company.

Then, the index of the percentage without inventory turnover obtained a favorable decrease of 3.11% of the result in the pretest 3.41% and in the posttest 1.06%, affirming the hypothesis.

The implementation of a web system influences the percentage without turnover for inventory management, managed by adults with Down syndrome in the Skyline company.

Finally, the inventory duration index obtained an increase of 3.09% of the result in the pretest 3.39% and in the posttest 1.02%, affirming the hypothesis.

The implementation of a system web influences the duration for inventory management, managed by adults with Down syndrome in the company Skyline.

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The Benefits of M-Health in Student Counseling Services to Overcome Stress

Shanti Wardaningsih

Abstract This study aims to explore the nursing students' needs in counseling to improve stress coping skills. This research uses a qualitative method, with a descriptive approach. Data is collected through interviews through discussion group groups, observations, and using field notes. Participants in this study were 8 people who were selected using the purposive sampling method. The validity of the data uses technical triangulation, peer debrification, member checks, and bracketing. Data analysis consists of organizing data, preliminary reading in the database, coding and organizing themes, presenting data, and compiling data interpretation. The results of this study indicate the needs of nursing students for psychosocial assistance that includes anticipation of the moments that cause stress, recognition of stress symptoms, problem-solving abilities, and counseling needs. The conclusion of this study is students need counseling to help in the learning process. This result is shown from the results of the interview stating that counseling is needed to help academic students. And students said counseling could be done online. They found 4 themes in the needs of nursing students and anticipation of the moment that causes stress to students, introduction of stress symptoms, problem-solving abilities, and counseling needs.

Keywords M-Health · Counseling service · Stress · Nursing student

1 Introduction

Students can be interpreted as a young generation that is expected to be an agent of change and social control of the environment, region, and country. The nursing is a provider of professional services/care that is humanistic, using a holistic approach, by referring to nursing professional standards using nursing ethics. So it can be

S. Wardaningsih (✉)
Master of Nursing, Postgraduate Program, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia
e-mail: shanti.wardaningsih@umy.ac.id

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concluded that nursing students are the younger generation who become agents of change and provide nursing care to patients in accordance with nursing professional standards. During education, nursing students will prepare themselves to become professional nurses and learn three important elements besides making nursing care, namely caring, activism, and professionalism [1].

With so many activities in students will make them the most fragile group exposed to homeostasis imbalances due to stress from academic activities. Stress in nursing students can be caused by their obligations to attend clinical practicums, skills exams, and other course work assignments, financial problems, interpersonal relationship problems, and adjustments in university life [2]. When students begin to feel depressed or stressed, there will be an impact that occurs. There was an impact of stress that appeared on students; the positive impact of student stress would be challenged to develop themselves and increase creativity. The negative impact of stress can be difficult to focus attention (concentration), decreased student motivation, and will even affect less adaptive behavior. The number of nursing students who experienced stress in 2016 at one of the universities in Sri Lanka found students who experienced stress reached (82.6%) [3]. Meanwhile, the number of UMY nursing students who live alone and experience depression is (81.4%) [4].

With the ease of students being exposed to stress, appropriate coping is needed for students. The purpose of coping is an individual's action or behavior, an individual's response in overcoming or reducing problems and pressures that are felt either stress or conflict, and a person's efforts to overcome psychological stress. The application of student coping mechanisms certainly varies, some cope positively, and some use negatively. The adaptive (positive) mechanisms are coping mechanisms in the form of problem solving, while maladaptive (negative) mechanisms are the opposite of adaptive which are more concerned with emotion in problem solving. Problem solving in students using adaptive can usually be done by making life changes, setting goals, determining priorities, time management, and taking action to reduce internal demands [5].

Psychosocial assistance needs to be done as a way to overcome or assist in solving internal and external problems. Psychological assistance itself is defined as a way to help someone overcome trauma due to problems experienced. The need for psychosocial/counseling assistance to students during education will be able to help students solve problems in academics and non-academics. After conducting interviews with 10 nursing students, 8 students said psychosocial assistance was needed by students, to help solve problems and help reduce psychological pressure. For this reason, it is necessary to know the stress coping mechanism of nursing students and to know the need for psychosocial assistance as one of the students' coping. If students do not know the stress coping mechanism, it will affect their academic and mental health.

2 Literature Review

2.1 Mental Health Problems in College Students

Stress is something that is expected but does not happen or a condition where there is a need that cannot be met. Stress is an action taken by the mind and body to adjust to responses involving the nervous system, circulatory system, immune system, and other organs. In addition, stress is also a psychosocial reaction or response (mental pressure or life burden). Stress is a positive or negative response that is perceived as pressure and can affect the psychological and physical individual. Stress that occurs in students is caused by problems related to emotional and physical. Meanwhile, three causes of students easily experiencing stress are, namely pressure in academic problems, the desire to get high grades, and anxiety. Nursing students are also prone to stress due to coursework, course loads, demands from parents to be successful in college, increasingly difficult course material, and increasing material complexity [6].

2.2 M-Health in Counseling

The use of technology in the provision of services in psychology is growing rapidly. Not only does telepsychology increase access and reduce disparities in mental health services, but telepsychology can quickly become the preferred method for mental health services. Mental health, but telepsychology, could quickly become the preferred method of mental health given how technology is intertwined in everyday life. M-Health is emerging as a significant tool to overcome barriers to mental health support access due to its ability to quickly reach and provide support to individuals in need of mental health support. M-Health provides an approach to adapt and initiate mental health supports at opportune moments, when they are most likely to be effective for the individual. However, the poor adoption of mental health apps in the real world suggests that new approaches to optimize the quality of M-Health interventions are urgently needed to realize the potential translational benefits for mental health support [7].

3 Research Health

This study uses descriptive qualitative research methods, namely research that describes a situation, event, symptom, or event that is happening now. The number of participants in this study was 8 people, with the criteria of nursing student participants in Yogyakarta, active semester students (I, II, III, and IV), students who do not live with parents, and are willing to become participants. The variable in this study is the

need for nursing students to psychosocial assistance as stress coping. Data analysis involves the process of organizing data, preliminary reading of the database, coding and organizing themes, presenting data, and preparing data interpretations [8].

4 Research Finding

4.1 Anticipation of Stress-Causing Moments

The results of the study found that the causes of nursing student stress include anxiety in lectures, family as a factor, difficulty in final exams, self-blame, and objective structured clinical examination (OSCE). The causes of nursing student stress are caused by several factors, environmental factors, clinical factors, academic factors, and intrapersonal and interpersonal factors [9].

Active in the Organization

Students usually not only seek knowledge in lectures, but active students will seek knowledge by organizing and seeking experience to improve soft skills. The organization is a vehicle and means of student self-development toward broadening horizons, increasing knowledge, and student's personality integrity. This study found that students who organize are sometimes constrained by the existing lecture schedule. Participants stated that stresses resulted from lectures and organizations, so they need time management, and participants also stated that as members of the organization sometimes replaced the responsibilities of the chairman in meetings. The results of this study are in line with the research of [10] which states that in organizational activities, stress arises due to many programs and responsibilities in the organization that must be completed, and the existence of responsibilities and the results show that campus organizational activities show (20%) students experience stress.

Lecture Anxiety

The results of this study found that anxiety that arises during lectures is caused by the lecture schedule and the biomedical pretest. Most participants stated that the cause of stress from lectures was due to the lecture schedule. The lecture schedule that is obtained at night before the lecture in the morning provides its own pressure for students. The results of this study are in line with research conducted by Muhnia et al. [11] which found 55 people (74.3%) felt their lecture schedule was tight. The lecture schedule, which is fairly sudden, gives anxiety to students who mostly have activities other than lectures. The results of this study are also in accordance with research conducted by Hidayatullah and Aminoto [12] who said there was a significant relationship between stress levels and lecture schedules. In addition, participants stated that lectures that combine research blocks with other blocks will put pressure on students. The results of the study are supported by the results of [13]

which states things that give anxiety to final year students working on their final project due to frustration, pressure, and demands.

Parents

The results of this study found that parents can be a cause of stress or put pressure on students. Participants stated that parents sometimes put pressure that requires students to only focus on lectures to achieve targeted grades and parents give students to stop in organizations. Participants stated that parents with conditions when they were hit by a disaster or in a bad condition made students think of them, so that sometimes made students unable to manage their lives such as eating, resting, and so on. The results of this study are in line with research conducted by Barseli et al. [14] which states that one of the stress factors resulting from outside academics is parents where students are highly pressured on their achievements by getting good exam results, pressure comes from parents, family, teachers, neighbors, peers, and self. Objective structured clinical examination (OSCE).

The results of this study found that OSCE can be one of the causes of students feeling stressed. The results of this study are in line with research conducted by Praptiningsih [15] showing that most students when undergoing OSCE will experience anxiety. Participants stated that the night before the OSCE took place, students would be encouraged to study harder in order to understand the material that had been obtained previously. The results of this study are supported by research from [16] which states that students feel more motivated to learn when experiencing anxiety, as long as anxiety is still fairly mild. In addition, participants stated that the implementation of OSCE with a short time sometimes made students rush in its implementation. The implementation of OSCE can put pressure and provide anxiety for students. The results of this study are supported by Guraya et al. [17] who stated that OSCE is the second highest anxiety-inducing assessment mode in the study.

Final Examination

Final examination is an exam conducted after the lecture block has been completed. The problem-based learning (PBL) approach: learning will use a block system; in one block, it will be passed for six weeks and in the last week of the exam week, the assessment system used at the Faculty of Medicine one of which is using multiple choice questions (MCQ). In this study, it was found that the cause of student stress was obtained from MCQ. In addition to the time of MCQ implementation of one session with the next session which is close together making pressure for students to study and prepare themselves, the number of questions was also found to be the cause of pressure during MCQ. Participants stated that when in the early semester and doing MCQs that had many questions gave their own pressure such as feeling nauseous during the process of working on questions. The results of this study are in accordance with research conducted previously by Coughlin and Featherstone [18] who said the cause of anxiety in the MCQ exam was due to a lot of lecture material by 59.7%.

Self-blame

The results in this study found that blaming yourself will give a sense of psychological pressure on yourself. Feelings that feel always guilty to themselves make students brood and harbor feelings of guilt. Partsipan stated that often thinking and feeling guilty makes a sense of pressure on oneself. The results of this study are in line with research conducted by Aryani [19] saying that individuals easily blame themselves for a mistake that occurs and compare their abilities or compare other people's achievements with themselves.

Difficulty Dividing Time

The results of this study found difficulty dividing time to be a cause of stress. During lectures, students have activities that are carried out in addition to teaching and learning. The students are expected to be able to give color to campus life through various activities under the coordination of formal student organizations. With activities carried out by students in addition to studying but also organizing, it is not uncommon for students to have difficulty in dividing their time. Participants expressed difficulty dividing time when MCQs were concurrent with other activities. The results of this study are in accordance with research conducted by Eldeeb and Eldosoky [20] which found an insignificant positive correlation in time management and stress.

4.2 Recognition of Stress Symptoms

Distress and Maladaptive

Distress is a negative form of stress. Partsipan states that distress makes a person go in a negative direction. The results of this study are in accordance with the research of [21] saying that stress is an unhealthy, negative, and destructive state. While maladaptive is a problem solving that a person does but in a negative way, participants stated that maladaptive is solving problems in a negative way, such as self-harm. The results of this study are in accordance with [22] which states that adaptive (positive) mechanisms are coping mechanisms in the form of problem solving, while maladaptive (negative) mechanisms are the opposite of adaptive which are more concerned with emotion in problem solving.

Eustress and Adaptive

Eustress is stress that has a positive impact on a person. Participants stated that eustress is what spurs them to be more positive or better. The results of this study are in accordance with the research of [21] that stress is any condition that can provide inspiration and can provide motivation to act positively. Adaptive is problem solving by finding a positive way out. Participants stated that adaptive is where someone looks for a way to solve the problems they face. The results of this study are in

accordance with [22] which states that adaptive (positive) mechanisms are coping mechanisms in the form of problem solving or looking to solve problems.

Impact of Stress

The results showed that students have recognized the impact of the stress they feel. This is stated by parts of the impact felt when experiencing pressure on lectures makes students motivated to be more active in learning. If anxiety appears at a moderate level and gives strength to do something, it helps individuals to build defenses so that the anxiety felt can be reduced little by little. The impact of stress felt apart from positive there are also negative results. Participants stated that the impact of stress made students sick with vertigo, besides that some said they became sleep deprived and made their hair fall out. Stress will affect the work of the Raphe Nucleus area, where the area affects the emotional process which turns out to have an impact on the hypothalamus region in the brain precisely in the Supra Chiasmatic Nucleus and results in a disturbed sleep process [23].

Symptoms of Stress

Stress symptoms are signs or changes that appear when someone experiences stress or feels depressed, and everyone has differences in responding to stress. Students will vary in responding to stress even though the cause of the stress they get is the same. When experiencing stress, eating becomes irregular and feels dizzy. Stress symptoms are generally divided into three aspects, first physical symptoms in the form of sleep disturbances and changes in appetite, symptoms in the form of not focusing on thinking, thinking becomes chaotic and thinking negatively, and emotional symptoms in the form of mood swings. Stress symptoms can be divided into four, namely emotional in the form of anxiety, fear, nervousness, anger, frustration, irritability, impatience, and depression; physical in the form of fatigue, headaches, muscle tension, indigestion, difficulty sleeping, and so on; behavior in the form of mood swings, blaming, changes in appetite, and so on; and psychological in the form of decreased concentration, loss of sense of humor, low self-esteem, and so on [21].

4.3 Problem-Solving Ability

Adaptation in the First Year

The first-time lecturing is the beginning of students to adjust to the new lecture environment. Participants stated that the first-time lecturing made students stressed which could be caused by a different learning system from high school to college. These results are supported by research by Augesti et al. [24]. Stress in early-level students is obtained by adapting students from the school environment to the university environment. The lecture schedules such as assignments, lectures, tutorials, and clinical skill laboratories that are dense and only felt for the first time after entering the world of lectures can be a cause of stress in early-level students.

Adaptation in the Final Year

In the final semester, lecture year is the time when students have begun to get to know and understand the perceived lecture system. Participants stated that lectures become heavy if two lecture materials are combined and increase the SKS load; besides that in the last year, they have their own burden by making a thesis that must be accompanied by lectures. The results of this study are supported by research by Ambarwati et al. [25] final year students, produce higher levels of stress because not only lecture assignments but also because they have to complete the final project, with the results obtained the majority of students experiencing moderate stress levels totaling 58 students (57.4%), experiencing severe stress with a total of 7 students (7.0%), due to internal factors, namely not being able to understand and respond to problems properly and from external factors, namely problems in the community, family and related to relationships with other people and also because of the higher level course load, the more difficult the course.

Activities with Gadgets

The current era is where young people easily access gadgets. The presence of smartphones is able to provide various benefits and conveniences for its users, especially for students. The results of this study found that all participants would use gadgets as a medium for stress diversion. Participants stated that in stressful conditions, they would usually watch YouTube, play social media, or turn off their cellphones. In this world, some Indonesian people are more likely to utilize their time for activities with electronic media such as television, laptops, cellphones, tablets, or the like rather than interacting with other individuals. The results of this study are supported by researchers [26] who state that music can provide positive energy when we are experiencing fatigue in dealing with a problem and as a mood booster when saturated; researchers also say music can affect the decline in depression in students.

Problem-Solving Method

Problem-solving therapy is one of the non-pharmacological treatments to reduce stress. Everyone's problem solving is different, and all ways are done to be able to escape or reduce the stress felt. The results of this study found that when feeling stressed or depressed, some participants stated more often to take a walk or choose to rest at home. Sleep can restore and rest the body, reduce stress and anxiety, and can improve ability and concentration. In addition, participants will also read books to divert stress. Distracting the mind by reading books, favorite television programs, and playing computer games can keep the mind busy [27].

Spiritual Way

Spirituality is something related to spirit, enthusiasm to gain confidence, hope, and meaning of life. The spiritual way is to get closer to the Creator, by doing worship activities or by listening to murottal. The results of this study found that praying, worshiping, and getting closer to Allah SWT provides a sense of calmness and is very effective for reducing feelings of stress. The higher the spirituality, the lower

the thesis stress in students. The Quran is effective for reducing academic stress at school. The doing therapy with dhikr has a significant impact in improving mental well-being [28].

Sharing with Family and Friends

When facing problems sometimes, we need support from the closest people such as family. Social support from friends and family will help students in dealing with academic stress. The results of this study found that telling stories to siblings will help in problem solving. Partsipan also stated that the advice given by relatives could help participants. The results of this study found that almost 7 out of 8 participants were reluctant to talk to their parents when facing problems. The telling stories with parents is a coping that is widely used by students. On the other hand, they only communicate to ask about news and tell other stories, so that problem solving by asking parents for help for students is not really used and only contact parents to be able to communicate. A significant relationship between family support and anxiety levels.

Social support from friends and family will help students in dealing with academic stress. Problem-solving individuals can directly focus problem solving on the problem by obtaining information and trying to find appropriate solutions or can also seek emotional support from friends. Stories to friends are something that people usually do, but in this study by telling stories to friends only as a media place to vent or tell stories to be listened to not as a way out of the problem. Participants stated that they did not need to give enough advice as a listener, and other participants said that telling stories to friends could sometimes give new problems. Peer counselors can handle problems that are classified as mild and moderate. Researchers found that participants did not really need help solving problems from friends, but friends were only people who could listen to the problems that students faced [29].

4.4 M-Health Consultation

A person certainly has their own limitations in problem solving. Some can solve it themselves, but some need other people to be able to give advice or just as a listener. So that each campus provides counseling services to students to be able to provide psychological assistance to students. Counseling guidance is one of the important components in education as a system. Participants stated that the implementation of counseling is needed to help student academics. The counselor has the right solution in solving the problems experienced by students and also has problem solving in accordance with his knowledge or experience. The counselor's job is a medium to provide assistance to people who experience problems or need a place to be able to seek help while in academia. Participants stated that they were maximizing the counselor internally [30].

The implementation of counseling in addition to counselors who are experienced and have the knowledge to be able to help students will be more comfortable with

facilities that can support the process of running counseling. Participants stated that the facilities needed are comfortable facilities, which can maintain privacy and have a less tense atmosphere. The counseling room has several facilities; administrative space for storing student data, guidance, and counseling workspace; individual counseling room for individual counseling services; and group counseling room for carrying out group guidance services. In addition, participants said they could hold facilities in the form of online counseling, which in its implementation the identity will be anonymized and can be a medium for students or lecturers who need a medium to be able to share and need help with problems. The effectiveness of using a smartphone-based mindfulness app has proven effective in reducing stress. Participants stated that online counseling was carried out by hiding the identity of students or counselees. The results of this study are in line with [31] which says there are advantages and disadvantages in the implementation of online counseling.

Advantages of online counseling/cybercounseling. Direct request from a shy counselee and then attend face-to-face and request online counseling, which means the counselee is more comfortable in communicating. Counselors can reach out to a wider range of counselees. Even without observable verbal and physical cues, most counselees find it easier to pour out their thoughts and feelings. The implementation of counseling between the counselor and the counselee is more flexible and by mutual agreement. With these advantages, the counselor must have theoretical and practical skills in carrying out cybercounseling maturely.

Weaknesses of online counseling/cybercounseling. The weakness of cybercounseling is that counselors do not pay enough attention to facial expressions and body language. It is not possible to strictly control behaviors that undermine the counseling dynamics. The growth of dynamics in the counseling process receives less attention. Counselors must have high imagination skills and have the ability to interpret the words written or the forms of motion and animations used in the communication process.

In this study, participants stated that academic supervisor was only met to ask about grades, as a place for academic-related discussions and had never used the function as an aid in helping non-academic problems. Participant also said that academic supervisor only met with students to fulfill the obligation to meet. The academic assistant lecturers have the function of fostering and directing students, determining the amount of study load that students will take, determining/deciding whether or not the students concerned can take the final semester exam, monitoring and guiding students for smooth study, and helping to solve problems faced by academic and non-academic aspects.

5 Conclusion

Stress coping ability is the need for nursing students from the theme of having anticipation of stress-causing moments, recognition of stress symptoms, problem-solving skills, and counseling needs. After this study, it is hoped that further researchers can

identify appropriate online counseling as well as the advantages and disadvantages for nursing science study program students and research other needs that can help as student coping so that varied data are obtained.

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Research on Optical Soft Tactile Sensor Data Collection for Deep Learning

Zhenyu Lu, Tianyu Yang, Yuming Dong, and Yan Liang

Abstract Optical tactile sensors have the advantages of high accuracy and small size. The measurement calibration of this kind of sensors often needs the help of deep learning. The accuracy of the dataset has a great impact on the training results of the deep learning model. We design a new method of 3D force data acquisition based on optical tactile sensor. This method solves the problem that the measured force value is deviated from the reference value after running for a long time. We use the same deep learning model in Baimukashev et al. (IEEE Robot Autom Lett 5(2):2618–2625, 2020 [1]) for comparison. The proposed method reduces the dataset error and improves the accuracy of the deep learning model.

Keywords Data collection · Sensors · Deep learning

1 Introduction

Robots play a very important role in all walks of life due to the development of the Internet of Things [2–4]. With the increasing use of robots in modern society, the functions of robots need to be gradually increased. Tactile sensing is the core function of a multi-functional robot. It can make robots have the ability of environmental perception and interaction being the same as humans.

According to previous studies [5–8], the composition of human tactile perception system is complex and precise. The human sense of touch is produced in collaboration with a variety of cells. These cells can be classified by function into rapid adapting (RA) units and slow adapting (SA) units. RA units include Meissner corpuscle and

Z. Lu · T. Yang (✉) · Y. Dong
Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, Shenzhen 518055, China
e-mail: ty.yang@siat.ac.cn

Z. Lu · Y. Liang
School of Resources and Environment, University of Electronic Science and Technology of China, Chengdu 611731, China

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Pacinian corpuscle. SA units include Merkel cell and Ruffini endings. Merkel cell is a kind of cell that locates on the surface of the skin. It is sensitive to static forces on the surface of the skin. When the skin touches an object, the Merkel cell can sense the position and the magnitude of the contact force. Similarly, tactile sensors need to get a more accurate measurement of contact force while maintaining the shape of objects.

Optical soft tactile sensor is based on the Merkel cell functions. This sensor uses a fiber array to transfer color and brightness information from siliceous colorful cylinder y. This kind of sensor is composed of different layers. In the elastic deformation range of such materials, the extent of deformation is proportional to the value of the force. The color and brightness will change due to the deformation and Poisson effect.

Deep learning has been widely used in soft sensors for measurement [9–11]. A well-designed deep learning network can help tactile sensors achieve more accurate force prediction. Some good results have been achieved. Li et al. [12] achieve slip detection using the data acquired by a GelSight sensor with the help of the deep neural network. Lepora and Lloyd [13] show that deep learning can be combined with optical tactile sensors to get accurate poses of 3D surfaces. Baimukashev et al. [1] combine optical sensor via plastic optical fiber guided imaging with a multi-output deep learning network. It solves the problem that optical tactile sensor is hard to be miniaturized. These aforementioned sensors will play a great role in medical robots in the future.

The size of optical fiber is very small, so the volume of sensor based on optical fiber conduction can be very small. Such sensors can use less information to obtain three-dimensional force information with the help of deep learning. In the past, the production process of deep learning dataset was collected in the process of continuous mechanical movement. For flexible sensors, the recovery of deformation has a certain hysteresis, and the data collected continuously will produce certain errors. At the same time, during the operation of the machine, the temperature rise will also cause errors.

Thus, we design a static data acquisition method to generate dataset for deep learning. The results show that the proposed method is more accurate.

2 Optical Tactile Sensor

This sensor is composed of three layers, and they are all made of silicone. As shown in Fig. 1, the first layer is black for blocking the outside light. The second layer is a fan pattern of red and yellow. The last layer is transparent and can provide space for light scattering. The first layer and the last layer are harder than the second layer because the second layer will deform and change the scattered light when this layer is pressed.

The sensor is prepared by mold method. In a defoaming machine, equal parts A and B of a silicone compound (SortaClear12, Smooth-on) are mixed uniformly

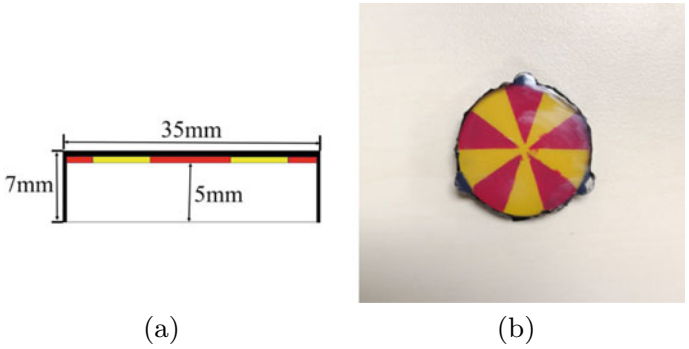

Fig. 1 Side view of sensor structure (**a**) and the picture of real sensor (**b**)

for 2 min before pouring into mold to cool. The second layer is made by two fan-shaped mold. Each mold is poured with different colors of silicone. The last layer is cylindrical transparent silicone.

The sensor's second layer becomes thinner when a normal force is applied to the sensor's surface. According to the Poisson effect, the RGB value and brightness of the scattered light will be changed. Thus, we can get the normal force value based on the collected picture, which can also be applied to the measurements of shear and torsion forces.

3 Data Collection

3.1 Platform

As shown in Fig. 2, the experiment platform is composed of five parts, i.e., camera, light source, optical fiber array, mechanical sensor, and mechanical arm. The optical fiber array that consists of 121 single-mode fibers is divided into two colors, in which 61 single-mode fibers are used for guiding the light from the light source, and other fibers export the scattered light from the sensor, which are captured on the other side by a camera (CCD, 640 * 480, U2801).

The white optical fibers guide the light source with a cooling device to avoid overheating. The picture obtained by the camera is exhibited in Fig. 3. The scattered light at the contact position with a force of 12 N is darker than that of the 1 N case. The adopted mechanical arm is an UR5e Robot made by UNIVERSAL ROBOTS company, and it is used for carrying mechanical sensors and programs. The mechanical sensor is a FT 300-S Force Torque Sensor made by ROBOTIQ, which can output the force information such as F_x, F_y, and F_z in real time. It is also used as the platform for carrying indentors, which are used to press against our soft sensor.

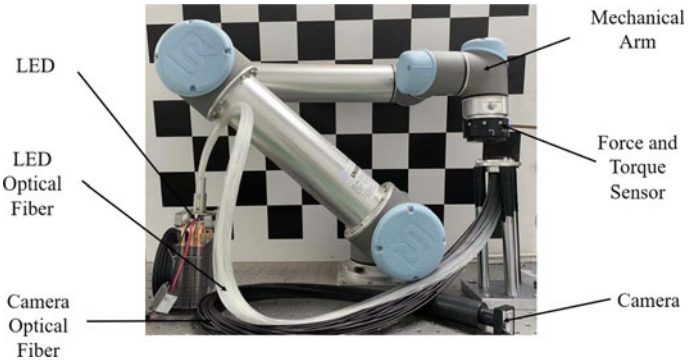

Fig. 2 Data collection platform

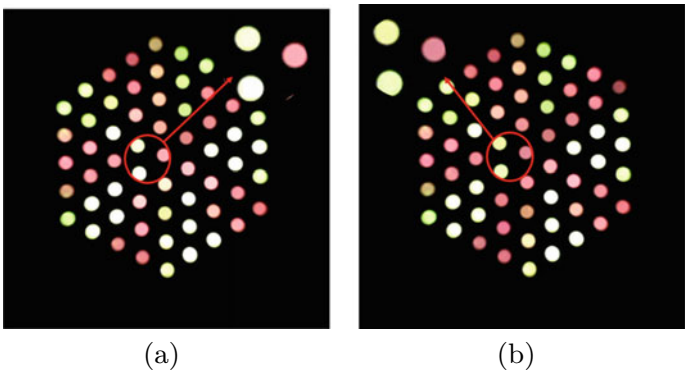

Fig. 3 Raw camera images. **a** Normal force of 1.2 N. **b** Normal force of 12.5 N

3.2 Dataset

LabVIEW programming is used to drive the manipulator and acquire mechanical sensor data in real time. Two indentors with a mechanical sensor are used to press against our sensor, which is the same as [1] to ensure that our results are achieved under the same condition. The 3 mm diameter indentor is used for normal collection, and the 18 mm diameter indentor is used to avoid slipping when it collects shear and torsion forces in a bigger contact area.

After each collection, the mechanical sensor moves back to the initial position for temperature float correction. In the normal force experiment, the robot randomly moves to 10,000 positions and employs the force up to 15 N. About 10,000 collection points (1250 locations $\times$ 8 depths) are collected. As for the shear force experiment, the robot first presses up to 35 N and then moves to 1000 random directions parallel to the sensing surface, we get 2000 collection points (1000 directions $\times$ 2 depths). In the torsion force experiment, the robot presses up to 35 N and then rotates 150

different angles, and the mechanical sensor measures 1200 contact points (2 locations × 4 depths × 150 angles). As a result, we get a dataset which consists of 10,000 normal force points (0–20 N), 2000 shear force points (0–15 N), and 1200 torsion points (0–35 N).

In the experiments of normal, shear, and torsion forces, the LabVIEW will get mechanical sensor output and real-time CCD camera picture when the mechanical sensor arrives at the given location and depth. Then, the dataset is divided into three parts (70% training, 15% testing, and 15% validation) for deep learning training, testing, and evaluation. The object of our research is the perception of static three-dimensional force. In order to ensure the relative stillness of the indenter and the sensor as well as the accuracy of the collected data, the experiment is designed to collect data after the indenter reaches the specified position and keeps stable. Compared with continuous data collection, the data collected in this way is more accurate. Moreover, the long-term operation of the robotic arm usually causes deviations. To mitigate this issue, the indenter in our experiment is programmed to return to the non-contact state for correction after each acquisition, which also improves the accuracy of data acquisition.

3.3 Data Preprocessing

During the data collection process, the measured force value is deviated from the reference value after running for a long time. To solve this problem, we make the mechanical sensor move back to the initial position after each collection point to correct the force value deviations, which is to eliminate force value deviations during the data collection process. At last, the dataset we collect has 6 labels (X location, Y location, F_n, F_x, F_y, F_z). F_n and F_z are created to distinguish the different diameter indentors as the data is collected. Specifically, F_n represents normal force collected by a 3 mm indentor, while F_z represents vertical force of torsion and shear forces collected by an 18 mm indentor.

4 Results

The same deep learning model is used for experiment. The binary cross-entropy (BCE) loss function with sigmoid activation function is used for contact force classification, and the MSE loss function is used for numerical regression. SDG optimizer is used for parameter iteration in network training. The initial parameters of the optimizer are learning rate of 0.0001, momentum of 0.9, and batch size of 8. The network training environment is two NVIDIA GeForce RTX 3060 (12G) graphics cards and AMD Ryzen 9 5950X 16-core processor CPU.

The outputs of a network are composed of two parts. The first is the classification output. The second is the regression output. If it is a normal force, network model

Table 1 Results of our dataset and [1]

		[1]		Our	
		Valid	Test	Valid	Test
Classification	Acc	1.00	1.00	1.00	1.00
Normal force (T)	X (%)	3.0	3.5	0.7	0.7
	Y (%)	4.7	4.6	0.7	0.7
	F_n (%)	6.9	7.8	1.2	1.4
Shear and torsion (T)	F_x (%)	2.4	2.6	0.4	0.3
	F_y (%)	3.5	3.6	0.7	0.6
	F_z (%)	5.6	5.4	4.3	3.9

outputs force value and position; otherwise, it outputs three force components in three directions. We modify a variable T for evaluating DL model training accuracy.

$$T = \frac{\text{RMSE}}{R} \tag{1}$$

R is the measurement range. The root mean square error (RMSE) is:

$$\text{RMSE} = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(y_i - y_{\text{true}})^2} \tag{2}$$

where m is the total number of data, y_i is the predicted value of the network output, and y_{true} is the real value of the actual measurement.

As shown in Table 1, our dataset gets more accurate results with the same deep learning model. For location discrimination and F_n, F_x, F_y, our dataset has made a huge lead. The process of data collection is dynamic in [1]. The position is not accurate because there is a delay in data transmission. Our method collects position data when the robot is static. For F_z, our dataset has no obvious advantages. At 35 N, the recovery performance and deformation of the silicone resin exceed the range it works, resulting in a large error. As for F_x and F_y, our method also achieves better performance. This further confirms our error conjecture about F_z. More accurate datasets can improve the accuracy and generalization of deep learning models. This increases the measuring range and accuracy of the optical sensor. And robots can perform more complex and sophisticated tasks.

5 Conclusion

For the optical soft tactile sensor, we designed a static data acquisition method. After collecting data, further data processing is carried out to solve the problem of measurement error caused by the temperature rise of mechanical sensor during

long-time operation. Finally, we use the same deep learning network in [1] to carry out the experiment. The results show that our data collection method has obtained better results in a larger measurement range.

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Identity Politics in Indonesian Authors: Bibliometric Analysis and Visualization

Shohibul Adib, Mega Hidayati, Muhammad Azhar, Hasse Jubba, and Zuly Qodir

Abstract Even now, scientists are still talking about the problem of identity politics. Due to the rise of religious and nationalist groups, identity politics practice results in the dissolution of social order. Using bibliometric analysis, this study seeks to evaluate diverse literatures and identify trends in the analysis of journal articles pertaining to the subject of identity politics in Indonesia. There were 223 document journal articles indexed by Scopus on the term "identity politics in Indonesia." After the data was re-identified using English keywords and the years 2017–2021 were chosen, 105 journal papers were discovered. To determine which works were influential and to define the structure of scientific genealogy, citation network analysis, co-citation analysis, content analysis, and publication trends of journal articles were performed. By using bibliometric analysis, a number of journals, authors, nations, articles, and themes were discovered. To comprehend the core of the investigation, the developing concepts are explained. The numerous literacies on identity politics in Indonesia are identified in this article, which also identifies pertinent areas for additional research.

Keywords Identity politics · Bibliometric analysis · Indonesian author

1 Introduction

One of the subjects that academics from all around the world, including Indonesia, discuss and investigate extensively is identity politics. Identity politics sparked a lot of discussion in a variety of groups because of the enormous prejudice that blacks and whites in the USA face. Identity politics is crucial in the fight for black citizens' rights against white control and the state because of the harsh treatment, extortion, and intimidation that black Americans endure [1]. The use of identity politics in America is inversely correlated to the use of identity politics in Indonesia, which is tied to problems of ethnic, faith, ideology, and special application in order to achieve

S. Adib · M. Hidayati (✉) · M. Azhar · H. Jubba · Z. Qodir
Islamic Politics, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia
e-mail: mega.hidayati@umy.ac.id

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power and manifests as leaders both at the local and central levels [2]. The study of identity politics in Indonesia has received a lot of attention from academics so far. In her writings, Fitri Ramdhani Harahap observes that identity politics undermine Indonesia's diversity of identities by undermining the enduring moral character of religion. This means that the connections between Indonesians are strained as a result of this religion [3]. Ahmad Syafei Maarif's research also revealed that ethnicity, religion, and local interests are more closely tied to identity politics in Indonesia than anything else. Elites generally represent these problems through their individual unique articulations [2].

These specialists' research centers, at the very least, on the topic of two powerful nations engaged in combat in a Muslim- and nationalist-dominated public arena. If this conflict is not handled carefully and correctly, it could destabilize the country's current political order [1]. Religion is viewed in the literature on identity politics as posing a danger to Indonesia's political stability and democracy. This study disproves prior studies by showing that political ideologies of religious identification are not the only major cause of integrity disintegration. On the other hand, identity nationalism can also be a catalyst for discord in Indonesia's practice of identity politics. This study demonstrates that there are other major factors contributing to the deterioration of integrity in addition to the politics of religious identity. Since identity politics are practiced in Indonesia, nationalism's identity can also serve as a catalyst for conflict in that country. This study demonstrates that there are other major factors at play in the loss of integrity than the politics of religious identity. Because, on the other hand, nationalism's identity can also serve as a catalyst for conflict in Indonesia's usage of identity politics. The objective of this work is to provide a sketch of identity politics in Indonesia using a quick bibliometric analysis that simultaneously applies two forecasting techniques, notably analysis of data search results on the Scopus panel and VOSviewer. Two questions can be created for this study as a result: Which patterns and characteristics can be found in journal articles written by Indonesian scholars? (B) What connections may be seen between the ideas developed in specialized journal pieces and Indonesian identity politics? It is possible to create new strategies for dealing with a number of issues, particularly the formation of identity politics that causes conflict, by looking for new policy options that are appropriate for the effect of the conduct of identity politics in Indonesia.

This study is based on the claim that identity politics subjects and concerns in Indonesia often have a connection to social conflicts. The issue of division is split into two main categories: religion interests and nationalism interests. Religious and nationalist identity politics are the two main forms of identity politics in Indonesia today. Each demonstrates the exclusivism of the dominant nationalist and religious factions [4] who both are still engaged in a public struggle for dominance. This is made worse by the political dynamics in Indonesia, which frequently rely on religious conflicts to uphold political dominance.

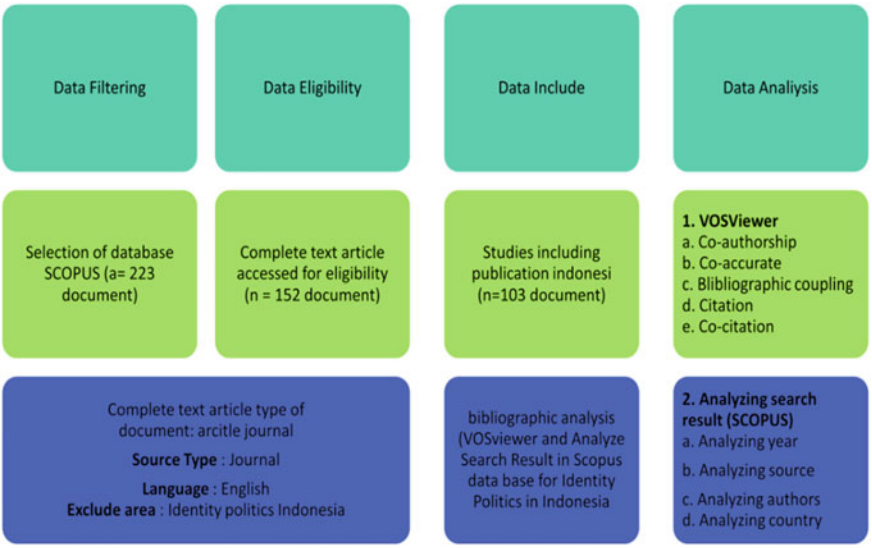

Fig. 1 Workflow for bibliometric analysis using VOSviewer

2 Research Methods

An analytical bibliometric review based on journal articles indexed by Scopus is used in this study. About 223 journal articles were retrieved after data collection using the term "political identity in Indonesia." The researcher then used English to further restrict the subject area for 2017–2021 and discovered 103 Scopus indexed journal papers that examined identity politics in Indonesia. The selected articles from the Scopus database are also saved in a CSV file. Then, two different analyses were carried out: one using the software VOSviewer and the other utilizing search results from the Scopus menu. Figure 1 below demonstrates the steps in this investigation are therefore shown.

3 Result

3.1 Trends in the Indonesian Journal of Articles and Publications on Political Identity

According to an examination of search results and VOSviewer, there have been more publications of articles connected to identity politics in Indonesia between 2017 and 2021, with the total number of documents reaching 103 articles. Then, as indicated in Fig. 2, there were 36 publications from January to August 2021. In 2020, there

were significantly more articles published than there were in 2019, because of the numerous political conflicts between powerful religious organizations that would affect Indonesia in 2020. Islam is battling nationalist forces for public acceptance, which has piqued academics' interest in writing about identity politics-related issues that will be hot in 2020. Up until the end of 2021, there may be an increase of publications.

According to VOSviewer, ten well-known journals with a reasonably wide amount of citations and total link strength were discovered to have gotten the majority of the articles about identity politics in Indonesia that Scopus had indexed, as shown in Table 1.

Based on a minimum frequency of two, as established by 49 authors, Fig. 3 shows a visual of authors who have had minimum single research document published in a Scopus indexed journal.

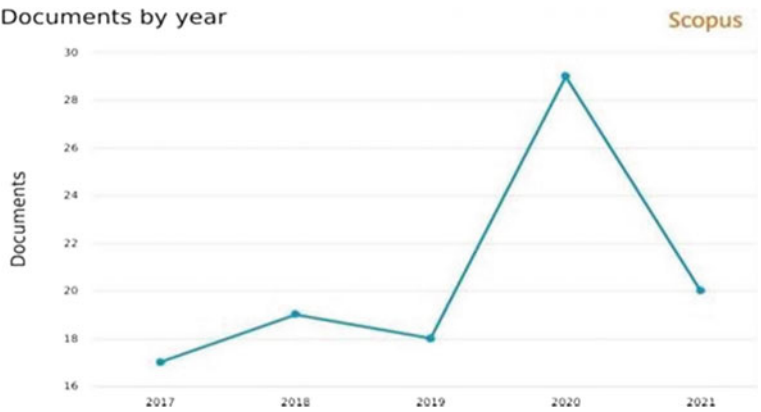

Fig. 2 Annual trend article analysis Scopus indexes political identity in Indonesia

Table 1 List of Scopus journals discussing identity politics in Indonesia

No	Journal	Document	Citation	Strength
1	Piety and Public Opinion understanding Indonesian Islam	1	16	16
2	Studia Islamika	2	11	15
3	Journal of Contemporary Asia	11	7	12
4	Asian Ethnicity	2	22	9
5	Contemporary Islam	1	59	9
6	City and Society	1	4	5
7	Pacific Review	1	12	4
8	Word Development	2	27	4
9	Asian Journal of Comparative Politics	1	4	2
10	Journal of Peasant Studies	1	39	2

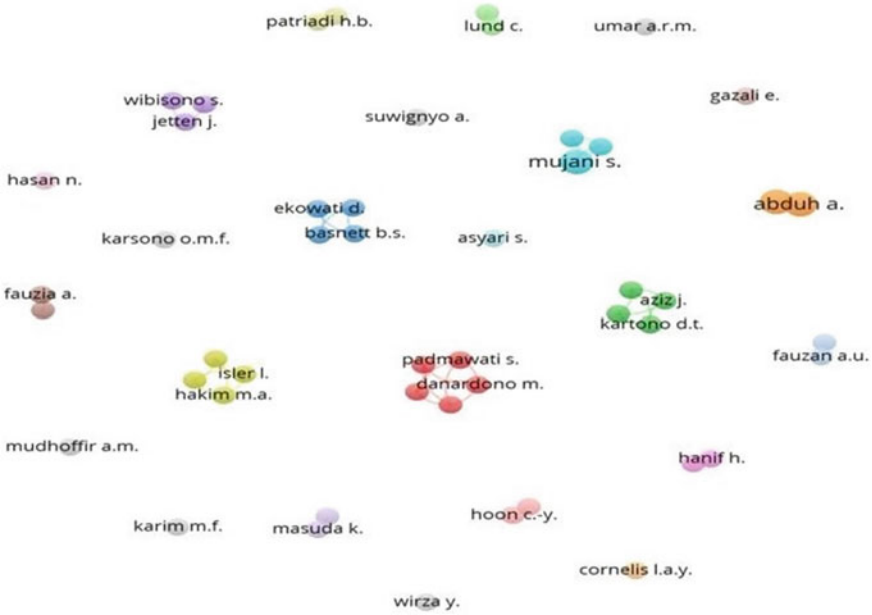

Fig. 3 Author network visualization based on analysis of co-authorship

Figure 4 illustrates how Indonesian authors frequently work with authors from other countries, including Malaysia, Australia, Norway, England, Japan, Denmark, and Norway.

3.2 The Subject of the Article Journal on Indonesian Identity Politics

Using VOSviewer analysis, 322 keywords were discovered. About 50 keywords have satisfied the requirement if the filter is applied with a minimum frequency of 2. Following that, we filter and select 21 keywords from a pool of 50 already-existing keywords that have a connection to two nodes. The stronger the relationship between the nodes, the closer their proximity. Using VOSviewer, identity politics in Indonesia are bibliometrically mapped and categorized into 5 groupings. Each cluster is colored differently: The first is red and contains nine keywords including "extreme," "gender," "identity," "media role," and "Islamism." Second, green clusters with words like municipal governance, political economy, and democracy. And last, there are blue clusters that resemble the terms nationalism, identity, and religion. Fourth, the word Indonesia, social media, and violence are contained in the yellow cluster. Fifth, the terms "tribe" and "regional election" are similar to the purple cluster (Figs. 5 and 6).

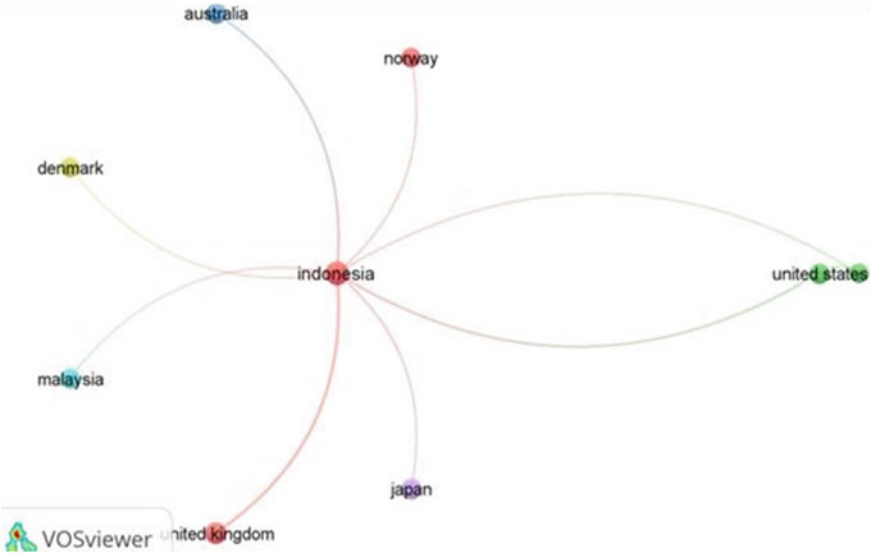

Fig. 4 Indonesian authors with foreign authors

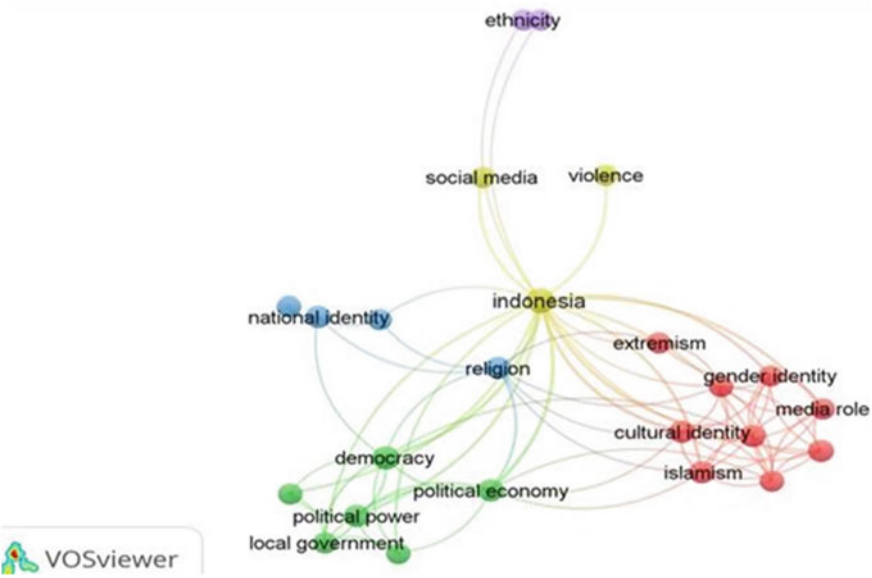

Fig. 5 Co-assurance network visualization

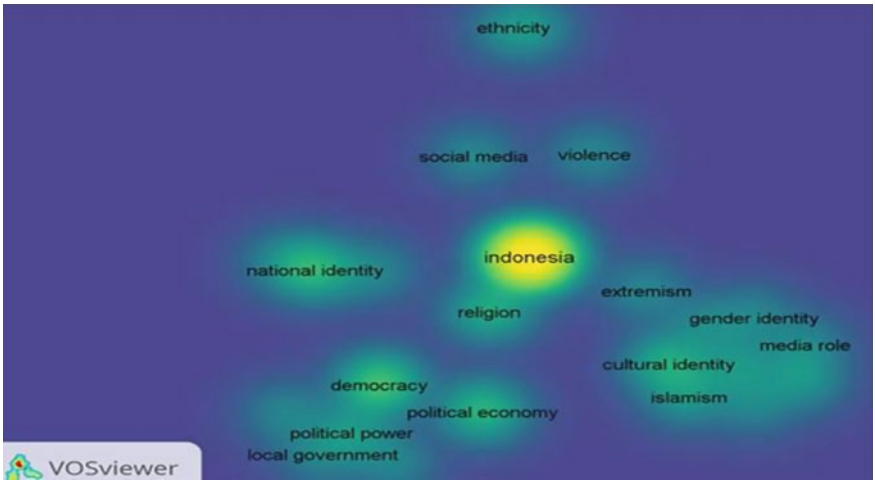

Fig. 6 Density visualization for co-assurance

4 Discussion

Using VOSviewer, identity politics in Indonesia are bibliometrically mapped and categorized into 5 groupings. Each cluster is colored differently: The first is red and contains nine keywords including "extreme," "gender," "identity," "media role," and "Islamism." Second, green clusters with words like municipal governance, political economy, and democracy. And last, there are blue clusters that resemble the terms nationalism, identity, and religion. Fourth, the word Indonesia, social media, and violence are contained in the yellow cluster. Fifth, the terms "tribe" and "regional election" are similar to the purple cluster. The results of this study showed that journal articles about identity politics in Indonesia have been widely embraced by the scientific community all over the world, based on the number of journal article citations and the level of collaboration between Indonesian authors and authors from other countries in the publication of Scopus indexed articles. This study therefore illustrates how frequently the author's subjects and concerns attribute the increasing diversity of links between social groupings in society to the effect of religion [5].

The findings revealed three different aspects: (a) Identity politics-related journal papers have been published in Indonesia, although this classification tends to be subjective and misses the fundamental issues; (b) the results of this study provide the basis for identifying troubling events that have a significant impact on the narrative that is created via the publication of journal papers that are Scopus indexed. Public opposition to government actions has been given legitimacy by the emotional attachments that communities have formed as consumers of narratives created through article writing.

A narrative that is no longer based solely on the quantity of research articles and journals published but instead takes into account a variety of factors that may have an impact on the general understanding of politics is provided by the findings. Additionally, they provide an overview of the patterns and traits of the articles that are published in the journals that Scopus indexes. Identity is a necessary process. The state of publications like these demonstrates how the narrative developed through research and article writing for journals with Scopus indexes has led to the gradual improvement of ties between community groupings, particularly nationalism and the Islamist group.

Since it concentrates on the latent threat that identity politics poses to the peace of the country and state, this study varies from other studies that have been done on identity politics in Indonesia. Some individuals think that politics of identity in Indonesia, particularly in the election of leaders, is one of the reasons why communities in different parts of the country are at odds with one another. This study affirms that political goals that are driven by political elites to seize and hold onto power in Indonesia through the manipulation of identity politics cannot be separated from identity politics in Indonesia today. It is believed that the conflict between nationalist and religious groups offers a chance to hide the incapacity of the current administration to address pressing national issues.

Accordingly, it is important to consider who, what, and how these interests are in order to understand the problem of identity politics. Political elites believe that identity politics is the most effective tool for reducing the electability and popularity of political opponents in order to win over the general public [6]. By entangling a person's or group's fanaticism in religious issues, elite groups are able to employ identity politics to resurrect the primordialism debate, which has caused significant splits and posed state nationalism is being contested. Several media reports that made allegations of right and wrong on both sides exacerbated the conflict over identity politics. The proliferation of reports and minutes has exacerbated conflicts between nationalist groups and religion, raised unresolvable identity politics issues [7], and created new issues with the dissemination of uncertain news. Most of these reports and minutes also contain lies, which have a significant impact on how people's lives are established [8].

5 Conclusion

The author's articles on identity politics are based on research prone to subjectivity and blaming religious organizations for social unrest rather than the subjects and concerns that elevate the concordance. Subjectivity-based problems provide conflict in the legitimacy of society. It will raise public awareness and inspire compliance with the law elsewhere if the subject of research and concern is grounded in something significant to promote peace. Political alliances founded on nationalist and religious identities have destabilized the nation, defined by the emergence of a collapse of trust in government.

This study has limitations because it is still evaluating trends and characteristics of journal papers written by Indonesian researchers indexed by Scopus. Consequently, these findings cannot be generalized. On the other hand, the bibliometric analytical method struggles to understand various issues and issues with Indonesian identity politics. This report makes recommendations for further studies that consider literature from sources including Google Scholar, crossref, Web of Science, and other sources. In order for a policy to operate more dynamically and effectively, it is also necessary to use a combined approach to obtain more comprehensive findings and feedback.

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Pedestrian Detection Based on Infrared Imaging Through Gray Transformation and Deep Learning

Zhenyu Lu, Tianyu Yang, Yuming Dong, and Yan Liang

Abstract Infrared images are widely used in night security. Compared with visible images, infrared images have lower pixels and poor imaging quality. The accuracy of pedestrian detection will be extremely poor. Considering these complex situations when the ambient temperature is high or complex, we combine the object detection with the unique temperature information of infrared image and propose a better method that can significantly improve the detection accuracy of infrared image in above situations. We carry out a variety of different preprocessing of the image and then carry out pedestrian detection of the processed image. This method has achieved a higher recognition accuracy in our own infrared image dataset. This will be applied in night security automation.

Keywords Gray stretch · Faster R-CNN · Infrared image · Pedestrian detection

1 Introduction

Infrared thermal imaging technology is widely used in military night target reconnaissance and missile tracking [1], civil fire monitoring, and disaster survivor search, industrial AEBS system [2–4]. In the field of pedestrian detection of infrared image, it can improve the accuracy of pedestrian detection. It is of great significance to improve the efficiency of rescue and save time and other use.

Z. Lu · T. Yang · Y. Dong (✉)
Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, Shenzhen 518055, China
e-mail: ym.dong@siat.ac.cn

Z. Lu · Y. Liang
School of Resources and Environment, University of Electronic Science and Technology of China, Chengdu 611731, China

Z. Lu · T. Yang · Y. Dong
The Chinese University of Hong Kong, Hong Kong, China

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In recent years, with the emergence of various deep learning algorithms and the improvement of computer computing power [5], many people use artificial intelligence to process infrared images. For example, artificial intelligence can be used to recognize infrared small objects [6], and RGB images and infrared images can be combined to obtain a higher detection rate [7].

However, many of the above processes fail to take full advantage of infrared image temperature information to improve the accuracy of infrared image detection. We choose the combination of infrared image gray stretch and temperature information to preprocess the infrared image and then carry out the training and detection of the deep learning network. The results show that our method has a relatively good improvement in the accuracy of pedestrian detection.

2 Data

There are many known infrared image datasets, but many datasets do not contain infrared image temperature information, so we use our own dataset. Testo 875-i infrared imaging device was used for data acquisition. Data collection was carried out twice, one in the afternoon and the other in the evening, respectively, in different parts of the campus, which fully guaranteed the diversity of data samples. We collected a total of 1260 images, each pixel of the image size is 160 pixels width and 120 pixels high, and temperature is in the range of image − 30 to 350 °C. We used testo's official software IRsoft to export the temperature information of these 1260 images to the excel table. Each table cell corresponds to an image pixel of the image and stores a specific temperature value. The temperature matrix in each excel table is then converted into a grayscale image. The grayscale images were then made into dataset in Pascal VOC's [8] format.

3 Methodology

We propose a new pedestrian detection mode based on infrared image that is preprocessed to improve the image quality before target detection. We have designed three ways of image preprocessing in total, and the object detection uses the existing deep learning algorithm Faster R-CNN [9]. In the preprocessing of infrared images by existing algorithms, most of them choose super-resolution to improve the image quality, but we do not choose this method. Because the super-resolution will take up too much computing power resources and more time, we use the method of gray transformation to improve the image quality. We choose three methods from the grayscale transformation: linear stretch, linear stretch to remove high temperature, and S-shaped nonlinear stretching. The following is a detailed description of our method.

3.1 Grayscale Transformation

Gray stretch is used to emphasize a part of an image. Gray stretch can improve the dynamic range of an image. The original low-contrast image can be stretched into a high-contrast image.

Linear stretch The first step is to determine the lowest temperature $T_{\min}$ and the highest temperature $T_{\max}$ in the image. Then the 256 grayscale values are evenly divided into maximum and minimum temperatures. The specific formula is as follows:

$$g = (t - T_{\min}) * \frac{255}{T_{\max} - T_{\min}} \tag{1}$$

where g is the gray value of each pixel point and t is the temperature of each pixel point.

Linear stretch to remove high temperature If the image pixel value is higher than 40 °C, then the gray level is set to zero, and the specific algorithm is as follows:

$$g = \begin{cases} (t - T_{\min}) * \frac{255}{40 - T_{\min}}, & t \leq 40 \\ 0, & t > 40 \end{cases} \tag{2}$$

where g is the gray value of each pixel point and t is the temperature of each pixel point.

S-shaped nonlinear stretch Here we will first set thermal imager temperature range − 30 to 350 °C and divide with 0–255 to a total of 256 gray value. The formula is shown below:

$$R = (t + 30) * \frac{255}{380} \tag{3}$$

where R is the gray value of corresponding pixels and t is the thermal imager receiving temperature (°C) of corresponding pixels. Then grayscale stretching is carried out on the temperature range of the detected target object. The formula is as follows [10]:

$$G = \frac{1}{1 + (m/R)^E} \quad G \in [0, 1] \tag{4}$$

where G is the gray value corresponding to each pixel point after stretching, m is the central value of gray stretch, and E is the slope of gray stretch. Then we use the following formula to make the grayscale to [0, 255]:

$$g = G * 255 \tag{5}$$

where g is the gray value corresponding to each pixel and G is the gray value corresponding to the pixel points obtained in Formula (1) (Fig. 1).

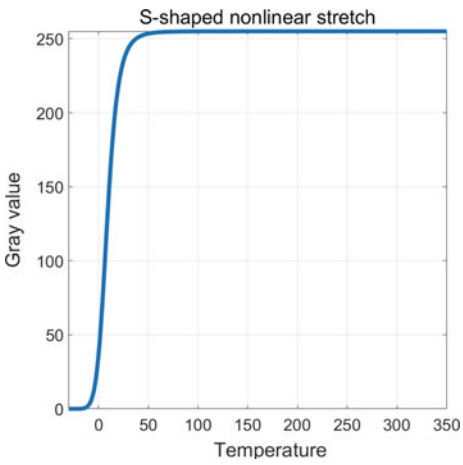


Fig. 1 S-shaped nonlinear stretch temperature–gray curve

3.2 Faster R-CNN

Faster R-CNN has been widely applied in the field of object detection. It is evolved from fast R-CNN [11]. On the basis of fast R-CNN, a regional proposal network (RPN) is added, which completely combines regional proposals and classification into one CNN, and it is an end-to-end model. The following will briefly introduce the implementation principle of RPN network.

Regional Proposal Network A region proposal network (RPN) takes an image (of any size) as input and outputs a set of rectangular object proposals, each with an objectness score [8].

The regional proposal network is composed of a fully connected network that generates both regional boundary and objective scores at each location in the feature map. As shown in Fig. 2, the network uses an $n \times n$ sliding window to traverse the entire convolution feature graph (L1 layer), and each sliding window will obtain a low-dimensional feature. The feature is then fed to sibling layers—a box regression layer (reg) and a box classification layer (cls), respectively [8].

4 Results

In this experiment, a total of three groups of images, S-shaped nonlinear stretching images, linear stretching images, and linear stretching to remove high temperature images, were used. In each group, there were 831 images in the trainval set and 429 images in the test set.

We used faster R-CNN for training our dataset on the TensorFlow framework. Compared to YOLO [12], faster R-CNN has a better effect. Before the training

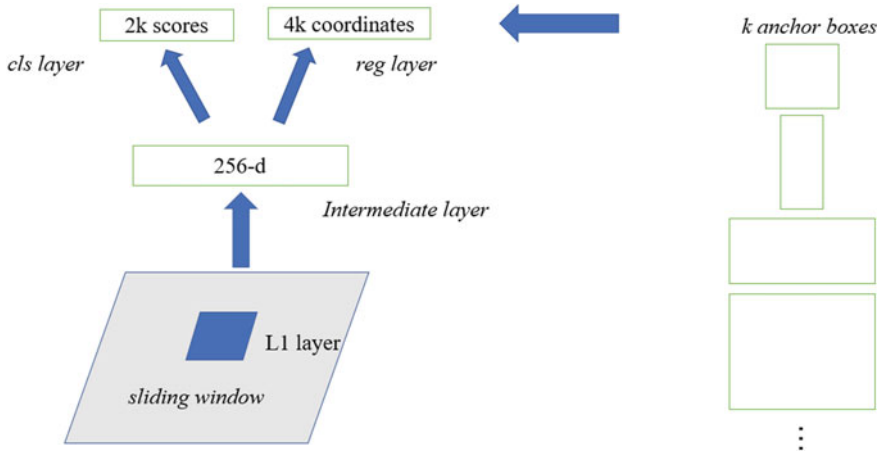


Fig. 2 S-shaped nonlinear stretch temperature–gray curve

Table 1 Results corresponding to different preprocessing methods

Method	Linear stretch	Linear stretch to remove high temperature	S-shaped linear stretch
mAP (%)	87.71	88.37	88.54

model, no additional parameters need to be set for the first two grayscale stretches, while specific parameters need to be set for the third grayscale stretch. Based on the results of our many experiments, the parameters for the third grayscale stretch. E is set to 26, and m is set to 7. The training network used a pre-trained model, and loss functions of three different preprocessing methods all tended to converge when 20,000 epochs occurred. Table 1 is the mAP results corresponding to different preprocessing methods.

What is different from the expectation is that after the model training, the mAP of these three methods is little difference, and the improvement of the latter two methods is not significant. After analyzing the dataset and the principles of methods, we find that one of the reasons is that most samples of images in the dataset do not have high temperature and complex environmental temperature. They only make up only a small part of the dataset, so the increase is not significant. For this reason, we specially identify and compare some complex images separately.

From the histogram in Fig. 3, it can be seen that the gray distributions of gray histogram after linear stretching to remove high temperature and S-shaped nonlinear stretching are obviously more uniform than that of gray histogram linear stretching and the gray distribution range are larger. From the perspective of images, pedestrian characteristics of linear stretching to remove high temperature and S-shaped nonlinear stretched images are easier to be identified than those of linear stretched images.

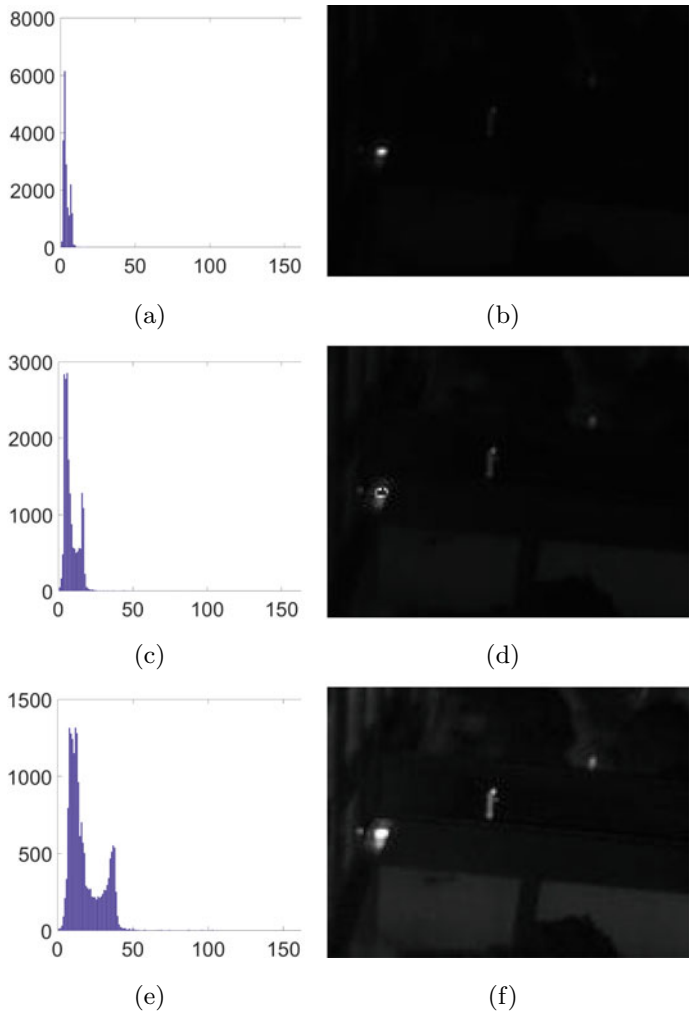
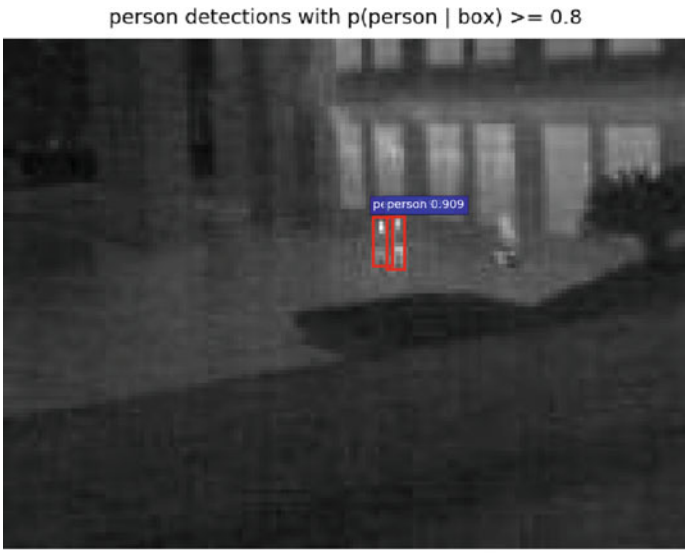
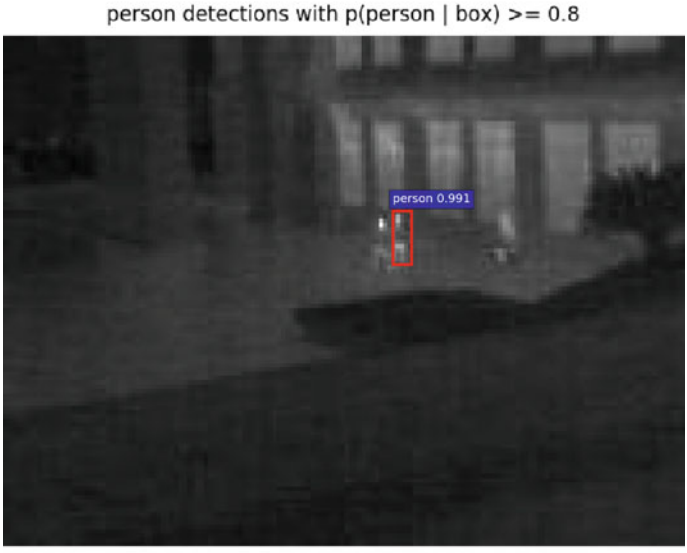


Fig. 3 **a** Gray histogram of the image after linear stretching, **b** the image after linear stretching, **c** the gray histogram of the image after linear stretching to remove high temperature, **d** the image after linear stretching to remove high temperature, **e** the gray histogram of the image after S-shaped nonlinear stretching, and **f** the image after S-shaped nonlinear stretching

Among them, the model of linear stretching training can only identify one person when two people are close to each other. And the S-type nonlinear stretch can easily identify two people. Figure 4 illustrates this phenomenon well. When the temperature of environment is similar to that of human, linear removal of high temperature model is prone to misjudgment. However, this is not the case with S-shaped nonlinear stretching. Figure 5 illustrates this phenomenon well.

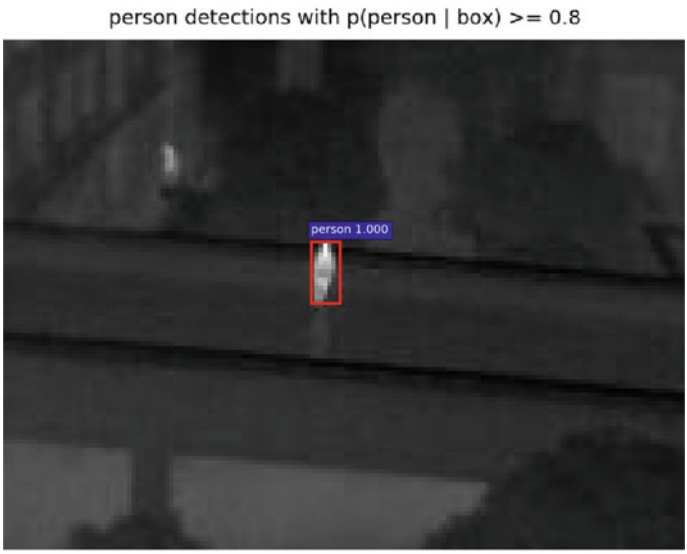


(a)

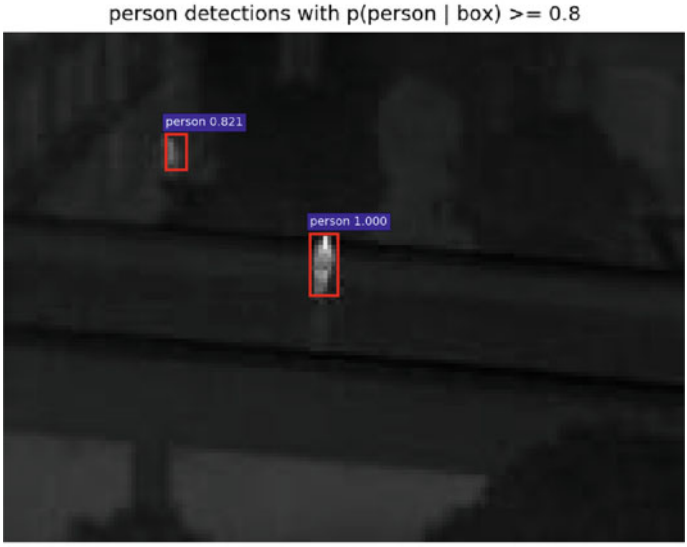


(b)

Fig. 4 **a** Result of S-shaped nonlinear stretch, **b** the result of linear stretch



(a)



(b)

Fig. 5 **a** Result of S-shaped nonlinear stretch, **b** the result of linear stretch to remove high temperature

In fact, we found that S-shaped nonlinear stretching has obvious advantages not only in the above situations, but also in the regression of frames, it is closer to the ground truth. Because of the low pixels of infrared images in dataset, it is difficult to show them in the paper. Interested scholars can check them by themselves.

5 Conclusion

Through the above experiments, we can clearly understand that the combination of infrared image gray stretching and deep learning pedestrian detection can achieve high accuracy. Gray stretching can not only enhance the detection feature information of objects, but also be unaffected by environmental temperature, even in high temperature environment. When the ambient temperature difference is large or small, the model performance can also be very good, which has high practical value.

However, the sample changes in this experiment are not enough, so we plan to further expand the type and number of samples in order to further improve the algorithm.

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Power Line Communication for Long-Distance Underwater Applications

Konstantin Chterev

Abstract Any remotely operated underwater vehicle, or ROV for short, is attached to the surface vessel with a cable called tether. The tether provides a physical connection, power and communication to the ROV. Historically, the tethers were complicated multi-wire cables with separate members for the required functionality. Even recent commercial vehicles use multi-wire arrangements to control thrusters and lights and provide communication channels for telemetry and video feed. This approach makes the tether expensive, heavy and unsuitable for long-distance underwater operations. This paper presents a novel approach using power line communication (PLC) over a tether. Instead of a multi-wire cable, a single twisted pair is used to provide power and communication. Considering the ROV requirement for power, communication throughput and latency, a tether is designed and manufactured. Tests were performed and proved the design's usability for long-distance ROV networking, using PLC.

Keywords ROV · Tether · Underwater communication · PLC · HomePlug

A ROV system consists of an ROV, a tether and a remote control console (RCC), see Fig. 1.

The tether serves three major functions:

– Physical connection
– Communication channel
– Power.

The first two are always present, where the power in some ROVs is not, as they are battery-powered, e.g. Blueye Pioneer [1]. Battery power provides some benefits, such as thinner tether, but it is very limiting for serious underwater work, so only powered tether will be discussed. To provide desired functionality, the tether's physical construction varies around the:

– Communication lines
– Power wiring

K. Chterev (✉)
Black Sea Research Fund, Varna, Bulgaria
e-mail: kc@bsrf.bg

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https://doi.org/10.1007/978-981-99-3236-8_74

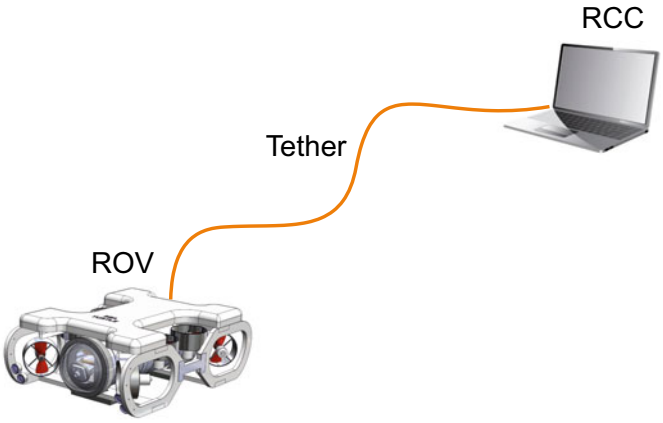
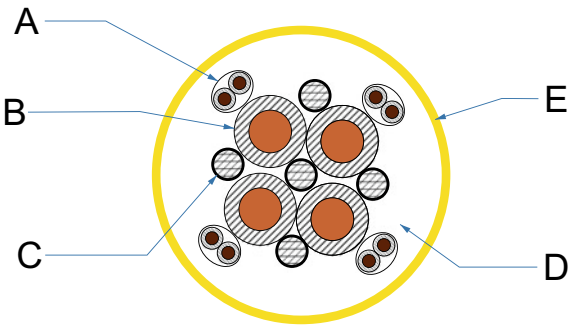


Fig. 1 ROV system

Fig. 2 SAAB SeaEye tether cross section



– Reinforcing members
– Protective outer shield(s)
– Buoyancy correction material.

As an example, SAAB Falcon SeaEye tether cross section is given in Fig. 2 [2].

– A—4× Shielded twisted pair (STP) communication wires
– B—4× multi-strand flexible power cables
– C—Reinforcing threads
– D—Buoyancy filler
– E—Protective outer jacket.

The number of wires, materials and arrangement varies; however, most tethers comply with the template in Fig. 2. In the following sections, the physical, power and communication properties of the tether are evaluated in detail.

1 Physical Connection

The tether's physical properties impact the ROV system in several ways:

– Recovery. The tether acts as a safety line for the submerged ROV. Usually, hundreds of metres below the surface, the ROV's chances for recovery, in case of a failure, depend on the tether tensile strength, which must be adequate to withstand the static and dynamic forces during the potential recovery procedure.
– Buoyancy. Any deviation of a neutrally buoyant tether negatively impacts the ROV system performance. The created buoyancy forces disrupt the movement and positioning, demanding continuous course corrections by the operator.
– Drag. The hydrodynamic forces, or drag, created by the ROV movement or water currents impact the ROV system so drastically that in some cases they are the limiting factor of the ROV operational depth. The drag is created by the ROV itself and the tether, where the latter plays a major role due to its length.

Ideally, the tether should have neutral buoyancy, high tensile strength and minimum drag. Unfortunately, these requirements contradict each other. With identical materials, high strength is achieved by adding more reinforcing threads. This leads to a larger diameter, leading to more drag. Usually, a compromise is made, balancing the physical requirements to fit the specific use case.

2 Communications

The tether provides the physical medium for the ROV system networking. Depending on the requirements, various solutions like Ethernet, fibre optics and other long-range network technologies could be used, consequently defining the tether construction. The underwater networking imposes some restrictions and nice-to-have features, so a match between the available options and these requirements must be found for the best tether design. The main requirements are:

– Long-distance communication (hundreds of metres)
– High throughput
– Full duplex
– Minimum pin count connectors
– Minimum number of wires
– Low cost
– Uncomplicated repair and maintenance
– Easy programming
– Easy adding new endpoints.

In this context, some of the most popular physical network technologies covering the requirements for throughput are given in Table 1 [3–5].

Table 1 Data transmission technologies

Technology	Material	Data rates	Distance (m)	Wires	Price
Ethernet 100BASE-T	Copper	100 Mbps	100	4	Low
Ethernet 1000BASE-T	Copper	1 Gbps	100	8	Med
Ethernet 1000BASE-SX	Fibre	1 Gbps	550	2	High
VDSL	Copper	25 Mbps	740	2	High
VDSL2	Copper	100 Mbps	2000	2	High
HomePlug AV2	Copper	2 Gbps	300	2	Low

Considering the requirement for easy maintenance, repair and potential cable extensions, as well as the maximum connectivity distance, all the Ethernet technologies are not suitable. The first two—100BASE-T and 1000BASE-T—are limited in distance and have high wire count. The 1000BASE-SX is ok in these, but the physical medium is a fibre optic strand, which is fragile and practically unrepairable on the field. The VDSLs look good, but their problem is the non-symmetrical modem configuration. These technologies are developed for broadband services, where on one end there is a router—usually a cheap device—but on the other end there is an industrial switch, which is really expensive and practically unobtainable on the mass market. Despite the limitations, most of the ROVs on the market use one or another of just mentioned options. The last technology—HomePlug—seems to be ignored, despite looking promising. The communication data rates are reasonable. The maximum distance is stated at 300 m, which is good enough and to be verified. The technology is cheap, as it is a commodity product. It is easy to implement and add new endpoints. HomePlug, called also Lan-over-Power, or more generically power line communication, is relatively new. Although the first attempts to use power lines for communications are more than 150 years old, a successful 10 Mbps networking is achieved in the mid-90s. A coalition of manufacturers founded the HomePlug Powerline Alliance in the early 2000s (www.homeplug.org), defining the standards and protocols, which later on were implemented and mass-produced in the form of home user modems. The idea is simple: in the early days, when Wi-Fi was in its infancy, the only way to wire a home network was to drill holes in the walls and use plastic conduits which carry the cables from the ADSL routers to the individual computers. It is messy and fixes net points' location to a specific LAN socket. HomePlug sorts this mess by providing LAN access via the mains power wiring and sockets. The HomePlug modems look like a power adapter with an RJ45 Ethernet socket(s). Some of the modern HomePlug adapters incorporate Wi-Fi as well.

A typical HomePlug home network consists of an internet router, several HomePlug adapters connected to the mains' sockets, standard CAT cables and computers/laptops connected to them, see Fig. 3.

As all the modems share the same physical channel, collision detection and prevention are implemented in the data link protocol. In the case of ROV comms, though, only peer-to-peer communication is required, see Fig. 4. This automatically reduces

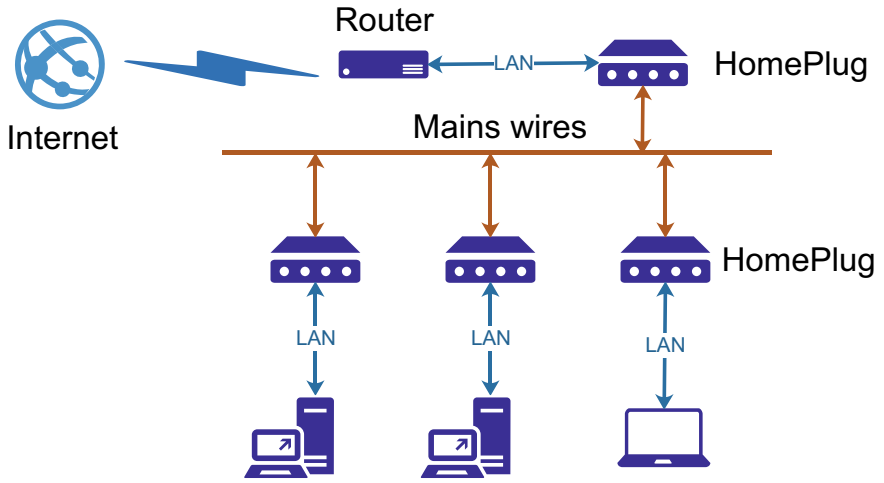


Fig. 3 Typical HomePlug home network

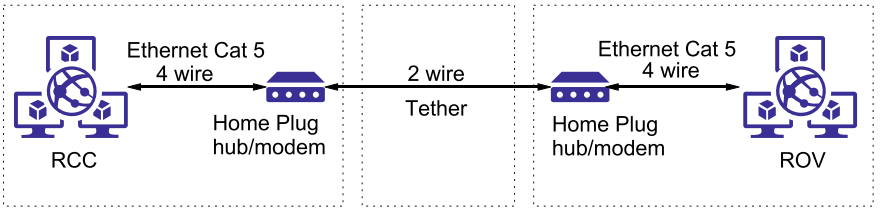


Fig. 4 Ethernet over HomePlug

Fig. 5 HomePlug AV2 carriers

the latency and increases the data transfer rates as only two endpoints are involved in the communications. Further, HomePlug is designed to work over unspecified power wires. If the tether wires design considers the specifics of the technology, much better data transfer rates and distances can be achieved.

HomePlug AV2 technology is based on orthogonal frequency division multiplexing (OFDM): a modulation scheme which uses 3455 separate carrier frequencies, 24.4 kHz apart to encode the network data stream [5], see Fig. 5.

The carriers are modulated using Quadrature Phase Shift Keying (QPSK). In general, the requirements for the physical communication channel are:

– Low attenuation
– Constant impedance over the whole frequency range
– Low cost
– Easy maintenance.

By far, the UTP cables are the cheapest and most widely used high-frequency transmission lines for wired networking [6]. With a throughput of more than 100 Mbps (CAT5 or better), the UTP is the obvious choice for the network physical medium. An attempt is made to use the same wires for power as well. The resulting wire pair will be called Power Twisted Pair (PTP) [7].

3 Power Twisted Pair Cable

The power wires in the tether must provide adequate voltage and current for normal ROV operation. The current rating depends on the wire cross section, while the maximum voltage depends on the insulation material and thickness. As the power requirements are known, an off-the-shelf wire can be chosen for the tether. A standard 2.5 mm^2 equipment wire is selected from www.farnell.com [8] for the project, and an attempt is made to use it as PTP, see Fig. 6.

A transmission line is defined by its characteristic impedance Z_0. It depends on the electrical properties and the geometry of the cable. Z_0 is an important parameter which defines the transmission line terminating load Z_l, see Fig. 7.

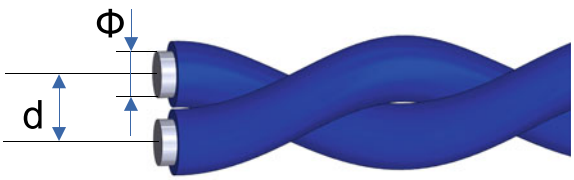


Fig. 6 PTP cable

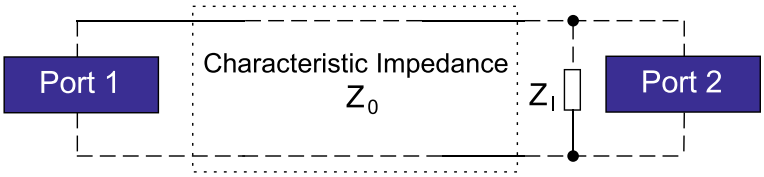


Fig. 7 Transmission line impedance and termination

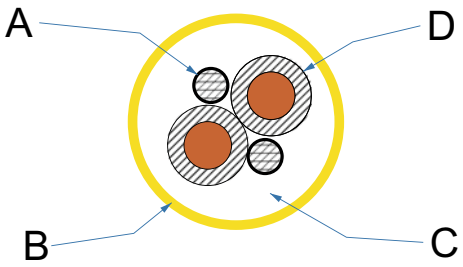


Fig. 8 Cross section of PTP tether

The specific value of Z_0 is not essential, as the termination resistance can be chosen arbitrarily to match it. From [9], the characteristic impedance of UTP is:

$$Z_0 = \frac{120}{\sqrt{\epsilon_r}} \ln \frac{2d}{\Phi} \tag{1}$$

Here, Φ is the diameter of the wire strands, ϵ_r is the insulation material dielectric constant, and d is the wire-to-wire distance, see Fig. 6. For the selected cable, the parameters are $\Phi = 2$ mm, $d = 3.6$ mm and $\epsilon_r = 5$. From there Z_0 is:

$$Z_0 = \frac{120}{\sqrt{5}} \ln \frac{2 \times 3.6}{2}$$

$$Z_0 \approx 68.7\,\Omega$$

Theoretically, the PTP can be used for both power and data transfer, making the tether design extremely simple, with only one pair of wires and additional members for strength, buoyancy and protection. Such cable is easy to maintain, repair and extend. At the same time due to its reduced number of wires, the smaller overall diameter reduces the drag, see Fig. 8. As the power requirements are covered by the selection of the correct cross section and insulation, the only check to be performed is the cable behaviour as a transmission line.

- A—Reinforcing threads
- B—Protective jacket
- C—Buoyancy filler
- D—Power Twisted Pair wires.

4 Test and Results

A cable was designed and manufactured—Fig. 9—according to the following specification:

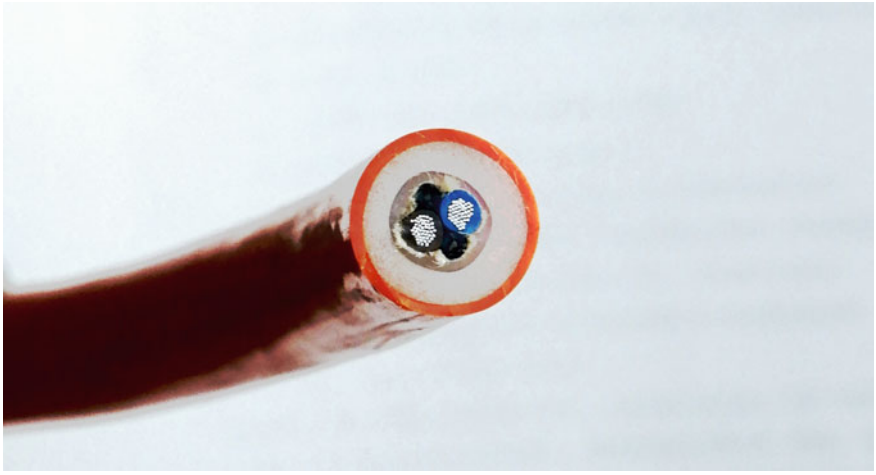


Fig. 9 Tether cross-section close-up

– Neutrally buoyant
– Bare copper conductors, 2 × 2.5 mm^2, stranded 48 × 0.25 mm
– Polyethylene insulation
– Vectran fibre braid, breaking strain > 250 kg
– Foamed polyolefin sheath
– Hydrolysis-resistant PUR outer sheath.

As the maximum power transfer of a signal over a transmission line is achieved when $Z_0 = Z_l$, it is desirable the characteristic impedance to be constant over the whole used frequency range. The Z_0 must be measured so that an appropriate value terminal load can be applied.

4.1 Setup

Measuring the characteristic impedance The characteristic impedance of a transmission line can be measured by Vector Network Analyser (VNA). The VNA measures the Z_0 and also the return loss parameter S11. It is desirable to get S11 as high as possible [10], but as the cable is already produced, this parameter is not controllable. The setup in Fig. 10 consists of a PocketVNA network analyser, tether and a variable load. When Z_0 matches the terminal load value R_{term}, S11 has a maximum value. The HomePlug frequency range is between 1.8 and 86.13 MHz, so the VNA range is set to 1.00–100.00 MHz [11] to cover it. As the calculated $Z_0 \approx 68.7\,\Omega$, a 100 Ω variable resistor is selected.

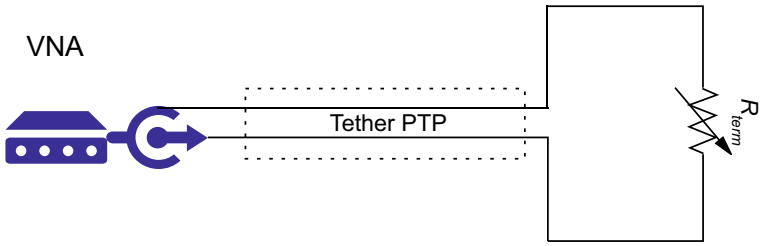


Fig. 10 Z_0 measurement setup

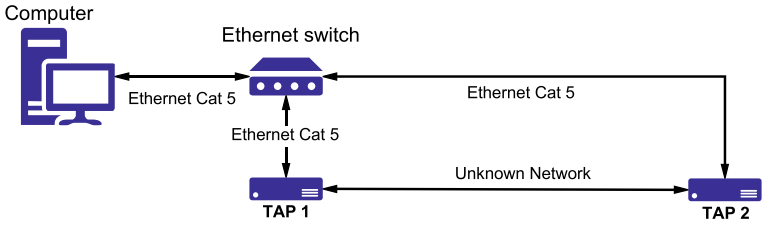


Fig. 11 Throughput test setup

Measuring the throughput and latency The test of the tether is to prove that throughput and latency are acceptable for long-distance ROV operation. There are commercially available devices called Terminal Access Point (TAP), designed for remote network traffic monitoring, that can be used for this purpose. The setup is shown in Fig. 11 and consists of two TAP devices Dualcomm ETAP-2003, an ordinary computer running Windows 10 OS, an Ethernet switch and the Unknown Network, which will be analysed for throughput and latency. The software used comes with Dualcomm hardware.

4.2 Methodology and Results

The characteristic impedance Z_0 is measured as follows: 20 separate measurements with a constant terminal load set from 5 to 100 Ω are made over the whole frequency range. The graph with the maximum overall S11 is selected. The measured Z_0 impedance over the frequency range of 1.00–100 MHz is $\approx 81\,\Omega \pm 12\%$, close to the calculated $\approx 68.7\,\Omega$. This gives the value of the terminal load $Z_l = 81\,\Omega$ used for the last two tests.

For the throughput test, four setups have been analysed with the following channels:

– 10 m of Ethernet Cat 5 cable between the TAP devices.
– HomePlug modems plugged to a dual power socket.
– HomePlug modems connected via 550 m tether without load.

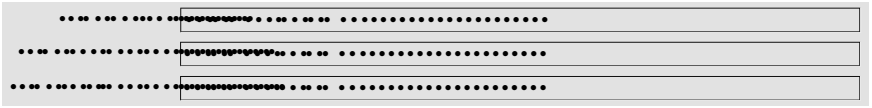


Fig. 12 Direct Ethernet Cat 5 cable

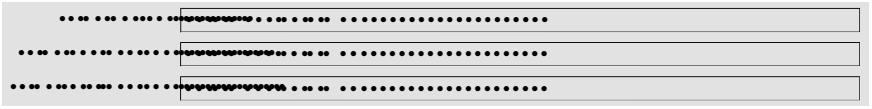


Fig. 13 HomePlug modems plugged closely

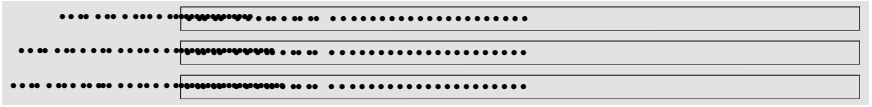


Fig. 14 HomePlug over long cable, no load

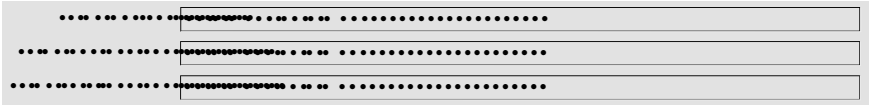


Fig. 15 HomePlug over long cable 2.2 kW load

– HomePlug modems connected via 550 m tether with 2.2 kW load.
– 10 m of Ethernet Cat 5 cable between the TAP devices, see Fig. 12.
– HomePlug modems plugged into a dual power socket, see Fig. 13.
– HomePlug modems connected via 550 m tether without load, see Fig. 14.
– HomePlug modems connected via 550 m tether, 2.2 kW load, see Fig. 15.

The network latency is tested by the "ping" command. The command returns the time a packet travels to and from the two network endpoints. The resulting screenshot is presented in Fig. 16.

5 Conclusions and Future Work

The direct Cat 5 connection provides the highest throughput, slightly less than 100 Mbps, which is expected. Despite performing the best among the four setups, Ethernet over CAT5 is not suitable for long-range networking, as discussed in Sect. 2. The HomePlug modems, closely connected, perform well with an impressive ≈ 75 Mbps up and ≈ 36 Mbps downstream (up and downstream are arbitrarily chosen). The PTP attenuates the signal, and with no load, the throughput is significantly lower,

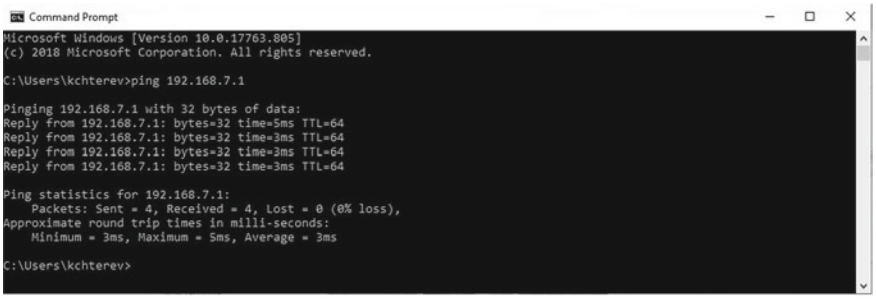


Fig. 16 HomePlug ping time measurement

at ≈ 9 Mbps up and ≈ 12 Mbps downstream. Surprisingly, where a 2.2 kW load is applied to the PTP, the throughput is much better ≈ 42 Mbps and ≈ 65 Mbps, respectively, which leads to a conclusion that the HomePlug modems are designed to work in a heavily loaded mains grid and optimised to match the much lower terminal load. This is subject to future work, where the modems will be analysed for the best matching load. The required minimum throughput for ROV networking is about 8.5 Mbps due to the video feed [12]. The latency, which affects the controllability, is desirable to be no more than 200 ms [13]. The results show clearly that PLC HomePlug technology over PTP tether can be used for a long-distance ROV networking, without compromising video quality and controllability.

Acknowledgements This work was supported by the European Regional Development Fund within the Operational Programme "Science and Education for Smart Growth 2014–2020" under the Project CoE "National center of mechatronics and clean technologies" BG05M2OP001-1.001-0008-C01.

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IIoT Network System from Data Collection to Cyber-Physical System Transmission Under the Industry 5.0 Era

Nasia Balakera, Fotios K. Konstantinidis, Georgios Tsimiklis, Evangelia Latsa, and Angelos Amditis

Abstract IIoT and Industry 5.0 have caused a technological revolution in the industrial field by setting new possibilities in monitoring and controlling of devices and machines. The fundamental characteristics of Industrial Internet of Things (IIoT) optimize production processes through the easy accessibility of data, improved safety conditions, and better maintenance forecasting. At the same time, Industry 5.0 and the IIoT provide more operational efficiency, interconnection, scalability, interoperability, time savings, and cost savings by using advanced technologies. In Industry 5.0, services require short response times and integration with cloud platforms that offer high response speeds, thereby achieving latency-free data transfer. The technologies that are used in the IIoT network that is studied in this research are TIA portal, Node-RED, and Node-RED Dashboard. These technologies are used to connect PLC S7-1200 with the IoT2050 Gateway through the industrial protocol PROFINET and finally transmit data to cloud platforms or other cyber-physical system through MQTT protocol. In general, the proposed architecture collects data from the industrial field and sends them to other systems located on local, fog, or cloud premises in order to store, process, and predict data that can be used in upper systems or cognitive digital twin schemas in a friendly way. In this paper, we propose a methodology that collects production data from the production machine and transmits them to the cloud, proposing a user-friendly step-by-step self-exploratory

N. Balakera (✉) · F. K. Konstantinidis · G. Tsimiklis · E. Latsa · A. Amditis
Institute of Communication and Computer Systems, Athens, Greece
e-mail: nasia.balakera@iccs.gr

F. K. Konstantinidis
e-mail: fotios.konstantinidis@iccs.gr

G. Tsimiklis
e-mail: georgios.tsimiklis@iccs.gr

E. Latsa
e-mail: remove@gmail.com

A. Amditis
e-mail: angelos.amditis@iccs.gr

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guide for integrators, programmers, and early stage researchers. The methodology is applied in cyber-physical-sorting system, achieving monitoring and controlling in real-time, and further processing of the system's data.

Keywords Industry 5.0 · Industrial Internet of Things · PLC S7-1200 · IoT2050 · MQTT

1 Introduction

Nowadays, where smart factories have started to become reality with the focus on automation, rather than the employment of humans within operations, Industry 5.0 makes its appearance. Industry 5.0 is an initiative, coined by European Commission in which the advancements of state-of-the-art technologies such as collaboration robots, artificial intelligence, augmented reality, and cognitive digital twins are used to empower the human workforce rather than progressing the level of automation. While Industry 4.0 basically involves horizontal and vertical integration, Industry 5.0 establishes collaboration between human and machines [1, 2]. Thus, Industry 5.0 is relayed on three pillars: (i) the development of human-centric solutions, (ii) the consideration of sustainability, and (iii) the development of resilient systems against disruptions [3].

In order to interconnect the physical and virtual world, researchers and manufacturers have started to deploy the cyber-physical system (CPS). CPS is a next generation engineered system that combines interacting networks of physical and computational components, while providing cloud-based data-access and processing services [4, 5]. This data exchange is achieved with the Industrial Internet of Things (IIoT), which in collaboration with cloud computing provides a real-time connection in cyber-physical networks between the virtual and the physical world [5, 6]. Real-time data processing, especially in the industrial field, is necessary for effective monitoring and controlling of production lines. According to this necessity, industries are dealing with a significantly large number of data that are produced by production lines in various industries such as food industry, automotive manufacturing, and production among others [7]. The large amount of data creates many difficulties to gather them from industrial equipment such the PLC and so the need to find a methodology, that makes easier and faster the collection and transmission process, is essential.

Finally, we propose an efficient IIoT network methodology that can collect data from industrial field and transmit them to cloud. It is a real-time procedure, where the data generated by sensors or actuators are transmitted to the PLC via PROFINET and subsequently transferred to the cloud via IoT2050 gateway. In IoT2050 data can be processed and be visualized before we upload them to cloud, where the integrator has the ability to monitor and control the industrial process. In order to evaluate our methodology, we are going to implement the proposed methodology to a cyber-physical-sorting system, gathering functional-based data.

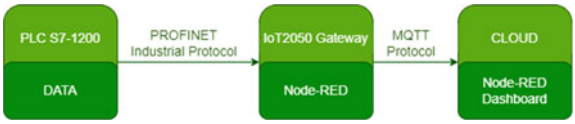

Fig. 1 Data flow from PLC to cloud platform

The manuscipt's contributions are summarized:

- The introduction of a methodology, which transmits data from industrial field to cloud in real-time.
- The proposed methodology enables real-time monitoring of industrial production lines and provides data for identifying system failures.
- This methodology is designed in such matter that can be implemented in a variety of industrial environments and ensuring user-friendly usage and programming.

Summarizing, our proposed methodology analyzes the interconnection of industrial network modules with cloud-based infrastructures via MQTT protocol enabling the real-time monitoring and controlling of industrial processes. The paper is structured as follows: Sect. 2 includes the tools and components used in the proposed methodology divided in hardware and software. Based on this, the experimental and evaluation process as well as the detailed analysis of the proposed methodology are presented in Sect.3. In the final chapter, we draw conclusions and suggest future research.

2 Tools

This section provides a general description of the hardware and software required for this methodology. Especially, in Fig. 1, the data flow from the PLC to the cloud is visualized. The industrial-based collected data from the PLC are transmitted to the IoT gateway through PROFINET protocol. The data are analyzed in the Node-RED software environment and transmitted to the cloud via MQTT protocol.

2.1 Hardware

SIEMENS PLC S7-1200 PLC stands as the main control unit of the production system, which operates and monitors the entire manufacturing processes [8]. In our topology, SIEMENS SIMATIC PLC S7-1200 CPU 1214C DC/DC/DC is used, with code 6ES7 214-1AG40-0XB0, as shown in Fig. 2.

In general, PLCs process the given information (inputs) which is sent from sensors, actuators, and/or other PLCs, execute the instructions from loaded program, and deliver the results (outputs) based on the provided information [9]. The components of PLC S7-1200 are (i) power supply and rack, (ii) central processing unit (CPU),

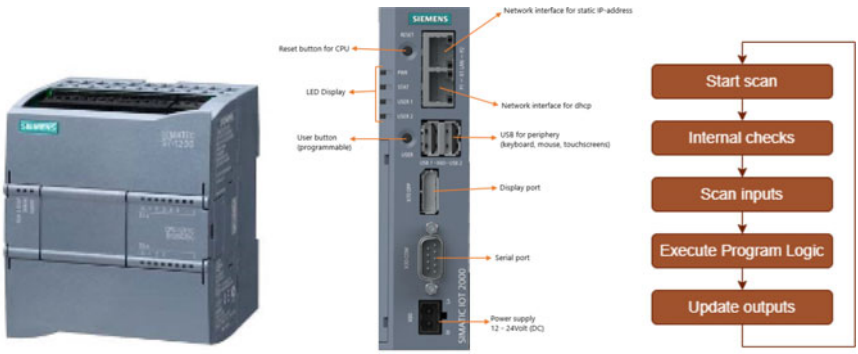

Fig. 2 S7-1200 PLC with the operating cycle of PLC's CPU and the IoT2050 gateway

whose operating cycle appears in Fig. 2, and (iii) I/O section [10]. The inputs of PLC should be the digital instruction signal and the state signal of the controlled object. Accordingly, the output of PLC is connected with the output execution unit to set into operation the object [8].

The SIMATIC S7-1200 PLC controllers stand as smart option with available extendable I/Os, communication capabilities, and intelligent features for automation tasks. The PLC's smooth integration into the framework of TIA Portal delivers standardized data management, predefined library and tools, as well as user-friendly operational experience. Error analysis procedures and error functions with error messages in TIA Portal, on the HMI, and on the Web server save commissioning times and production downtime [10]. The main communicated interface type of PLC is PROFINET with functions such as IO controller, IO device, SIMATIC communication, and Web server [11]. PROFINET is an industrial Ethernet solution designed for exchanging data between controllers and devices in an automation setting. In industries, Ethernet is the communication medium (physical and data link layers in OSI model), and PROFINET is the protocol (application layer in OSI model) [12]. Lastly, with the simplicity of PROFINET networking communication and the flexibility of modular programming, this system can face a variety of complex tasks [8].

SIEMENS IoT2050 Gateway In order to gather the data from PLC and transfer them to cloud premises, the SIEMENS IoT2050 gateway basic is required and visualized in Fig. 2. The IoT gateway is designed for industrial IT solutions directly on the factory field, while at the same time, it can be integrated into solutions for industrial edge applications [13]. The main advantages of this device are the variety of external and internal interfaces (Fig. 3) as well as the ability to program its interfaces in high-level languages. These characteristics result in low need of maintenance.

IoT2050 gateway is an intelligent central hub that integrates communication technologies to connect end-devices with backend platforms and then to the cloud via IoT. At the same time, it translates protocols for data encryption, processing, management, and filtering. SIMATIC IoT2050 does not support any communication protocol for data exchange by default. Therefore, it is required integration with open-source

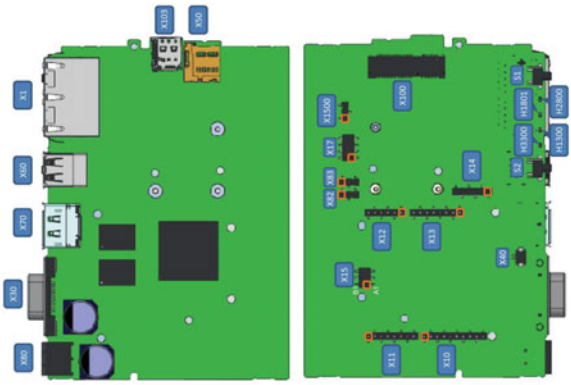

Fig. 3 Motherboard of IoT2050 Gateway

libraries and functions to enable communication with other devices. The most common program which is used to program and manage the SIMATIC IoT2050 is Node-RED, and we will analyzed it later [13, 14]. Moreover, the standard protocol for IIoT-transmission-to-cloud process is MQTT. The MQTT is a messaging protocol relayed on publish/subscribe schemas that enables distributed data exchange among devices through a central unit named edge data broker [15]. This function is really desirable in IIoT, as it provides an easy way to add new devices without touching the existing infrastructure and since new devices only need to communicate with the broker. In addition, this protocol is also used to send real-time data to augmented reality applications for real-time monitoring and alerting, facilitating in the human-centric pillar of Industry 5.0 [16]. Thus, in a multi-platform solution, MQTT protocol is used from Node-RED to link IoT2050 gateway with cloud, and, also, IoT2050 can easily remotely control device of peripherals via MQTT [17].

In general, an IoT gateway has layered architecture and connects the IoT sensors with cloud server. The following are the main software and hardware layers of the IIoT gateway:

- **Hardware Infrastructure**: It includes the memory specification and the processing power. The selection of this hardware depends on the specifics and the complexity of the implemented application.
- **Software Module**: In order to reduce the connectivity cost and simplify the integration, the selected OS should match with the existing systems.
- **Analysis Module**: It ensures that received data is transformed into useful information.
- **Application and Drivers Platform**: This platform facilitates the connectivity new devices and network module and the development of applications.

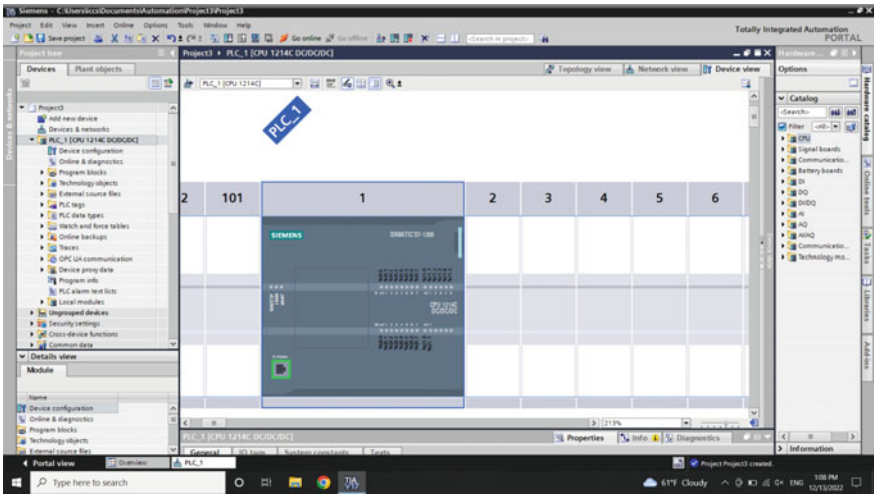

Fig. 4 TIA portal programming environment and simulation of PLC S7-1200

2.2 Software

TIA Portal In the world of industrial automation, PLCs are the dominant types of automatic controllers. Consequently, engineers have aim to create a software to provide PLC with the ultimate abilities to maximize the outcome. In order to program PLC, the totally integrated automation portal (TIA portal) programming environment is recommended, as shown in Fig. 4. The TIA portal provides an engineering framework for implementing automation solutions in all industries worldwide. With this program, it is achieved the design, proper operation, maintenance, and upgrading of automation systems. In particular, a circuit representation of the system controlled by each PLC is made in order to apply various simulations in the system. Through the TIA Portal, the PLC can, also, be connected to other devices such as human machine interfaces (HMIs), PC systems, or other PLCs [18]. As for the language that TIA portal uses to create this circuit program, it is called ladder logic. This language that uses graphical diagrams to describe the circuit diagrams of the studied logic hardware. Its main use is to create software for PLCs for industrial monitor and control use cases [19].

Node-RED Node-RED has gained immense popularity in the IoT space by modeling pieces of application functionality between IoT devices such as sensors, cameras, and wireless routers. The Node-RED tool is a software module that integrates IoT-ready devices, APIs, and cloud services, while a set of nodes creates communication hubs between protocols and platforms. A user-friendly editor for drawing flows makes easier the integration among the clusters.

In order to create these flows, Node-RED leverages Node.js which is based on JavaScript. Node.js is used for the lightweight runtime, taking full advantage of its

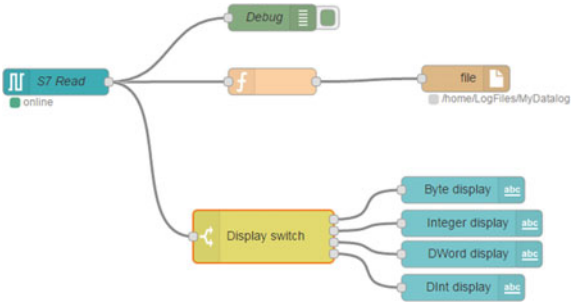

Fig. 5 Example flow-code in Node-RED

event-driven, non-blocking model, and so it facilitates operating at the network's edge on low-cost hardware such as the Raspberry Pi and in the cloud. It uses, also, JavaScript object notation (JSON) to describe metadata. Regarding the type of programming, this is flow-based programming. Flow-based programming divides each problem first into data, then into processes associated with the data and finally into networks which connect the processes together. Processes are grouped into a flow in order to achieve a task, and subsequently, flows are grouped to achieve higher order tasks, etc. An example flow-code in the Node-RED tool is shown in Fig. 5 [20].

A significant task of Node-RED is the connection of PLC and IoT gateway, which requires Node-RED's official PLC S7-1200 libraries, while automated modules categorize and select required blocks to function the PLC components. In this way, the PLC is connected to Node-RED through the programmable interface of TIA portal, and so it is connected with the IoT gateway as well. Thus, by means of programmable blocks, data collection and transfer to cloud are achieved. Even though controlling of PLC is possible directly from the IoT gateway without the mediation of a cloud platform, in this paper, we recommended the use of cloud platform called Node-RED dashboard, which is fully compatible to Node-RED functions [17].

Node-RED Dashboard The Node-RED dashboard is based on the original AngularJS framework and consists of a collection of nodes in Node-RED tool that allows to create Web dashboard that directly interacts with the flow-code. By using these nodes, the integrator can replace inject nodes with buttons and instead of printing to the debug, he can send the data directly to a Web component such as a gauge or a table. These nodes create a single-user interface, unlike a classic multi-user Web page. This means that any changes made to the dashboard are immediately mirrored to any other user viewing it [20, 21].

3 Experimental and Evaluation Process

In this section, the experimental and evaluation procedure is described, where our suggested methodology for collecting data is presented. The implementation was succeeded with TIA portal v17 and IoT2050 Firmware V1.2.1. Both programs ran

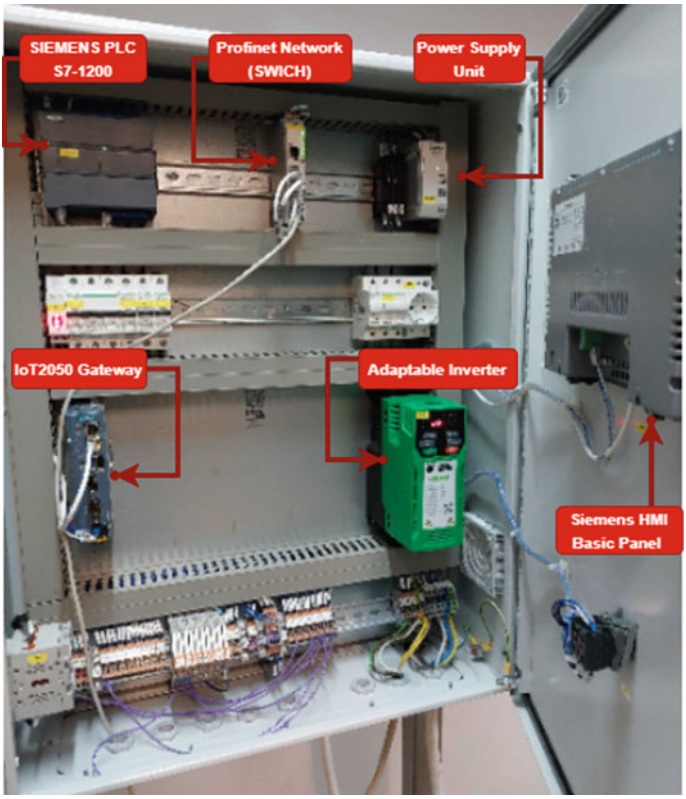

Fig. 6 Control unit of the described CPSS

into a laptop with NVIDIA T600 graphics, 12th Gen Intel Core i7 processors and 32GB of 4800MHz DDR5. Firstly, the multi-sensor-cyber-physical-sorting system (CPSS) is analyzed, on which we study and test the IIoT network communication. Then, there is a description of the data type that this CPSS can send to PLC. Finally, the proposed methodology is analyzed.

The importance of CPSS's use in this study is that this system provides a large amount of real-time data which need collection and process, creating a great opportunity to test the efficiency of our methodology. Our CPSS identifies the type of under-inspection material and autonomously sort it with the use of advanced robotic [22]. As shown in Fig. 6, the architecture of CPSS's control unit consists of the PLC S7-1200, the PROFINET network switch, the power supply unit, the IoT2050 Gateway, the adaptable inverter, and HMI panel.

In these control unit and particularly in PLC S7-1200, different types of data are processed and transferred to cloud. Those data are mainly coming from the conveyor through an adaptable inverter. The inverter by adjusting the AC frequency is achieved the controlling and monitoring of conveyor's speed, direction, and type of movement.

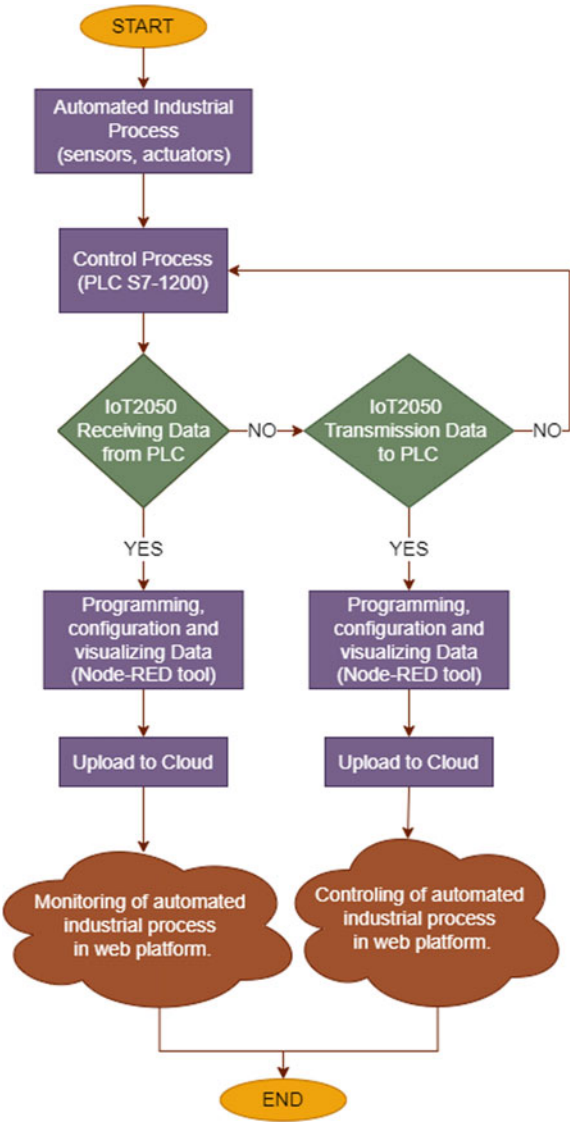

Fig. 7 Flowchart of data journey in this methodology

Specifically, the conveyor has the ability to move in different speeds, back or forward, and stable or unstable. Thus, these data are transferred to PLC, processed there and sent to cloud platforms via IoT2050 Gateway.

In practical terms, either remotely with cloud platform and Node-RED tool or in the field with HMI panel, we set the suitable speed and direction of conveyor depends on the application. From this application, the amount and the types of data are varied, but it is important to emphasize the route that they follow. As shown

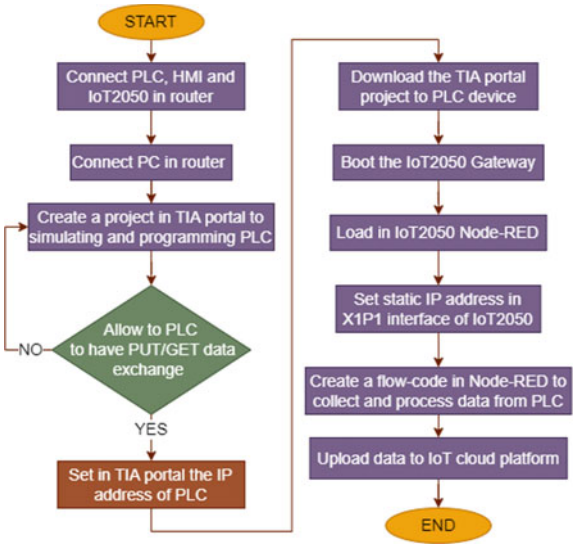

Fig. 8 Flowchart of the proposed methodology for collecting and transmitting data in industrial environment

in Fig. 7, the route of data begins from the sensors and actuators, as they exchange data with PLC, where the control process takes place. If IoT2050 receives data from PLC, then IoT2050 through Node-RED tool programs, configures, and visualizes the data and uploads them to cloud, where the integrator can monitor the automated industrial process in Web platform. If IoT2050 transmits data to PLC, then IoT2050 through Node-RED tool, respectively, programs, configures, and visualizes the data and uploads them to cloud, where this time the integrator can control the automated industrial process in Web platform.

In order to be implemented this data route, the integrator should follow the simple steps of our proposed interconnection methodology, as shown in the flowchart of Fig. 8. As a first step, an integrator should connect PLC, HMI, and IoT2050 in the same switch or router and then the switch or router with PC or laptop. These connections in physical layer are made with Ethernet cables. In PC, the integrator should create a project in TIA portal to simulate and program PLC. It is important to allow the PUT/GET procedure of the PLC settings and set on TIA portal the IP address of PLC so that PLC and router are in the same network. Then, the integrator imports the program in PLC device. In parallel, as far IoT2050 gateway concerns, the integrator should boot the IoT2050 and load the Node-RED in it. Then, as shown in Fig. 2, IoT2050 has two Ethernet interfaces X1P1 and X1P2. X1P1 interface is the one used in this method and is set to static IP address. After completing network connections, to open Node-RED, the integrator can apply either a ssh connection or simpler just connect via a browser. When Node-RED is opened, the integrator creates a flow-code to collect and process data from PLC. Finally, the latter step of the proposed methodology reflects on the Node-RED dashboard. The integrator by using specific nodes for Node-RED dashboard creates a platform where data are

Table 1 Explanatory table of our proposed methodology's steps

Steps	Actions	Done
STEP 1	Connect PC, PLC, and HMI in router. The purpose is to connect all the devices under the same network in order to facilitate the communication between them	
STEP 2	Download TIA portal tool to PC, where the integrator can create the project's simulation	
STEP 3	Create a new project in TIA portal. There the integrator adds the combination of devices and by creating a circuit in ladder language simulates the system	
STEP 4	Go to the device configuration in PLC's settings and allow to PLC to have the ability of PUT/GET data exchange	
STEP 5	In device configuration, also, set the IP addresses of PLC in PROFINET interface. It is important, that PLC's IP address is located in router's network	
STEP 6	Run a simulation of the project to reassure its proper operation and then download the TIA portal project to PLC device	
STEP 7	Boot the IoT2050 gateway by using a SD-card, where it is saved the software given from SIEMENS and so the Node-RED tool is loaded in IoT2050	
STEP 8	Set static IP address in X1P1 interface of IoT2050 and then connect IoT2050 via Ethernet with router in order to set IoT2050 in the same network with the other devices	
STEP 9	Open Node-RED tool and create a flow-code in it to collect and process data from PLC. Insert, also, in flow-code the IP addresses of IoT2050 and PLC	
STEP 10	Upload data to IoT cloud platform by using the special nodes and functions of Node-RED tool. Finally, data are visualized in cloud platform	

uploaded and visualized. Then, the integrator can monitor the industrial process and detect any system's malfunctions in real-time. The integrator can, also, interfere in industrial process by reprogramming the system and make any changes required to improve the industrial process.

In order to assist any integrator, programmer, and early stage researcher, we create a user-friendly step-by-step self-exploratory guide of our methodology. This guide consists of ten simple steps presented in Table 1 to facilitate the interconnection of the SIEMENS devices referred in Sect. 2. Thus, they will precisely aware of the required actions during the implementation process, as well as their overall progress.

4 Conclusion and Future Work

This paper proposes an IIoT data collection system and cyber-physical system transmission methodology that is compatible with I5.0 systems. Specifically, we proposed a method for collecting data from industrial fields, processing them, and uploading them to the cloud. In accordance with the I4.0 architectural design principle,

this method improves the maintainability and adaptability of each legacy system by incorporating it into upper cyber-physical systems or smart factories, while adding cutting-edge sensors via MQTT to the production lines. The visualization of real-time data contributes significantly to the monitoring and control of the industrial process, a necessity for large and multilayered industries in particular. Lastly, gathering the knowledge from this manuscript, authors formulated a step-by-step self-exploratory guide to easily integrate production lines to the cloud. In future work, we will expand this methodology by collecting data from additional CPSS devices in order to develop flexible and user-friendly monitoring interfaces. We are, also, going to test the proposed methodology to other MQTT brokers in order to examine and ascertain time complexity and operating cycles.

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Modeling the Integration of Machine Learning into Business Processes with BPMN

Marius Take, Christoph Becker, Sascha Alpers, and Andreas Oberweis

Abstract Machine Learning (ML) models offer diverse and wide-ranging capabilities to improve business processes. These can be an important success factor for increasing the degree of automation of process execution. Nevertheless, there is currently a lack of possibilities to explicitly model business processes which contain ML. This paper presents requirements for tools supporting explicit modeling of ML in business process models. In addition, it is elaborated how these aspects could be formally modeled because more formal modeling of ML cases allows more options for analyzing and using (e.g., executing) models. Overall, the presented approach describes a comprehensive tool concept for the step-by-step support of explicit modeling the integration of ML applications in business processes modeled with Business Process Model and Notation (BPMN), so that actual process models without ML can easily be extended to process models with ML. For this purpose, besides the extension of existing process patterns, a catalog of so-called sub-process templates is presented, which enables process engineers to derive application-specific sub-process models for different ML functions. Each sub-process template represents multiple BPMN process models and is expressed using the Case Management Model and Notation (CMMN) standard.

Keywords Business process modeling · Machine Learning · Artificial Intelligence · Process patterns · Process templates · Case Management Model and Notation · Business Process Model and Notation · Color-coding

M. Take (✉) · C. Becker · S. Alpers · A. Oberweis
FZI Forschungszentrum Informatik, Software Engineering, 76131 Karlsruhe, Germany
e-mail: take@fzi.de

C. Becker
e-mail: christoph.becker@fzi.de

S. Alpers
e-mail: alpers@fzi.de

A. Oberweis
e-mail: oberweis@fzi.de

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1 Introduction

Machine Learning (ML) provides capabilities for a wide range of problems and enables users to increase the degree of automation with regard to process execution. Therefore, the integration of ML services into business processes in a meaningful way is currently a relevant question [1] and an ongoing challenge with respect to the effectiveness and broad application of ML in enterprises [2]. Currently, there is no comprehensive solution to address this problem in a structured manner.

Explicit modeling of ML integration in process models is needed, for example, in the planning phase of ML implementation projects and for the planning of process adaptions. For example, the action guide for ML implementation projects of Pokorni et al. [3] and the AI-Journey of Kreutzer and Sirrenberg [4] include the phases *Use case concept* or *systematic preparation of the AI deployment*, where appropriate modeling capabilities would be useful. In addition, early modeling of target processes, which include ML, enables a common understanding of goals and improves transparent and structured planning of human ML interactions. The modeling of target processes, which include ML, also allows the identification of resulting changes at an early stage. By comparing the actual processes with the modeled target processes, changes regarding operations, involved departments, and required competence profiles of employees (if competences have been annotated in the models) can be easily detected. However, especially modeling ML activities is difficult for companies with little ML experience. By extending existing approaches and introducing construction recommendations, this paper presents a tool concept for the structured extension of actual processes without ML to target processes with ML especially for decision-makers and project coordinators.

In the following, the terminology template is used to describe a model that encapsulates different process design options. Process patterns, on the other hand, are used here as a recommendation for transforming process models like software design patterns (see *design patterns* in [5] and [6, 7]). Both concepts are used on different levels. The process patterns are used in the following to make rough adjustments at a higher level of abstraction (especially relevant for the stakeholder decision-maker, project coordinator, etc.). The modeling options of the associated individual sub-processes are visualized with the templates (to additionally provide first detailed information for ML experts and programmers). This division is shown in the overview Fig. 1.

Business processes are typically modeled using standardized modeling languages, such as Business Process Model and Notation (BPMN) from the Object Management Group (OMG). This paper focuses on the BPMN specification language, because BPMN has become the standard notation for modeling business processes [8, 9]. However, many other languages can be used [10], and therefore, the concepts presented in this paper are suitable for other modeling languages as well. In addition, this paper abstracts from specific ML algorithms, and the concepts are generally applicable.

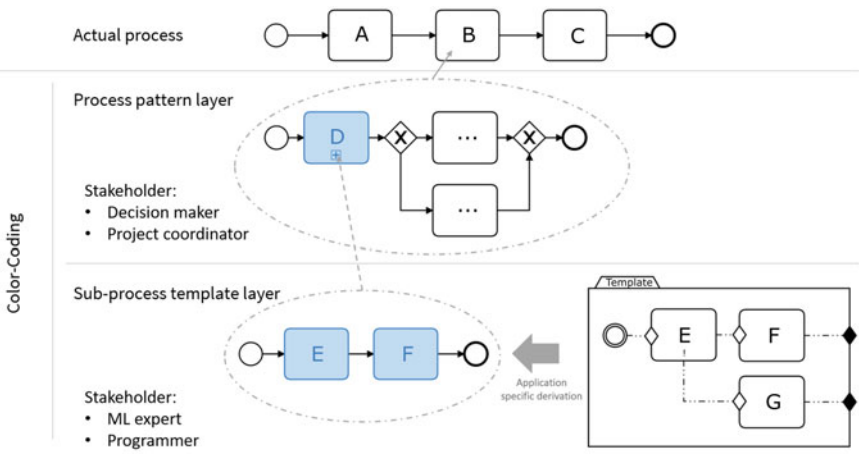

Fig. 1 Overview of the hierarchy levels and the approach

In the following section, an overview of related work is presented, followed by Sect. 3 with a listing of requirements for the approach. Section 4 considers an extension of the approach color-coding which can be applied across both hierarchy levels (see Fig. 1). Hereafter, in Sect. 5, the level of process patterns is presented, and in Sect. 6, the level of sub-process templates. Finally, in the last two sections, the requirements from Sect. 3 are addressed again in order to evaluate the presented approach, and the content is summarized in a conclusion.

2 Related Work

There are only few papers dealing with the explicit and standardized modeling of ML integration in business processes. Lukyanenko et al. [2] noted in 2019 that there is still limited research between conceptual modeling and ML. However, according to [2], conceptual modeling could be helpful in increasing understanding about the training data and modeling process changes. Lukyanenko et al. [2] present several proposals for the use of modeling languages in this context. With the so-called color-coding, an extension is presented, which marks attributes that are relevant as input for the ML model. This approach will be adopted in Sect. 4. Besides presenting suggestions for the use of modeling languages, it is also important to provide information on how typical processes with ML methods are modeled and which tasks have to be considered. The so-called process patterns are suitable for this purpose. Process patterns can represent best practices [11, 12] and already exist in general as well as specifically for different application domains (for an online catalog of papers on process patterns, see Fellmann et al. [13] (www.bpmpatterns.org)—for patterns

in BPMN see, e.g., [14–16]). Wolters et al. [1] establish process patterns concretely for the ML integration and thus address the objective considered here. These process patterns are taken up in Sect. 5 and consider the integration from a high-level perspective, according to Wolters et al. [1] own statement. To provide more detail, these are extended by a necessary flexible modeling possibility of sub-processes in Sect. 6.

But also other approaches can be regarded as being related, for example, a whitepaper from Google, which presents the possibility to use Continuous Delivery and pipelines to increase automation in the development of ML models [17], or the product Microsoft Azure ML, in which additionally training pipelines can be created graphically via drag and drop. The approach presented below differs from these products first of all in terms of the target group. As described in Sect. 1 (and Fig. 1), the group of decision-makers and project coordinators is addressed at the process pattern level by enabling approaches for a clear visualization of desired target processes. The primary objective pursued by tools such as Azure to train ML models therefore also differs from the objective addressed here. Here, standardized recommendations are to be presented on how ML and the resulting new information can be integrated and used in processes already in use (with tasks, decisions, etc. without any ML reference). The focused target group of decision-makers and project coordinators also leads to the difference in terms of the specification language. For modeling general business processes in companies, the modeling language BPMN is often chosen (see Sect. 1), and therefore, concepts, which are specifically intended to support BPMN modeling, should be addressed.

3 Requirements and Objectives

Various requirements can be identified for tools which support modeling business processes including explicit expression of ML. With explicit expression of ML in business process models, we mean a precise and specific model notation extension to enable further use of the model, e.g., with respect to the semi-automated implementation of the processes or the semi-automated comparison of target and actual models. Basic requirements for modeling languages (such as the need to manage complexity or the need for shared understanding [2]) are not explicitly mentioned in this paper, but should of course remain fulfilled if modeling languages are extended (see color-coding in Sect. 4). For example, [18] and [19] present a listing of appropriate requirements, such as *expressive power*, *reusability*, *simplicity,* and others. The identified specific requirements for the tools or for their results are:

- **Graphic identifiability of ML**: Visual representation of which tasks in the process have an ML reference and are relevant for which stakeholder.
- **Separate instantiation**: Separation of different modeling contexts over time (e.g., for training and prediction processes).

- **Different levels of abstraction**: Depending on the specific role of stakeholder, detailed information on integration, implementation, and realization as well as a clear, general presentation is helpful.
- **Possibility of application-dependent specification**: Modeling ML in business processes should be possible for many application domains. To ensure that the integration also includes process details (and does not become too general), it is necessary to make it possible to specify application-dependent processes, e.g., by selecting specific required tasks from a set of given tasks.

The objective is to present a tool concept with possibilities to extend processes without ML to processes with ML for which all requirements are fulfilled. To address the requirement of separate instantiation, in the following, a distinction is made between two process phases. The training phase, on the one hand, includes processes that are executed for the initial introduction or the updating of existing ML models. The application phase, on the other hand, includes processes in which trained ML models are applied. A connection between these two phases is possible. In addition, a subdivision into further contexts would also be conceivable by keeping a catalog of process patterns and sub-process templates separately for each phase.

In order to fulfill the other requirements as well, approaches from the literature are extended on the one hand, as the approach of Lukyanenko et al. [2] (Sect. 4) and the process patterns of Wolters et al. [1] (Sect. 5), and a new complementary method is presented (Sect. 6) on the other hand. For the creation of separate patterns and templates as well as for the coloring of ML-relevant tasks, it is useful to group the individual ML functions into classes. The resulting classes *preprocessing*, *design and training*, *evaluation*, *prediction,* and *data storage* are based on the Cross-Industry Standard Process for Data Mining (CRISP-DM) [20], which is also used in [2], and on the Cross-Industry Standard Process model for the development of Machine Learning applications with Quality assurance methodology [CRISP-ML(Q)] [21], which is based on CRISP-DM. Figure 2 visualizes the mapping of the activities. Due to the low automation possibilities, the *business and data understanding* activities have no influence on the resulting classes.

The deployment activity is included only for the purpose of completeness. It is planned to cover the deployment in a future publication. Here, the deployment in the training phase is simply understood as the modeling of the process of the application phase.

4 Color-coding

As mentioned in Sect. 2, Lukyanenko et al. [2] propose to extend grammars by coloring ML-relevant components. They present as an example the coloring of attributes to clarify which attribute represents the target attribute and which attributes should not be used for training ML models. In the context of process modeling, this approach can be transferred by coloring individual tasks, such as already applied by

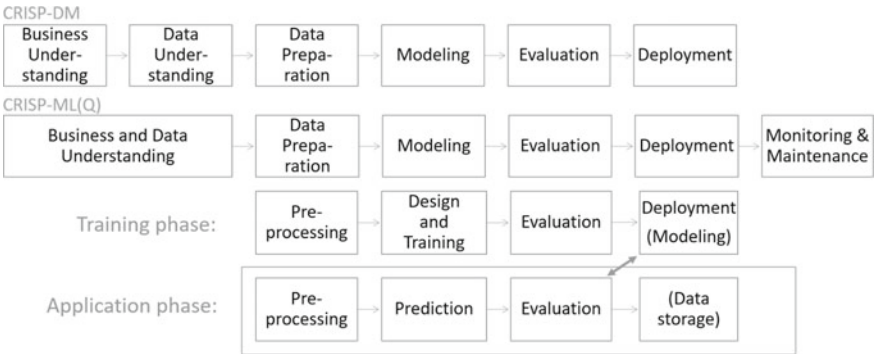

Fig. 2 Derivation of ML function classes from the CRISP-DM and CRISP-ML(Q) activities. The CRISP-DM activities are from [20] and the CRISP-ML(Q) activities from [21]

Fig. 3 Example color-coding of the ML function classes

Wolters et al. [1]. We propose to extend this approach in such a way that color-coding is used to visualize to which ML function class a task belongs—similar to what is shown in Viadee's exemplary process representation [22]. Five different colors are thus required for the five function classes. The color-coding approach can thus be implemented, for example, as depicted in Fig. 3. The colors used are supported by the Camunda Modeler[1] and can be documented in the XML description.

5 Process Layer

Process patterns are also an approach which already exists. Process patterns can be different in type and can be used in different areas (see, e.g., [23]). In addition, specific BPMN process patterns exist for the integration of ML [1]. The process patterns of Wolters et al. [1] address fundamental integration capabilities at a high level of abstraction. The patterns can be adjusted to provide further details associated with the application of the patterns. The added new tasks are all ML related and can be assigned to the ML function classes. Thus, color-coding can be applied directly, and the assignment of the tasks to the sub-process templates (see Sect. 6) is given.

[1] https://camunda.com/platform/modeler/.

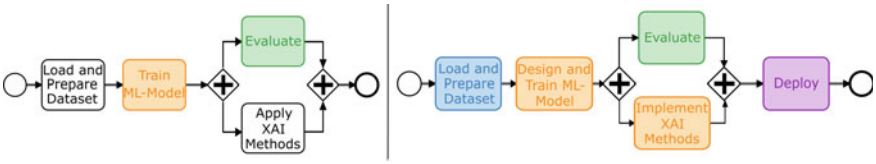

Fig. 4 Training process of Wolters et al. [1] (left) and the extension (right)

In Sect. 5.1, this extension is done exemplarily for a pattern from the training phase and in Sect. 5.2 for a pattern from the application phase. However, also the other patterns of Wolters et al. can be adjusted accordingly. In total, 14 patterns are presented in their publication, including patterns for drift detection and use of anomaly detection.

5.1 Process Patterns for the Training Phase

Wolters et al. [1] present in the group training a simplified visualization of an exemplary process for training ML models. This process can be interpreted as a process pattern, but it differs from the application phase process patterns in that here instead of addressing a single functionality, the entire scaffolding of the training is considered. To apply the ML function classes and the color-coding approach, the process pattern can be extended as shown in Fig. 4. In particular, a new task is added, which will perform the deployment as provided in CRISP-ML(Q).

5.2 Process Patterns for the Application Phase

Predominantly, the process patterns of Wolters et al. [1] address the application phase. Figure 5 shows for example the visualization of the process pattern *Decision-Support AI-First*. This can be extended by adding a separate task for preprocessing the data needed for prediction. In addition, during the application of the pattern, a direct collection of labeled data can take place. The pattern requires that a user manually evaluates the predicted decision. This decision can be documented, and thus, a labeled dataset is simultaneously created. Analogously, the other process patterns of Wolters et al. [1] can be adapted or extended.

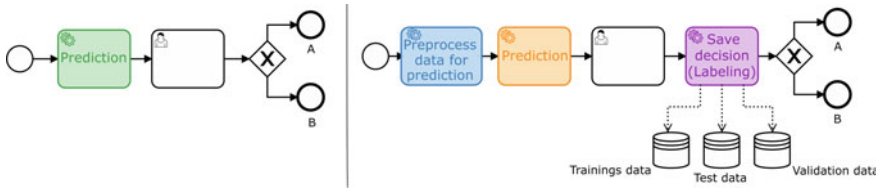

Fig. 5 Process pattern *Decision-Support AI-First* of Wolters et al. [1] (left) and the extension (right)

6 Sub-process Layer

To model further details of the ML integration, the ML-related tasks of the process patterns can be replaced by sub-processes. To support the flexible and application-specific creation of these sub-processes, so-called sub-process templates are introduced as a kind of construction specification. A sub-process template is presented for each ML function class, so that a sub-process can be derived for each ML-relevant task of the process patterns (see, for example, *preprocessing* and *evaluation* in Fig. 4 or *prediction* in Fig. 5). The principle of sub-process templates is presented in Sect. 6.1. This is followed by the listing of the concrete templates for the ML function classes, both for the training and application phases. The presented sub-process templates should be understood as a basis for discussion of the idea—accordingly, the templates are not to be considered as complete.

6.1 Case Modeling with CMMN

Depending on the application domain and the relevant functions, specific processes often differ, so that, when considering a large number of application domains, a large set of different BPMN models needs to be introduced. Therefore, this section presents a way to describe a class of BPMN processes in a compact and clear way. The basis for this is provided by the modeling language Case Management Model and Notation (CMMN), which is also a standard from the OMG. CMMN allows a higher degree of flexibility in modeling than BPMN [24]. The precise definition of the notation elements is given in the specification [25]. For the approach presented here, the following elements are particularly relevant.

The grouping element that encloses the individual tasks is the CasePlanModel-Shape. Tasks can be related to each other. This is indicated by a dashed line and a diamond. An empty diamond represents an EntryCriterion and means that the connected task must be completed before the task with the diamond can begin. The filled diamond—ExitCriterion—means that the connected task must be completed before the CasePlanModel with the diamond can be completed. In addition, AND and OR relationships can be modeled. An OR relationship requires multiple diamonds (see Fig. 6—Task C), and an AND relationship is represented by connecting multiple

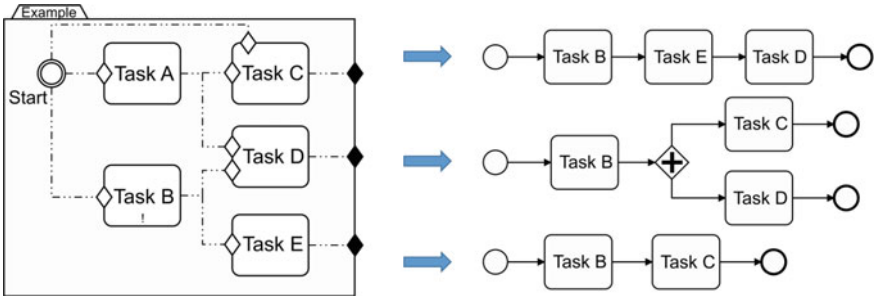

Fig. 6 Example of a CMMN model from which three processes are derived as examples

tasks with only one diamond. Furthermore, an exclamation mark can be used in the task symbols to indicate that the respective task is mandatory [25].

In this paper, CMMN is used to describe a class of BPMN processes. Figure 6 visualizes the approach by deriving three process models from the given exemplary CMMN model.

Without grouping the process models using the represented CMMN model, a lot of individual process models would have to be listed to cover all possibilities. CMMN thus offers the possibility to compactly describe different processes within one single graphical model.

In order to derive BPMN process models from CMMN models, an adapted interpretation of the CMMN models is required. To be able to display a sequence of optional tasks, for example, the following adjustment must be taken into account: if a direct relationship exists between two tasks, this relationship must be respected in the derived process model, regardless of whether the execution requirement of CMMN has already been fulfilled by another task or event. For the example in Fig. 6, this means that if Task A and Task C are included in the resulting process model, Task A must always be executed before Task C.

The presented CMMN models are called sub-process templates in the following, as mentioned earlier, since these represent a set of possible sub-processes.

6.2 Sub-process Templates for the Training Phase

The sub-process template for data preprocessing is shown in Fig. 7. The tasks and their relationships are based on the preprocessing steps presented in [20, 26–28] as well as on own experiences from the project Intelligent Diagnostics.[2] With the sub-process template, process engineers can now derive suitable sub-processes depending on the specific use case, and these can be integrated in Fig. 4 as a sub-process of the preprocessing task (*Load and prepare dataset*).

[2] www.intelligente-diagnostik.de.

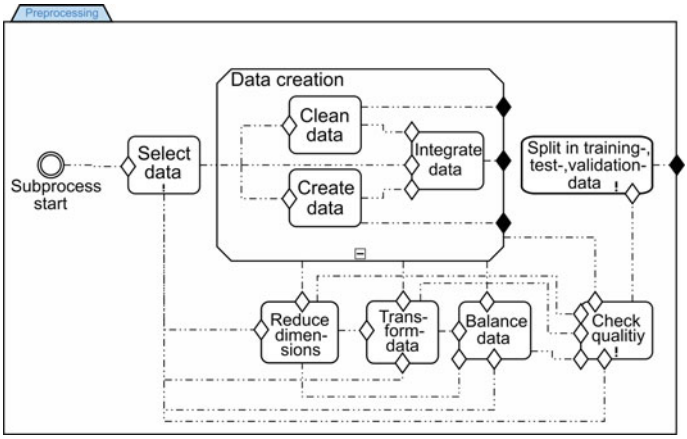

Fig. 7 Preprocessing sub-process template for the training phase

Possible tasks from various publications [29–31] were also collected and grouped for the creation of the *Design and Training* sub-process template. The resulting sub-process template is shown in Fig. 8. In particular, this distinguishes between a later possibly direct integration of an ML model (task *Save in standardized file format*) and a planned execution of an ML model as an external service (task *Define prediction endpoints*). With regard to possibilities of direct integration and deployment of ML models within service tasks, a further paper is planned. The communication with an ML model that is operated as an external service can be implemented, for example, using an adapter design pattern especially for ML models [32].

The sub-process template in Fig. 9 enables the derivation of specific sub-processes for the evaluation task in Fig. 4. The tasks originate from [20] and have been supplemented with corresponding additional obligatory tasks.

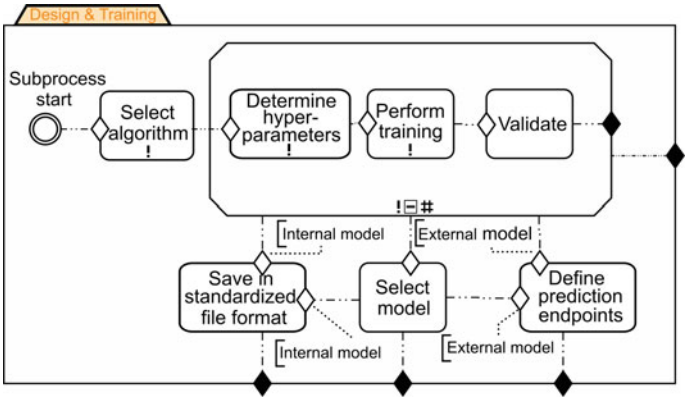

Fig. 8 Design and training sub-process template for the training phase

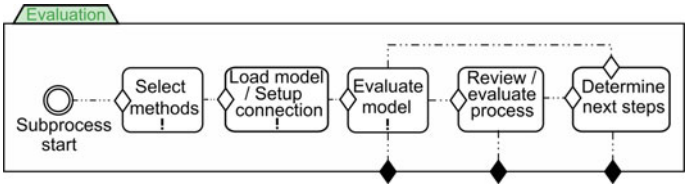

Fig. 9 Evaluation sub-process template for the training phase

6.3 Sub-process Templates for the Application Phase

Preprocessing in the application phase differs from preprocessing in the training phase in the sense that a single data item (application) is considered instead (training) of a set of data. The preprocessing steps that affect the entire dataset are therefore not relevant in this case. This concerns the tasks *clean data*, *balance data*, *check quality,* and *split in training, test, and validation data* in Fig. 7. The remaining tasks for preprocessing are quite similar in the training and application phase, but generally do not have to be performed more than once.

For the unambiguous integration of ML models for prediction, the sub-process template shown in Fig. 10 can be used. The publications [1, 22, 33] were considered to identify the tasks for this purpose. In addition, the tasks *Load model* and *Transform Output* were added to be able to consider functionalities for embedding the model separately and to have the possibility to convert the format of the prediction result into a format that is needed in the following tasks.

The task of data generation (is for example contained in the process pattern *Decision-Support AI-First* as task *save decision*—see Fig. 5) addresses the acquisition of training, test, and validation data during the execution of the application process. Only two steps are necessary for this. Firstly, a direct allocation to the training, test, or validation datasets must take place in order to be able to use test data

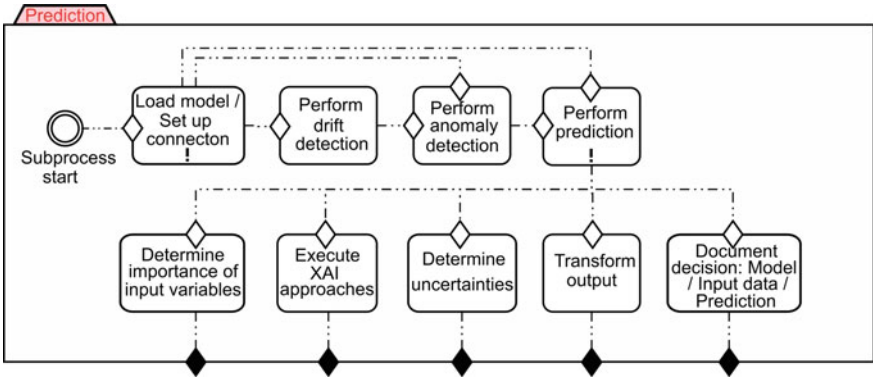

Fig. 10 Prediction sub-process template for the application phase

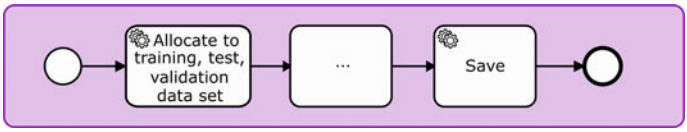

Fig. 11 Data storage sub-process for the application phase

directly during the application phase, and secondly, the data must be documented appropriately. In this case, the sub-process is modeled as a standard BPMN process pattern (see Fig. 11), since no flexible adaptation with respect to concrete use cases is necessary.

The ML model evaluation during the application phase is based on this test dataset, which is continuously extended by users. Compared to the ML model evaluation in the training phase, the ML model evaluation in the application phase is used to check whether the current data can still be predicted by the ML model with sufficient accuracy. The sub-process template for evaluation in the training phase (Fig. 9) is only adjusted by removing the task *Check Process*. The other tasks can also be useful in the case of ML model evaluation during the application phase.

7 Analysis

The presented approach consists of the following steps: firstly, the actual process is considered, and suitable process patterns are selected. These process patterns extend the actual process without ML to a target process with ML. For detailed modeling of concrete activities, the appropriate sub-process templates can then be selected for the tasks of the inserted process patterns. The tasks contained in the sub-process templates are analyzed to determine whether they are relevant for the respective use case. Depending on this determination, suitable sub-processes can be derived. This procedure results in a model of the target process with associated sub-processes (see Fig. 1).

As a first step of the evaluation, the approach is analyzed theoretically. A detailed evaluation is planned and will follow soon. As required in Sect. 3, the introduced approach shall meet the mentioned requirements. The graphic identifiability of ML is fulfilled by using and extending the color-coding approach. By using different colors per function class, stakeholders can directly focus on the ML-related tasks relevant to them. The separate instantiation is enabled by splitting into training and application phases. The respective processes can thus be modeled and executed separately. Also, other splits can be made by simply grouping the process patterns and sub-process templates accordingly. The different levels of abstraction are made possible by the division into processes and sub-processes. For a general overview of the integration of the ML models (e.g., for decision-makers and project coordinators), considering the business process at the process level is sufficient. In addition, the sub-processes

derived from the sub-process templates provide a detailed breakdown of the individual tasks per ML function. Due to the flexible derivation of sub-processes from the sub-process templates and the flexible integration of these into the process patterns of [1], application-specific processes can be designed. The requirement of the possibility of application-dependent specification is thus also fulfilled. Since the processes are still available in BPMN notation, no general requirements for modeling languages are violated. The CMMN sub-process templates are regarded as a tool from which BPMN processes are derived and not as resulting models, so no further checks are necessary for this. Thus, all introduced requirements are addressed and fulfilled by the presented approach.

8 Conclusion

In this paper, a concept for the supported procedure of a clear and structured integration of ML within business process models was presented, which combines the color-coding approach, presented adapted process patterns and newly introduced sub-process templates. This approach enables decision-makers, project coordinators, process developers, etc. to accurately plan desired target processes at an early stage. By modeling specific sub-processes, initial concepts for the implementation (and thus for ML experts and programmers) can also be modeled at a detailed level. The sub-process templates thereby provide an overview of the possible tasks per ML function and offer a construction recommendation for the selected tasks. The requirements identified for the tool concept (Sect. 3) could all be achieved, as shown in Sect. 7.

Nevertheless, usability improvements can be implemented in subsequent work, for example, by enabling automated derivation of sub-processes depending on the selected tasks of the sub-process templates. In addition, it is necessary and planned to extend the evaluation of the approach presented in this paper. As described in Sect. 6, the set of templates presented is not yet (content) complete and is intended to serve as a basis for future work. Furthermore, there are other ways of clearly modeling the integration of ML into BPMN processes that should be explored. For example, different swim lanes could be used for the clear labeling of ML tasks. Also, concrete code implementation patterns for the individual tasks of the sub-process templates will be considered in a subsequent paper.

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Design of a Monitoring System for the Environment of a Cockfighting Barn Based on the Internet of Things

Orlando Iparraguirre-Villanueva, Wilson Pujay-Iglesias, Andrés Epifanía-Huerta, and Michael Cabanillas-Carbonell

Abstract The Internet of things (IoT) technology constitutes a radical change in the quality of life in society, allowing the interconnection of hardware and software; this technology is in constant development, and its application is being exploited in the poultry sector, generating important benefits in this field of action, such as the digitization of production processes. In this context, this chapter implements a monitoring system for the environment of a poultry house based on IoT, with the capacity to process, analyze, and store information obtained through sensors and other devices. The V-based methodology was used. The system is composed of three layers: a monitoring web system layer, a data layer, and the third layer, a layer for detecting information from the house. This layer oversees the data loading process through the set of wireless sensors installed in the shed. In addition, the database is hosted in the cloud, thus eliminating the installation of local servers. The web system layer is composed of the system administration module and the monitoring module, accessed through roles. To test the system, it was put to the test for twelve days, the results obtained indicated that the time to determine the temperature, humidity, and air quality decreased to 28 s after the implementation of the system, making this proposal serve as a support tool for the automatic monitoring of the variables of the galpón environment.

Keywords Monitoring · IoT · Design · Cockfighting · System

O. Iparraguirre-Villanueva · W. Pujay-Iglesias
Universidad Autónoma del Perú, Lima, Perú
e-mail: oiparraguirre@ieee.org

W. Pujay-Iglesias
e-mail: wpujay@autonoma.edu.pe

A. Epifanía-Huerta
Universidad Nacional de San Martin, Tarapoto, Perú
e-mail: aepifaniah@unsm.edu.pe

M. Cabanillas-Carbonell (✉)
Universidad Privada del Norte, Lima, Perú
e-mail: mcabanillas@ieee.org

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1 Introduction

The Internet of things (IoT) technology has completely changed the way of traditional poultry breeding in the poultry sector, including fighting cocks. Nowadays, people and/or companies that are dedicated to the breeding of fighting cocks have started to use modern technologies such as IoT to improve the quality of breeding with the integration of hardware, software, and the internet. One of the biggest risks that the fighting cocks sheds is the entry of pathogens, which cause different diseases; for this, it is necessary to have information that helps to prevent and control these pathogens. Cockfighting is quite popular in many Asian, Central, and South American countries; it is also true that it represents one of the oldest and most genuine traditions in the USA [1]. The poultry sector in recent years has had great advances, technologies have been applied, and more intelligent and automated methods [2], such as radio frequency technology, IoT, Bluetooth, and communication protocols for monitoring and control [3, 4]. Likewise, there is environmental control in poultry houses [5]. Research on implementations of automatic monitoring systems together with mobile networks and cloud platforms in poultry systems [6] has provided us with new ideas for developing similar poultry monitoring systems. IoT has become one of the most important technologies. Although IoT technology has advanced in many aspects, in the poultry sector, specifically in the breeding of fighting cocks, there are no tools that provide them with timely information on the environmental variables of the poultry house. IoT brings a lot to the poultry sector, not only saving time for those interested in monitoring the poultry houses but also substantially improving the growth of fighting cocks [7] generating a direct economic benefit to the owners [8].

Therefore, this project designs an environment with hardware and software to monitor the environmental variables of a poultry house. The system considers the following variables to be measured: temperature, humidity, and air quality. At the same time, it should also include an early warning traffic light. The aforementioned variables are obtained from the Arduino microcontroller through serial communication and are processed in a web server of the system, and then transmitted to a user terminal, through which the environmental variables can be observed, and thus make better decisions to prevent and avoid the entry of pathogens that may affect the health and welfare of fighting cocks. The goal of the system is to monitor temperature, humidity, and air quality using IoT technology.

2 Bibliographic Study

Cockfighting is a Hispanic tradition and is more accentuated in Latin America, cockfighting has different modalities, which go according to the weapon that is used and the dimension of this, and its performance will depend largely on the style of upbringing that has had; therefore, it is necessary to know the factors that help their growth for better performance in the field of action. In the poultry sector, technology

has shown a significant role, in allowing process automation. In this context, several works related to the automatic monitoring of poultry houses have been reviewed. The poultry sector is one of the economic segments that are growing due to the incorporation of technology and good practices. [9] proposed a model to automate the process of poultry farms, using IoT for management-related activities, with the purpose of minimizing manual work, through an automated system and consumed by an application. Also, [10, 11] proposed a system that combines hardware and software for mobile systems, allowing the integration of wireless sensors to manage poultry farms. Similarly, in [12] the authors designed and implemented an automated poultry farm with distinctive features to have intelligent control in the poultry houses. Similarly, in 2022 [13] the authors designed software with IoT technology to monitor air pollution for a period of time.

There are four key variables that directly affect the rearing of fighting cocks, and these are temperature, humidity, light intensity, and stocking density. The authors in 2018 [14] proposed a project to protect and monitor the environment of a poultry house based on IoT technology, where the software-based hardware is able to monitor parameters related to the environment, such as air temperature, O_2 and CO_2 concentration level, and NH_3. Also, in 2018 [15] developed the Poultry Chain Management (PCM) platform to collect data from the poultry production process for the purpose of determining quality at each stage and identifying critical issues that cause process inefficiencies. Similarly, in 2021 [16] they developed an IoT-based smart monitoring system installed in a waste container for sending data to a web server. Furthermore, in 2019 [17] they developed a device that connects to an application to monitor humidity, temperature, and air quality in an enclosed environment to continuously collect data and send the information to stakeholders to warn with a call if the air has exceeded the certain set threshold. Along the same lines, in 2021 [18, 19] realize the importance of IoT Technology to optimize water consumption, for which they designed an IoT-based smart meter, aiming to analyze an efficient data collection algorithm for smart metering applications.

3 Methodology

3.1 System Architecture

The system architecture is shown in Fig. 1. The system is divided into three tiers: the top tier, responsible for system management, the middle tier, where the data service layer is located, and the bottom tier (which includes all hardware installations).

The top-level manages software that provides a graphical interface divided into a monitoring module and a system administration component. As for the middle tier, a data services layer hosted in the cloud is used to store the information generated by the lower and upper tiers and, at the same time, a reciprocal communication network is created through the server configuration. In the lower layer, in the sheds, the

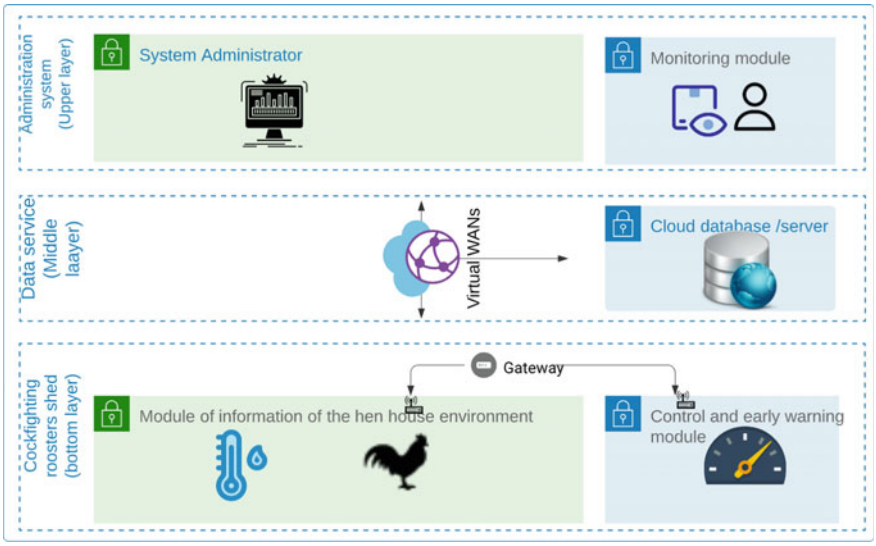

Fig. 1 General system architecture

environmental sensors, receiving device, Wi-Fi transmission, and single-chip microcontroller allow timely configuration of the environmental parameters of the shed to obtain information on temperature, humidity and air quality, and other equipment placed in the shed. A hybrid local area network is used for data transfer between the surveillance system and the local data center. According to the reviewed works, we found the three most used forms of wireless transfer, such as Bluetooth, Wi-Fi, and ZigBase. Since Wi-Fi offers the longest data transmission range and highest speed, this technology is selected as the wireless transmission method for this work.

3.2 Bottom Layer Management System

There are several types of wireless sensors that comprise the lower layer of the system. These sensors are in charge of collecting, transmitting, and managing the data information that has been uploaded previously.

Figure 2 shows the wireless sensor network in the shed; it is understood that all these sensors are connected to a server, this server has the following features: a wireless network card, an Intel (R) Core (TM) i7-10510U processor, 16 GB RAM memory (DDR4 3200 MHz) as the main features, among others. For the processing and uploading of the data generated by the terminal node, a web system was developed to achieve the respective monitoring. Table 1 shows the characteristics of the environmental sensors. As a result of the implementation of the data bus to transmit

the variables of the environment surrounding the shed to the microcontroller, sensors are used to measure the variables of that environment.

Several steps are involved in the processing of the data obtained from the environment by the microcontroller. The first step is to package the data in the data packet format and upload it to the server wirelessly, and the second step is to upload it to the database. To make the connection between the terminal and the server in order to send and receive data, a one-to-many connection is needed to communicate the data collected from the wireless sensors in the galp environment. The nodes created in the terminals are responsible for packaging the data and use socket technology to transmit the packets to the IP address and port of the server. Once the information is

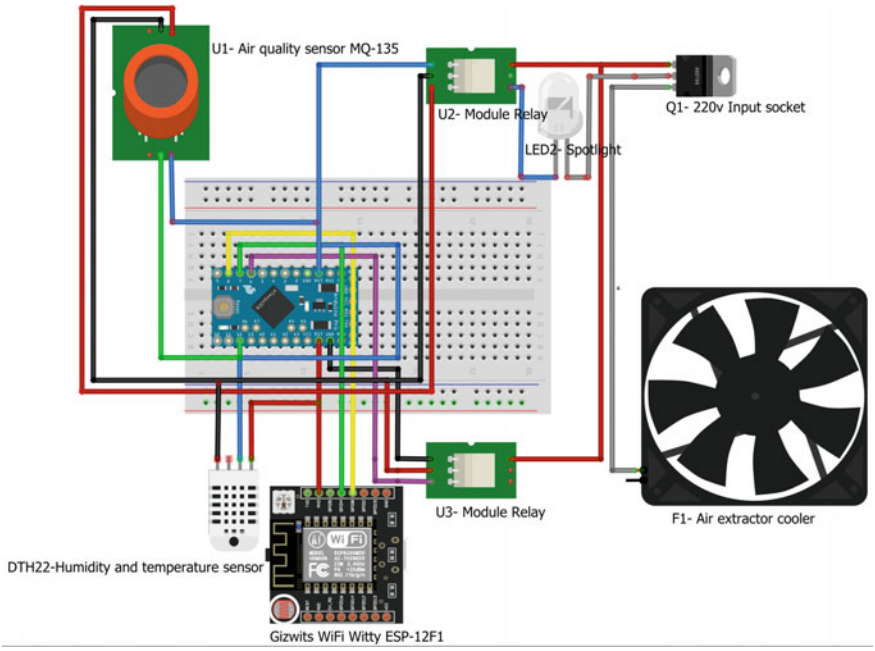

Fig. 2 Prototype design and composition of the wireless sensors in the shed

Table 1 Characteristics of environmental sensors

Sensor	Distance	Resolution	Accuracy	Model
Temperature humidity. Air quality	− 39 to 75 °C	0.1 °C	±0.5 °C	DHT22
	0–100	0.01	±5%	
Detection range (ppm)	*Amonico*	*Alcohol*	*Benzene*	MQ-135
	100–300	10–300	10–1000	
	NO*x*, smoke, and carbon dioxide (Not specified)			

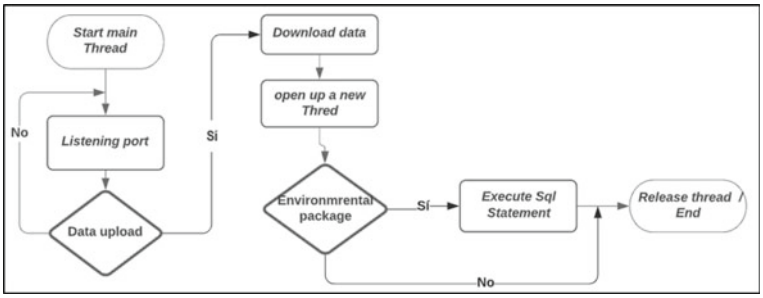

Fig. 3 Environmental information screening data flow diagram

received by the server, it downloads the data packet for processing. The processing flowchart is shown in Fig. 3.

It is necessary to configure a routing node in the house to send the data packet to the cloud database. The system can also continue to function in case the connection to the cloud database is lost. For this purpose, local transmission strategies have been developed, so that the information generated in the shed is not lost until the connection is re-established.

3.3 Specifications and Implementation

The V-methodology is used in various software development processes, which represents a sequence of steps in the life cycle of a project, this methodology allows for bringing together a cross-functional team, which means that members can work collaboratively and self-manage as a team [20]. For the development of the monitoring module of the present work, we chose to use this methodology, which is closer to the development of the system. This methodology has five phases: Specifications, Global Design, Detailed Design, Implementation, and Unit Testing—Integration. However, for the development of the case in the implementation phase, the phases of global design and detailed design are included. In this first stage, all the requirements to be implemented in the web system for monitoring are defined, as shown in Table 2.

Table 2 Web system requirements analysis

Functional requirements of the web system
RF1 Create web system database
RF2 Design and development of the home page and application maintainers
RF3 Design and development of the interface for monitoring the variables of the shed environment

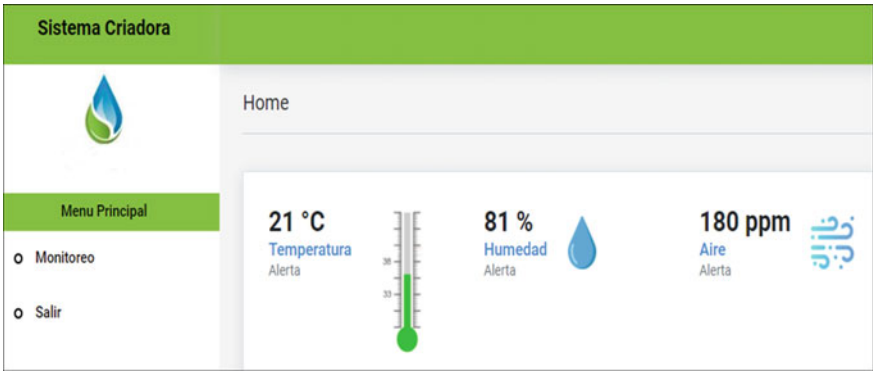

Fig. 4 Parameter monitoring interface

In this phase, the development of the web system begins, following the requirements established in Table 2. The same that has been developed integrating the two modules (system administration module and variables monitoring module) is managed through roles established for each stakeholder. Figure 4 shows the results of the three indicators obtained through the system located in the house environment, and these variables are monitored and configured according to the age of the roosters since it is not possible to establish a specific parameter, whether temperature, humidity, or air quality for the entire development cycle.

Figure 4 shows the web interface for monitoring temperature, humidity, and air quality, for which the user must have access credentials, credentials access is not possible, the same criterion is used for the system administrator, who has access to other system options such as manage users, variable configuration, monitoring option, alerts. Regarding the programming between the web system and the hardware, the following devices were used: DHT22, MQ.135 sensors, the relay module, the Wi-Fi module, the Arduino 1.8.19 IDE, and the Arduino board, among other components. Figure 5 shows a section of code where the programming of the humidity and temperature sensors and the results obtained as a test from a terminal of the programmer can be observed.

```
float rzero = mq135_sensor.getRZero();
float correctedRZero = mq135_sensor.getCorrectedRZero(temperature, humidity);
float resistance = mq135_sensor.getResistance();
float ppm = mq135_sensor.getPPM();
float correctedPPM = mq135_sensor.getCorrectedPPM(temperature, humidity);

sprintf(buffer,"%d,%d",temperature,humidity);
serialBT.println(buffer);
```

Fig. 5 Parameter execution test

Other complementary functions to the variables of temperature, humidity, and air quality that the web system has are: generating reports in different formats, and sending emails with alerts; however, for this project we focus on measuring temperature, humidity, and air quality.

3.4 Testing

In this phase, the web system was tested together with the hardware system installed in the shed. Unit tests were performed with respect to the web system; likewise, connection tests were performed on the wireless sensor network installed in the shed, and it was concluded that the tests were satisfactory. Likewise, to demonstrate the functionality of the system in the present investigation, measurements of the three variables were taken during 12 days in the GalleBruce shed in the city of Lima. In this work, to validate the results, the scientific method was followed, for which the pre-experimental design was used, carrying out the evaluations at two "pretest" moments and "posttest," each element is described in Table 3. The alert levels of the three indicators are shown in Table 4.

$$G_e \; O_1 X O_2$$

Table 3 Description of design elements

Elements	Description
Ge	Experimental group: the measurement is performed at three points during the day
O_1	It is the measurement and recording of the variables before implementing the application system. Pretest measurement
X	Web application with (IoT) = object to evaluate
O_2	Evaluation of data of the experimental group "posttest"

Table 4 System alert levels according to the three indicators

Alert level	
High (Red)	When the value of one of the three indicators exceeds the parameters established as optimal
Medium (Green)	When the value of the indicators is within the parameters established as optimal
Low (Yellow)	When the value of one of the three indicators is below the parameters established as optimal

4 Results and Discussion

The objective of this work is to implement an IoT-based web-based solution for the purpose of monitoring temperature, humidity, and air quality in a fighting cock barn. For this purpose, the first tests were performed, considering the following criteria: time to determine temperature (PKI-1), time to determine humidity (KPI-2), and time to determine air quality (KPI-3). Data collection was carried out by means of an observation sheet and an automated register. The results obtained are shown in Fig. 6.

Table 5 shows the average time as a result of the KPI. The results obtained for each KPI, both pre and post, were performed for a period of 12 days. A considerable decrease in time was evidenced for each indicator, so it means that the web system with IoT is a support tool to reduce the monitoring time of temperature, humidity, and air quality.

# día	Horas de lectura	KPI-1		KPI-2		KPI-3	
		Pre	Post	Pre	Post	Pre	Post
	07:00 am	320	30	324	30	325	30
1	12:30 pm	350	29	355	29	330	29
	06:00 pm	280	30	285	30	275	30
	07:00 am	330	28	335	28	330	28
2	12:30 pm	380	29	390	29	380	29
	06:00 pm	260	27	270	27	265	27
	07:00 am	310	30	315	30	315	30
3	12:30 pm	300	30	305	30	305	30
	06:00 pm	250	27	260	27	255	27
	07:00 am	305	38	310	38	300	38
4	12:30 pm	340	30	350	30	335	30
	06:00 pm	260	29	255	29	265	29
	07:00 am	315	30	320	30	310	30
5	12:30 pm	320	28	320	28	315	28
	06:00 pm	260	29	270	29	255	29
	07:00 am	310	28	320	28	300	28
6	12:30 pm	300	29	305	29	310	29
	06:00 pm	250	29	260	29	256	29
	07:00 am	310	30	305	30	305	30
7	12:30 pm	360	28	350	28	350	28
	06:00 pm	260	29	260	29	255	29
	07:00 am	320	28	315	28	315	28
8	12:30 pm	350	29	355	29	345	29
	06:00 pm	260	29	265	29	255	29
	07:00 am	330	20	320	20	330	20
9	12:30 pm	400	30	395	30	496	30
	06:00 pm	250	30	260	30	255	30
	07:00 am	325	29	330	29	320	29
10	12:30 pm	360	29	350	29	350	29
	06:00 pm	260	27	265	27	255	27
	07:00 am	330	28	325	28	325	28
11	12:30 pm	400	29	390	29	400	29
	06:00 pm	260	30	275	30	265	30
	07:00 am	320	28	325	28	325	28
12	12:30 pm	380	28	375	28	380	28
	06:00 pm	260	27	270	27	260	27

Fig. 6 Pretest and posttest results

Table 5 KPIs

Indicator	Pretest	Posttest
KPI 1: Time to determine the temperature	310.00	28.83
KPI 2: Time to determine humidity	313.00	28.83
KPI 3: Time to determine air quality	311.00	28.83

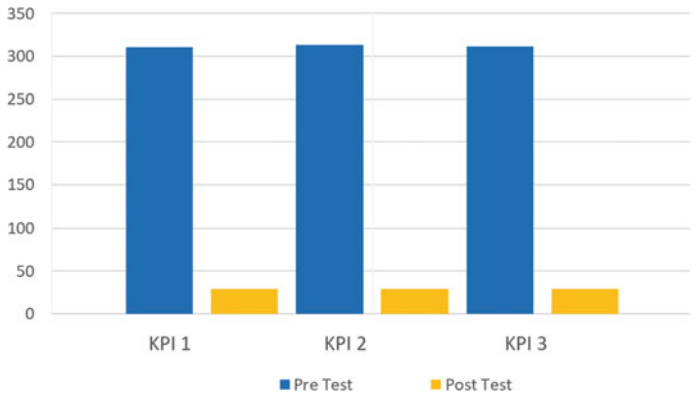

Fig. 7 Comparison of KPIs before and after the test

Figure 7 shows that the average of the three KPIs has been reduced considerably, and therefore, it can be said that the time required to measure the indicators has improved.

Results KPI-1

Figure 8a shows the individual standard deviation of KPI-1: the time to determine the temperature with respect to the mean is 2.36 s. The confidence interval is 95%, and the confidence interval for the median is 28.03 and 29.63. In the normality test, in quartile 1, 28 s was obtained. In quartile 3, 30 s was obtained, which indicates that 70% of the time to monitor the temperature is less than this value. Figure 8b presents the normality test for KPI-1 in the posttest. The result shows that p has obtained a value of less than 5%, thus confirming that the processed and analyzed data have a non-normal behavior.

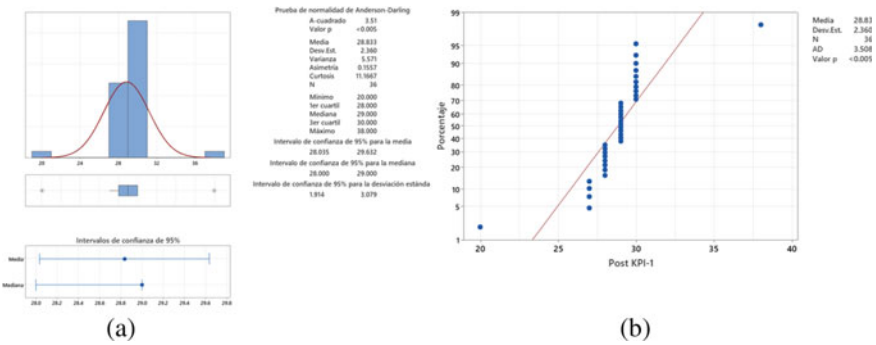

Fig. 8 KPI1 statistics, after the implementation of the web solution

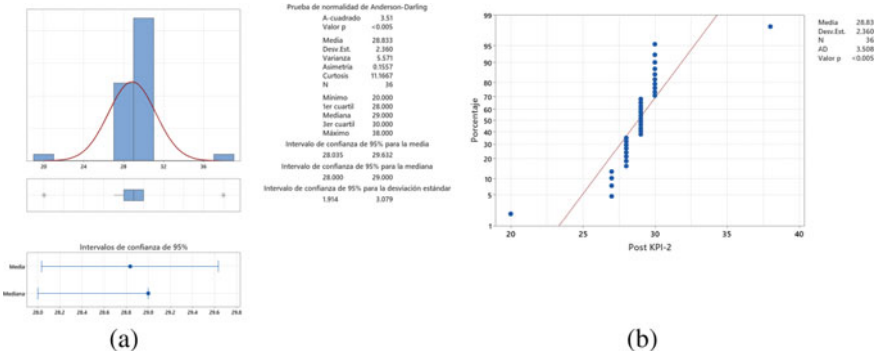

Fig. 9 KPI-2 statistics, after the implementation of the web solution

Results PKI-2

Figure 9a shows the individual standard deviation of KPI-2: The time to determine the humidity with respect to the mean is 2.36 s. The confidence interval is 95%, and the confidence interval for the median is 28.03 and 29.63. In the normality test, in quartile 1, 28 s were obtained. In quartile 3, 30 s were obtained, indicating that 70% of the time used to determine humidity is less than this value. Figure 9b presents the normality test for KPI-2 in the posttest. The result shows that p has obtained a value lower than 5%, thus confirming that the processed and analyzed data have a non-normal behavior.

Results PKI-3

Figure 10a shows the individual standard deviation of KPI-3: the time to determine the air quality with respect to the mean is 2.36 s. The confidence interval is 95%, and the confidence interval for the median is 28.03 and 29.63. In the normality test, 28 s were obtained in quartile 1. In quartile 3, 30 s were obtained, indicating that 70% of the time to determine air quality is less than this value. Figure 10b presents the normality test for KPI-3 in the posttest. The result shows that p has obtained a value lower than 5%, thus confirming that the processed and analyzed data have a non-normal behavior.

5 Conclusions

In this paper, a system is built to monitor the environmental parameters of a cockfighting barn, whose purpose is to monitor temperature, humidity, and air quality. The system is composed of three modules. Making use of intelligent sensors where a wireless network has been built and a database for data storage, achieving stable communication between the hardware and software modules. There was a significant improvement in the time to determine the temperature of the shed, allowing a

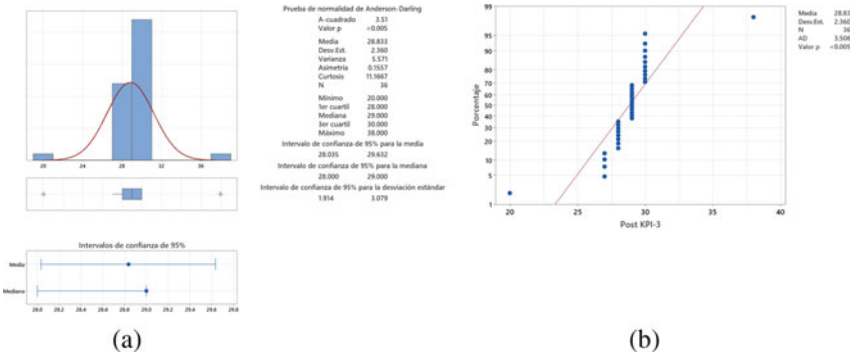

Fig. 10 KPI-3 statistics, after the implementation of the web solution

decrease in time from 310 to 28.83 s. Likewise, the time to determine the humidity was considerably reduced from 313 to 28.83 s, and the time to determine the air quality was reduced from 311 to 28.83 s. The changes in the times have been satisfactory, considering that at the beginning the monitoring of temperature, humidity, and air quality was done in a traditional way. The results have made it possible to manage the house in a better way, creating the best conditions for the growth and performance of the fighting cocks. The contribution of this work is fundamental for the development of new future works related to the poultry industry and is supported by the IoT technology. This is with the purpose of contributing to improving the quality of life of fighting cocks. New predictive functionalities could be implemented in this work, and thanks to the data collected, it is possible to perform behavioral analysis of the variables. Finally, after the implementation, it was demonstrated that the monitoring system reduces the monitoring time of the different variables involved in the research, as well as having access to the information, and with it, taking pertinent actions in favor of the growth of the fighting cocks.

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A Convolutional Neural Network of Low Complexity for Tumor Anomaly Detection

Vasileios E. Papageorgiou, Pantelis Dogoulis, and Dimitrios-Panagiotis Papageorgiou

Abstract The automated detection of cancerous tumors has attracted interest during the last decade, due to the necessity of early and efficient diagnosis that will lead to the most effective possible treatment of the impending risk. Several machine learning and artificial intelligence methodologies have been employed aiming to provide trustworthy helping tools that will contribute efficiently to this attempt. In this article, we present a low-complexity convolutional neural network architecture for tumor classification enhanced by a robust image augmentation methodology. The effectiveness of the presented deep learning model has been investigated based on three datasets containing brain, kidney, and lung images, showing remarkable diagnostic efficiency with classification accuracies of 99.33%, 100%, and 99.7% for the three datasets, respectively. The impact of the augmentation preprocessing step has also been extensively examined using four evaluation measures. The proposed low-complexity scheme, in contrast to other models in the literature, renders our model quite robust to cases of overfitting that typically accompany small datasets frequently encountered in medical classification challenges. Finally, the model can be easily re-trained in case additional tumor images are included, as its simplistic architecture does not impose a significant computational burden.

Keywords Convolutional neural networks · Tumor detection · Biomedical image classification · Data augmentation · Entropy · Artificial intelligence

V. E. Papageorgiou (✉) · D.-P. Papageorgiou
Aristotle University of Thessaloniki, Thessaloniki, Greece
e-mail: vpapageor@math.auth.gr

D.-P. Papageorgiou
e-mail: depapage@math.auth.gr

P. Dogoulis
Department of Computer Science, University of Luxembourg, Luxembourg, Luxembourg
e-mail: dogoulis@iti.gr

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1 Introduction

Applications of artificial intelligence (AI) in medicine continue to grow and affect every aspect of cancer care. These applications fall into two main categories, namely supervised and unsupervised learning [1, 2]. In supervised learning, computers learn and adapt by studying labeled biomedical instances to copy the diagnostic skills of experienced oncologists. Three of the most common and deadly tumors that affect people's quality of life in everyday life are brain, lung, and kidney tumors, making their early detection an important concern.

A brain tumor is an abnormal mass of tissue where cells grow uncontrollably. Based on the World Health Organization (WHO), these types of tumors account for less than 2% of human cancers, although their severe morbidity and associated complications make timely diagnosis an important concept in the field of medicine [3]. Intracranial tumors can be fatal, worsen the patient's standard of living, and can affect men, women, or children.

Lung cancer ranks second, accounting for approximately 11.4% of total cancer cases, with an estimated 2.2 million lung cancer cases only. Lung tumors represent the leading cause of death due to cancer, with deaths accounting for 18% of all cancers [4]. The survival rate of patients suffering from lung tumors 5 years after diagnosis ranges between 10 and 20%. Screening with low-dose computed tomography (CT) could aid in the timely detection of lung tumors so that the disease can be possibly treated. In addition, it has been reported that the patient's likelihood of living a long life increase if the tumor is timely diagnosed and treated successfully [5].

Renal cell carcinoma (RCC) is the sixth most ordinary cancer among all tumors in men and the tenth most common in women. Despite advances in understanding the molecular biology of RCC and refinements in therapies, treating patients with RCC at any stage of the disease is challenging. Detection of early-stage renal tumor has improved in recent decades with the use of cross-sectional imaging [6]. Most renal carcinomas are initially detected as incidental renal masses on cross-sectional imaging performed for unspecified disease. Although most are discovered as small renal masses (70%), earlier definitive therapeutic intervention for these tumorous regions has not led in a notable advancement in cancer mortality [7].

In our analysis, we present convolutional neural network (CNN) architecture of low complexity for tumor anomaly diagnosis. The reduced complexity of the proposed network makes it suitable for studying small datasets which often accompany medical analyses, compared to many articles that employ complex and computationally expensive schemes. This architecture not only eliminates the likelihood of overfitting—which can be a major issue in both statistical and AI models [8]—but also increases the flexibility and adaptability of the approach, as it can be re-trained without significant computational cost in the occasion where new MRI or CT images are added to the dataset. In addition, various data augmentation techniques have been implemented and their respective impact on classification efficiency has been studied in detail.

In contrast to most studies included in the literature, our novel architecture has been tested on not only one, but three tumor datasets. These datasets contain normal, benign, and malignant instances corresponding to brain, lung, and kidney tumors. Hence, the variety of different datasets and the diversity of cancer classification problems, validate the trustworthiness of the produced detection efficiency, rendering our approach a reliable medical tool that can be easily utilized in modern oncology.

2 Related Work

Regarding medical imaging, there are a variety of algorithms from the field of AI for brain cancer classification/detection. Characteristic examples are support vector machines (SVM) [9], *K*-nearest neighbors (KNN) [10], and artificial neural networks (ANN) [11]. In parallel, CNNs seem to be the most suitable for processing MRI or CT images due to their high classification performance. There are several articles that address binary and multiclass tumor challenges, utilizing a number of state-of-the-art deep CNNs. The most relevant articles regarding our analysis correspond to binary classification attempts of MRI and CT images displaying brain, lung, or kidney tumors.

The authors in [12–14] combine image augmentation and preprocessing methods with conventional CNN methods aiming to classify benign and malignant tumors with accuracy of 97.5%, 94.1%, and 98%, respectively. In [15–17], hybrid CNN-SVM models are used for binary classification with corresponding accuracies of 88.54, 95, and 95.62%. The authors in [16, 17] propose the usage of ResNet for the part of the feature extraction and an SVM for the feature extraction. The examined tumor images were preprocessed by entropy segmentation techniques and resolution enhancement.

Regarding lung tumors, in [18, 19] the authors use SVM classifiers and CNN GoogleNet based on the IQ-OTHNCCD dataset. In [18], the authors preprocess the images from CT using Gaussian filters, bit-plane slicing, and image segmentation and achieve an accuracy of 89.88%, while in [19] they implement the Gabor filter and regions of interest (ROI) extraction with a grouping accuracy of 94.38%. Other machine learning attempts for lung cancer classification include the utilization of KNN [20], SVM [21], Naive Bayes [20], and random forests [22]. In [23], the authors implement CNN architectures such as VGG16, MobileNet, AlexNet, DenseNet, VGG19, and ResNet with efficiency between 48 and 56% for the classification of normal, benign, and malignant tumors. Polat and Mehr [24] utilize a hybrid 3D CNN-SVM with a classification efficiency of 91.81%.

Finally, several articles have addressed renal cancer detection, particularly using preprocessed forms of CT images. In machine learning approaches to discriminate between benign and malignant tumors [25–27], most studies focused on discriminating between low-fat angiomyolipomas and renal cancer with promising results, with the AUC metric reaching values between 0.90 and 0.96. Han et al. [28], using a modified GoogleNet architecture, encountered lower performance on a 3-class

problem for identifying papillary RCCs (pRCCs) compared to clear cell RCCs (ccRCCs) and chromophobe RCCs (chrRCCs), compared to the binary classification problem of ccRCCs compared to non-ccRCCs. Furthermore, Li et al. [29] identified low- and high-grade ccRCC, respectively, based on MRI combined with patient history and radiologist-assigned imaging features and achieved an AUC of 0.845.

3 Methodology

In this part, we describe the complete framework that was constructed in order to train our proposed architecture and boost its generalization ability. In more detail, we analyze the source of each dataset and the classes that are contained. Then we provide the proposed low-complexity convolutional neural network, and finally, we describe the data augmentation method that was applied. We also describe in detail the main concepts of the CNNs as well as the metrics that are used in the inference stage.

3.1 Convolutional Neural Networks

Convolutional neural network is a class of ANN architectures that are most commonly based on the convolution kernels. These networks are mainly used in visual-related problems such as video classification, image segmentation, and medical image analysis. A CNN includes the basic modules of *convolutional layers* (which are the most important parts of feature extraction), *pooling layers* (which are utilized in order to reduce the dimensionality of the preprocessed matrices), *batch normalization layers* (which are helpful in the computational stability during training) as well as the *fully connected layers* (which is used as the feature selection mechanism).

Convolutional layers consist of kernel sets representing the model's trainable parameters that are modified after each iteration. Let the three-dimensional matrix $\mathbf{X}^l \in \mathbb{R}^{\boldsymbol{M^l} \times \boldsymbol{N^l} \times \boldsymbol{C^l}}$ be the input of the l-th convolutional layer and $\boldsymbol{G} \in \mathbb{R}^{m \times n \times c^l \times S}$ be a four-dimensional matrix, representing the S kernels of l-th layer, of spatial span $m \times n$. The output of the l-th convolutional layer will be a three-dimensional matrix defined as $\boldsymbol{Y}^l \in \mathbb{R}^{M^l - m + 1 \times N^l - n + 1 \times S}$. This matrix results from the equation

$$y_{i^l, j^l, s} = \sum_{i=0}^{m} \sum_{j=0}^{n} \sum_{k=0}^{c^l} G_{i,j,c^l,s} \times x^l_{i^l, j^l, k}. \tag{1}$$

Relation (1) is applied for all $0 \leq s \leq S$ and for any spatial span satisfying $0 \leq i^l \leq M^l - m + 1$ and $0 \leq j^l \leq N^l - n + 1$. Let $\mathbf{X}^l \in \mathbb{R}^{M^l \times N^l \times C^l}$ be the input of the l-th layer that is now a pooling layer of size $n \times m$. We assume that n divides M and m divides N and the stride equals the spatial span. The output is a matrix $\boldsymbol{Y}^l \in$

$\mathbb{R}^{M^{l+1}\times N^{l+1}\times C^{l+1}}$, where

$$M^{l+1} = \frac{M^l}{n}, N^{l+1} = \frac{N^l}{m}, C^{l+1} = C^l, \tag{2}$$

while the polling layer operates upon $\mathbf{X}^l$, dimension by dimension. In our network we utilize two max pooling layers, resulting in outputs produced based on

$$y_{i^l,j^l,c} = \max_{0\le i\le n, 0\le j\le m} x^l_{i^l\times n+i, j^l\times m+j,c}, \tag{3}$$

where $0 \le i^l \le M^l, 0 \le j^l \le N^l$ and $0 \le c \le C^l$.

On the other hand, the fully connected layers constitute the second part of the convolutional neural network, aiming to efficiently select the most valuable features extracted from the convolutional layers. Noteworthy transition operations that connect the above layers are the batch normalization and ReLU operations. The rectifier function is described as

$$y_{i,j,c} = \max\left(0, x^l_{i,j,c}\right), \tag{4}$$

with $0 \le i \le M^l, 0 \le j \le N^l$ and $0 \le c \le C^l$. The input matrix $\boldsymbol{X}_i$ corresponding to the i-th medical image is passed through the set of successive layers and a label $\hat{y}_i$ is produced. Then an error is calculated using a defined loss function. In most cases, cross-entropy loss is utilized, which is denoted as L_{CE}. In our occasion, where we train our network in binary classification scenarios, we utilize the binary cross-entropy loss function (L_{BCE}), which is defined as

$$L_{BCE}\left(y_i, \hat{y}_i\right) = -\left(y_i * \log\left(\hat{y}_i\right) + (1 - y_i) * \log\left(1 - \hat{y}_i\right)\right), \tag{5}$$

where $y_i = \{0, 1\}$ corresponds to the image's ground truth. The produced error is then utilized in the learning procedure representing the modification of the *trainable* parameters of the network based on an optimization algorithm. The majority of the analyses in the literature use Adam or AdamW algorithms as optimizers.

3.2 Datasets

The brain cancer dataset contains 3000 images that can be utilized for the training/test of the proposed CNN architecture. The dataset is highly balanced, where 1500 images correspond to normal and 1500 images to tumorous cases. It is an open-access dataset and has been uploaded on Kaggle.[1]

[1] https://www.kaggle.com/datasets/ahmedhamada0/brain-tumor-detection.

The dataset containing lung tumors was organized by specialists in the Iraq-Oncology Teaching Hospital/National Center for Cancer Diseases (IQ-OTH/NCCD)[2]. The dataset contains 1097 labeled images, consisting of 416 normal, 120 benign, and 561 malignant cases. Since our problem is a binary classification issue of detecting tumorous regions, we labeled as abnormal (or tumorous) all instances where a benign or a malignant cancer was present.

The kidney cancer dataset[3] was retrieved from a collection of cancer-related datasets, which contains cases of brain, breast, and other types of cancer. It contains 10,000 images corresponding to images of 5000 normal and 5000 tumorous cases, representing a completely balanced set.

3.3 Augmentation Pipeline

Different image-based operations are used as part of the proposed augmentation pipeline. These are *Gaussian blur*, small modifications of the contrast, hue, brightness, and zoom of each image (*color jittering*) as well as *rotation* and *translation. Gaussian Blur* is used as a cleaning mechanism of the image since it removes high frequencies in regions of the image and is commonly used as a denoising tool. Random *resize* ensures that the model will focus on infected regions of the image independently of its height or width. Simultaneously, *rotation* and *translation* push the model to search for the tumorous region in different areas of the image and finally *color jittering* is used in order to help the model learn features that are not dependent on the color of each image, since there is also a variation in the pixel values among the grayscale images, but mainly on the shape of tumorous and healthy regions. After the augmentation procedure, the MRI and CT images displaying brain, kidney, and lung tumors are cropped automatically, aiming to remove their outer black parts that do not represent valuable information for the examined phenomenon.

3.4 CNN Architecture

In this paragraph, we present a low-complexity CNN scheme including seven main layers. The first four (two convolutional and two max pooling) contribute to the feature extraction process. In addition, the three remaining fully connected layers take advantage of the extracted features to achieve noteworthy classification performance (Fig. 1). Two-dimensional grayscale images of size 100×100 are placed as inputs to the proposed CNN architecture. We arrived at this choice after extensive experimentation, since the selected small input size is accompanied by low computational burden without deteriorating the model's efficacy.

[2] https://www.kaggle.com/datasets/adityamahimkar/iqothnccd-lung-cancer-dataset.

[3] https://www.kaggle.com/datasets/obulisainaren/multi-cancer.

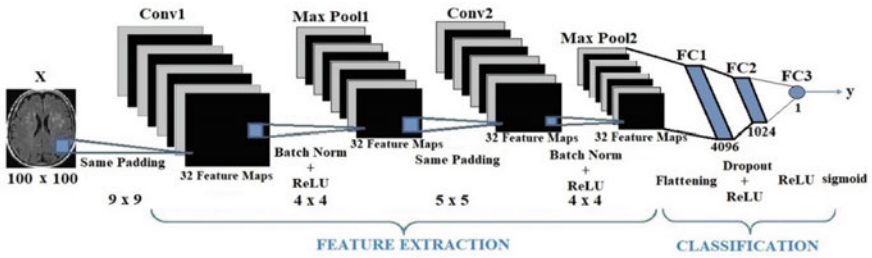

Fig. 1 Diagrammatic representation of the low-complexity CNN scheme

Firstly, a convolutional layer consisting of 32 kernels of 9×9 spatial span is encountered, while the extracted feature maps go through a max pooling layer of size 4×4. This pattern is replicated and contains a 5×5 convolutional and a 4×4 max pooling layer. In both cases, *same padding* is utilized before the implementation of the convolution, while the above layers are accompanied by ReLU and batch normalization operations. The second part consists of three fully connected layers including 4096, 1024, and 1 node, correspondingly. Between the first two layers, exists a dropout operation aiming to eliminate the likelihood of overfitting.

4 Results

The proposed low-complexity scheme is employed to investigate the overall classification efficiency on all three datasets containing lung, kidney, and brain tumors. For each dataset, we implemented a stratified splitting strategy of ratio 70:30, before and after the implementation of the augmentation methodology to maintain balanced classes during the training and test phases. Thus, we result in test sets containing 900, 1500, and 329 images for the brain, kidney, and lung datasets correspondingly.

Several learning rates were utilized during the training phase, namely $\eta = \{0.0001, 0.0005, 0.001, 0.005, 0.01, 0.05, 0.1\}$, while the best classification results are generated for $\eta = 0.005$. The training process has been implemented for 50 epochs using the Adam, providing a less smooth but more efficient training procedure compared to other optimizers, like the stochastic gradient descent (SGD).

The augmentation methodology has been applied to the training set only. Since the lung cancer dataset includes 416 normal and 681 abnormal images, the application of the augmentation step helps to balance the two classes studied. For kidney and brain tumors this is not a concern, as these sets already have a 50:50 ratio between the two examined categories.

In Table 1, we observe the classification efficacy of the presented CNN on the previously mentioned test sets. Also, Table 2 displays our model's capacity after the employment of the augmentation pipeline. In both cases, our model presents significant tumor detection efficacy, especially for the augmented datasets, where we

Table 1 Classification performance of the low-complexity CNN based on the three examined datasets without augmentation

	Accuracy (%)	Specificity (%)	Recall (%)	$F1$ score (%)
Brain tumors	98.44	99.09	97.88	99.89
Kidney tumors	99.78	96.55	99.61	99.78
Lung tumors	97.27	99.11	96.76	98.05

Table 2 Classification performance of the low-complexity CNN based on the three examined datasets with augmentation

	Accuracy (%)	Specificity (%)	Recall (%)	$F1$ score (%)
Brain tumors	99.33	98.88	99.78	99.34
Kidney tumors	100	100	100	100
Lung tumors	99.70	100	99.49	99.74

encounter accuracies of 99.33%, 100%, and 99.7% for the brain, kidney, and lung tumors, respectively. Moreover, according to Tables 1 and 2, kidney tumors represent the best-classified type of tumors, before and after the employment of augmentation. Another important observation is the minor differentiation between the evaluation measures of specificity and recall, leading to the conclusion that our model classifies equivalently effectively both tumorous and non-tumorous instances, regardless of the cancer type.

The augmentation procedure has improved the model's overall classification efficacy in all three investigated scenarios, a fact that is supported by all four evaluation measures. More specifically, the testing accuracy is increased by 0.89% for brain tumors, 0.24% for kidney tumors, while the most prevalent increase is evident for lung cancer with an increase of 2.43%. In addition, we observe notable increases in the recall and the specificity regarding kidney and lung tumors of 2.73% and 3.44%, respectively.

More information about the amount of correctly classified instances of each class is provided by the above confusion matrices (Fig. 2). These three matrices correspond to the presented results of Table 2, concerning the case of the augmented training set. Finally, the diagrams of Figs. 3 and 4 display the evolution of the training/test losses and accuracies during the 50 epochs, showing a quite smooth training process, validating the robustness of the proposed AI model.

5 Discussion

In this article, we present a convolutional neural network scheme of low complexity for tumor anomaly detection. The limited complexity of our network renders it ideal for studying datasets including limited number of observations, that usually

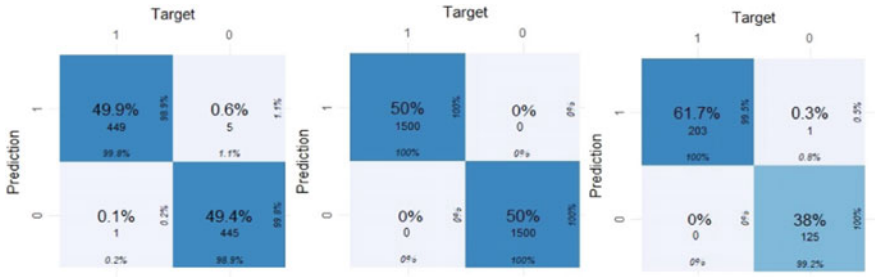

Fig. 2 Confusion matrices of the CNN accuracy for brain, kidney, and lung images

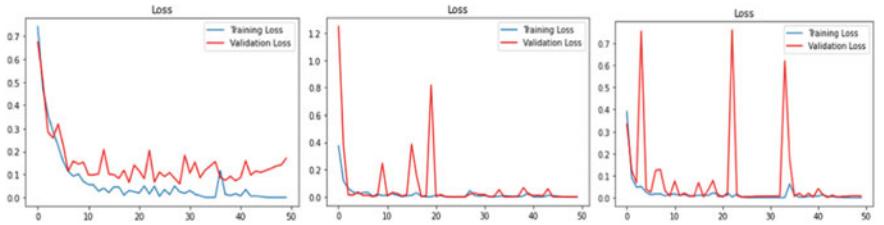

Fig. 3 Training/test losses for the brain, kidney, and lung cancers during 50 epochs

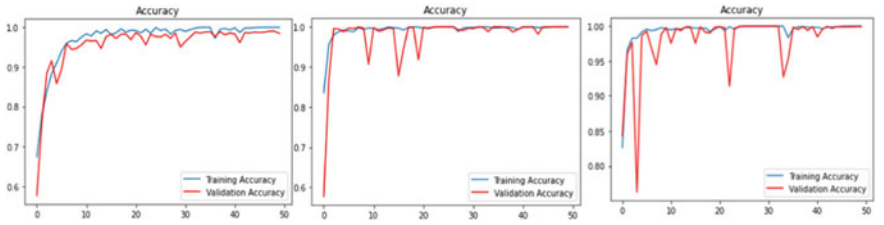

Fig. 4 Training/test accuracies for the brain, kidney, and lung cancers during 50 epochs

accompany medical studies, compared to many papers in the literature that use more complex and computationally expensive schemes. CNNs with more convolutional and more complex fully connected layers were tested although without improving detection accuracy. Several augmentation techniques have been applied, including Gaussian blur, color jittering, rotations, resizing, and translations, while we examine their influence on the detection capability of our deep learning model. The variety of datasets and the diversity of classification challenges, enhance the robustness of the presented detection efficacy, rendering our approach a reliable medical tool.

We showed that the proposed low-complexity convolutional neural network is able to produce notably accurate results based on the four examined classification metrics used throughout the analysis. The selected augmentation pipeline forces the detector to learn features that focus on the tumorous regions which are independent from

pixel-related features, such as the brightness or hue. The increase in the evaluation metrics is obvious, resulting in accuracy scores of 99.33%, 100.00%, and 99.70% for the brain, kidney, and lung cancer, respectively. On top of that, since the cardinality of the medical-related datasets is mostly limited, deep architectures may fall under the threat of overfitting [30, 31]. Other interesting approaches that used machine learning algorithms like random forests [22] or more complex AI schemes [12–17, 23, 24, 28] generated robust results with the highest testing accuracy being 98%. Our low-complexity network coupled with the data augmentation overcomes this challenge and can be easily implemented under real-world circumstances, while its simplistic architecture encourages its retraining when new data is presented.

Since new types of cancer may occur, scientists should focus more on the generalization of their methods or the construction of architectures that will be able to provide robust results with limited amounts of data. Regarding future work, our objective is to take advantage of the knowledge of deep pre-trained networks, such as ResNet50 on ImageNet, in order to create pipelines based on transfer learning and related vision techniques. It would be interesting to apply a teacher–student method to approach the problem under the few-shot or no-shot learning scenario. Finally, it would be interesting to examine cancer occurrence simultaneously with the emergence of other chronic diseases, through causality or correlation measures [32, 33], which may lead to more precise treatment approaches.

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How To Test The Machine Learning Algorithms That Are Common in Big Data Applications

Daniel Staegemann, Christian Daase, and Klaus Turowski

Abstract The extensive use of information and, thereby, also the application of big data (BD) technologies, are some of the biggest influencing factors in today's society. However, due to the sheer deluge of data, it is not feasible to turn them into usable information in a manual fashion. Instead, automated approaches are required, which makes machine learning (ML) algorithms an important part of the corresponding technical ecosystem. Yet, besides the pure provisioning of the algorithms, it is also necessary to make sure the delivered quality is sufficient. Hence, the testing of the ML algorithms in the BD context with its specific challenges is highly important. For this reason, in the publication at hand, based on previously identified BD standard use cases, the common ML applications are identified and it is discussed, how they can be tested, providing future researchers and practitioners in the domain with valuable insights on how to create better quality BD applications.

Keywords Big data · Machine learning · Testing

1 Introduction

Since today's society is heavily focusing on data and the contained information [24], and this situation can be expected to continue in the future; the development and improvement of the corresponding technologies are an extremely important task. For this reason, the term big data (BD) was coined to indicate the complexity of the corresponding endeavors [39]. One particularly important aspect is the challenge to

D. Staegemann (✉) · C. Daase · K. Turowski
Otto-Von-Guericke University Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany
e-mail: daniel.staegemann@ovgu.de

C. Daase
e-mail: christian.daase@ovgu.de

K. Turowski
e-mail: klaus.turowski@ovgu.de

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deal with the contextual processing of this data deluge. Due to the sheer volume, it is oftentimes not feasible for humans to deal with the data and, instead, automated approaches are necessary. Therefore, machine learning (ML) algorithms play an important role in many use cases. However, as for the various other parts of BD applications [34], it is not only important to have the algorithms to deal with a certain task but also to make sure that they actually work as intended and deliver high-quality results. Yet, the corresponding testing is often a quite challenging task. Hence, the publication at hand is aimed to answer the following research question (RQ):

RQ: How can the testing of the machine learning algorithms that are common in big data applications be conducted?

To answer the RQ, the paper is structured as follows. After this introduction, the background section provides the foundation for the ensuing considerations. Then it is analyzed, which ML uses typically occur in BD applications. This is followed by a discussion of the corresponding approaches for their testing. Finally, a conclusion is given and avenues for future research are outlined.

2 Background

In this section, big data as a general concept will be introduced. Afterward, corresponding standard use cases will be briefly discussed. However, for more in-depth insights and concrete examples, we recommend the consultation of the underlying publications.

2.1 Big Data

Even though the term big data is widely used, it has no universally applied explanation. Instead, there are several slightly differing definitions, which all aim to describe it [39]. One of the most popular ones comes from the National Institute of Standards and Technology (NIST) and explains that big data "consists of extensive datasets primarily in the characteristics of volume, velocity, variety, and/or variability that require a scalable architecture for efficient storage, manipulation, and analysis" [9].

Volume refers to the amount of data as well as to the number of records that have to be processed [28]. Regarding this, it is noteworthy that not only a growing number of data points is generated and registered for the various subjects of interest [29] but also the relevant size metric over time changed from gigabytes or terabytes to petabytes or even zettabytes for some cases [8].

Velocity also refers to two aspects. On the one hand, this is the pace of incoming data that have to be handled by the system and on the other hand the speed that is required for the fulfillment of processing request [12]. Variety describes the multitude of different data sources, structures (structured/ semi-structured/unstructured),

types, and notational conventions that can be present in a single BD application [13]. Even though gathering diverse information can provide significant benefits through improved insights, their integration also poses a major challenge. Variability denotes the changes regarding the previously described dimensions. Because the real world is continuously evolving, the same applies to which data are deemed relevant in which quantity. Consequently, to ensure a high level of flexibility and scalability, this dynamic must also be considered when envisioning BD systems [32]. Moreover, some events can cause a change in the received data without prior long-term warning (e.g., the sudden outbreak of a pandemic that fuels online shopping), which brings further challenges regarding the system's flexibility [21]. Further, another prominent characteristic, that is not mentioned in the initial definition, but is especially relevant in the context of ML, which heavily relies on data quality, is the veracity, which describes the trustworthiness of different data sources [9]. As a second characteristic outside the initial definition, which is highly important for ML, the validity signifies refers to the temporal component. Despite data having a high veracity, they might still be inadequate for some tasks because they are too old to be relevant anymore for the desired purpose [8, 9].

Overall, however, it can be stated that BD is usually used to describe situations in which the data are too voluminous or too complex to be handled by traditional tools and approaches and, therefore, necessitate the use of highly sophisticated tools that are specifically designed for that task.

2.2 Big Data Standard Use Cases

While the use of BD applications is very diverse, they can generally still be mapped to one of nine standard use cases (SUC) as shown in previous works [38, 38]. Thus, these SUCs, as described in the following, can be used as a foundation for the research endeavor described in this publication.

In **SUC 1–Data Analysis Improvement**, one of the main challenges is to process and analyze a huge amount of unstructured data that are incoming with high speed.

SUC 2–Batch Mode Sensor Data Analysis focuses on the integration of data from heterogeneous devices and sensors, which, however, has not to be done in real time but is gathered and then analyzed in batch mode. The aim is often to uncover patterns, discover deviations, and to visualize the findings.

The **SUC 3–Smart City** is associated with huge amounts of diverse data that can be structured, unstructured, permanent, or transient and can contain many different kinds of information. Further, due to the prevalence of personal data, privacy-preserving techniques play an important role.

Those are also often relevant in **SUC 4–Multi-Level Problems**. Besides that, the ability to store, search, and query large amounts of data play an important role. Further, unstructured data such as images and handwritten documents as well as their processing in batch mode characterize this SUC.

Another challenge is inherent to **SUC 5–Expand Data Sourcing**. Here, the data from various sources and adhering to heterogeneous structures need to be combined. Hence, extensive preprocessing is highly relevant. However, in contrast to SUC 1, here, real-time processing is usually not required and instead batch processing is used.

For **SUC 6–Data Connection** the combination of widespread collections of information to improve decision-making is envisioned. Since the applications are usually highly critical, it is important to assure the correctness of the utilized data. Further, additional steps like classification or anonymization might be needed.

In **SUC 7–Decision Support**, heterogeneously structured data are analyzed in real time. To create value, classifications, statistical analysis and similar approaches are utilized and visualization techniques are used for the presentation of the results.

The **SUC 8–High-Speed Analysis** has its focus on the (near-) real-time processing of structured and unstructured data as well as the immediate availability of the results for further use.

Finally, **SUC 9–Process Optimization** mostly builds on real-time analysis of data that is incoming with high velocity but also batch processing can be used for certain tasks. Since the focus is on the identification of recommendations on how to improve certain processes, clustering, and visualization techniques are important in this SUC.

3 Machine Learning in Big Data

To gain an understanding of the use of ML in BD applications, the previously described BD SUCs will be analyzed regarding their utilization of ML. Subsequently, the identified applications will be further discussed.

3.1 Machine Learning Applications in the Big Data Standard Use Cases

When analyzing the papers that were used in [38], for the creation of the SUCs, it can be seen that in the 43 papers, 16 [2, 3, 5, 6, 10, 16–18, 22, 23, 25, 26, 30, 31, 35, 41,] were linked with the use of machine learning. For the extension of that work [37], the same applied to three [15, 20, 40] out of five papers.

While the combined list is of course still by no means exhaustive with regard to the entirety of BD projects that use ML, the comprehensive nature of the underlying studies allows it to be seen as, at least somewhat, representative.

Hereby, the applications spanned a plethora of domains and tasks, highlighting the general versatility of ML as a crucial part of a BD pipeline. In the medical

sector, ML helps to monitor and analyze the patients' vital signs, provide predictions, and trigger alerts in case of emergency. Another prominent area is transportation, where oftentimes the traffic and its patterns are analyzed to act accordingly, but also predictions are sought after to, e.g., forecast passenger demands. The automated detection of financial rumors and fraud detection are application areas from the financial domain. Highly prominent across domains is the analysis of data provided by IoT sensors, including the search for anomalies, trends, and patterns, but also the creation of predictions based on the acquired data. When it comes to a company's management of customers, ML is utilized for the prediction of behavior or sentiment. Other use cases are the mining and comparison of documents, the amalgamation of heterogeneous data to get comprehensive assessments in complex situations, including the automated creation of appropriate visualizations, and the detection of failures and anomalies in recorded event data as they can be, for instance, be found in manufacturing.

3.2 The Identified Machine Learning Applications

When analyzing the ML applications that were outlined in the previous section, there are some main types that can be identified. While the field of ML is generally pretty diverse in the sense that the corresponding applications usually have to be customized and trained for the specific use case [19]. Some general similarities within these classes still prevail. On a very high level, those are on the one hand the prediction of current information that cannot be known for sure or future events and behaviors and on the other hand the analysis of previous or current data to create insights. However, due to the diversity and based on the analyzed cases, the latter group can be further partitioned. Here, the types that stand out are the automated analysis and comparison of huge bodies of archived texts, the automated learning of systems based on certain conditions and factors, and the fusing and analysis of (oftentimes rather) heterogeneous data to derive new insights or trigger actions. Further, even though the exploitation if IoT sensors can generally be assigned to the last group, due to their prevalence in today's society [4] and the stronger focus on real-time analytics, it is separately mentioned.

In the case of predictions, the potential benefits of a correct assessment can be considerable. However, since actions that are (not) taken based on the predictions might, depending on the use case, heavily influence the considered phenomenon or aspect, the observation of the algorithms' quality is a highly challenging task. An example is the prediction, in which customers are most likely to buy an expensive product as a result of a targeted advertisement that is, however, too expensive to be used outside of a small sample of the entire customer base. Here, it is neither verifiable if someone who got the advertisement and bought did it because of the marketing nor if someone who didn't get the ad and also didn't buy would have done it if they were addressed by marketing.

In contrast, the automated analysis and comparison of texts can, theoretically, be fully assessed and evaluated for specific cases. Yet, the sheer volume that can be found in BD cases makes this prohibitively time- and resource-consuming, which is also the reason for the use of ML algorithms in the first place.

When it comes to the automated learning and adjusting of systems during their runtime, of big challenge can be the fact that it is not only about success or failure but about finding the optimal solution. This is, however, hard to determine not only for productive purposes but also as a baseline for comparisons with the achieved one.

The analysis of data to determine, inter alia, clusters, trends, patterns, conditions, or anomalies is, in turn, oftentimes based on heterogeneous data sources (e.g., combining different newspapers and social media to assess the public sentiment and discover trends) that make their integration a big challenge on top of the actual analysis.

4 Testing Approaches for the Identified Big Data Machine Learning Applications

As outlined in the previous section, the testing of ML applications is oftentimes complicated by the fact that it is either not possible or not feasible to determine if they actually provide good-quality results. Yet, it is of course still necessary to assure at least to some degree that the algorithms' output is adequate for the desired purpose. Therefore, despite a certain degree of uncertainty, the testing is still a crucial activity [27].

Even though the implementation of the concrete testing of the ML applications naturally needs to be conducted highly specific to the requirements of the regarded case, at least some general concepts can be identified.

The most accurate strategy is, of course, the use of sufficient amounts of real data, for which the optimal processing result is known. Because in that case, the testing comes down to the comparison of the achieved result with the optimal one. However, this is often not feasible [27], which is why alternatives are needed.

To test if a prediction algorithm is working as intended, backtesting [11] can be used. Here, historical data are fed to the algorithm and it is asked to provide forecast from the point of time of these data up to a more recent point in time that is, however, still in the past. Thereby, the actual situation at that point in time is known and can be compared with the created prediction, allowing to assess its quality. Hence, the factor of uncertainty can be eliminated. Yet, this cannot account for unforeseeable sudden events and also not for slowly evolving environments that also require the algorithms and data sources to change over time [32], which reduces their fit for the chosen point in the past.

For the testing of algorithms that focus on tasks like text analysis (e.g., categorization, spell checking, or sentiment analysis) or comparison, the creation of either entire datasets or the inclusion of well-known texts or text passages into an existing

set is feasible strategies [36]. In doing so, the fabricated data can be designed in a way that allows to explore the system's functionality. For a similarity-based book search engine, for instance, one of the existing books could be chosen. Subsequently, artificial entries with a high similarity are created and inserted into the dataset. In the following, these should be the new recommendation, due to their high similarity. For annotations, in turn, several documents could be annotated manually (or by tools whose use is prohibitively slow or expensive for the incorporation into day-to-day operations) to create a high-quality baseline [1] with the expectations that the algorithm's results should be the same or at least similar. Further, this is not only limited to texts, but can also be applied to other (and arguably more complex) types of data, such as images or videos, that shall be annotated by ML algorithms, like, for example, videos [14].

When it comes to the testing of systems for the analysis of huge bodies of data (independently of their type or structure) and the available ones are not known in-depth, but only on a rudimentary level, one approach is to analyze its statistical properties and then create synthetical data with the same properties. Because they are created, all the specific details are well known (respectively can be engineered to fit the respective purpose), the desired quantity can be had, and due to the overall properties being similar to the original data, comparability can be assumed [7]. Subsequently, the algorithm can be tested using these data, which allows the well-informed comparison of the obtained results with a previously determined baseline (e.g., the optimal results or results that were achieved by a slower or more costly algorithm). Moreover, if there are no usable data at all, their creation for testing purposes is also important. However, in this case, they cannot be modeled after an example and, instead, the corresponding rules have to be developed based on the expected properties of the envisioned actual workload. While these strategies can generally be applied to a variety of algorithms and also for the special case of data from IoT devices, the difficulty of creating high-quality synthetic data heavily depends on the complexity and the heterogeneity of the required data.

Besides these ML-specific tests, especially in a BD setting, it is of course also necessary to test the integration of the algorithms into the application as a whole to verify a correct data flow [34]. Further, when using the tests not in the traditional way but in the course of the test-driven development approach, they have to be set up before the actual coding and then (automatically) executed and evaluated in a repeated manner after each change to the code [33].

5 Conclusion

With information becoming more and more essential for today's society, the ability to generate the same from data and, thereby, the concept of BD and the corresponding applications also gained significance. In this context, ML plays an important role as a way to facilitate the analysis of huge volumes of oftentimes complex data. However, additionally to the mere implementation of the respective algorithms, it is

also necessary to ensure that they actually provide results of sufficient quality. This means that they have to be thoroughly tested. For this reason, in the publication at hand, common ML applications in BD scenarios were identified. To assure a comprehensive foundation, this was based on previous works that determined BD standard use cases. Subsequently, common testing approaches for the found ML applications were outlined. Thereby, future researchers and practitioners in the domain are provided with a starting point on how to test the ML parts of their BD applications.

However, in the future, the set of ML-related BD cases could be expanded by searching in databases that were not used by the foundational paper. Moreover, the testing methods could be amended by additional approaches that are more niche in nature and were, therefore, not yet considered.

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NFT and Digital Art: Ukrainian Experience of Using Cryptoart

Maryna Tolmach, Viktoriia Volynets, Yuliia Trach, Olena Chaikovska, Svitlana Khrushch, Kateryna Kotsiubivska, Renata Danielienė, and Paulius Danielius

Abstract Digital developments continue to change our culture, relationships, and ways of doing business. The world of virtual assets does not stand still. Following the creation of thousands of cryptocurrencies that exist only in the form of a digital record, the virtual market began to gradually evolve in a cultural direction. The mutual influence of art and technology is emphasized. Approaches to the use of the concept of cryptoart are analyzed, and the features of this artistic phenomenon are determined. The question regarding the formation of the value of cryptoart is outlined. The problems of the impact of cryptocurrency and NFTs are gaining significant importance for the formation of perspectives and trends in the development of modern culture and art. To date, this issue is in the field of view of researchers, and the main patterns of development of the NFT market and its influence on art require further

M. Tolmach (✉) · V. Volynets · Y. Trach · O. Chaikovska · S. Khrushch · K. Kotsiubivska
Kyiv National University of Culture and Arts, Konovaltsia Ye. 36, Kyiv 01601, Ukraine
e-mail: margo@knukim.edu.ua

V. Volynets
e-mail: vika-volynets@knukim.edu.ua

Y. Trach
e-mail: trach.yuliia@knukim.edu.ua

O. Chaikovska
e-mail: oachaikoska@knukim.edu.ua

S. Khrushch
e-mail: svetlanida@knukim.edu.ua

K. Kotsiubivska
e-mail: kateryna@knukim.edu.ua

R. Danielienė · P. Danielius
Vilnius University Kaunas Faculty, Muitinės 8, 44280 Kaunas, Lithuania
e-mail: renata.danieliene@knf.vu.lt

P. Danielius
e-mail: paulius.danielius@knf.vu.lt

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study. Examples of Ukrainian cultural and artistic projects using NFT technologies, which have financial, cultural, technological, and social significance in the conditions of war in Ukraine, are presented.

Keywords NFT · Cryptoart · Digital art

1 Introduction

Digital developments continue to change our culture, relationships, and ways of doing business. The world of virtual assets does not stand still. Following the creation of thousands of cryptocurrencies that exist only in the form of a digital record, the virtual market began to gradually evolve in a cultural direction. "NFT" was chosen as Collins Dictionary's word of the year for 2021 [1]. Using non-fungible token (NFT) specifically to sell art drawn attention to both this technology and digital art. Digital art received an additional boost with the development of the concept of blockchain technology, which is the basis of NFTs. The field of digital art was the first to see widespread use of NFTs, thanks to blockchain technology's ability to provide unique signatures and ownership.

The problems of the impact of cryptocurrency and NFTs are gaining significant importance for the formation of perspectives and trends in the development of modern culture and art. To date, this problem is in the field of view of researchers, and the main patterns of the NFT market's development and its influence on art require further study.

2 NFTs Are Boosting Digital Art

2.1 The Relationship Between Art and Technology

Art has always been closely related to the development of technology. When most industries were just discovering this or that technology, the art world was already using it. The emergence of the camera allowed the digitization of works of art, 3D technology allowed galleries, museums, and other institutions to make their collections more accessible to a wide audience, and virtual and augmented reality technologies made the experience of interacting with art more interactive. The emergence of the Internet has become not only a tool for demonstrating and popularizing art but also a source of inspiration and a way of creating it. The development of social networks has made art even closer, allowing artists to communicate directly with their audience and display and sell their work without intermediaries. Art and cultural institutions aim to create a unique experience for their visitors, increasingly using new ICT for the display, promotion, and conservation of their collections.

The relationship between art and science, art and technology worries philosophers of art and art historians since the possibility of technical reproduction of artworks appeared. The use of the latest digital technologies in art paradoxically influenced the acceleration of the process of intellectualization, algorithmization, automation of art, and the spread of intuitive synthetic judgment in science. Art actively interacts with modern technologies, leads to the emergence of new art movements, and goes beyond the traditional perception of works purely for aesthetic value [2].

Our societies are defined by the manifestations of our culture reflected in trade. The art, music, entertainment, and literature that best represent us as human beings acquire value and, in turn, become valuable, inevitably commoditizing them. Everything that makes us human will be part of our digital universes [3]. Art has always sought to be a part of the Internet environment, and currently actively uses all those technologies that are fundamental to the metaverse, that is, VR, AR, MR, and others.

Equally important, art gave impetus to the development of the NFT market—an essential part of the virtual economy of the metaverse. At the same time, the benefits of NFTs became the basis for the emergence of a new artistic movement—cryptoart and have defined new ways of creating, collecting, and owning works of art.

2.2 The Concept and Impact of NFTs

The European Union Intellectual Property Office (EUIPO) considers NFTs as: "unique digital certificates registered on a blockchain that identify digital elements but are distinct from those digital elements" [4]. For the Office, the term non-fungible tokens on its own is not acceptable. The type of digital item authenticated by the NFT must be specified. These digital assets first appeared in 2017 on the Ethereum platform. They quickly gained popularity due to a creative idea, wide opportunities for implementation. Unlike standard cryptocurrencies, each token is unique and has no analogues.

Therefore, the potential use of NFT tokens allows any product to be digitized or transferred to the blockchain. They can apply to both real/tangible assets (original artworks) and fully digital products. With the help of innovative NFT technology, the following objects can be tokenized: rare and non-standard domains; the right to own a physical asset, such as a home, a car, or an object of art; tickets for concerts, football matches; tweets of popular people; licenses for books, films, or songs; collectibles, stamps, coins, etc.

The innovation of the NFT market is that it pushes to rethink the concept of ownership in the digital dimension. It proved that our habit of getting content online for free by simply copying it is unfair to those who create and distribute digital works. The NFT market has established the same rules that apply to the "traditional" art market: a digital work has a buyer who pays for its ownership. The application of NFT can become a new tool in the field of intellectual property management and create

new opportunities for the market and its participants, making it more convenient, because operations with tokens are cheap, simple, and faster than operations with real objects to which they are attached.

Thanks to blockchain properties, NFTs act as tamperproof digital certificates of authenticity written and signed by artists. These technologies lend uniqueness to digital files, which, by definition, can be reproduced endlessly. They ensure that buyers own both the genuine digital work and the original "print"—something that was previously impossible. These two parameters, important for collectors, give the work of art a financial value and allow it to be (re)sold like a traditional work of art [5]. This opens up new perspectives for artists to monetize their digital artwork more easily, which does not create new artistic practices, but influences the art market.

In 2021, NFTs have become very popular among art dealers, collectors, and even museums [6]. Monetization of digital artworks through blockchain has allowed digital art to find its place in the art market. Since 2007, artist Mike Winkelman, known as Beeple, has created one drawing every day. He combined all five thousand of his own works into a collage and called it Everydays—The First 5000 Days. Having put up a collage in the form of an NFT token at a price of $100 on March 11, 2021, Winkelman received $69 million. This was the first time that Christie's auction house sold a JPG file at auction. Due to the sensational of Beeple's collage, many private art galleries and auction houses have started to include cryptoartworks in their catalogs [5], thus opening the world of art to a new audience.

As a result of the pandemic, people began to spend more time at online events, in particular exhibitions, and museums began to digitize their collections. For museums, NFT technology can be one of the potential sources of funding, expanding the virtual experience, and engaging the audience. The British Museum, the Uffizi Gallery, Vienna's Belvedere, the Institute of Contemporary Art in Miami, the Universal Hip Hop Museum, and others are among the museums that have started to use NFT tokenization of classic works of art and include cryptoart in their collections. It is thought that NFTs in museums, as part of the new digital ecosystem of the metaverse, will help ensure that art can be funded and enjoyed by a truly global audience in the future, so that cultural assets can be accessed and enjoyed by everyone [7].

The market cap of cryptoart as of the beginning of 2023 is $1,765,630,813.15 (1,321,322,806 ETH). The world is actively buying and selling digital art objects in the form of NFT tokens, from paintings and unreleased songs of favorite artists to virtual sneakers and tacos. Total Artworks Sold: 3,842,275 [8].

After unprecedented growth in 2021 against the background of cryptocurrency depreciation, the NFT market is also showing a significant decline during 2022. The cryptographic art segment is also experiencing some decline across the board, but is doing well-compared to the overall market. The number of collectors who bought or sold a work of art decreased by half, and the volume of trades decreased by 38%.

According to the Non-Fungible report for Q3 2022 [9], the era of NFTs where profit and speculation reigned supreme is probably over, and gradually a new page in the history of this technology is currently being written. If the trends observed during 2022 are to be believed, the utility of tokens seems to take precedence over the concept of financial investment.

In particular, it found that major players from all walks of life and all industries continue to launch NFT-related innovations: video games, finance, entertainment, fashion, sports, and more. There is no sector in the world that is not currently working on its own NFT projects, officially or unofficially.

2.3 Cryptoart and NFT Arts: Concepts, Features, and Value

The use of NFT in art has led to the emergence of new concepts such as NFT art, cryptoart. The definition of cryptoart is still evolving, and the future of the asset is yet to be determined. Jason Bailey was one of the first to use the concept in 2018 and made the argument that "art native to the blockchain has its own aesthetic and represents a new and important movement within art." He called this movement/aesthetic CryptoArt [10]. Popular early examples of cryptoart were analyzed including CryptoKitties, CryptoPunks, Rare Pepe, CurioCards, and Dada.nyc. [10].

Laura Copelli explored the phenomenon of cryptoart from a technological point of view on the one hand and a conceptual and aesthetic perspective on the other [11]. Digital art is defined as art created or presented using digital technology. This includes both art that uses computers and technology as its creative media, as well as traditional art in digitized form. Digital art identifies a certain artistic practice that began to exist long before cryptoart. The term cryptoart is specifically related to blockchain technology and classifies all works of art without any particular distinctions that refer to a specific system of authentication and registration, namely distributed blockchain. In fact, NFT and cryptoart solved the main problem of digital creativity, which was reproducibility. By enabling ownership of a digital object, NFTs enable digital objects to have a single owner, turn digital objects into assets, and provide the attribute of rarity that is an important factor in creating value in traditional art.

Franceschet and Colavizza [12] propose a decentralized view on cryptoart based on the viewpoints of different actors within the system: cryptoartists, collectors, galleries, art scholars, and data scientists. Cryptoart is defined as "a limited edition digital art, cryptographically registered with a token on a blockchain." Tokens represent a transparent, auditable origin and provenance for a piece of digital art. Blockchain technology allows tokens to be held and securely traded without the involvement of third parties. Analyzing the origin of cryptoart, the authors talk about conceptual art as a predecessor, and find many common characteristics. The artistic phenomenon of cryptoart is most attractive to a broader and younger cohort of potential artists and collectors, including the crypto community, and provides new ways to engage audiences and interact with the community.

Turning to the economic aspects of NFT, the appearance of NFT in the art market offers many advantages for all contributors in terms of rapid monetization. But due to the high speed and relative lack of curatorial control over the publication of artworks, "artwork hyperinflation" or "over-tokenization" can be a significant problem for crypto-artists [12].

Traditionally, art critics, curators, dealers, and collectors play an important role in artistic recognition, assessment of the aesthetic and market value of works. Thanks to NFT, artists have the opportunity to distribute their work to a larger audience and free themselves from intermediaries, which, on the other hand, is calling into question the traditional codes of the art world. Among the reasons for criticism of NFTs are the impact on the environment, as well as the belief of some artists that NFTs contribute to the financialization of art [5].

Is cryptoart defined by its properties as a financial instrument, or by the aesthetics of a specific digital artifact? Aesthetics became a defining characteristic of art during the Enlightenment. Aesthetic appreciation remains the most significant way collectors differentiate one NFT from another, abstracting from price and market trends.

Based on available data from SuperRare marketplace, researchers identified what non-fungible tokens (NFTs) are actually contributing to visual culture beyond simply fuel for financial speculation and environmental extraction and what aesthetic and thematic priorities of cryptoart community [13]. Searching for the aesthetics of cryptoart requires examining the standards by which crypto-artists as well as collectors currently differentiate NFT artworks and define them as something more than digital artifacts that have been tokenized.

Interesting opinion of Massimo Franceschet, who calls art cryptoart as beautiful example of a side effect of a blockchain technology [14]. Unlike traditional art, cryptoart offers absolute data availability and generates a huge amount of openly available structured and unstructured data about artworks, transactions, social data, and this is perhaps the main feature that distinguishes it from traditional art and thus will allow to study the mechanic of success in art and creative industries, research cryptoart features. For example, Franceschet used sentiment analysis on the textual metadata to mine the sentiment of each artwork to discover what sentiment poles and emotions are expressed by crypto-artists when they create digital art and find out if crypto-collectors are influenced by these emotions when buying digital art [14].

NFTs allow us to shape our cultural identity in a non-physical way and challenge us to think differently about how we perceive value. Users show their identity through collections as part of the blockchain [3]. NFTs can be used to build a highly engaged community, creating value beyond simple ownership by functioning as membership tickets or cards to access events or exclusive offers. [15]. There are now many NFT communities with different personalities and goals, and people often see membership in such communities as part of their identity. In this way, NFT ownership provides an immediate shared text for communication with other people. Both online tools and offline events can be used to support such communities and build NFT culture.

All of these benefits make owning the associated NFTs more valuable—and almost paradoxically, this increase in the value of ownership comes in a form that helps separate the value of ownership from the purely financial opportunity of reselling. [16].

Habrel considered the current phenomenon of cryptoart from an artistic point of view [17]. NFTs brought questions of value and legitimacy in digital art and drew the attention of creators to new channels of communication and the formation of new decentralized communities. Cryptoart is considered as a new era in art.

3 Digital Art and Blockchain in Support of Ukraine

3.1 Virtual Assets in Ukraine

Ukraine is ranked third on Chainalysis's 2022 Global Crypto Index [18], climbing up a spot from the previous year. Ukraine is among the top five countries in the world with the largest number of owners of cryptocurrencies [19]. Verkhovna Rada of Ukraine adopted Law No. 3637 "On Virtual Assets" on February 17, 2022, which determines the legal status, classification, and ownership of virtual assets, regulates transactions with cryptocurrencies, and provides for changes applicable to legal relations with the circulation of virtual assets in Ukraine, determines the rights and obligations of market participants, the principles of state policies in the sphere of virtual assets turnover. It also introduces financial monitoring measures for virtual assets. This law will allow foreign and Ukrainian cryptocurrency exchanges to operate legally. The Ukrainian government began using cryptocurrency donations as a way to fund Ukrainian military and humanitarian aid during the Russian invasion.

3.2 NFT and Cryptoart in Ukraine

The Ukrainian art community shows a constant interest in the use of blockchain technologies. In 2022 in Ukraine, more than 900 artists tried to realize themselves in this direction. In recent years, the development of cryptocurrencies and the possibilities of cryptoart became the topic of many exhibitions, conferences, hackathons in Ukraine, and several online communities for artists [17].

Such as CryptoArt Ukraine community created in February 2021 and to help Ukrainian creative people to understand and use the cryptoecosystem and NFT, especially to develop their careers, to promote Ukrainian cryptoart scene globally, as organized, progressive, and friendly community with representatives from different genres. Community members have created over 2000 individual NFTs or NFT collections and continue to raise funds through their NFT artwork to support Ukraine [20].

In addition to placing NFT artworks on the most popular marketplaces, initiatives are being developed in Ukraine to create Ukrainian platforms for the sale of NFT art. For example, platform V-Art combined NFT marketplace and IP rights to trade and

manage digital art assets with immersive tech for a greater experience. The combination of NFT + , virtual exhibition technology, networking tools, and high-quality content forms an ecosystem for artists, collectors, and other art market professionals. V-Art seeks to provide the intellectual infrastructure through curation, editorial, and blogs, webinars, and conferences with experts as well as honest analytics to build a community of like-minded stakeholders around itself [21].

In December 2022, the digital operator "Lifecell" launched an NFT marketplace "NFT Talkers," where NFT technology will help raise funds to support Ukraine, and artists will be able to speak the language of art. The platform allows to place charity collections, the funds from which will be transferred to the state charity initiative UNITED24 [22].

3.3 NFT Collections in Support of Ukraine

In the conditions of Russia's large-scale invasion of Ukraine, despite the significant devaluation of cryptocurrencies on the world market, NFT art is used to collect funds to support Ukraine. Ukrainian crypto-enthusiasts actively use new technologies, attracting additional funding for humanitarian and military needs. A large number of NFT initiatives have been launched to support the Ukrainian army and the Ukrainian people, in particular, digital artists create a large number of charitable NFT collections. Digital art objects talk about war, human loss, and suffering. Each initiative is unique and carries a deep meaning. Let's list some of them.

Birds of hope. A team of 14 artists called NTF-UA created a collection of bird images consisting of 305 NFT tokens of 2 categories. Binance cryptoexchange became a partner of this charitable NFT-action. The goal is to popularize Ukrainian art, give artists the opportunity to earn money from their work, and support charitable funds in Ukraine. 50% of the funds are transferred to a state charitable organization [23].

One Proud Nation. The One Proud Nation NFT collection is a set of 10,000 unique anti-war-themed digital art pieces. 100% of funds will go to charity in Ukraine. The idea behind these tokens is that the people of Ukraine have been always fighting for their rights and the opportunity to choose their own path. On February 24, Ukrainians united even more to protect the country from the enemy and later to rebuild the state in which they want to live. The collection was created by MintyMint software development company. Its co-founder Yaroslav Usov believes that art cannot stop violence, but it can make an important contribution—become additional financial support for the Ukrainian army. The collection is hosted on the OpenSea platform [24].

Ukrainian Spirit NFT Collection. This charitable initiative created to support Ukrainians courageously defending their country, lives, and freedom [25]. Ukraine is known for talented people in the fields of art, science, sports, and IT, who unite in the face of hardships, selflessly sacrificing everything for one, with a spirit that

cannot be defeated. Each series of NFTs consists of five tiers, embodying one characteristic of Ukrainian identity: Help, Unity, Will, Love, and Peace, as well as its united spirit. The project combines art, innovation, and charity and aims to create a community capable of supporting people in need. The collected funds will be sent to humanitarian aid to Ukrainians.

Ukrainian Renaissance. A collection of postcards with cities affected by shootings. Creative agency Isobar Ukraine launched a series of true images. The developers chose regions that were heavily damaged by enemy shelling. The idea of the project is based on a simple analogy: As a rule, people buy postcards, want to remember their trip, and admire beautiful landscapes. Currently, such pictures have lost their original meaning, because some cities are painful to look at. The development team believes that the collected funds will help restore the former appearance of the beautiful Ukrainian cities [26].

Digital art for real life. The gallery of NFT artworks put together to fundraise money for the Ukrainian Army's needs and support Ukrainian defenders who stand up to Russian invaders [27]. Before the war, in June 2021, Ukrainian artists from different regions created art sculptures, which are symbols of Ukrainian culture and recovering engineering talent. The collection interprets the spirit of the fight for independence, strength, and courage by combining art with modern technologies. The aim is to raise up to 500,000 USD to support protectors of the democratic values and peace in Ukraine! The gallery was designed by the NGO "Noosphere Association" together with the CTRL/ART/D agency in March 2022.

Avatars for Ukraine. Charity NFT collection of the iconic digital art created in response to the largest war since WWII. A group of top video game and cinema digital artists, credited for game hits Rainbow Six, Warframe, Stalker, Metro, Prey, Halo, League of Legends, Asphalt, organized a charity NFT auction to raise money for medical aid for the Ukrainian defenders. The uniqueness of the collection is that all artworks by more than 50 talented Ukrainian digital artists were created during the first months of the war [28]. Presented avatars for a free nation embodying the spirit of Ukraine in its struggle for existence. In the first charity auction, 23 artworks were sold for 12,656 ETH / $25,403.25.

3.4 Cultural and Artistic Projects Using NFT Art

In the conditions of war, the artistic community creates unique cultural and artistic projects that combine art, blockchain, and modern digital technologies. Their purpose, in addition to fundraising, is to record the events of the war through the prism of art, popularize Ukrainian culture, and preserve cultural heritage. Such projects are supported by the blockchain community and the government.

Mint for Ukraine. This is the first NFT collection of a million copies of its kind, created by artificial intelligence reflecting Ukrainian culture and values for the

purpose of preserving Ukrainian art and raising funds for aid. It's a result of unique collaboration between visionary artist Phil Bosua and artificial intelligence [29].

There are 29 sub-collections inspired by Ukrainian writers, poets, filmmakers, artists as well as ordinary Ukrainian people and cultural symbols. AI interpreted text, background music, and reference images. Among sources of inspiration are Lina Kostenko, Oksana Zabuzhko, Oles Honchar, Oleksandr Dovzhenko, Maria Prymachenko, Ihor Pavlyuk, Ivan Marchuk, Ukrainian symbols, and Ukrainian people. MintForUkraine invites anyone to replace the paintings for free by easily creating a wallet and donating funds via chosen currency or cryptocurrency. Donations will go to support Ukrainian culture, artists and cultural institutions (10%), and humanitarian support of Ukraine (90%) through a proven network of charitable organizations. The aid includes the supply of first-aid kits, medical and humanitarian support to citizens of Ukraine, grants for students, scientists, and technical communities whose work was disrupted by the Russian invasion [29].

Mom, I see war. The project is dedicated to Ukrainian children affected by the war. With the help of blockchain technology, the authors want to show and preserve in history the various feelings and emotions that children felt during this terrible time, from fear and despair to hope and faith in victory [30]. More than 13,500 images were received. The photo collection is publicly available on the project website and on social networks. Children's drawings from Ukraine and all over the world will be combined into a collage that will be put up for charity NFT auction, proceeds will be transferred to the humanitarian aid fund for children affected by the war.

Meta History: Museum of War. The world's first NFT war museum was recently launched in Ukraine [31]. The project was created in order to spread the truth about the military invasion of Russia, crimes against civilians. This development combined blockchain technologies, art, and recording of historical events. The first part of the collection will feature the works of Ukrainian artists, and subsequent issues will include works by foreign authors. These paintings will be carefully selected by famous designers. All digital works are presented as tokens. They can be purchased by any collector or investor. The project was launched by the Ministry of Digital Affairs and the Ukrainian blockchain community. Ukrainians are sure that the museum in NFT format and other NFT collections can change the course of the war and help restore peace in Ukraine. The collected funds, directed to the humanitarian needs of Ukrainians and the needs of the army, will support the victims and strengthen the resistance of Ukraine. Therefore, modern technologies are aimed both at the enrichment of individual investors and at the support of social projects.

Ukrainian Heritage Hub. A project that combines modern digitization and blockchain technologies to preserve cultural heritage. Currently, several initiatives have been launched in Ukraine to digitize cultural heritage as a way of preservation in wartime conditions. The task of the project is to launch digitization processes at the national level to preserve Ukrainian cultural heritage from destruction by the Russian army. It involves the digitization and transformation of objects of national and

cultural heritage (such as artworks, artifacts, museum exhibits, architectural monuments, and other objects of cultural heritage are under threat) on the Blockchain, which will become a reliable protector of Ukraine's national legacy. This will help preserve priceless examples of architecture, literature, paintings, and sculptures and fix on the blockchain the rights of Ukraine as the founder and successor of Kyivan Rus in the digital world, where no one can encroach on it [32].

4 Conclusion

In the digital age, there is an urgent need to quickly adapt to changes and implement new tools that help digitize and preserve the assets that represent value to us. The hype surrounding the use of NFT is not revolutionizing art, computer games, or intellectual property itself, but the use of the NFT tool is important because it creates new opportunities for authors and rights holders to distribute their works safely and profitably.

Therefore, the NFT market can become the engine of modern art, as it creates a balance between art and technology. NFT boosting digital arts and changing the concept of interaction of art market participants. Research into cryptoart continues, not only as a financial instrument but also about the formation of the value of digital works of art. In particular, the value of NFT art may be determined by aesthetic preferences, uniqueness, belonging to certain communities, and support of common values.

The field of cryptoart in Ukraine is actively developing. During the war in Ukraine, digital art and cryptoart in particular began to be used for charitable purposes to finance military and humanitarian needs. The combination of art and modern technologies also become one of the tools of struggle and attraction of support for Ukraine. Art projects using blockchain technologies have great cultural, social, and technological significance. The use of digital technologies in culture leads to a rethinking of the forms of cultural and artistic interaction, to the emergence of new cultural phenomena, which constitutes a wide field for further research.

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26. Ukrainian Renaissance—Collection|Opensea. https://opensea.io/collection/untitled-collection-122449389
27. Digital art for real life Collection|Opensea. https://opensea.io/collection/ukrainianartforlife
28. Charity NFT Collection|Avatars for Ukraine, https://www.avatarsforukraine.com
29. Mint for Ukraine|A million unique AI-generated NFTs. https://mintforukraine.org
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Mobile Application System with Arduino to Improve the Communication Process with Hearing-Impaired People

Alberto Velasquez Fernandez and Michael Cabanillas-Carbonell

Abstract The objective of the study is to determine how the mobile application system with Arduino influences the communication process of hearing-impaired people. The SCRUM methodology is used in an experimental design, with explanatory scope, and a quantitative approach. A population of 70 deaf associates. With a sample of 60 deaf associates, forming the experimental group of 30 deaf associates and the control group of 30 deaf associates. The dimensions of referential, inter-referential, and self-referential communication were considered as indicators, concluding that there are improvements in the experimental group compared to the control group.

Keywords Hearing impairment · Mobile application · Arduino · Communication process

1 Introduction

Regarding speech disability, because people are born deaf, they have not been adequately stimulated with the language of their environment, and as a consequence, they also present speech disability [1]. In adults in the world, hearing impairment is disabling when it exceeds 40 decibels. In the case of children in the world, hearing impairment begins at 26 decibels and hearing loss in any of its categories will have future consequences in speech clarity, emotional management, and learning [2–4]. The World Health Organization (WHO) stated that a little more than 5% of the world's population, approximately 466 million human beings, have moderate or profound hearing loss, projecting that by the year 2050, it will be 10% of the world's population [3, 4]. Using WHO disability terminology, the group of people with impaired hearing can be restricted into two groups: hearing-impaired and hearing-impaired [5]. In Peru, the National Council for the Integration of Persons with Disabilities [6]

A. V. Fernandez · M. Cabanillas-Carbonell (✉)
Universidad Privada del Norte, Lima, Perú
e-mail: n00165348@upn.pe

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stated that the first survey conducted by experts of the National Institute of Statistics and Informatics regarding disability was carried out in 2012, with the results that in Peru there were 532,209 Peruvians with unalterable hearing impairment, representing 1.8% of the total population. Regarding communication and sign language, communication helps to disseminate knowledge, information, and different forms of relationships between people. The difficulty of communication between people with hearing impairment and people with normal hearing is due to the lack of knowledge of sign language (SRL) where the combination of gestures, finger movements, and language is used. It is a methodical language where meanings are assigned to each gesture. There is no universal SRL, but it is diverse by region and country. The best known are American Sign Language, French Sign Language, Indian Sign Language, and Japanese Sign Language, and in Peru, Peruvian sign language is used [7–12]. Regarding the use of emerging technologies for the hearing-impaired, there have already been some attempts to create a database for the SRL. The computer can be programmed to translate the SRL into text format, and in this way, a hearing-impaired person can communicate with a hearing-impaired person. SRL was initially technologized through gloves or robotic hands with sensors, then with the advent of digital communication and image processing techniques, a large number of devices, mobile applications (App) that translate voice and text to sign language, static, then dynamic, real-time sign language recognition information systems, information system architecture, hardware, data transfer science algorithms. Communication tools that replace or support natural speech are rapidly increasing, and currently, there are many research works related to the translation or recognition of various sign languages around the world, based on different methods [1, 5, 7, 9, 11, 13, 14].

Research on emerging technologies and translation of Peruvian sign language. Therefore, since the current research on this subject in Peru is very limited, it is necessary to contribute to the knowledge of Peruvian sign language translation. Having reviewed that, in today's world, emerging technologies are supporting communication with people with hearing impairment [14, 15]. In Peru, there is very little use of sign language at national, regional, and local levels for people with hearing impairment, especially those who were born deaf or who have had hearing loss from a very young age, the severe or profound level of severity is the most prevalent in hearing impairment. They are enrolled in special schools where they are taught sign language, lip reading, and writing so that they can communicate among themselves and their closest relatives. In reality, in Peru, hearing-impaired people tend to communicate only among themselves. There are also barriers in the environment because the rest of the people do not master sign language or are indifferent to learning it. It is for this group of hearing-impaired people that their right to be able to communicate with everyone should be recognized. There is no uniformity in the sign language, and it cannot be adapted on a universal scale. So there is a Peruvian sign language (PSL or LSP), and there is also a sign language by regions of Peru. In conclusion, we want to determine the best features for the development of a mobile application with Arduino, which on the basis of Peruvian sign language and the common language of the listener can communicate with all people, with people with hearing impairment and that is usually accompanied by speech disability. Through the approach of

human rights and disability, thanks to the initiative of the development of this mobile application with Arduino in Peru we want to improve the communication process of all its inhabitants. The following work is organized as follows: first subtitle 2 Bibliographic Study, then subtitle 3 where everything about the methodology and its development is mentioned, then comes subtitle 4 with the results and discussions that show in detail the work and results of the indicators that will be checked with the descriptive analysis, and as the last subtitle 5, the conclusions will be explained.

2 Bibliographic Study

According to Sampieri et al. [16], he mentions that: "The dependent variable is not manipulated, but measured to see the effect that the manipulation of the independent variable has on it." All human beings need communication as it supports them in transmitting knowledge, finding out about things and various forms of connection between people as the referential dimension comes to be when communication is related to the outside world or the world of objects and is linked to the news or information. The inter-referential dimension is the intercommunication or interaction between people or social agents. The self-referential dimension is when communication is used to present oneself to others and to the world, for example, politicians, and artists, use blogs, and intimate diaries [17, 18]. According to Sampieri et al. [16], the independent variable must be controlled and manipulated and, in turn, must always be ahead of the dependent variable. The mobile application is software that works with applications, just as the computer works with programs [19]. Arduino is a company that provides microcontrollers, with open-source code that allows the development of fun programming with interactive hardware and software projects [20, 21]. Disability is considered a limitation and is approved in 1990 being an impairment for some activities both physical and mental and emerging technologies help to understand new technologies and handle large amounts of information facilitating communication to the disabled [22–24]. Hearing impairment or deafness is considered a disadvantage of hearing loss and at the time of being able to communicate, it is difficult for the first time and as time goes by it is difficult to understand people who hear or are different in an environment or group, since they do not perceive the sounds [1, 25, 26]. Peruvian sign language is used by means of a sign language that interpreters and deaf people continuously use as exercises, hand and body movements, visual attention, and gestures in their meetings or events that they organize because they mostly form groups among themselves [22–24, 27].

3 Methodology

Research methodology is the understanding of understanding the methods that facilitate and enable obtaining the necessary techniques to investigate reach the objectives and maintain a goal of solving given problems in any approach [16].

3.1 Research Design and Type

The SCRUM methodology is to be used and developed by different sprint, and the research design is experimental type, quasi-experimental sub-type in its scope or level of research of explanatory type, with a quantitative approach.

3.2 Population and Sample

A population of 70 deaf associates was taken. A sample of 60 deaf associates, forming the experimental group of 30 deaf associates and the control group of 30 deaf associates, using an instrument validated by 03 experts with master's degrees.

3.3 Data Collection Instruments

In the data collection, the quantitative technique was applied using SPSS 23.0 programs, after testing the reliability of the measurement instrument with the homogeneity of the questions, with the Cronbach's alpha coefficient.

3.4 Methodology Development

Sprint 1—Welcome to the COMSORYO application

That means communication of the deaf and hearing (COMSORYO) has the purpose of showing the logo and different signs of the alphabet to familiarize and a command written lead reading for a deaf link to understand in signs that are COMSORYO, in the second sprint lectura_sordo about what is the application, a microphone button for the listener where the system translates the reading to voice, an arrow on the right side of the keyboard which allows linking to the third sprint and finally an icon that allows connecting by Bluetooth. All the images are taken and designed by the author Alberto Velasquez Fernandez and supervised by the different technical analysts and engineers for their respective manufacture and development. Figure 1a shows the

block code for the development of the different functions of Sprint 1, and Fig. 1b shows the design made in the same Spring 1 of the COMSORYO application.

Sprint 2—lectura_sordo

Explain to the hearing-impaired person, by means of signs, what COMSORYO means, taking a certain time to build the signs by means of paint of approximately one month since it was difficult to do it and in Fig. 2a, the programming in blocks, but in this case, the link was applied to return to Spring 1. In Fig. 2b, the design of what COMSORYO means in Peruvian sign language and the alphabet letter in the upper left part of the sign with an upper and lower scrolling facility including a button to return that indicates the back arrow that was commented previously.

Sprint 3

Figure 3a shows the block code that allows Fig. 3b the operation of the design of Sprint 3, with access to the next page and a link of the lead color command is a free test access that in this sprint, allows free access to the most important part of the system that corresponds to the fourth sprint. Since the hearing-impaired people wanted to reserve the right not to access personal data that could harm them, it is for that reason that no user or password was created, but in the case that it is taken as a business it would have certain rules for access and registration.

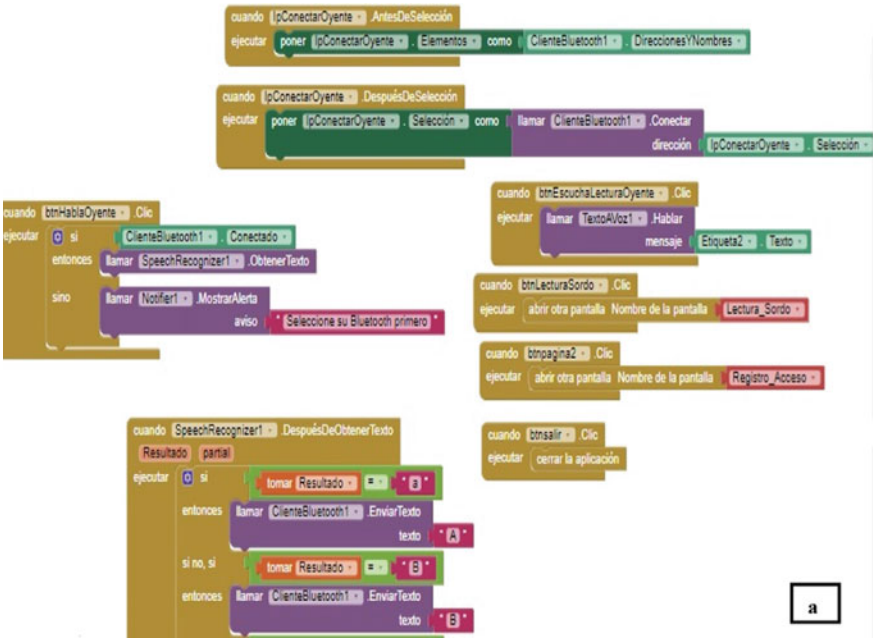

Fig. 1 Interfaces developed in Sprint 1

Fig. 1 (continued)

Sprint 4

Figure 4a shows the code block that will allow the hearing-impaired person to facilitate their communication and learn a little more with the system as shown in Fig. 4b the advantage of having the signs and their respective letters on the keyboard of the application is that they become familiar with WhatsApp and can identify the letters and signs at the same time. The different sprint has a green label where it mentions that the buttons or keys are for deaf or hearing-impaired people, a white arrow command to go to the previous sprint, an Ipconnect button that will connect

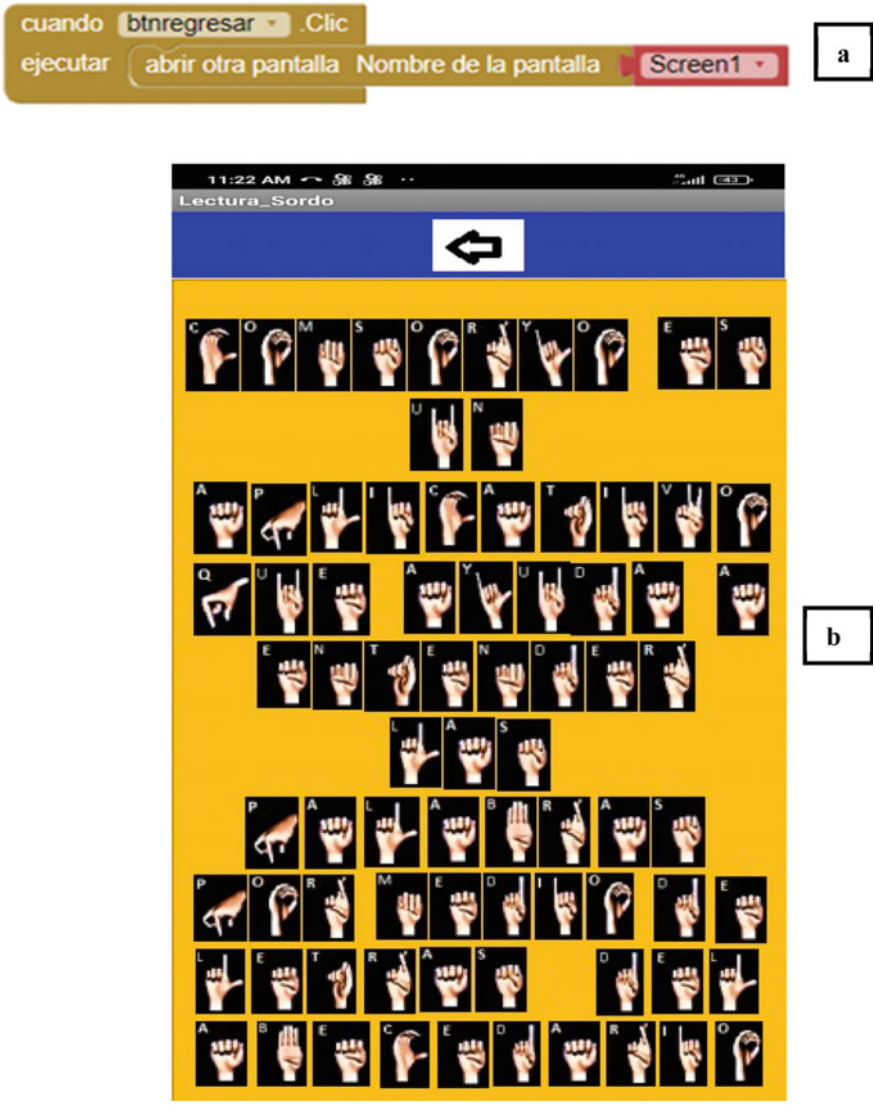

Fig. 2 Interfaces developed in Sprint 2

in Bluetooth mode with the access code 1234 to the application and at the same time by a Bluetooth device with a red LED that will stop flashing when connected to the signal. To connect in Fig. 5a of Sprint 4.

In Fig. 5a, after connecting to the Arduino through the Bluetooth of the device and the Bluetooth of the application in conjunction with the physical Bluetooth of the Arduino in Fig. 5b, it will start to receive the order, without the need for the memory to be filled, the reason is very easy a btnDeleteAll button was created where

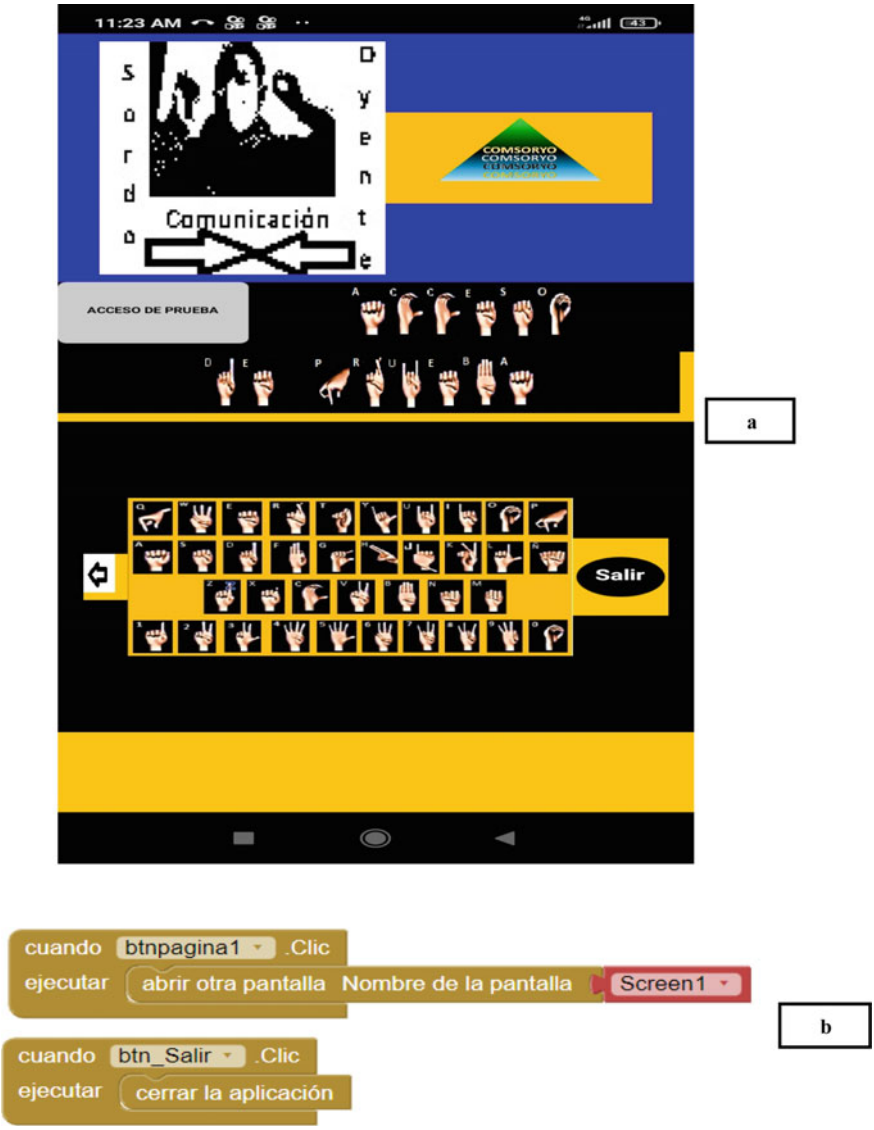

Fig. 3 Interfaces developed in Sprint 3

it will obey the order and allow it to rewrite another word. As visualized in the examples with the COMSORYO application, which by means, which was created a btnDelete button that deletes a letter from the display and another btnSpace button plus a btnSend button that sends from the device what you want to be shown or not on the display, we see indeed that it facilitates communication to the hearing-impaired

Fig. 4 Interfaces developed in Sprint 4

person and makes us hearing people curious how it works and in taking more interest in the subject of communication with deaf people and enter into their world.

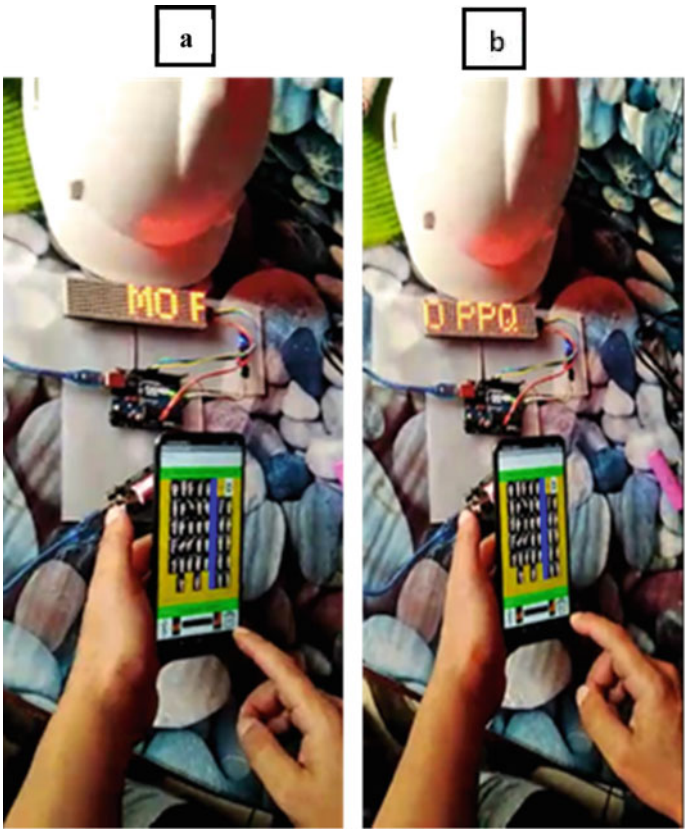

Fig. 5 Interfaces developed in Sprint 4

4 Results and Discussion

4.1 Descriptive Analysis

Indicator 1—Referential dimension. Figure 6 shows a similarity in the results obtained, in both pretest 60 and posttest 60, the value of the mean that does not favor the hearing-impaired person, due to the descriptive analysis shown, and this means that it will not facilitate the system or complicate communication, thanks to the survey conducted for the respective verifications.

Indicator 2—Inter-referential dimension. The results obtained show a minimal difference in Fig. 7, the mean value in the pretest is 59 and in the posttest is 60, these numbers favor the hearing-impaired person since the descriptive analysis shows that the system will facilitate communication with the hearing person.

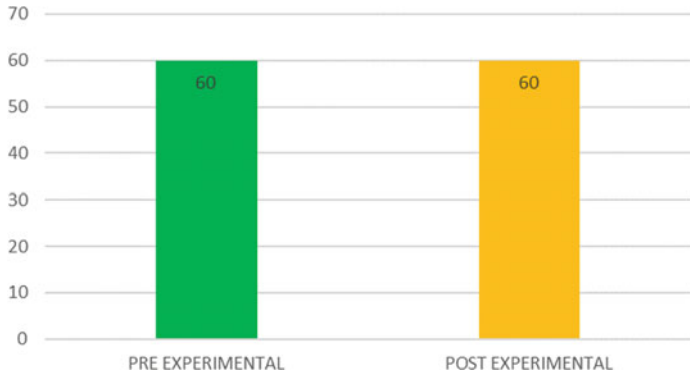

Fig. 6 Mean of pretest and posttest of Indicator 1, communication of the referential dimension

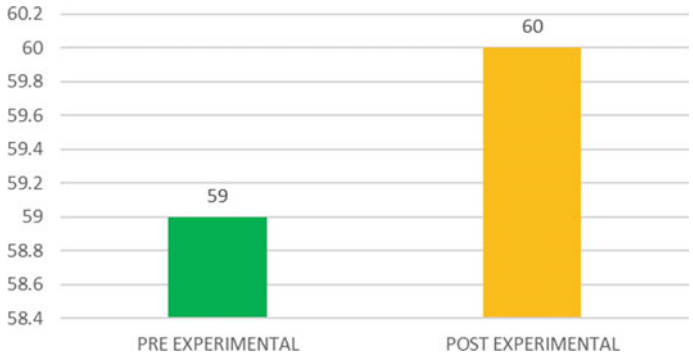

Fig. 7 Mean of pretest and posttest of Indicator 2, communication of the inter-referential dimension

Indicator 3—Self-referential dimension. The test with the survey has given results that are visualized in Fig. 8 where it determines how the descriptive analysis verifies, the value of the mean showing in the columns of pretest 59 and posttest 60, giving the opportunity to the hearing-impaired person, to be able to have an understandable presentation thanks to the system improving their communication with the listener and facilitating the fulfillment of more objectives and goals.

The satisfaction percentages in Fig. 9 show the different results in shapes and sizes of column bars, where the highest percentage is 52% in pre-experimental indicator 1 and the lowest percentage is 2% in indicator 2, also pre-experimental.

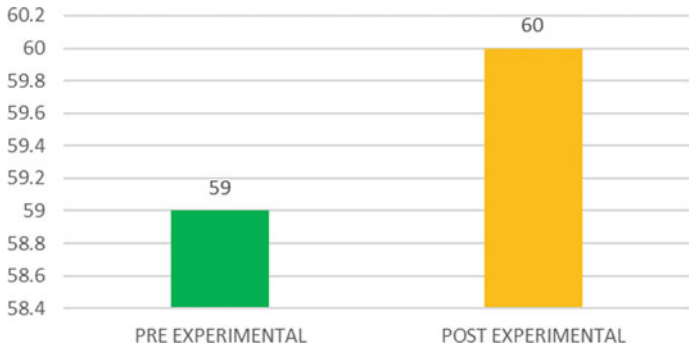

Fig. 8 Mean pretest and posttest of Indicator 3, communication of the self-referential dimension

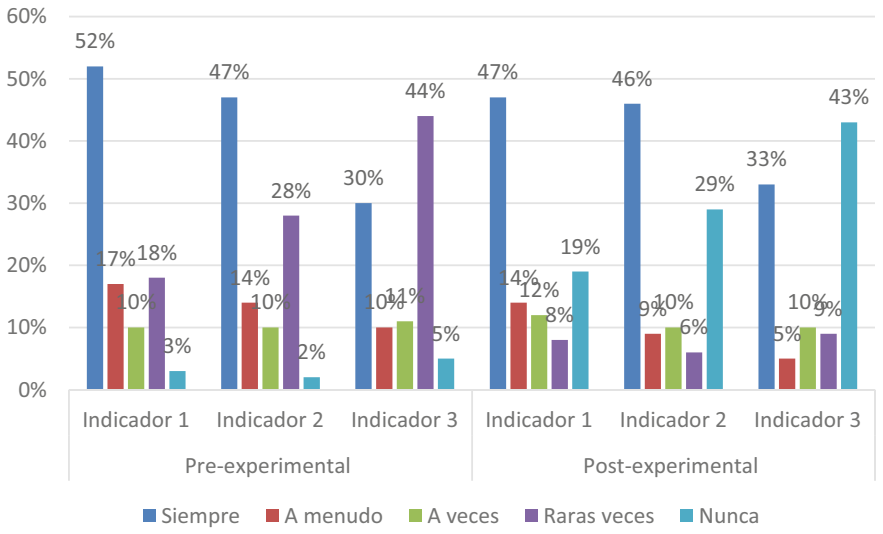

Fig. 9 Percentages of satisfaction of pretest and posttest experimental results obtained for each indicator

5 Conclusions

Applying the mobile application system with Arduino to improve the communication process with hearing-impaired people in the association of the deaf with opportunity for all. San Juan de Miraflores. 2022. The following conclusions are reached.

It was determined; a non-significant influence of the mobile application system with Arduino in the referential dimension with its indicator visual recognition of communication media, going from start to plan with averages of the mean from pre-60 to post-60 in the referential dimension of the communication process in the experimental group. As observed ($p > 0.05$), it means that this system is not useful

for the deaf or hearing-impaired person to get references for things or news. It was specified; a significant influence of the mobile application system with Arduino in the inter-referential dimension with its indicator recognition of means of communication between people, passing from the beginning to the expected with averages of the mean from pre-59 to post-60 in the inter-referential dimension of the communication process in the experimental group. According to what was observed ($p < 0.05$), it means that this system helps and serves the deaf or hearing-impaired person to be able to communicate with a hearing person.

It was established; a significant influence of the mobile application system with Arduino in the self-referential dimension with its indicator presentation of my person, passing from start to plan with averages of the mean from pre-59 to post-60 in the self-referential dimension of the communication process in the experimental group. According to what was observed ($p < 0.05$), it means that this system is useful for the deaf or hearing-impaired person to be able to communicate with a hearing person. We hope that it will be of great help for the deaf or hearing-impaired person, so that in any place that he or she needs it, he or she can communicate with hearing people and explain in a clear way what he or she does, for example, a form of presentation on his or her helmet and say that he or she is a painter, bricklayer or carpenter and in this way be able to express what he or she wants to say so that he or she can be hired and obtain benefits of having his or her work noticed, not making such a costly investment.

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Evaluating Prospects in Programming with Features in Graphic Function Use

Tomoharu Kobayashi, Fumiko Harada, and Hiromitsu Shimakawa

Abstract Evaluation of thinking will become more important in Japanese programming tasks in the future. We propose a method for creating and analyzing quantitative features as an aid to evaluation in group learning. Based on the process of thinking activities in programming tasks, task experiments were conducted. Feature vectors were created from the data obtained in the experiment and visualized using principal component analysis. As a result, we discovered the possibility of identifying on the spot the condition of students with poor prospects. This will provide an unprecedented quantitative evaluation method for thinking activities during programming tasks.

Keywords Programming · Computational thinking · Source code · Figure drawing · Feature vector · PCA

1 Introduction

1.1 Programming Education in Japan

From the 2020 academic year onward, education in Japan has been based on the new government course guidelines. As a result, programming education has become compulsory in primary and secondary education and has gained importance. In the programming education guide published by the Ministry of Education, Culture, Sports,

T. Kobayashi (✉) · H. Shimakawa
Graduate School of Information Science and Engineering, Ritsumeikan University, Kyoto, Shiga, Japan
e-mail: tomoharu@de.is.ritsumei.ac.jp

H. Shimakawa
e-mail: shimakawa@cs.ritsumei.ac.jp

F. Harada
Research Organization of Science and Technology, Ritsumeikan University, Kyoto, Shiga, Japan
e-mail: harada@de.is.ritsumei.ac.jp

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Science and Technology, the term "programming thinking" is used as a keyword. This programming thinking is a mindset and ability that can be developed through programming education. In a word, it is the ability to construct procedures. The guide says that one major goal is to develop programming thinking.

However, there are two educational issues about it. First, it is unclear how to evaluate the thinking process. This is due to the lack of experience in the new educational system. Second, it is difficult to evaluate thinking ability in group learning. To evaluate thinking skills, for example, simple calculations and correct memorization of theorems are not enough. As in a proof problem, the process of how to use them to derive the necessary matter is important. It is physically impossible for a teacher to observe the thinking processes of more than ten students at a time. It is also tough to evaluate tasks with different characteristics using a common indicator, as there is currently no standard. In this paper, we focus on these issues and propose a new evaluation method in programming education to solve them.

1.2 Programming Education in Overseas

Many countries have already started programming education earlier than Japan. Programmatic thinking, discussed in Sect. 1.1, which is an educational goal, is what we call computational thinking [1] in other countries. In countries with advanced programming education, there are many studies that relate programming to computational thinking. Tikva et al. [2] and Fagerlund et al. [3] present a review of the literature related to computational thinking. This study refers to a lack of indicative research examples in the evaluation of computational thinking and to the causes of this lack. One of the causes is the difficulty of grasping the reality of the thinking process itself. Another cause is that the results of each study may be dependent on regional differences and curriculums. Programming thinking is based on the idea of computational thinking, so issues related to computational thinking are common. Therefore, solving these two causes is necessary to tackle the educational issues discussed in Sect. 1.1.

As the first solution to these problems, this paper deals with a thought-readable task suitable for primary education. In this way, we clearly define how we grasp the thinking in programming. Second, the method is independent of the environment and the individual so that it can be applied to a variety of situations. Specifically, we create a quantitative evaluation indicator. In this paper, our policy is to deal with figure drawing tasks and to convert source code into features, and these policies are discussed in detail in Sect. 2.

2 Policies for Issue Resolution

In Sect. 1, we mentioned the issues in Japanese programming education and proposed our policy to solve them. The policy is to use graphic drawing tasks as the target of analysis and to use source code as a feature. In this chapter, we mention the policies in detail.

2.1 Use of Figure Drawing Tasks

According to reports on the implementation of programming education in Japan, the majority of elementary schools use visual languages such as Scratch and Viscuit. These tools are used because they are suited for primary education. Methods of operation are sensible and user-friendly. It is easy to recognize mistakes because the execution results can be visually confirmed. In this way, programming that has visual results is more challenging for the beginner. Based on these considerations, we suggest that it is necessary to be limited in the tasks targeted in this paper to find an evaluation method for thinking activities during programming.

There are different styles of programming, depending on the content of the task being handled. It is not realistic to present an evaluation method covering all of them. There are two important points. The first is to target intuitive tasks applicable to elementary education. The reason is that the educational issues discussed in Sect. 1 are about elementary education in Japan. The second is that the structure of the solution is unique. Tanigawa et al. [4] found that there are common patterns among students in figure drawing tasks. The tasks they used were tasks with a set order in which to draw. If the order of drawing is not specified, there will be an unlimited number of correct procedures, making it difficult to distinguish between good and bad thinking. Similarly, if a procedure can be described by a series of different pairs of functions, it becomes difficult to determine the correctness of the procedure. Therefore, it is necessary that the expression of the program is unique in evaluating the thinking during the task. If such is the case, it is possible to discern students' thinking patterns from their answers, as in the study by Tanigawa et al. However, Tanigawa et al. only focus on final answers. In this paper, we propose a method to evaluate students' thinking during solution of a task.

2.2 Conversion of Source Code to Features

In evaluating students' thinking activities during programming, time series data arising from students' activities is necessary. Bosch et al. [5] and Grafsgaard et al. [6] and Jaques et al. [7] estimated students' emotions in learning, including programming, from sensing data of body movements and eye gaze. There are many studies like

these that estimate tendencies during learning from sensing data that may be useful. However, in actual education, it is too costly to provide a sensor for each student.

So what kind of data is being dealt with in studies that focus on computational thinking? Guggemos et al. [8] showed a relationship between students' computational thinking ability and surrounding factors. Wei et al. [9] showed the direction of an effective approach for improving computational thinking by conducting a controlled experiment in elementary school subjects. Different from sensing data, these studies connect the quality of computational thinking to indicators such as questionnaires for students and the scores that students earned on tasks. However, data obtained after a task cannot be used to estimate thinking about the contents of the task in the process of answering it. If the data are not time series data that occur during the solution process, we will miss the timing of interventions that are closely related to the contents of tasks.

Based on these considerations, in this paper, we propose to use source code as feature data for evaluating thinking during programming. Source code can be collected without special equipment such as sensors. In addition, their content is the idea itself that the student hopes to realize. Observing changes in source code will help estimate the student's thinking about programming tasks. However, dealing with source code as text is not a good way to analyze thinking about tasks. This is because it is difficult to derive semantic differences from variations in textual expression. Therefore, in this paper, we aim to provide a quantitative evaluation indicator by converting the source code into features of vector expression. In Sect. 3, we describe in detail the methods used to deal with source code as a feature.

3 Quantitative Evaluation of Thinking by Feature Vector

In Sect. 2, we found the possibility of distinguishing students' thinking patterns in programming tasks such as those represented by figure drawing. In addition, we established a policy to handle the source code as time series data for estimating the students' thinking in the task. In this chapter, we describe a method for using source code as vectorized features.

3.1 Procedure for Creating Feature Vector

In this section, we propose a method to convert source code into feature vectors. Figure 1 shows the flow of creating feature vectors based on source code. Next, we describe the procedure of creating feature vectors according to Fig. 1. As a general flow, function logs are obtained from the source code, and feature vectors are obtained from the function logs.

First step is to obtain source code. While students are solving programming tasks, we record their source code sequentially. In this way, a source code for each timepoint

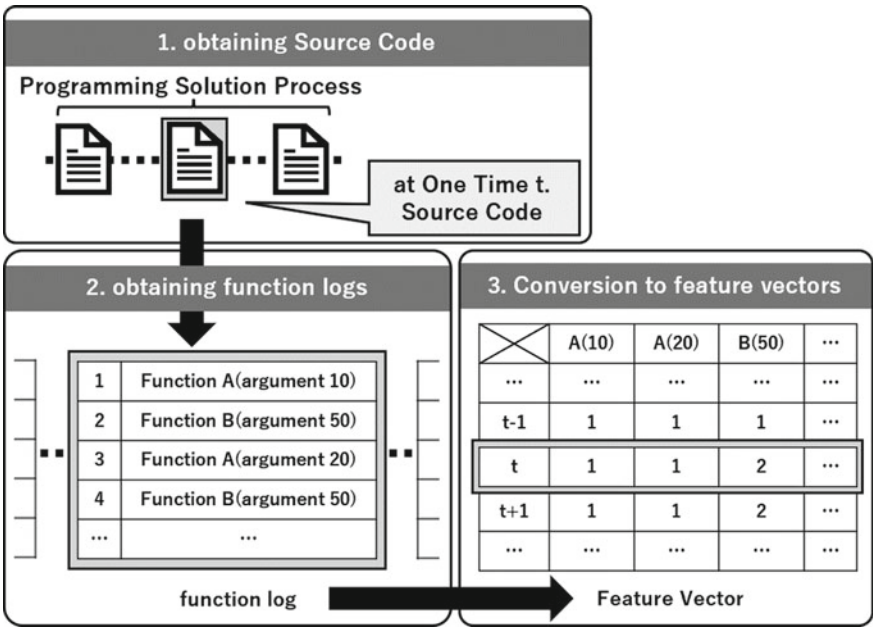

Fig. 1 Procedure for creating feature vector

becomes a single sample of time series data. In our data collection experiment in Sect. 4, we recorded source code at 1s intervals. The time interval should be set to sufficiently follow changes in source code during programming, for example, a change that one function increases. We consider that one second is sufficient for that time interval, taking into account keyboard input of source code and editing of puzzles such as Scratch.

The second step is to obtain the function log. The number of functions written as text in source code may be different from the number of functions called. This is because iterations and conditional branches determine the order of functions to be called. Therefore, the order in which functions are called during operation and the values of their arguments are important in order to properly represent what the student intends to achieve. From each source code recorded during the task, we obtain logs of functions and arguments when it is executed. Therefore, a time series data of function logs is created, equal to the number of source code samples. In Sect. 4, we realize function logging on the back end by replacing drawing functions handled in tasks with functions that log themselves when they are called.

The third step is to obtain feature vectors. A sequence of feature vectors is a combination of functions and arguments that occur in source code. We measure how many times each combination is called by referring to the function log. If the number of columns is n, the image is that of a $1 \times n$ horizontal vector. Then, it will be a feature vector with the number of rows for the time series length by measuring it for all function logs.

The above is the procedure for converting the time series data of source code into a feature vector. By measuring the number of function calls, the source code at time point can be turned into a vector representation of numbers. In addition, the subject of this paper is to use it as a quantitative indicator to evaluate students' thinking. In Sect. 4, the process of executing the obtained source code to generate function logs and feature vector is performed in a batch. However, the conversion of the obtained source code into function logs and feature vectors can be done in parallel with obtaining the source code itself. Therefore, it would be possible to use the feature vectors generated during class tasks for immediate intervention, although a delay of a few seconds should be considered.

3.2 Distance Evaluation of Thinking State

In Sect. 3.1, we created a feature vector for quantitative evaluation, based on the idea that source code well represents thinking about a task. Furthermore, it is important to know what kind of time series changes in the feature vectors are expressed by the progression and regression of the student's thinking state. To this end, we should consider how the activity of thinking develops during programming. In this section, we explain our assumptions about the development of thinking activities during a task and a method for distance evaluation of thinking, based on these assumptions.

When solving programming tasks, students' answers are expected to approach the correct answer in a stepwise manner. It is difficult to construct the perfect structure, such as a flowchart, needed for a task from the beginning. A novice programmer unfamiliar with programming would construct the structure halfway through or would implement the conditional branch later, for example. If the drawing task has a unique procedure, such as a drawing song, students will naturally implement it according to that procedure. This is because the coordinates of an object are affected by the previous procedure. In a drawing task, the brush is the object. In this study, graphic drawing tasks were employed to clarify the criteria for evaluating thinking. However, this assumption would be common in many programming situations.

In addition, we consider that the activity of constructing elements step by step follows a transition similar to a tree structure. As discussed earlier, students' thinking is expected to approach a correct answer in a stepwise manner. This is because source code required for a correct answer can be divided into stepwise elements. Stepwise elements are those necessary for coding, such as the configuration of each component, iterative expressions, and conditional branches. If a unique procedure for a task is defined, the order in which each element should be implemented will naturally be defined. Depending on the student's ability, they might skip some of the stepwise elements. However, even in such cases, there is an absolute flow of steps that approach a correct answer.

Of course, it is possible to make a mistake during the solution. A mistake is to code differently from the correct one for the element to be realized. In that case, students would make modifications to the same element until the result of that execution is

correct. Thus, for each graded element, a pattern of errors occurs around the pattern of correct answers. Thus, a pattern of errors occurs around the pattern of correct answers for each of the stepwise elements.

Based on these assumptions, we propose a method for evaluating students' thinking during tasks. The feature vectors described in Sect. 3.1 are, so to speak, coordinates that represent the stages of the student's thinking during the task. The feature vector is a transformation of source code, and it is closely related to the patterns that occur during a solution. If the students' thinking process on a given task extends as in the hypothesis, the feature vector is an indicator for grasping that movement. If the number of columns of feature vectors is the number of dimensions, the vector at each time point obtains a position in a multidimensional space as a coordinate. Specifically, we try to capture movements in students' thinking activities by observing changes in the coordinates of vectors in time series. In Sect. 4, we will examine whether feature vectors obtained in experimental tasks can grasp the movement of the student's solution process.

4 Data Collection Experiments and Feature Vector Analysis

In order to confirm the method described in Sect. 3 in practice, we conducted a task experiment for the purpose of collecting data. In Sect. 4, we describe this experiment. In addition, we describe the process of converting collected data into feature vectors and the results of analysis.

4.1 Outline of the Task Experiment

We conducted an experiment of solving a figure drawing task for 26 undergraduate and graduate students. There were two tasks, each with an approximate solution time of 30 min. The programming language used for tasks was Python, and the standard library Turtle Graphics was used for drawing graphics. All participants had learned how to use Python and were able to handle functions for drawing without any problems after explanation in a tutorial. They could ask their supervisor any questions about the descriptions. This is to eliminate as much time as possible for stagnation due to writing errors, which is not a concern regarding the content of tasks. In addition, since participants basically used their own computers to solve tasks, it is believed that they were able to solve tasks like in their usual coding.

Figure 2 shows one of the two tasks used in the experiment. Note that the text in Fig. 2 is in Japanese because it shows tasks that were actually handled directly. In tasks, the left side of the screen is a description of a graphic drawing task. It consists of an animation in Gif format, an image of the completed drawing, and text of supplementary explanations such as numerical values. On the right side of the screen is the editor. There is a source code editor at the top and a box with debug

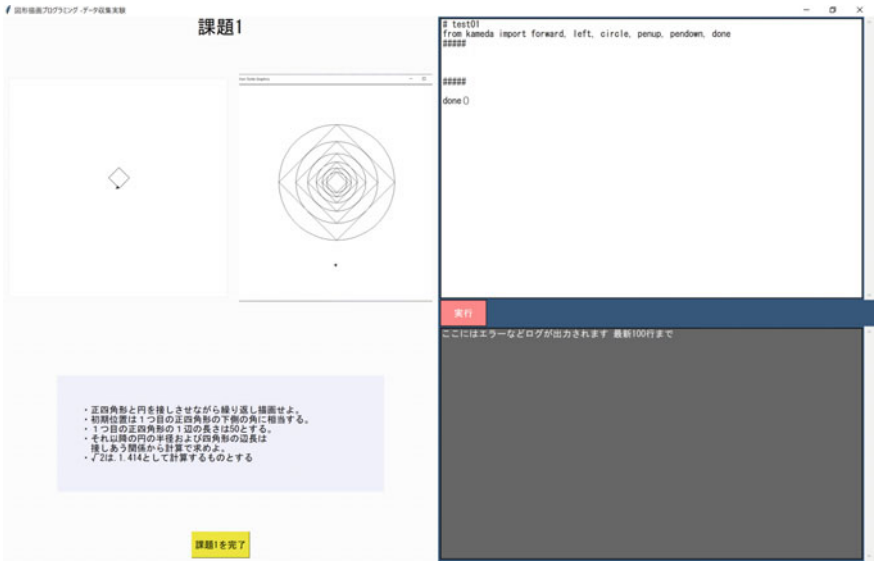

Fig. 2 Figure drawing task in the data collection experiment

log output at the bottom. There is an execution button in the center, which can be pressed to check the drawing result with current source code.

As a result of this experiment, we collected data of source code for 23 of the 26 participants. Based on the reactions of three participants who solved tasks at first, contents of tasks were changed, and the difficulty level was adjusted. Therefore, we determined that the data for those three should not be included in the analysis. About 17 (74%) were able to solve the first task, and 19 (83%) were able to solve the second task. In both tasks, the percentage of students who solved these tasks in a given time was less than half of the total number of students who solved the tasks. Therefore, participants were divided into three categories: those who completed the task within 30 min, those who took more than 30 min to complete the task, and those who did not complete the task within the time and gave up. As a result, the difficulty level of tasks was appropriate for participants, and there was a moderate progression of thinking.

4.2 Attention to Conversion to Feature Vectors

We converted source code collected from the experiment in Sect. 4.1 into feature vectors. In this section, we list some considerations when creating feature vectors. As explained in Sect. 3.1, for each participant, there is a time series of source code data. In this experiment, source code was recorded every second, so the number of

files recorded would be about 1800 for a 30-min solution process. Also, we ran those files in our logging environment to get function logs, but the execution can be an error. In such cases, the features obtained from the source code, which had been successfully executed at the previous timepoint, were taken over. Basically, syntax errors occur during the process of writing the source code, so the feature vector would change at the time when one's hand stops.

Regarding feature vectors, we consider the setting of feature columns to be very important. Columns of feature vector are combinations of functions and arguments. Basically, combinations are needed in columns that should be used in that task. However, it would not be an exhaustive representation of students' solutions. This is because incorrect argument values will result in combinations that should not be there. In this analysis, for each function, functions called with incorrect arguments are measured as other. If the argument is a continuous value, assuming the wrong argument will result in unlimited column subdivisions. In addition, the number of combinations that should be there may be too many or too few when mistakes are made. We added columns of the total number of times each drawing function was called to the features, so that the features include information on the overall number of function calls.

In this analysis, for each drawing function, the following are included in the sequence of feature vectors. The total number of functions, each in combination with the arguments required to draw the task, and a combination of the other. In two tasks used in this experiment, the number of columns of this feature was 23 for the first task and 30 for the second task.

4.3 Principal Component Analysis of Feature Vectors

Principal component analysis (PCA) was applied to 23 feature vectors obtained through previous sections. By applying PCA, dimensions of feature columns are compressed to two dimensions. The purpose of this is to visually check coordinates of student's solution process. The contribution ratio up to the second principal component was 0.664.

Note that the features were normalized before PCA. The feature values of the correct answer were set to the maximum values. Columns with combinations of other arguments were dealt with exceptionally. They were converted to values that took the natural logarithm and added 1 if it exceeded 1. The number of combinations with arguments that are not essentially invoked could be excessive. This is mainly the case when the argument is wrong for a function inside a repeated expression. This phenomenon has a biased effect on the PCA fit, so we made an exception to this process. This process suppresses large values, but the closer the value is to 1, the more its face of magnitude can be retained.

Figure 3 is a scatter plot of the set of time series feature vectors of the participants. The vertical and horizontal axes of each graph are the first and second principal components. The scatter plots at the top show the ideal step-by-step flow of correct

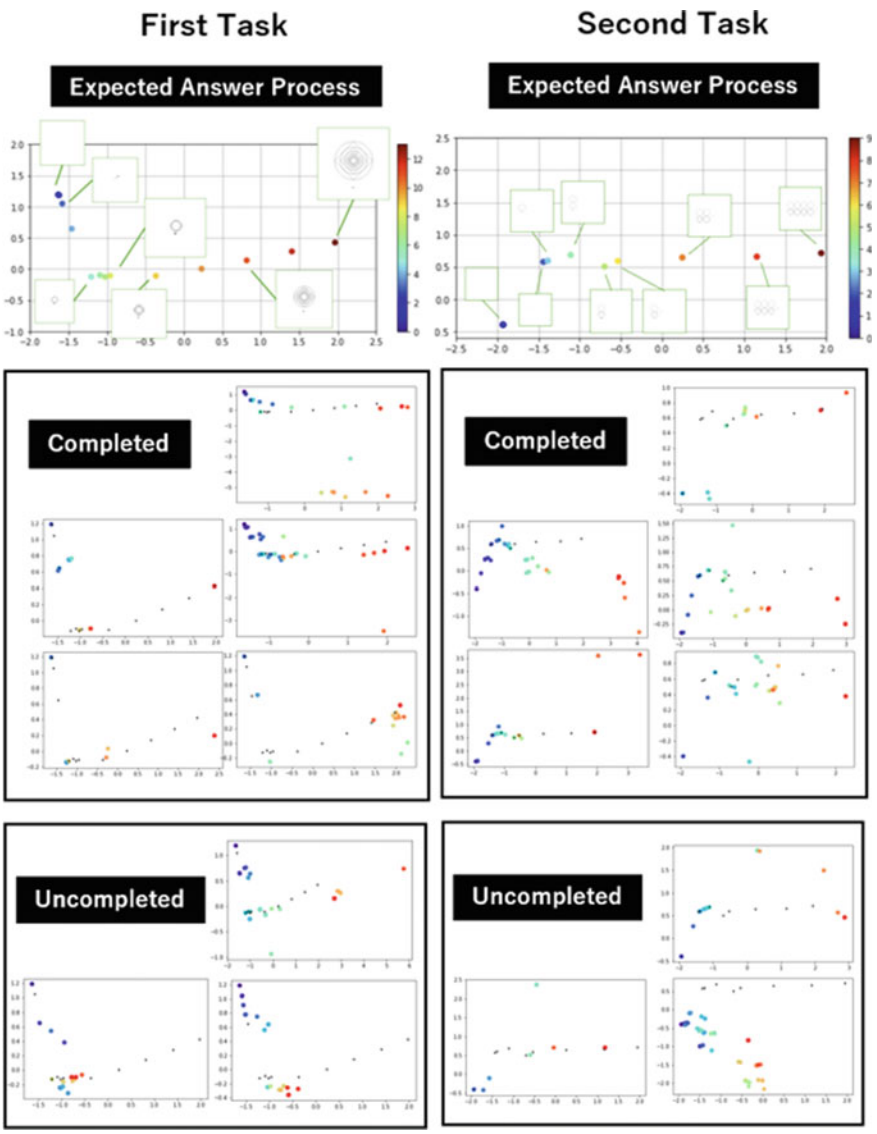

Fig. 3 Scatter plot with coordinates of vector applied PCA

answers in the first and second tasks. They are colored according to the color scale in chronological order of occurrence. (If these are not color images, they may be difficult to see.) In each task, the five examples that reached the correct answer and the three that didn't are to be included as representatives of the participants. In participant's examples, the correct answer at the top is indicated by a black dot. The plot of participants' chronological vector coordinates changes color from blue at the beginning to red at the end.

We discuss what we can confirm from these results. First, as assumed in Sect. 3, the stepwise flow of positive responses was found to exist in a somewhat linear fashion. Some of the correct respondents also had a group of points that nestled into the flow of correct answers. However, due to differences in representation in the tasks, some of the final answers existed at positions in the scatter plots that were outside of the correct answers, even though they were roughly the same drawing results. For the incomplete ones, we found that many of the point clouds stopped in the middle of the party flow. It can also be seen that they stayed at the same coordinates for a long time by the colors consisting of color scales. This means that when a student's thinking is stuck, its characteristics can be inferred from the degree of change in the coordinates. It can also be seen throughout that the description of the error moves the point to a coordinate far from the correct answer.

According to the results of this section, focusing on time series changes in feature vectors is effective for thought evaluation. There is a step-by-step flow that serves as the trunk of the solution process during programming. The feature vectors during the challenge to the phasing factor are also surrounded including mistakes. If the feature vector deviates significantly from that trunk, it can be easily identified as an inappropriate prospect direction. In addition, if there is no movement in the feature vector and the branches of the solution process do not grow, it can be judged that the student does not have prospects. Moreover, it was confirmed that this method can visually determine these facts.

5 Conclusion

In this paper, we mainly discussed the handling of feature vectors, with the goal of evaluating students' thinking during programming. The figure drawing task employed in the assignment has a good track record for beginning students, and the thinking seems to be easy to read. Assumptions about the thinking activity during the task defined how the feature vectors could be used for evaluation. The feature vectors are quantitative indicators based on the source code in the task. An experiment to actually obtain this feature vector was conducted and analyzed. The results of the two-dimensional plots by PCA showed that the students' thinking activities could be read from the feature vectors. In particular, it was possible to determine visually enough from the results of the plots to determine if there was a lack of prospects and if the mistakes were quite out of line.

For future outlook, more careful handling of feature vectors needs to be considered. First, regarding the column setup, we would like to separate the ranges for the other columns or take out only those that occur frequently. This may allow for a better representation of the content of the mistake case in the feature vector. Other future developments include preprocessing the principal component analysis and making the task more relevant. We intend to further improve the effectiveness of the feature vectors discovered in this paper.

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National Policy Evolution: A Survey of the Opportunities and Impact of Artificial Intelligence Policies in International Cybersecurity

Taylor Rodriguez Vance

Abstract Artificial intelligence as an emerging technology that is pervasive, evolving, and constantly changing direction in both the public, private, and academic sectors**.** With artificial intelligence being integrated into the daily lives of citizens, in home appliances, in social media platforms, and in their work processes, nation states have been sprinting to keep up with the ever-changing technological landscape with appropriate policies and regulations. An additional aspect that nation states must consider with regard to policy and implementation of this technology is the utilization of artificial intelligence by bad actors, including those that target national governments. Nation states must be able to address this threat and have the capability to defend their critical infrastructure. This research evaluates the current international policy instruments that exist relating to artificial intelligence, with a focus on those policy instruments that address cybersecurity. The quantitative results will provide an improved understanding in the current policy instruments by government entities for nation states in the realm of artificial intelligence, identify potential future areas of priority, as well as address and gaps in policy based on current issues.

Keywords Artificial intelligence · International policy · Cybersecurity · Emerging technology · Security

1 Background

When understanding advanced technology and its impact on citizens, national governments, and industry, it is key to evaluate the lifecycle phase that the technology is in. Historically, these technologies such as cloud computing, blockchain, Internet of things (IoT) tend to follow the same path through certain recognizable phases. These stages occur in the following order: Market Development (Stage 1), Market Growth (Stage 2), Market Maturity (Stage 3), Market Decline (Stage 4) [1].

T. R. Vance (✉)
Capitol Technology University, Laurel, MD 20708, USA
e-mail: trodriguezvance@captechu.edu

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With regard to this research, this is important to note as the point in which a nation state determines that national policies and regulations need to be developed and implemented is being evaluated. For artificial intelligence, it can be assumed that the technology is squarely in the Stage 3, Market Maturity. This is due to several factors, including but not limited to, the wide adoption of the technology in consumer and business devices and processes, the extent of scientific research in the area, and the number of existing policies and regulations. When it comes to the policy development and adoption of government entities for emerging technologies, there is typically a point at which this occurs for the majority of technologies, at least on a larger, public scale. Once a technology enters the Market Maturity stage, government entities typically begin wider adoption within the government itself [2]. In today's highly technological world, there is a heightened focus on security of that world by nation states, focusing on cyberspace. An emerging technology such as artificial intelligence can be a capacity builder for governments in a variety of sectors, but that also means that it can be a capacity builder for bad actors that want to act maliciously against those nation states. This puts high importance on the understanding, development, investment, and implementation of artificial intelligence in cybersecurity for government entities.

There has been significant research conducted in general in the areas of artificial intelligence; however, this paper addresses research specific to the artificial intelligence policies and regulations addressing cybersecurity and national security concerns. The relevance of this survey paper is to provide a baseline for the current policy instruments that exist for artificial intelligence and cybersecurity to set a foundation for future deeper research into the role that policy plays in actual government operations and applications.

2 Methodology

This survey paper provides a quantitative evaluation of the existing national policies and regulations for artificial intelligence and cybersecurity for government entities. For the purposes of this research, only specific target groups, government entities, and related policy instruments were evaluated. The research involved the utilization of several authoritative and formal databases and tools to identify the sets of existing national policies and regulations and primary document sets directly from governmental websites. The data set categories were divided into three sections: national governments, sub-national governments, and international entities.

The data sets were then further divided into the types of policy instruments, to include 24 explicit types. The data set was then analyzed and categorized to identify all data specific to cybersecurity and security policy instruments. This data set was pulled from a live repository of over 800 artificial intelligence policy initiatives from 69 countries, territories, and the European Union [3]. These policy instruments were then compared to government documents provided directly by government websites to identify priority and any shift in priority.

It was found that there is a significant amount of policy instruments dedicated to artificial intelligence; however, a significant gap in the number of policy instruments that address cybersecurity and artificial intelligence for government entities. These results led to the conclusion that although artificial intelligence is in the Market Maturity stage of a product's lifecycle, national policy instruments addressing consumer and industry evolution exist but there is a severe lack in policy instruments that address cybersecurity and national security for artificial intelligence for government entities.

3 Results

Throughout the course of this research, several key results were identified. The results and the related analysis are provided below by topic area. The following data points represent a limited view of the true values based on limited access and unavailability of further data sets.

3.1 Policy Instruments by Government Type

The initial phase of this research began with the evaluation of policy instruments by government type. Overall, there were 548 policy instruments that were categorized into target group: governmental entities [4]. Comparatively, this target group had the largest number of policy instruments out of the eight target groups, diverging significantly from other target groups including Research and Education Organizations and Economic Actors (Individuals). Historically, the adoption and development of policy occur much later in government agencies than in any other target group. It is an interesting data point that the target group for government entities exceeds the number of policy instruments for other target groups and future research could provide further insight and correlation as to why this may be.

National Governments. There were 505 policy instruments that were categorized in the sub-target group of national governments [5]. The top three highest density of policy instruments associated with national governments were national strategies, agendas and plans (178), emerging AI-related regulation (127), and Public Consultations of Stakeholders or Experts (105). These policy instrument types include 24 explicit categories as shown in Fig. 1. This data set could represent the alignment with the Market Maturity stage that artificial intelligence is in with the amount of policy instruments for nation states dedicated to government entities.

The attribution of these policy instruments spans over 60 countries. The highest density of policy instruments is in the USA (52), the UK (41), and Columbia (25). It could be inferred that nation states with governments that have been focused on emerging technologies will be the ones with the most policy instruments for artificial

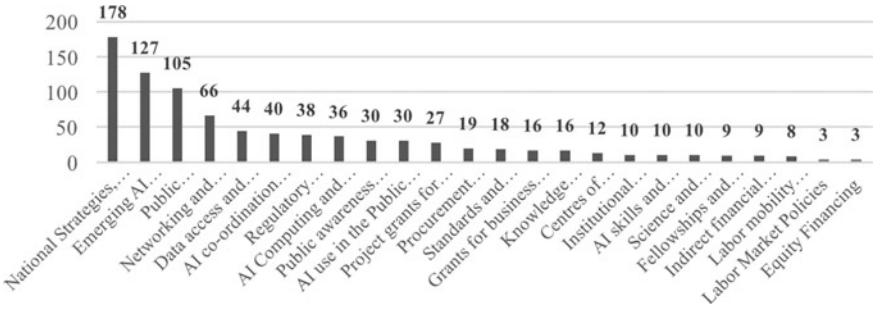

Fig. 1 Policy instruments for national governments by policy instrument type

intelligence. This can be seen in the top two nation states, USA and UK. An interesting data point, however, is that Columbia currently has more policy instruments than all other nation states listed in this database. Further research should be conducted to better correlate this finding to the level of maturity in governmental operations and applications for artificial intelligence (Fig. 2).

Subnational Governments. There were 107 policy instruments that were categorized in the sub-target group of subnational governments [6]. The top three highest density of policy instruments associated with subnational governments was national strategies, agendas and plans (57), Public Consultations of Stakeholders or Experts (23), and Networking and Collaborative Platforms (22). These policy instrument types include 24 explicit categories as shown in Fig. 3. This could represent the focus of subnational governments in pursuing the development national strategies, regulations, and participating in collaborative groups for artificial intelligence.

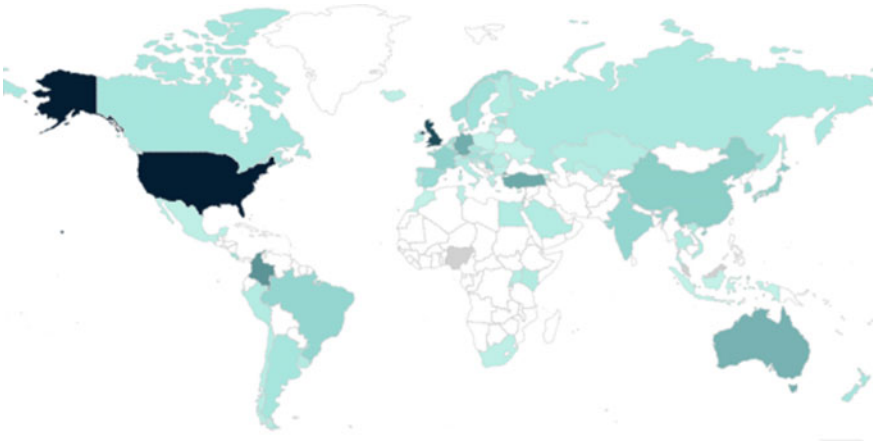

Fig. 2 Visualization of national government policy instrument count by country

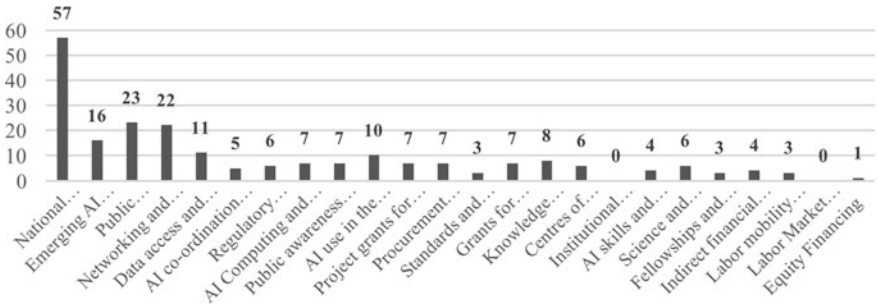

Fig. 3 Policy instruments for subnational governments by policy type

The attribution of these policy instruments spans over 60 countries. The highest density of policy instruments is in the Columbia (11), the Japan (7), and the Netherlands (6). This could represent the desire of subnational government entities, such as states or regions, within a nation state to develop policy instruments specific to artificial intelligence. The data set could also represent the potential expanded ease of policy instrument creation at a lower governmental level for certain countries. Based on the data, it could also be inferred that there is more internal development occurring within nation states on artificial intelligence policy than external development. The analysis to make this determination could be conducted in future research to provide further correlation (Fig. 4).

International Entities. There were 101 policy instruments that were categorized in the sub-target group of international entities [7]. The top three highest density of policy instruments associated with international entities were national strategies, agendas and plans (28), emerging AI-related regulation (26), Public Consultations

Fig. 4 Visualization of subnational government policy instrument count by country

of Stakeholders or Experts (17), and Networking and Collaborative Platforms (17). These policy instrument types include 24 explicit categories as shown in Fig. 5. This could represent the focus of international entities in participating in the development of national strategies, regulations, and participating in collaborative groups for artificial intelligence.

The attribution of these policy instruments spans over 60 countries. The highest density of policy instruments is in the UK (5), Columbia (5), and the USA (2). This could represent the maturity of these nation state's artificial intelligence programs and their national strategies to address it. While international entities are not widely regarding as critical influencers in policy adoption, studies have proven that these groups are important in the initial stages of pushing for change and updates in governmental policy [8] (Fig. 6).

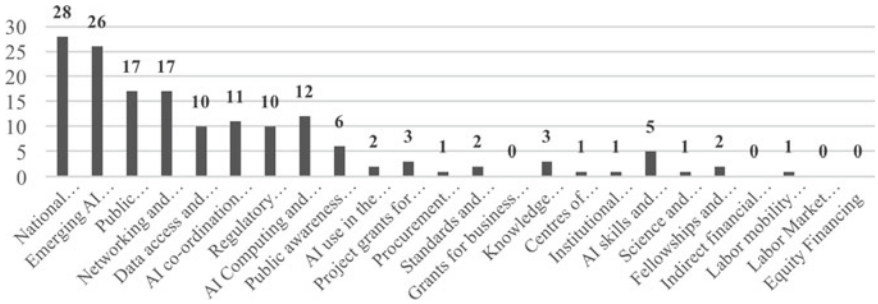

Fig. 5 Policy instruments for subnational governments by policy type

Fig. 6 Visualization of international entity policy instrument count by country

3.2 Cybersecurity-Related Artificial Intelligence Policy Instruments

To evaluate the quantitative impact of cybersecurity or national security-related artificial intelligence policies, the above data had to be decomposed and evaluated in detail. To describe the analysis and results, the outcomes are provided below categorized by the top three policy instrument types identified for each sub-target group. There is a limitation to this research based on the availability of the data and the ability to analyze the data points at a granular level. The following results and analysis depict the policy instruments that are specific to cybersecurity in artificial intelligence.

National Strategies, Agendas, and Plans. In total, there were 263 policy instruments for national governments, subnational governments, and international entities. There was one policy instrument that was specifically focused on cybersecurity in artificial intelligence. This policy instrument is titled Cybersecurity for AI Deployment, and it originates from Colombia. The policy encompasses the establishment of measures that expand digital trust and improve digital security, with the responsible party being the Ministry of Information Technology and Communications, National Planning Department, and the Office of the President of the Republic of Colombia. In further analysis, there were an additional 46 artificial intelligence policy instruments that mention cybersecurity, national security, and/or defense within the actual document. These policies originate from countries including but not limited to the USA, Australia, Turkey, and Korea. These policy instruments were specific to the National AI Strategy of the countries of origin. An additional high-level evaluation of cybersecurity policy instruments was conducted to compare the amount that artificial intelligence was mentioned in related security policy instruments. A random sampling of 15 nation states and their national cybersecurity policy was conducted, and it was identified that 26% of the policy instruments mentioned or addressed artificial intelligence. [8] This data point was identified specifically for national strategies, agendas, and plans category due to the availability of both cybersecurity and artificial intelligence data that was not available for the later categories.

Emerging AI-Related Regulations. In total, there were 169 policy instruments for national governments, subnational governments, and international entities. When excluding the same policy instruments that were included in the above section, there were no additional policy instruments that address cybersecurity in artificial intelligence for government entities. The data sets that are included in this category have a high crossover rate with the data sets categorized as national strategies, agendas, and plans, at roughly 82%. This means that policy instruments that are categorized under emerging AI-related regulations are also categorized under national strategies, agendas, and plans, and this provides some limitation to the true numbers associated with each category. Of the policy instruments that are specific to this category, the primary topic areas were regulatory documents for self-driving cars, privacy-related policies associated with facial recognition, and artificial intelligence ethics. For this survey paper, the accessibility to international cybersecurity regulations was

limited and it is represented as a potential future work for this research. However, the gap in efficient international cybersecurity regulations was a topic at the 2022 World Economic Forum, and it was discussed how the lack of harmony creates complex and costly processes for compliance that do not support more secure international cyberspace [9]. This highlights the gap in both artificial intelligence and cybersecurity-related regulations that exist in the international community.

Public Consultations of Stakeholders and Experts. In total, there were 145 policy instruments for national governments, subnational governments, and international entities. When excluding the same policy instruments that were included in the above section, there were no additional policy instruments that address cybersecurity in artificial intelligence for government entities. The majority of policy instruments that were categorized as Public Consultations of Stakeholders and Experts were addressing the development of advisory councils or working groups to address national development of artificial intelligence for specific nation. These policy instruments were focused on the internal (to the nation state) advancement of artificial intelligence and not specific to international cooperation. There were seven policy instruments that outlined international cooperation, to include nation states such as Canada, USA, India, and the European Union. These policy instruments outline ongoing partnership between the nation states; however, none of the instruments address cybersecurity for artificial intelligence explicitly. Similar groups and initiatives for cybersecurity-related policy instruments were evaluated at a high level for this research. It was identified that roughly 15% of the cybersecurity-related Public Consultations of Stakeholders and Experts address or mention artificial intelligence. There were no policy instruments that addressed cybersecurity for artificial intelligence in detail, which means any more than a minor section or talking point in the policy instrument.

Networking and Collaborative Platforms. In total, there were 105 policy instruments for national governments, subnational governments, and international entities. When excluding the same policy instruments that were included in the above section, there were no additional policy instruments that address cybersecurity in artificial intelligence for government entities. The primary topic areas in the policy instruments for Networking and Collaborative Platforms were coalitions or collaborative groups within business, government, and academia to further advance artificial intelligence implementation to meet health services or societal impact goals. The secondary topic area identified digital transformation and innovation being the primary focus of the policies surrounding artificial intelligence. These policy instruments and platforms do not address cybersecurity for artificial intelligence explicitly.

4 Future Work

The results of the research conducted in this survey paper indicate the need for future research in this area. Although both artificial intelligence and cybersecurity are in the Market Maturity stage of the product lifecycle and have been adopted widely by consumers, businesses, academia, and government, there is a gap in the policy instruments that specifically address cybersecurity for artificial intelligence. [10] This research also identified the potential issue with utilizing policy instruments as an indicator of a nation state's maturity in the area, future research could be valuable in identifying the correlation between the policy instruments and the applications and operations for government entities in artificial intelligence. Lastly, there is the opportunity to further evaluate and analyze the crossover between cybersecurity policy instruments and artificial intelligence policy instruments to better understand the true gaps and needs in stand-alone cybersecurity for artificial intelligence policy instruments. There are many opportunities for future work that stem from the research of cybersecurity and artificial intelligence for nation states and government entities, and it should not be inferred that the above opportunities are the only available research areas.

5 Conclusion

Artificial intelligence has become a priority emerging technology for most nation states around the world. The number of policy instruments that exist for each target group, national governments, subnational governments, and international entities, provides evidence to the national goals and focus of nation states. Through the course of this research, however, it was identified that there is a large gap in the number of policy instruments that address both cybersecurity and artificial intelligence in a stand-alone document. There were opportunities identified that could address crossover between existing cybersecurity policy instruments and artificial intelligence policy instruments to better understand the areas that are covered pertaining to cybersecurity for artificial intelligence. It is evident that the evolution of technology requires the focus of nation state governments to ensure protection from bad actors, government digitization, and public service innovation [11]. This research is just the start of the research required to develop solutions and understand the impact that artificial intelligence has on national cybersecurity.

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Numerical Simulation of the Thermal and Acoustic Environment in Office Spaces

Eusébio Conceição, Maria Inês Conceição, Maria Manuela Lúcio, João Gomes, and Hazim Awbi

Abstract The simulation of the acoustic and thermal environment in office spaces is developed and applied in this study. A virtual thermal and binaural simulator is considered. The habitants' thermal and clothing numerical systems are evaluated in the virtual thermal simulator. The direct sound component and the indirect sound component are evaluated, and the reverberation time (RT) is calculated by the virtual binaural simulator. This study is conducted in an office equipped with a system of ventilation with horizontal confluent jets methodology and occupied by two habitants. The space RT and the environmental variables surrounding to the simulator and in the office space are evaluated.

Keywords Simulator · Comfort · Reverberation

E. Conceição (✉) · M. M. Lúcio
FCT—Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal
e-mail: econcei@ualg.pt

M. I. Conceição
Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, N° 1, 1049-001 Lisboa, Portugal
e-mail: ines.conceicao@tecnico.ulisboa.pt

J. Gomes
CINTAL, Campus de Gambelas, 8005-139 Faro, Portugal
e-mail: jgomes@ualg.pt

H. Awbi
University of Reading, Reading RG6 6AW, UK
e-mail: h.b.awbi@reading.ac.uk

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1 Introduction

The virtual simulator is used to evaluate the integral thermal phenomena and the acoustic phenomena. It uses the simulator of the geometry and the simulator of the surrounding surfaces of the room. The virtual simulator evaluates the influence of the variables calculated around the habitants'. It also calculates the simulator temperature distribution, TC and acoustic level.

In this work, the calculation of the room surface temperature, airflow near the simulators, TC and acoustic RT is important.

This study applies the building thermal modelling (BTM) software, the human thermal modelling (HTM) software, CFD software and the sound propagation modelling (SPM) software. The CFD software uses a differential methodology, while the other software considers an integral methodology.

The BTM software calculates the temperature in all surrounding opaque, transparent and indoor surfaces as well as the airflow rate in the inlet and outlet locations that the habitants are subjected to. This BTM software calculates the thermal comfort (TC) level according to Fanger [1], ISO 7730 [2], ASHRAE 55 [3] and Conceição et al. [4] and the air quality level, ASHRAE 62 [5]. The BTM software considers five components. The first is the integral balance of the energy equations which are important to calculate the temperature distribution. The second is integral balance of the mass equations, used to calculate the contaminants and water vapour. The third is the building geometry (see Conceição and Lúcio [6]), important to calculate the 3D grid generation. The fourth is the inlet and outlet airflow rate (see Conceição et al. [7 and 8]), calculated using the tracer gas techniques, and the final component is the ventilation system (see Conceição et al. [9]).

The HTM software calculates the temperature in the habitant tissue and clothing. The HTM software calculates the TC level (see Fanger [1], ISO 7730 [2] and ASHRAE 55 [3]) and the draught risk (DR) (see ISO 7730 [2] and ASHRAE 55 [3]). The HTM software is presented in Conceição et al. [10], using a coupling methodology with the CFD.

The SPM software is divided into two parts: space sound propagation, used to calculate the sound trajectory inside the space, and binaural simulator, used to calculate the RT level.

The SPM software considers geometrical methodologies and mathematical methodologies. The propagation of the sound depends on both internal occupied geometry and environmental variables levels. The acoustical geometrical methods use an image source method and consider the multi-reflections, the diffractions and the refractions in the surfaces of the space, to graphically develop a trajectory between the different sources and the different receivers. The numerical calculation considers the source as the mouth and the receivers as not only in the left ears but also in the right ears.

The binaural simulator uses the sound received in each ear to evaluate the RT, between other parameters. The RT is evaluated, for the left and the right ears, considering the time to be required in the decay 60 dB between the start of the simulation. Its calculation uses a sound intensity level regression evolution, resorting to logarithm equations, when the simulator receiver is located in the left simulator and right simulator ears.

Other studies, related to the propagation of the sound, were developed (see also Schetelig and Rabenstein [11], Savioja et al. [12], Funkhouser et al. [13], Funkhouser et al. [14] and Funkhouser et al. [15] and Taylor et al. [16]). The acoustics RT that used in the simulator is the one presented in DL [17].

The CFD software calculates the internal airflow in the spaces room and in the habitants' surroundings space. CFD software calculates the air quality, ASHRAE 62 [5], in the respiration area, and the DR according to ISO 7730 [2] and ASHRAE 55 [3].

The generation of the grid in the habitant geometry is made in vehicles, buildings and in other spaces. It is developed by resorting to equations for the different dimensions and different positions, and the neighbouring space geometry. The space geometry, among others, is used to calculate the solar radiation, the heat exchange by radiation as well as the acoustic distribution. The time used in the calculation and the accuracy obtained in the results are influenced by the grid used in the generation.

The geometry in the CFD and human thermal response (HTR) software is based, respectively, on volume elements and surfaces. The surfaces calculated in the HTR software are used in the assessment of the exchanges of radiation heat among the habitants and the neighbouring surfaces as well as the incident solar radiation.

The main objective of this study is to calculate the environmental variables around the habitants, the acoustical distribution inside the space and the space RT to which two habitants are subjected inside the office room equipped by horizontal confluent jets.

2 Numerical Software

This work was performed in an office, with dimensions of 4.50 m in the x length, 2.55 m in the y width 2.50 m in the z height. The office has installed 1 table, 2 chairs, 1 exhaust ventilation system and 1 inlet ventilation system (horizontal confluent jets system). It is also occupied by two virtual simulators seated around an office table (see Fig. 1).

The simulation uses a horizontal airflow, promoted by four ducts located in the corner walls. The horizontal airflow, coming from a group of linear nozzles, is promoted along the wall surfaces. The nozzles are distributed between 20 and 70 cm (over the floor level).

The exhaust ventilation system considers an air duct, which is located over the head level and is connected in the ceiling.

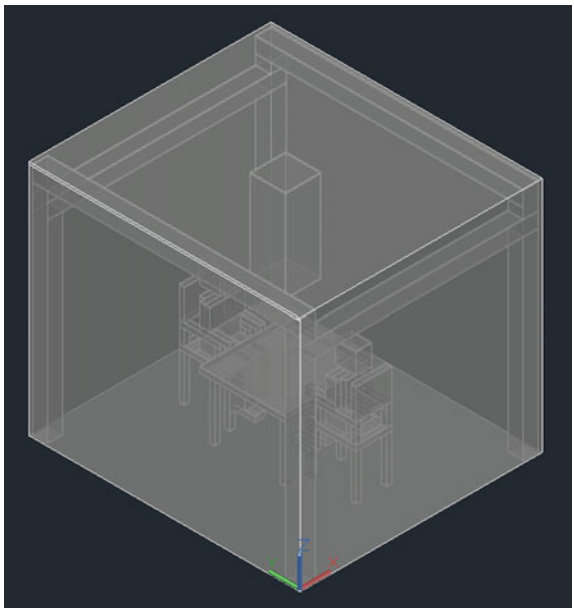

Fig. 1 Scheme of the office room equipped with one inlet system and one outlet system and occupied by two simulators

The simulation considered the following conditions:

- Level of activity is 1.2 Met.
- Level of clothing is 1 Clo.
- Air temperature of the external environment is 0ºC (winter conditions).
- Mean temperature of the internal air is 20 ºC.
- The coefficient of wall absorption is 20%.

In this study, two case studies are evaluated (velocity of the inlet air):

- 1.25 m/s;
- 5 m/s.

Figure 1 shows the geometry considered in the numerical simulation. This geometry, which simulates the office space, is analogous to a physical experimental chamber.

Three geometries were considered in the numerical simulation: a geometry applied in the HTM and the BTM, a geometry used in the CFD and a geometry used in the SPM software.

This geometry used in the SPM software (see Fig. 1) was simplified in comparison with the original geometry leading to a reduction in the number of considered surfaces used in the Propagation of the sound evaluation. The methodology considered in the model also groups of surfaces in planes and in the end considers a total of 378 surfaces.

3 Results

This section presents the airflow surrounding the habitants and in the office space, the propagation of the sound, as well as the RT.

Figures 2 and 3 present the air temperature of the two habitants of the Case A and the Case B, respectively.

In accordance with the obtained results, Case A verifies a higher air temperature in the habitants when compared to Case B. This fact is related to the air velocity in the habitants for the Case A being lower than for the Case B.

The upper body sections verified higher air temperature around the habitants than the lower body sections, for both cases. This aspect is related to the air velocity near the habitants in the upper habitant's sections being lower than in the lower habitant's sections.

In this study, four situations are analysed in the SPM software. For each habitant, a sound is applied in the source (mouth of habitant) and the receiver is observed (right and left ears of the other habitant).

The propagation of the sound trajectory between the source and the receiver is shown in Fig. 4. This calculus considers the direct trajectory, first reflection trajectory and second reflection trajectory. In Fig. 4a, the direct and first reflections are considered, while in Fig. 4b the direct, first reflection and second reflections are considered.

The result of the mean RT calculation, considering the source point located in the mouth of a habitant and the reception point located in the left ears and right ears of the other habitant, is 0.43 s.

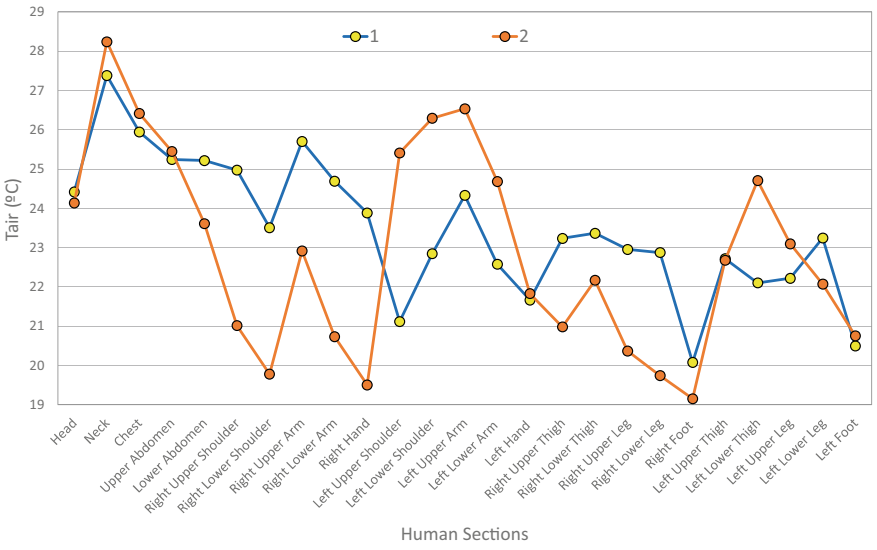

Fig. 2 Temperature of the air in the habitants in the Case A

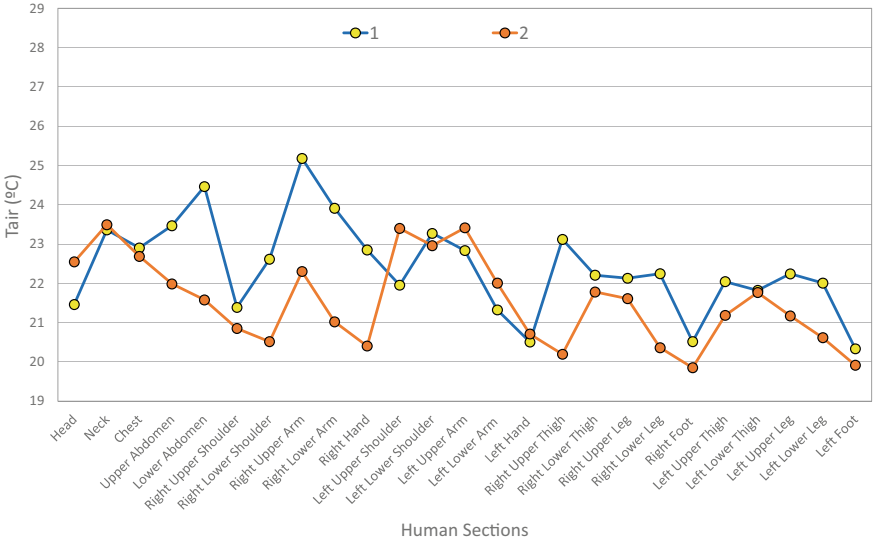

Fig. 3 Temperature of the air in the habitants in the Case B

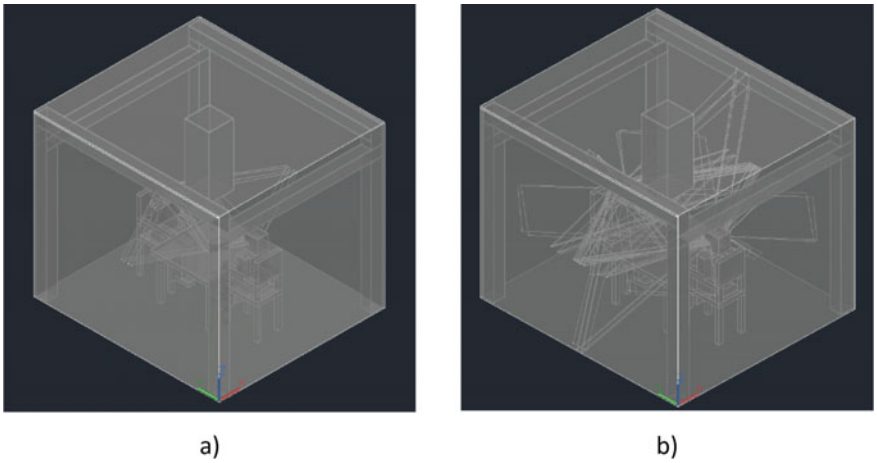

Fig. 4 Propagation of the sound trajectory from the source point to the receiver point, **a** when the direct trajectory and first trajectory reflections are considered and **b** the direct trajectory, first trajectory reflection and second trajectory reflections

In future works, a more detailed analysis will be performed on the influence of the reflection numbers in the evaluation of the RT.

4 Conclusions

The virtual design of an integrated thermal-acoustic simulator applied inside offices was analysed in this work. The work, which used a thermal-acoustic simulator, analyses the environment and the acoustic conditions.

In the environmental conditions, the air temperature in the habitants is higher in studied Case A than in studied Case B and the air velocity in the habitants in the studied Case A is lower than in the studied Case B. For both cases, the air temperature near the habitants in the upper habitants sections is higher than in the lower habitants sections and the air velocity in the habitants in the upper habitants sections is lower than in the lower habitants sections.

When the mouth of a habitant is considered as the source and the left ears and right ears of another habitant are considered as the reception, the mean RT is 0.43 s.

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Measuring the Sensitivity of Image Captioning Metrics to Caption Perturbations

Ingrid Hrga and Marina Ivasic-Kos

Abstract Image captioning systems based on deep neural networks have made significant progress in generating image descriptions in fluent language. Despite the achieved success, one of the main challenges remains automatic evaluation of the results. Recently, research efforts focused on the development of increasingly sophisticated automatic metrics have intensified significantly, so finding an appropriate way to compare metrics has also gained importance. A good automatic metric should match the ratings human evaluators would assign to captions, so a common way to evaluate them is to compute the correlation with human judgments. In this paper, we chose a different approach that could complement the results of correlation analysis in order to get a more complete insight into a particular metric. In this regard, we analyzed how various caption perturbations affect the scores of selected image captioning metrics. We constructed a dataset of various caption modifications and analyzed the changes in scores resulting from such perturbations.

Keywords Automatic metrics · Image captioning · Evaluation

1 Introduction

Over the past few years, image captioning systems based on deep neural networks have made significant progress in generating image descriptions in fluent language, primarily of generic scenes. Such systems mostly follow an encoder-decoder architecture, where the encoder first creates a vector representation of the image, and

I. Hrga (✉)
Faculty of Informatics, Juraj Dobrila University of Pula, Pula, Croatia
e-mail: ingrid.hrga@gmail.com

I. Hrga · M. Ivasic-Kos
Faculty of Informatics and Digital Technologies, University of Rijeka, Rijeka, Croatia
e-mail: marinai@uniri.hr

M. Ivasic-Kos
Center for Artificial Intelligence, University of Rijeka, Rijeka, Croatia

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the decoder then generates a description conditioned on that vector. Typically, a convolutional neural network is used on the encoder side and on the decoder side a variant of a recurrent network with an attention mechanism [1, 2] or, today even more commonly, a network without convolutions or recurrent connections based entirely on self-attention [3, 4].

However, despite the achieved success, one of the main challenges of automatic image captioning still remains the evaluation of the results. An image can be described in different ways, depending on which aspect is given more importance, and yet each of these descriptions could be accurate and perfectly suitable [5]. Moreover, two descriptions can contain almost the same words, but convey completely different meanings, which makes the evaluation particularly challenging [6, 7]. Generated captions can be evaluated by humans; however, such engagement is slow, expensive, and highly subjective. For this reason, automatic evaluation is usually preferred [7].

A common set of automatic metrics for evaluating image descriptions consists of BLEU [8] METEOR [9], ROUGE [10], CIDEr [6], and SPICE [7]. They all output a score that quantifies the match between the generated sentence and reference descriptions. However, such reliance on n-gram matching, without considering the image at all, ultimately results in poor correlation with human judgments [11, 12], which is a major criticism often encountered in papers. In contrast, more recent works [13–15] propose metrics that measure the semantic similarity of descriptions and images in an embedding space, which shows a promising direction as such metrics more closely match the ratings that would be assigned by human evaluators. And with the intensification of research efforts in proposing increasingly sophisticated alternatives, finding an appropriate way to compare them is also gaining importance.

A common way to evaluate automatic metrics is to calculate system-level and caption-level correlation with human judgments by using publicly available datasets, such as Flickr8 [12] or Pascal-50S [11], which contain human ratings in addition to images and descriptions. However, this approach does not provide insight into the subtle differences between metrics and how they deal with various errors in the descriptions. Therefore, the authors in [16] pointed out the need to create additional diagnostic sets with different distractors, which could help to validate image captioning models and metrics more thoroughly. As the choice of the metric that will "guide" the system during learning directly affects the subsequent capabilities of the system, it is necessary to carefully choose the most suitable ones.

In this paper, we follow the latter approach and examine the sensitivity of selected automatic metrics to various description perturbations. The goal of the experiments is to discover how well a metric can capture subtle changes in captions. For this purpose, we have created a set of descriptions consisting of captions and several of their modifications in which individual words or characters have been replaced, inserted, or deleted, mostly based on WordNet synsets [17].

The paper is structured as follows: After the introductory part, in the second section we give a brief overview of common metrics for evaluating automatically generated descriptions. The third section presents the dataset of perturbed captions, the metrics employed, and the experimental setup. In the fourth section, we analyze the results of caption perturbation experiments and in the last give a conclusion and guidelines for future work.

2 Background and Related Work

Automatic image captioning metrics can be categorized according to the inputs they take to calculate the score into reference-only, image-aware, and reference-free. The latter represents a desirable goal because it is closest to the way humans evaluate descriptions; i.e., humans do not need references to judge whether a description is appropriate for the image it describes and whether the sentence is sufficiently fluent and grammatically correct. Another categorization can be made according to the approach they use to calculate the score into rule-based, learning-based, and embedding-based metrics.

The previously mentioned set of standard metrics belongs to rule-based reference-only metrics. BLEU [8] is one of the most widely used metrics for evaluating machine translation and was among the first to be adopted for evaluating image captioning systems. It calculates the score as the geometric mean of n-gram precision in matching candidate and reference descriptions, which is additionally corrected with a brevity penalty to avoid overly short sentences. METEOR [9] is another metric borrowed from machine translation. It computes the harmonic mean of unigram precision and recall of matches between candidates and references, for which it additionally uses stemmers, WordNet [17] synonyms, and paraphrase tables. ROUGE [10] is a set of metrics originally intended to evaluate text summaries. For image captioning, the preferred variant is ROUGE-L, which calculates the longest common subsequence of tokens between a candidate and a reference, without requiring consecutive matches. CIDEr [6] is a consensus-based metric specifically designed to evaluate image captions. It uses term frequency-inverse document frequency (TF-IDF) *n*-gram weighting to compute the cosine similarity between the candidate and reference sentences. SPICE [7] is also designed to evaluate image captions by comparing scene graphs of candidate and reference sentences based on their semantic propositional content.

In contrast to rule-based metrics, some authors propose learning-based metrics, such as LEIC [18], which relies on a model learned to distinguish machine-generated descriptions from those written by humans. However, such learning can require significant computing resources, making the application impractical.

More recent works are based on the use of pre-trained models for mapping candidate and reference descriptions or descriptions and images into a common vector space where cosine similarity can be easily computed. For instance, WMD [19] is a distance function that relies on word2vec [20] embeddings to calculate the similarity

between two documents, or in this case, captions. BERTScore [21] uses BERT [22], a language representation model pre-trained on a large corpus of texts, to create contextual embeddings for each token from a sentence. Because it uses the whole sentence as the context, it allows better handling of problems with polysemy, i.e., problems that could arise when the same word has more than one meaning. BERTScore is also a reference-only metric, which computes the cosine similarity between candidate and reference tokens. VILBERTScore [14] uses image and reference information to create image-conditioned contextual embeddings of tokens with VILBERT [23], a BERT-based task-agnostic representation model. VIFIDEL [13] is another metric that takes the image into account when calculating the score. The score reflects the semantic similarity between the labels of objects depicted in the image and the words in the captions, relying on WMD to measure their similarity in an embedding space. It can also be used when references are not available. CLIPScore [15] uses CLIP [24], a multimodal vision and language model, with two encoders: one for the image and one for the text to create their vector representations. The score is obtained based on the cosine similarity between the image and the candidate caption. One benefit is that such direct comparison of images and descriptions makes it possible to notice some aspects in the generated descriptions that may not be present in the references. On the other hand, relying only on the image brings some limitations regarding the assessment of grammatical correctness and fluency, where BERTScore shows an advantage. For this reason, in addition to a reference-free CLIPScore, the authors also proposed RefCLIPScore, which can be computed when references are available.

3 Methods and Experimental Setup

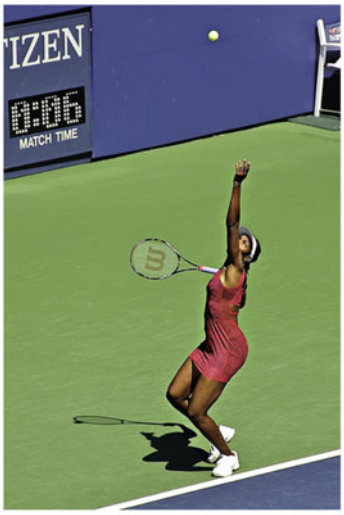
3.1 Datasets

As a starting point for generating caption perturbations, we took a standard captioning benchmark dataset, MS-COCO [25], and one of its extensions, FOIL-COCO [16]. The MS-COCO dataset consists of complex images of everyday scenes, with at least five human-generated captions. The FOIL-COCO dataset consists of ~300 k captions (original and modified) for nearly 100 k images from COCO dataset. Each modified sentence has exactly one word replaced by another from the same COCO label supercategory (e.g., cake → pizza). We used the images from the validation set of the COCO 2014 version and randomly selected 1000 images that were also used in the FOIL dataset. After the initial selection, we got a total of 2935 sentences.

3.2 Caption Perturbations

In our experiments, we used 19 caption transformations. For some of them, we used NL-Augmenter [26] (in the list below marked with *), while the rest were custom-made to have more control over word selection. Similar to the FOIL dataset, most of the transformations changed a single word, while one was based on character substitution. Our transformations differ from the FOIL dataset because are not limited only to objects (nouns). In contrast, we used WordNet synsets to select individual words, i.e., synonyms and antonyms. WordNet is a large lexical database in which words of similar meaning are grouped into synsets (sets of synonyms) and interconnected by lexical and semantic links [17].

We used the following approach: First we tokenized the sentences with the NLTK punkt tokenizer [27]. Then, each token was tagged with its part-of-speech (POS) tag. Based on the POS tag, we chose a noun, verb, or adjective as a candidate for modification, deletion, or insertion. If there were several candidates, we chose one by random selection. Finally, we used WordNet to find synonyms or antonyms for the selected candidate. For each of the 2935 original captions, we tried all the selected transformations. However, not all transformations were appropriate or possible for each of these sentences. For example, in some sentences there were no adjectives, while for some words there was no adequate synonym or a corresponding antonym. Below we list the transformations with examples for the caption shown in Fig. 1.



"a woman is getting ready to strike a tennis ball"

Fig. 1 An image from the COCO [25] dataset with a corresponding caption

Transformations based on the replacement of one word are:

- replacing one word (noun, verb, or adjective) with a synonym, i.e., a word with a similar meaning: *"a woman is getting **quick** to strike a tennis ball"*
- replacing one word (noun, verb, or adjective) with an antonym, i.e., a word with the opposite meaning: *"a woman is getting **unready** to strike a tennis ball"*
- gender swap*: *"a **man** is getting ready to strike a tennis ball."*

Transformation based on word order is:

- subject and object swap*: *"a **tennis ball** is getting ready to strike a **woman.**"*

Transformations based on word insertion are:

- synonym insertion (noun, verb, or adjective): *"a woman is getting ready to strike a tennis **clod** ball"*
- antonym insertion (noun, verb, or adjective): *"a woman is getting **unready** ready to strike a tennis ball"*
- filler word insertion*, i.e., adding words that add noise but do not contribute to the meaning: *"a woman is **actually** getting **actually** ready **uhm** to strike a tennis ball."*

Transformation based on word deletion is:

- word deletion (noun, verb, or adjective): *"a woman is getting ready to strike a tennis."*

Transformation based on character change is:

- butter finger*, i.e., adds noise by replacing characters similar to typing errors: *"a wlman is getting ready to strike a tennis ball."*

Replacing a word with a synonym does not change the meaning of the sentence, or changes it only to a lesser extent, while replacing it with an antonym significantly contributes to the change, which should also be reflected in the scores. The insertion of additional words should examine how metrics deal with redundant information. The deletion of words should examine how well the metrics recognize missing information. Gender swap should examine possible bias, while subject-object swap creates sentences that have the same bag-of-words representation, but semantically represents a more significant change. Inserting filler words or typos tests robustness to noise.

3.3 Metrics

For the experiments, we chose a set of standard metrics (BLEU, METEOR, ROUGE-L, CIDEr, and Spice) as reference-only rule-based and BERTScore, CLIPScore, and RefCLIPScore as embedding-based metrics. For each of the metrics, we compute system-level and caption-level scores.

4 Results

Table 1 shows the change in system-level scores of the transformed captions compared to the original captions. It can be noticed that for almost all metrics the biggest score drop was due to the introduction of noise ("butter finger" and "filler word insertion").

If the replacement of a specific word with an antonym is observed, METEOR and SPICE showed the biggest change, especially if the word was a noun, while the smallest change was for adjectives. It is interesting that CLIPScore in both versions reacted rather weakly to the substitution of verbs, which may indicate insufficient understanding of the activities shown in the picture.

It is interesting that BLEU1 and BLEU2 showed an increase in scores when deleting certain words, especially in the case of adjectives. Given that BLEU is based on exact n-gram matching, these were likely words not present in the references, so their exclusion had a beneficial effect on the scores. These were also the only increases, while in all other cases the scores decreased.

Other metrics responded significantly to the deletion of nouns, while the impact of deleting adjectives and verbs was significantly smaller. Given that image captioning systems are largely object-focused, this kind of insensitivity to verb and adjective errors may give systems significantly higher ratings than might be appropriate.

Insertion of redundant words in the form of synonyms or antonyms generally did not have a significant effect on decrease in scores, with CLIPScore, RefCLIPScore, and METEOR showing the greater resistance to such change. BERTScore showed a slightly higher sensitivity here, and that slightly more in the case of verbs.

In general, inserting redundant synonyms or antonyms and replacing words with synonyms had no significant effect on the results. With such transformations, only BERTScore proved somewhat more sensitive to verbs.

The gender swap is particularly interesting. The biggest change in scores occurred in both versions of CLIPScore, while BERTScore proved to be the least sensitive. It should certainly be further investigated why BERTScore reacts so weakly to gender substitution, especially since it is known that large language models are not immune to gender bias [28].

On the other hand, the substitution of subjects and objects had a significant effect only on BERTScore and ROUGE, and to a lesser extent on BLEU4. This raises the question of whether the metrics can really detect the nuances in language, and whether they are suitable for giving a general assessment of a system if they do not respond to such semantically important changes.

When looking at individual metrics, all BLEU variants showed almost the same behavior, only with BLEU4 being more sensitive to subject and object swap, while BLEU1 and BLEU2 hardly reacted to such a change. BLEU in all versions was the least sensitive to word deletion, while it was the most sensitive to noise. Apart from noise, METEOR showed the greatest sensitivity to the replacement of nouns with antonyms, which can also include gender swaps, while it was the least sensitive to the insertion of additional words or replacement with synonyms. ROUGE proved to

Table 1 Percentage decrease in system-level scores due to applied transformation

Transformation	BLEU4	METEOR	ROUGE	CIDEr	SPICE	CLIP	RefCLIP	BERT F
Replace antonym (*A*)	15.95	7.15	3.93	15.14	8.30	3.73	2.86	16.46
Replace antonym (*N*)	23.77	16.83	10.32	24.84	28.41	3.13	3.13	17.10
Replace antonym (*V*)	22.06	9.36	4.87	26.95	5.98	0.60	1.07	25.54
Butter finger	30.99	**22.72**	13.19	43.70	**35.25**	4.23	5.25	**34.21**
Delete word (*A*)	3.16	6.04	1.11	5.67	6.19	2.04	1.07	12.80
Delete word (*N*)	8.30	11.50	4.49	17.21	23.00	4.30	3.77	24.01
Delete word (*V*)	11.51	8.77	1.62	8.70	1.65	0.92	0.92	18.88
Insert filler words	**51.46**	8.92	10.67	**52.53**	14.09	3.47	2.99	31.64
Gender swaps	25.61	16.73	11.91	12.44	30.32	**7.64**	**6.34**	2.36
Insert antonym (*A*)	18.81	3.19	3.73	15.94	4.55	1.63	1.49	18.65
Insert antonym (*N*)	21.97	5.06	3.74	22.62	4.93	0.42	0.90	17.25
Insert antonym (*V*)	20.31	3.62	3.81	25.70	5.60	0.31	0.77	24.57
Insert synonym (*A*)	20.19	3.32	3.74	23.43	1.21	0.32	0.91	21.22
Insert synonym (*N*)	19.90	3.36	3.69	25.23	3.74	0.82	1.41	19.98
Insert synonym (*V*)	20.03	3.29	3.77	25.47	6.38	0.70	0.99	24.36
Subject–object switch	31.41	4.01	**19.03**	10.10	6.31	1.32	1.69	24.23
Replace synonym (*A*)	17.17	2.36	3.70	22.17	0.62	1.00	0.98	18.69
Replace synonym (*N*)	13.65	2.47	5.72	24.90	1.29	2.03	2.32	20.47
Replace synonym (*V*)	22.87	2.78	5.47	28.58	5.46	1.26	1.52	25.84

A, *N*, *V* represent adjective, noun, verb, respectively. The biggest change is marked in bold

be most sensitive to noun substitution and least sensitive to word deletion. CIDEr showed similar changes to ROUGE, except that it turned out to be quite insensitive to gender and subject-object swap. SPICE, on the other hand, showed similar changes as METEOR, but it also proved to be quite insensitive to verb deletion. Both versions of CLIPScore showed similar reactions, with only a slight difference in intensity. RefCLIPScore was, for example, even less sensitive to the deletion of verbs compared to CLIPScore, and more sensitive to character substitutions that resemble typos. BERT Score was the least sensitive to gender substitutions, and apart from noise, it reacted more strongly to verb substitutions than other metrics.

Figure 2 shows a comparison of the distributions of caption-level scores computed with BERTScore and CLIPScore on original captions and selected transformations. It can be seen that these metrics reacted differently to transformations, which makes them complementary.

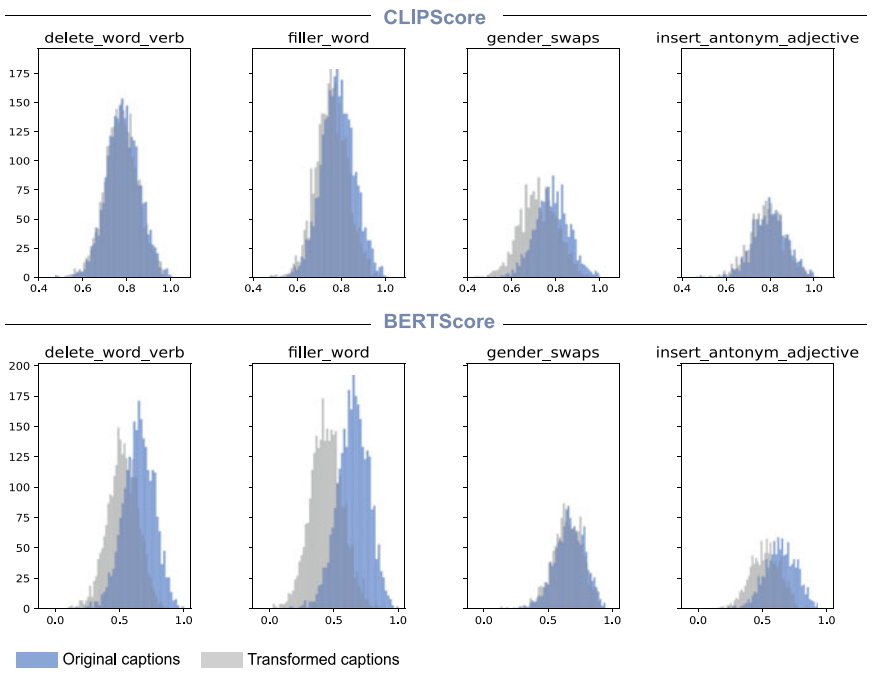


Fig. 2 Distributions of caption-level scores computed with CLIPScore (*top row*) and BERTScore (*bottom row*) on original captions and selected caption transformations

5 Conclusion

In this paper, we investigated the sensitivity of selected image captioning metrics to various caption perturbations. For this purpose, we have prepared a set of captions obtained by applying 19 different transformations to the original descriptions from the MS-COCO dataset. We then measured the change in scores resulted from such alterations. The experiments showed that metrics respond differently to changes in sentences, but almost all of them respond most strongly to the addition of noise, such as filler words or typing errors. Interestingly, reactions to some transformations, such as gender or subject-object swap, were significantly less intense than expected, indicating that there is still no metric that can cover all aspects of captions. Therefore, this analysis could help to find complementary metrics and provide insight into possible weaknesses or insensitivities that could be used to artificially increase the score of a system without increasing the quality of the output. For example, given that CLIPScore and BERTScore have shown to be complementary in many aspects, their combination could provide a more rounded view of the system that generated the captions.

We intend to expand the research to a larger set of current metrics and to analyze the outputs of different systems as well. One limitation of the research that we intend to address is that we relied only on WordNet for word selection. In our future research, we will use some of the more advanced models for computing similarity in embedding space.

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Auditorium Design and Occupants Comfort Evaluation

Eusébio Conceição, João Gomes, Maria Inês Conceição, Maria Manuela Lúcio, and Hazim Awbi

Abstract This article evaluates how solar radiation influences the thermal comfort of the occupants of an auditorium with circular geometry under winter conditions. The auditorium is divided into four amphitheatres of equal dimensions and glazed surfaces of equal dimensions are mounted throughout its outer envelope. The occupants' thermal comfort is assessed by the Predicted Mean Vote index (PMV). The building thermal software used is based on two numerical models, the Circular Auditorium Geometry and the Circular Auditorium Thermal Modelling. The Circular Auditorium Geometry is based on geometric cylindrical coordinates. The Circular Auditorium Thermal Modelling evaluates, in a transient regime, the thermal response of the auditorium and thermal comfort provided to its occupants. Compartment ventilation is provided by mechanically ventilated outdoor air at an air renewal rate directly linked to the number of occupants. The incoming solar radiation in the two amphitheatres with the glazed surfaces facing north is low, while in the two amphitheatres with the glazed surfaces facing south, it is too high. Consequently, in general, the occupants' thermal comfort level is unacceptable in north-facing amphitheatres for being too cold and in south-facing amphitheatres for being too hot. So, to ensure that the thermal comfort level of the occupants is acceptable, a strategy was implemented that consisted of adapting ventilation and the level of clothing during occupancy.

E. Conceição · M. M. Lúcio
FCT—Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal
e-mail: econcei@ualg.pt

J. Gomes (✉)
CINTAL, Campus de Gambelas, 8005-139 Faro, Portugal
e-mail: jgomes@ualg.pt

M. I. Conceição
Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, N° 1, 1049-001 Lisboa, Portugal
e-mail: ines.conceicao@tecnico.ulisboa.pt

H. Awbi
University of Reading, Reading RG6 6AW, UK
e-mail: h.b.awbi@reading.ac.uk

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Keywords Building thermal software · Geometric design · Solar radiation · Thermal comfort

1 Introduction

Resorting to solar radiation as a source of renewable energy in buildings is a common strategy these days [1]. This use must particularly be carried out passively. In the winter season, passive heating through glazed surfaces [2] can be used to decrease the heat needed from active sources in heating interior spaces [3]. However, even in the winter season, spaces inside buildings may overheat due to solar gains [4]. Therefore, it is justified to carry out preliminary studies to characterize how solar radiation influences thermal behaviour in the interior spaces of buildings. This knowledge will make it possible to propose solutions that can take advantage of this energy resource in a more efficient way [5, 6].

The building under evaluation in this work is a circular auditorium consisting of four equal amphitheatres provided with glazed surfaces throughout its exterior envelope. This type of building is commonly occupied by a large number of people in activities usually associated with teaching or conferences. It is therefore important to ensure that the auditoriums present conditions that promote acceptable levels of thermal comfort [7, 8], indoor air quality [9], draught risk [10], and acoustics [11]. The circular auditorium of this study uses passive solar radiation as a renewable energy source, so its thermal response and the comfort conditions available to its occupants must be evaluated. If they are insufficient, solutions that improve this thermal response can be proposed.

The main purpose of this work is to assess the thermal response of a circular auditorium similar to the one existing in a university building located in the south of Portugal, whose climate is of the Mediterranean type. The study is carried out under extreme cold conditions in the region in the winter season. For this, there was a need to evolve a methodology that permits generating the geometry of this type of circular building. From the implementation of this geometry, the building thermal response and the thermal comfort conditions provided to the occupants will be evaluated, in a transient regime. Given the results obtained, solutions will be proposed to improve the conditions observed.

2 Models

The building thermal software used in this work has been developed over the years by the authors. Considering the type of building studied here, two numerical models were applied: Circular Auditorium Geometry; and Circular Auditorium Thermal Modelling.

The Circular Auditorium Geometry is founded on geometric equations to create the building's design. These equations are defined in cylindrical coordinates. The design of the circular auditorium takes into account the side, stage and rear walls, floor, ceiling, steps, and glazed surfaces. The output data of the Circular Auditorium Geometry is then employed as input to Computer Aided Design (CAD) software and the Circular Auditorium Thermal Modelling. The application of CAD methodologies is frequent in studies involving buildings [12, 13].

The Circular Auditorium Thermal Modelling is based on conductive, convective, radiative, and evaporative phenomena. It uses integral energy balance equations to compute the temperature distribution and integral mass balance equations to compute the mass distribution of water vapour, carbon dioxide, and other contaminants. The temperature distribution is calculated within spaces, on interior bodies, on opaque and transparent bodies, and on the various layers that make up the opaque surfaces. The mass distribution is calculated within spaces and on interior bodies. The system of equations thus constituted is solved by the Runge–Kutta–Felberg numerical model with error control. More details and applications of this type of numerical model are shown in the articles by Conceição and Lúcio [14] and Conceição et al. [15].

The Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) people indices, introduced by Fanger [7], are commonly used to assess the level of thermal comfort in occupied spaces. The PMV index is established from indoor environmental variables and personal variables. Indoor environmental variables are air velocity, air temperature, relative humidity, and mean radiant temperature. Personal variables are the level of metabolic activity and the level of clothing insulation. The PPD index is given by an exponential equation dependent on the PMV index. More details, including theoretical foundations, about the PMV/PPD model can be found in Rad et al. [16]. The international standard [8] employs these indices to characterize the thermal comfort provided to the occupants of a building. In this study, it is considered that the thermal comfort level of the occupants is reasonable if the PMV values are accordingly to the C category established by this standard. Category C is defined by $-0.7 \leq \text{PMV} \leq +0.7$ and $\text{PPD} < 15\%$. The application of this thermal comfort condition is shown in the studies developed by Conceição et al. [17, 18].

3 Methodology

The virtual circular auditorium is divided into four equal amphitheatres as can be seen in Fig. 1. These amphitheatres are numbered and oriented as follows: 2, north-east; 3, north-west; 4, south-west; and 5, south-east.

The auditorium is essentially made up of opaque surfaces, except for the entire outer envelope, where 36 glazed surfaces of equal size were installed. These glazed surfaces are used to supply heating to the spaces inside the amphitheatres from the passive use of incoming solar radiation, available according to the path of the sun throughout the day. The numbering of the glazed surfaces per amphitheatre and

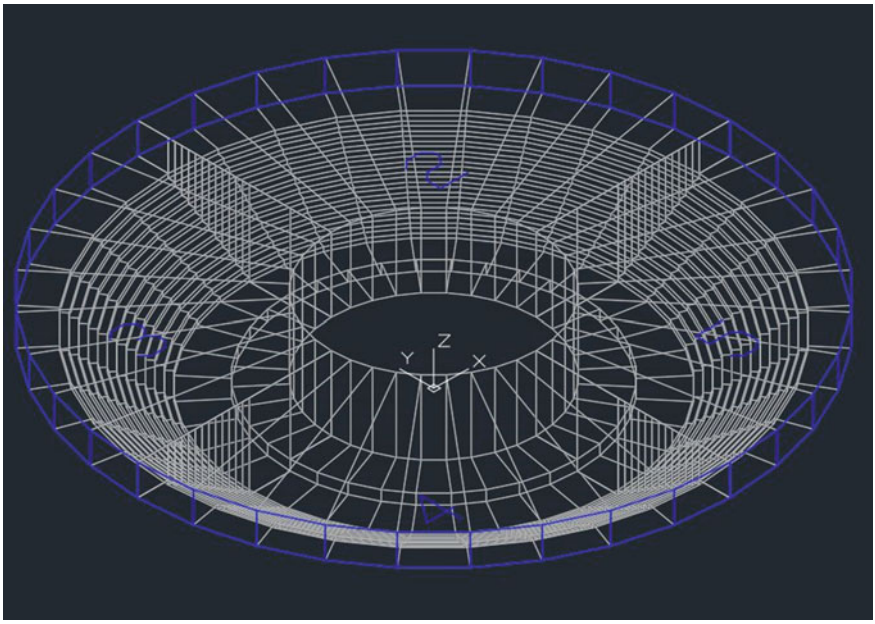

Fig. 1 Virtual circular auditorium divided into four equal amphitheatres

considering the counter-clockwise direction is as follows: 1–9 in amphitheatre 2; 10–18 in amphitheatre 3; 19–27 in amphitheatre 4; and 28–36 in amphitheatre 5.

The occupation cycle for all amphitheatres is as follows: in the morning, between 8 and 12 h; in the afternoon, between 14 and 18 h.

Each amphitheatre is occupied by 50 people, each 1.7 m tall and weighing 70 kg. In this study it is assumed that the occupants have a level of metabolic activity of 1.2 met, a typical value found in a space similar to a classroom, and a clothing insulation level according to the values presented in Table 1. These values are obtained from tables available in the ISO 7730 [8] standard.

The air renewal rate used is as follows: unoccupied, 0.01 m^3/h; with occupants, according to the values presented in Table 2.

Table 1 Clothing insulation level (Clo) of occupants during the cycle of occupation

Amphitheatre	Occupation cycle				
	8–10 h	10–11 h	11–12 h	14–16 h	16–18 h
2	2.3	2.3	2.3	2.3	2.3
3	2.3	2.3	2.3	2.3	2.3
4	2.0	2.0	2.0	1.0	1.0
5	1.0	1.0	0.75	0.75	1.0

Table 2 Air renewal rate (m^3/h) during the cycle of occupation

Occupation cycle	Amphitheatre			
	2	3	4	5
8–12 h	0.20	0.20	0.40	0.60
14–18 h	0.20	0.20	1.20	0.95

The numerical simulation also involves the five days prior to the one whose results will be presented.

4 Results and Discussion

4.1 Incoming Solar Radiation

Figure 2a–d show the incoming solar radiation evolutions on the glazed surfaces of amphitheatres 2, 3, 4, and 5, respectively. In these Figures, the numbers 1 to 36 correspond to the numbering of the glazed surfaces.

As can be seen in Fig. 2, amphitheatres 4 and 5 receive much more solar radiation through their glazed surfaces than amphitheatres 2 and 3. Amphitheatres 4 and 5 have their glazed surfaces predominantly facing south while amphitheatres 2 and 3 have their windows facing predominantly north. The glazed surfaces of amphitheatre 4 have an orientation distributed between south and west so, as seen in Fig. 2c, most of the solar radiation received by this space occurs during the afternoon. On the other hand, the glazed surfaces of amphitheatre 5 have an orientation distributed between south and east, so, as seen in Fig. 2d, most of the solar radiation received by this space occurs during the morning. Likewise, a similar situation can be seen in amphitheatres 2 and 3: amphitheatre 2 has some glazed surfaces that receive solar radiation during the morning due to the solar incidence coming from northeast to east; amphitheatre 3 has some glazed surfaces that receive solar radiation during the afternoon due to the solar incidence coming from northwest to west. Glazed surfaces 7–13 do not receive solar radiation because they face north. Therefore, as can be seen in buildings located in the northern hemisphere, the contribution of solar radiation to the heating of the interior space will be greater in amphitheatre 4 in the afternoon and in amphitheatre 5 in the morning. On the other hand, in amphitheatres 2 and 3, this contribution will generally be of little significance, only having some meaning during the early morning in amphitheatre 2 and in the late afternoon in amphitheatre 3.

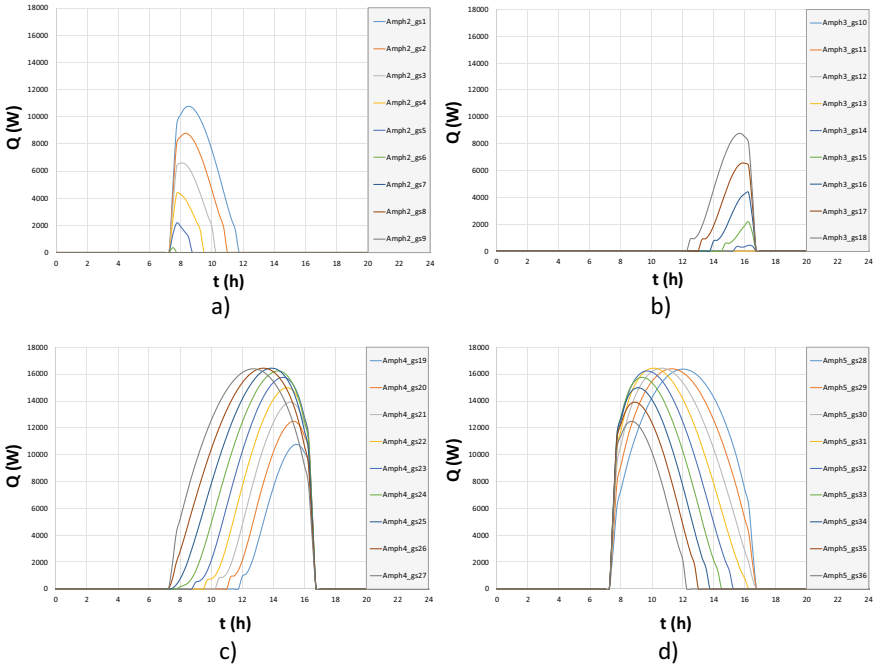

Fig. 2 Incoming solar radiation. The initials "gs" stand for glazed surface and the associated number is related to its numbering: **a** amphitheatre 2; **b** amphitheatre 3; **c** amphitheatre 4; **d** amphitheatre 5

4.2 Indoor Air Temperature

The air temperature (Ta) evolution over the course of a day can be seen in Fig. 3. In amphitheatres 4 and 5, the effect on the indoor Ta of the interaction between solar radiation, ventilation implemented, and heat transferred by the occupants can be verified.

In amphitheatre 4, when occupied in the morning, the indoor Ta remains relatively stable, around 18 °C, until about 10 am, at which time the indoor Ta starts to rise to 21.1 °C checked at noon. During this period the ventilation is on, and the incoming solar radiation only starts to influence the temperature of the indoor air after 10 am. Until 10 am, the effect of ventilation on lowering the temperature is offset only by the heat transferred from the occupants. Between noon and 2 pm, the space is unoccupied and ventilation is turned off, so the indoor Ta evolution essentially depends on the incoming solar radiation. When occupied in the afternoon, the ventilation is turned on again, and the indoor Ta increases from 26.6 to 27.4 °C, verified around 3 pm, after which it decreases again to 21.8 °C, verified at 6 pm. Until 4 pm, the evolution of the indoor Ta is essentially due to incoming solar radiation; from this time onwards, the indoor Ta evolution depends on the effect of ventilation not being compensated by the heat transferred by the occupants. In amphitheatre 5, at the beginning of the

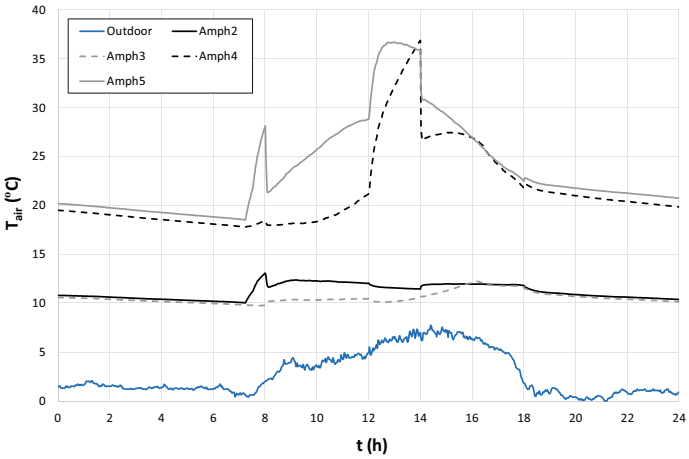

Fig. 3 Evolution of air temperature outside and of air temperature inside of the four amphitheatres

morning, the air temperature increases as a function of the increase in the incoming solar radiation through its glazed surfaces. When the occupants enter, ventilation is turned on, so the air temperature drops rapidly from 28.1 to 21.3 °C. When occupied in the morning, the indoor Ta gradually rises to 28.8 °C depending on the contribution given by the incoming solar radiation and the heat transferred from the occupants. Between noon and 2 pm, the space is unoccupied and ventilation is turned off, so the evolution of the indoor air temperature essentially depends on the incoming solar radiation. When occupied in the afternoon, the ventilation is switched on again, and the indoor Ta drops from 30.8 to 22.5 °C. This evolution of the indoor Ta is due, in addition to the entry of cold outside air provided by the ventilation, to the decrease of incoming solar radiation not being compensated by the heat transferred by the occupants.

In amphitheatres 2 and 3, the outcome of incoming solar radiation on indoor Ta is barely perceptible. During the occupation, its influence is verified only in the first two hours in amphitheatre 2 and between 2 and 4 pm in amphitheatre 3. In amphitheatres 2 and 3 the indoor air temperature remains very low, between 10.0 and 13.0 °C, and between 9.8 and 12.2 °C, respectively. Fundamentally, the heat transferred by the occupants can only compensate for the decrease in indoor Ta caused by ventilation.

4.3 PMV Index

The PMV index evolution during occupancy can be seen in Fig. 4. Figure 4a presents the evolution of the PMV index over the morning period and Fig. 4b presents the evolution of the PMV index during the afternoon period. The results obtained show that, essentially, all the amphitheatres present acceptable levels of thermal comfort.

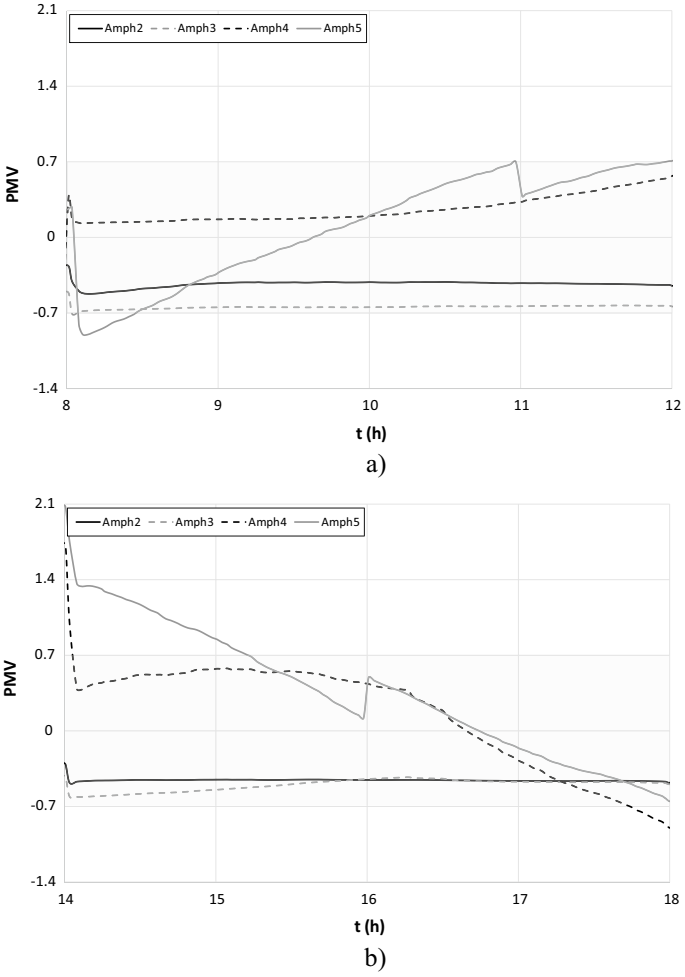

Fig. 4 PMV index evolution in the four amphitheatres during occupancy: **a** in the morning; **b** in the afternoon. The area marked in light green defines category C [8]

Amphitheatres 2 and 3 show acceptable levels of thermal comfort, as per category C [8], by PMV negative values. During the occupation cycle, amphitheatre 4 generally presents acceptable levels of thermal comfort, as per category C [8]: when in the morning, by PMV positive values; during the afternoon, by PMV positive values until around 4.45 pm and after this time by PMV negative values. During the occupation cycle, amphitheatre 5 generally presents a reasonable level of thermal comfort, as per category C [8]: in the morning, by PMV negative values between around 8.30 am and around 9.40 am and between around 9.40 am and noon, by PMV positive values; in the afternoon, by PMV positive values between around 3.15 pm and around 4.45 pm and between around 4.45 and 6 pm, by PMV negative values.

5 Conclusions

This paper describes the numerical work carried out on the thermal response of a circular auditorium divided into four amphitheatres with identical dimensions. The geometry of this auditorium was obtained from a numerical model developed for this purpose. The study was carried out under extreme cold conditions in the southern Portugal region in the winter season. The consequences of solar radiation entering this auditorium during the day were considered in this study. The thermal conditions afforded to the occupants were computed, during the occupancy cycle of this auditorium, through the PMV index.

Amphitheatres 2 and 3 have their glazed surfaces predominantly facing north, so they only receive some solar radiation in the early morning by the glazed surfaces facing northeast (amphitheatre 2), or in the late afternoon by the glazed surfaces facing northwest (amphitheatre 3). During occupancy, in these spaces, the indoor air temperature is low (around 10–12 °C) and an acceptable thermal comfort for the occupants is reached, within Category C, by PMV negative values [8].

Amphitheatres 4 and 5 have their glazed surfaces predominantly facing south. Depending on the orientation of its glazed surfaces, amphitheatre 4 receives most of the solar radiation during the afternoon and amphitheatre 5 receives most of the solar radiation during the morning. During the occupation cycle, in amphitheatre 4, the values of the air temperature inside vary between around 18 °C and around 21 °C in the morning and between around 22 °C and around 27 °C in the afternoon. Air temperature values can be considered acceptable both in the morning and in the afternoon. With regard to amphitheatre 5, air temperatures vary between around 21 °C and around 29 °C in the morning and between around 23 °C and around 31 °C in the afternoon, values that during some periods can be considered high in winter conditions in buildings located in the southern region of Portugal. In general, in these spaces, thermal comfort reaches acceptable levels for the occupants, in accordance with Category C [8], during the occupancy cycle: in amphitheatre 4, by PMV positive values in the morning and by PMV positive values until around 4.45 pm and after this time by PMV negative values in the afternoon; in amphitheatre 5, during some periods by negative or positive values of the PMV, either in the morning or in the afternoon.

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Web System with RFID Technology to Improve the Internal Control of Attendance

Maribel Karina Flores Ramirez and Michael Cabanillas-Carbonell

Abstract The creation of new technologies in the world is constantly evolving, and teaching methods are changing, for which it is necessary to develop new software or computer tools that automate the procedures to be followed by the actors and even the way they plan to learn, responsibility and punctuality and satisfactory progress of learning and, therefore, the development of new software or automated systems. The proposed solution is to develop a web-based system using RFID technology to improve internal control, integrate several processes, optimize time and reduce costs, and update information in a timely manner and without losses. For the development of this work, the SCRUM methodology. After surveying the purchasing time, an average value of 90.55 was obtained, which corresponds to a reduction of 45.6%, and for the satisfaction of the administrative employees an average value of 4.55, which is an increase of 150%. It is concluded that the RFID-based system positively impacts purchasing time**.**

Keywords RFID · Productivity · Internal control · Optimize times · Scrum methodology

1 Introduction

The creation of new technologies in the world is constantly developing and changes in teaching methods, so it is necessary to develop new software or computer tools that automate the procedures to be fulfilled by the actors and even in the way of conceiving learning, responsibility, punctuality, and training advance satisfactorily

M. K. F. Ramirez · M. Cabanillas-Carbonell (✉)
Universidad Privada del Norte, Lima, Perú
e-mail: mcabanillas@ieee.org

M. K. F. Ramirez
e-mail: N00082240@upn.pe

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and with it the development of new software or automated systems which do not go unnoticed since the use of technologies is a solid support to strengthen changes and improvements in processes [1].

Controlling the attendance records of teachers and students ensures the availability and reliability of the information required at any given time. The design and development of an automated process system with a radio-frequency system for the Peruvian Institute of Tourism and Finance—IPT Peru will allow the administrative area to automate its processes [2].

The Peruvian Institute of Tourism and Finance—IPT Peru, since its inception as a place of education has presented a number of situations, basically that all processes are performed manually. An administrative staff of the institute is responsible for carrying out the attendance control of both teachers and students and at the same time taking out the homework of teachers, which affects the time, and extra compensation to staff; this situation, while it is true that it takes much more time than expected, since many teachers and students are late or missing class dictation, without proper control of their attendance. Therefore, the administrative staff of the institute to corroborate whether students are present in their respective classes, and it should be noted that this whole process is done manually. They verify attendance in the classrooms, which takes time for the use of personnel in this activity; the teacher also registers attendance on forms established by them, so the teacher also takes a long time to register it.

The type of research that will be carried out in this project is experimental (since quantitative and qualitative research is being developed) since it will verify the hypothesis: There is a significant improvement in the internal control of attendance at the Instituto Peruano de Turismo y Finanzas—IPT Perú due to the use of the web system with RFID technology. Therefore, a survey will be developed to validate the indicators and thus measure the reliability of the project. The author defines the experimental design as one in which the researcher manipulates an untested experimental variable under strictly controlled conditions. Its objective is to describe how and why a phenomenon occurs or may occur. It seeks to predict the future, to elaborate prognoses which, once confirmed, become laws and generalizations tending to increase the accumulation of pedagogical knowledge and the improvement of educational action [3].

As a solution it is proposed to design a web system with RFID technology to improve internal control, which will allow the integration of the different processes, optimizing time and reducing costs, in addition to having the information updated, in time and without losses; it will also help to make decisions that will help to take advantage over others in their field and the power to continue growing. In this sense, the objective of this research is to create a web system with RFID technology to improve internal control at the Instituto Peruano de Turismo y Finanzas—IPT Perú and determine the impact on the internal control of the attendance of administrative staff, teachers, and students by implementing the web system with RFID technology.

2 Bibliographic Study

There are several technologies on the market to easily enter product information into a computer system. The most popular is undoubtedly the barcode, which is very cheap and easy to implement. However, it has many drawbacks: It can store little information. For example, barcodes used on food products contain only 12 digits [4]. RFID technology is similar to a bar code, it allows radio-frequency reading, the tag must not be visible, and the tag and the reader are different.

2.1 RFID Types

2.1.1 Active

They do not need power from the antenna to be activated or to send data to the antenna since they have their own battery. They allow greater communication range (30 m approx.) have greater data storage capacity, and some may include additional sensors such as temperature sensors**.**

2.1.2 Semi-Active

This type of card has its own battery to activate its circuitry, but to send the information it receives from the radio waves emitted by the antenna. They are more expensive than passive cards but provide a greater range of communication (between 10 and 15 m approx.).

2.1.3 Passive

Passive tags do not have a built-in power supply; they use the electromagnetic field generated by the reader to activate and transmit data. The advantages of this type of tags are their low acquisition and maintenance cost, their size is smaller than active and semi-active tags. The main disadvantages are the short distance for the reading range (between 3 cm and 9 m approx.) and the additional sensors. The SCRUM methodology is a combination of different stages in an iterative and incremental manner, starting with the design of tests for a given feature before implementation; the main objective is to increase adaptability in the process [5]. On the other hand, its implementation in an organization's software projects has a positive impact on frequent changes, fast delivery, and risk reduction, allowing the integration of the system with the company in all its processes and knowledge areas [6]. Guarantees the required stability allowing the maturity of the team and relevant decision-making [7].

3 Methodology

For the development of this work, the SCRUM methodology was used because it is used for agile software development and is tailored; it is about planning projects in small blocks or Sprint, which is reviewed and improved since the objective is to control and plan the project. Always each Sprint or iteration, the previous work is reviewed and improved, and the same is done each week; based on this, the activities are prioritized and planned as the Sprint progresses. Figure 1 shows the life cycle of the SCRUM methodology.

3.1 Investigate Design and Type

According to its approach, this research is considered an experimental type, developing quantitative and qualitative research. According to its purpose, it is applied research since it seeks the resolution of a certain problem, and its objective is the application of knowledge or theories to give an answer to a specific problem or need, it generally takes a certain question and tries to find a definitive and complete answer.

Classified on the basis of the degree of manipulation of variables, it would be experimental research. Experimental research is any research conducted with a scientific approach, where one set of variables is kept constant, while the other set of variables is measured as the subject of the experiment.

3.2 Population and Sample

According to Ref. [8], the study population is a set of defined, limited, and available cases that form the basis for the selection of the sample and cases that meet a set

Fig. 1 Life cycle of the SCRUM methodology

Table 1 Total IPT population: Lima headquarters

Involved	Quantity
Administrative staff	4
Teachers	16
Students	20
Total	40

of predetermined criteria. The sample to be taken in the study is 40 people who use attendance marking daily (Table 1). The sample is the subset or portion of the universe or population in which the study is conducted [9]. For the present investigation, the sample will be made up of the 40 people identified in the population.

In addition, to verify the level of reliability, the SSPS is used as a calculation tool by applying Cronbach's alpha formula and to obtain the reliability in such a way that it reflects the probability of success that is expected.

The statistical formula for reliability (Cronbach's alpha).

$$\alpha = \frac{K}{K-1}\left[1 - \frac{\sum S_i^2}{S_T^2}\right] \tag{1}$$

K: The number of items.
$S_i{}^2$: Sum of item variances.
$S_T{}^2$: Variance of the sum of the items.
α: Cronbach's alpha coefficient.

3.3 Data Collection Instruments

For data collection, a survey will be carried out where an evaluation format will be taken into account and the evaluation mode will be specified in such a way that the type of analysis, personal data of the evaluated person, evaluation date, instructions on how the evaluation will be carried out, the number of pre-questions, type of statement, and the score that each of the questions will reach will be taken into account.

3.3.1 Technique

Survey

According to [10], a survey involves gathering data by interviewing people, the in-survey method involves a structured questionnaire given to respondents that are designed to elicit specific information. For [11], surveys systematically obtain information from respondents through questions, either in person, by telephone, or by

mail. According to [12], surveys are interviews with a large number of people using a pre-designed questionnaire. According to the aforementioned author, the survey method includes a structured questionnaire that is given to the respondents and is designed to obtain specific information corresponding to the indicators, therefore, to the variables or data concepts used. The en survey will be used for the present study. This tool will be used to obtain information about the variables being investigated; it will be applied personally, individually, or collectively and will reflect the variables and indicators.

Instrument

According to the reference [13], in principle, a data collection instrument is any resource that the researcher can use to approach the phenomena and extract information from them. In this way, the instrument synthesizes all the previous work of the investigation and summarizes the contributions of the theoretical framework by selecting data that correspond to the indicators and, therefore, to the variables or concepts used. The survey is a technique that consists of obtaining information about a part of the population or sample through a questionnaire or interview [14]. The information is collected through questions that measure the various indicators that have been determined in the operationalization of the terms of the problem or the variables of the hypothesis.

Validity

To validate the reliability of the survey, the instrument to be used is the questionnaire (survey—Likert scale) [15], Cronbach's alpha will be used, which indicates that if the alpha value (to be found with the SPSS program) is equal to or >0.8, it means that it passes the reliability test.

4 Results and Discussion

4.1 Normality Test

To carry out the hypothesis test, 40 people were taken as a sample, for which the Shapiro–Wilk normality test will be performed to determine whether the research variables have a normal distribution among themselves. In this work, it is mentioned: If the significance level is < 5%, it is determined that the sample does not come from a normal distribution; otherwise (>5%), it is determined that it comes from a normal distribution; that is, the null hypothesis is accepted.

H0: The variable internal control of attendance has a normal distribution.
H1: The variable internal control of attendance does not have a normal distribution.

Formula de Shapiro–Wilk.

Table 2 Shapiro–Wilk normality test for the variable internal control of attendance

	Shapiro–Wilk		
	Statistician	gl	Sig
Internal attendance control	0.848	40	0.000

$$W = \frac{\left(\sum_{i=1}^{n} a_i x_{(i)}\right)^2}{\sum_{i=1}^{n} (x_i - \breve{x})^2} \tag{2}$$

$x_{(i)}$: Number of the ith position in the sample

a_i: Tabulated coefficient for each sample size and the i position of the observations.

$\breve{x}$: Sample mean.

With the help of SPSS software, the following formula will be used to obtain the results:

As shown in Table 2, the significance level has a value of 0.000 which is < 5%, or in decimals which is a.005. Therefore, the null hypothesis is accepted and the alternative hypothesis is rejected, concluding that the variable internal attendance control has a normal distribution.

4.2 Descriptive Analysis

4.2.1 Descriptive Analysis of the Variable Internal Control of Attendance Pretest

This part details and analyzes the results obtained from the data collection. These data are based on the dimensions and variables related to the research. Table 3 and Fig. 2 show the distribution of the internal control of attendance variable where 0% is very high, 35% is high, 55% is moderate, 10% is low, and 0% is very low.

Table 3 Frequency table of the variable internal attendance control in pre-test

		Frequency	Percentage	Valid percentage	Cumulative percentage (%)
Valid	Very high	0	–	–	0
	High	14	0.35	0.35	35
	Moderate	22	0.55	0.55	90
	Low	4	0.10	0.10	100
	Very low	0	–	–	0
	Total	40	100%	100%	

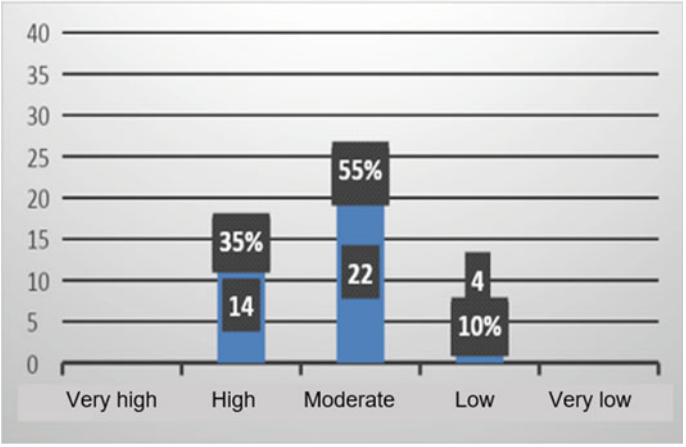

Fig. 2 Distribution graph of the variable internal control of attendance in pre-test

Table 4 Frequency table of the reliability dimension in pre-test

		Frequency	Percentage	Valid percentage	Cumulative percentage (%)
Valid	Very high	0	–	–	0
	High	5	0.13	0.13	13
	Moderate	31	0.78	0.78	90
	Low	4	0.10	0.10	100
	Very low	0	–	–	0
	Total	40	100%	100%	

4.2.2 Descriptive Analysis of the Pretest Reliability Dimension

Table 4 and Fig. 3 show the distribution of the reliability dimension, where 0% has a very high level, 13% has a high level, 78% has a moderate level, 10% has a low level, and 0% has a very low level.

4.2.3 Descriptive Analysis of the Usability Dimension Pretest

Table 5 and Fig. 4 show the distribution of the usability dimension, where 0% is very high, 5% is high, 80% is moderate, 15% is low, and 0% is very low.

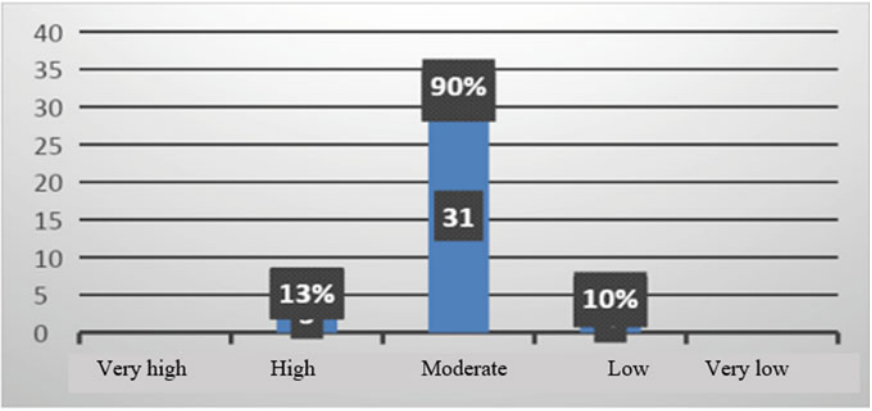

Fig. 3 Reliability dimension distribution bar chart in pre-test

Table 5 Usability dimension frequency table in pre-test

		Frequency	Percentage	Valid percentage	Cumulative percentage (%)
Valid	Very high	0	–	–	0
	High	2	0.05	0.05	5
	Moderate	32	0.80	0.80	85
	Low	6	0.15	0.15	100
	Very low	0	–	–	0
	Total	40	100%	100%	

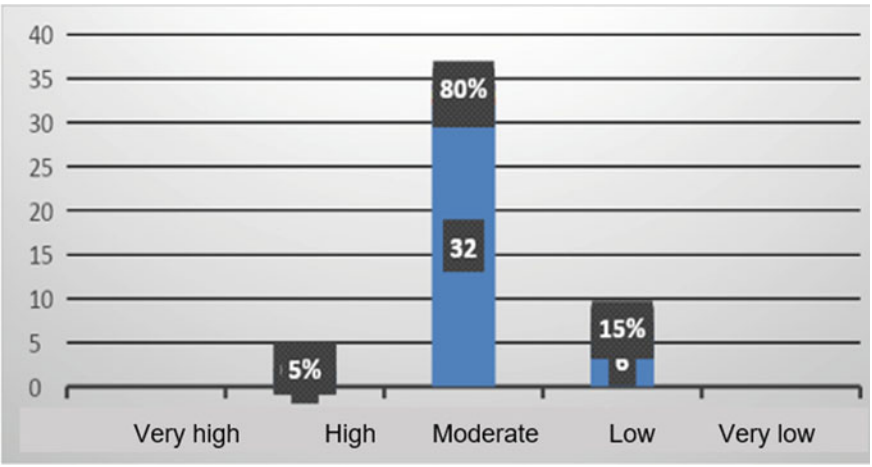

Fig. 4 Usability dimension distribution bar chart in pre-test

Table 6 Frequency table of the attendance control dimension post-test

		Frequency	Percentage	Valid percentage	Cumulative percentage (%)
Valid	Very high	0	–	–	0
	High	40	1.00	1.00	100
	Moderate	0	–	–	100
	Low	0	–	–	100
	Very low	0	–	–	0
	Total	40	100%	100%	

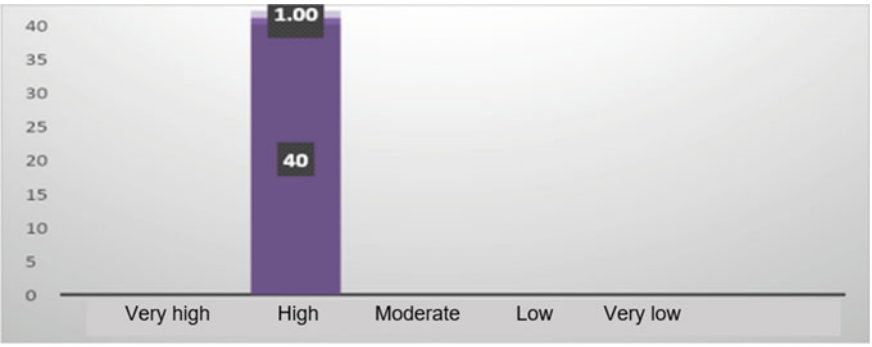

Fig. 5 Distribution bar chart of the internal control of attendance dimension in post-test

4.2.4 Descriptive Analysis of the Variable Posttest Attendance Control

Table 6 and Fig. 5 show the distribution of the internal control of attendance dimension, where 0% has a very high level, 100% is high, 0% is moderate, 0% is low, and 0% is very low.

4.2.5 Descriptive Analysis of Posttest Reliability Dimension

Table 7 and Fig. 6 show the distribution of the reliability dimension, where 0% is very high, 5% is high, 95% is moderate, 0% is low, and 0% is very low.

4.2.6 Descriptive Analysis of the Usability Dimension Post-test

Table 8 and Fig. 7 show the distribution of the usability dimension, where 0% is very high, 5% is high, 55% is moderate, 10% is low, and 0% is very low.

Table 7 Frequency table of the reliability dimension in post-test

		Frequency	Percentage	Valid percentage	Cumulative percentage (%)
Valid	Very high	0	–	–	0
	High	2	0.05	0.05	5
	Moderate	38	0.95	0.95	100
	Low	0	–	–	100
	Very low	0	–	–	0
	Total	40	100%	100%	

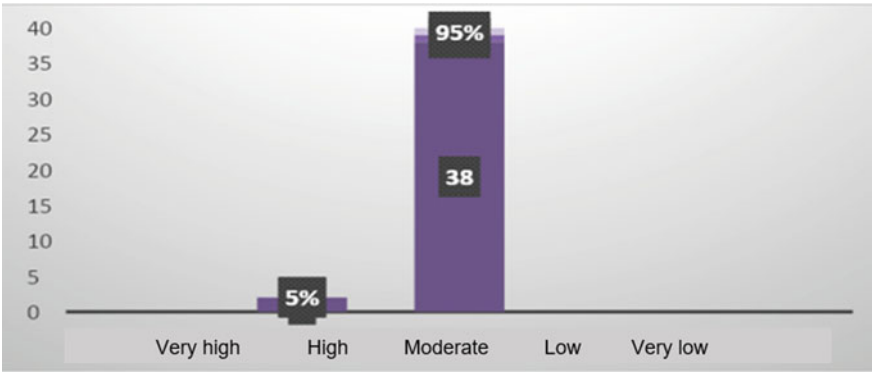

Fig. 6 Reliability dimension distribution bar chart in post-test

Table 8 Usability dimension frequency table in post-test

		Frequency	Percentage	Valid percentage	Cumulative percentage (%)
Valid	Very high	0	–	–	0
	High	2	0.05	0.05	5
	Moderate	32	0.80	0.80	85
	Low	6	0.15	0.15	100
	Very low	0	–	–	0
	Total	40	100%	100%	

5 Conclusions

Nowadays, institutions have been forced to develop new strategies that allow them to grow and reach more users. These circumstances led to the objective of the present research work, which was to determine the influence of the implementation of a web system with RFID technology based on the SCRUM methodology to contribute

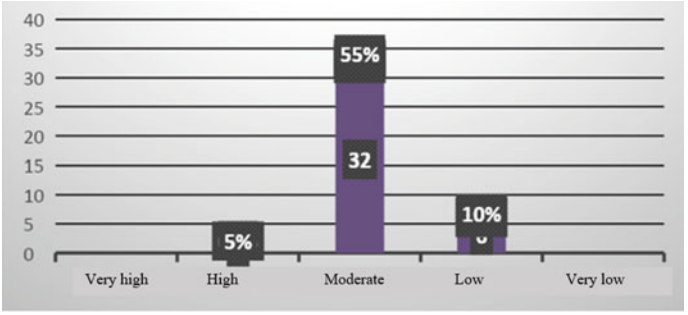

Fig. 7 Usability dimension distribution bar chart in post-test

to the improvement of the internal attendance control process, based on the "Instituto Peruano de Turismo y Finanzas—IPT Peru Sede Lima" (Peruvian Institute of Tourism and Finance—IPT Peru Lima Headquarters).

From the data obtained, it can be inferred that, for the post-survey of purchasing time, an average value of 90.55 was obtained, which represents a reduction of 45.6%, and for administrative staff satisfaction, an average of 90.55 was obtained. A mean value of 4.55 was obtained, representing an increase of 150%. It is concluded that the RFID-based system has a positive influence on the institute's purchasing time, since it allowed a reduction in internal control time, thus achieving the objectives expected in this research. In addition, it is concluded that the SCRUM methodology has a positive influence on the satisfaction of those in charge of the administrative part of the "Instituto Peruano de Turismo y Finanzas—IPT Peru Sede Lima," since it allowed to increase the degree of satisfaction, thus achieving the objectives specified in this research.

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Disaster Relief Donation Matching System and Users' Incentives

Junya Fukumoto

Abstract After a large-scale natural disaster, the material convergence problem occurs in the affected area. Its two primary causes are the lack of an effective information-sharing mechanism and an efficient matching mechanism between disaster survivors' needs and available supplies. The authors developed a disaster relief donation matching system to address this problem. There is a risk of many potential donors not using the system and trying to make direct contact with disaster victims to offer in-kind donations. In this study, we analyze the incentives of potential donors to access and utilize the matching system through an economic experiment.

Keywords Matching system · Material convergence · Users' incentives

1 Introduction

When a large-scale natural disaster occurs, a large quantity and variety of relief supplies are delivered to the affected areas quickly. The relief supplies are transported to collection points in the disaster area, temporarily stored, and then delivered to disaster victims. Because large supplies concentrate in a short time, the collection points become overloaded and over-capacitated. In addition, this causes secondary problems, such as high-priority supplies not reaching disaster victims. These problems are referred to as material concentration problem [1, 2]. Although it was first mentioned in the 1950s [3], very little research has been done, making it one of the most important, ironically the least studied problem.

J. Fukumoto (✉)
Tohoku University, Sendai, Japan
e-mail: junya.fukumoto.e3@tohoku.ac.jp

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Many studies are focusing on humanitarian logistics in operations research [4, 5]. The topics include supply chain network design, facility location, transportation planning under uncertainty, and vehicle routing. One of the particular features of this researches is to address inefficiency in humanitarian logistics processes. Optimization frameworks are commonly used, and consequently, centralized decision-making is generally assumed in the analysis. However, the optimization framework has limitations in tackling the material convergence problem triggered by heterogeneous donors feeling strong sympathy and desire to help disaster survivors. The root causes of the material convergence problem are difficulties in collecting relevant information and the lack of a coordinating mechanism for donors' independent and heterogeneous decisions. The optimization framework can be applied after these causes are removed.

Arnette et al. [6] divided the supplies delivered after a disaster into three categories based on priority criteria: high priority (HP), low priority (LP), and non-priority (NP). NP represents supplies that cannot be used in the disaster area as relief supplies, LP represents supplies that may be needed in a few days, and HP represents supplies that should be used immediately. The arrival of large quantities of NP supplies will cause various problems in the affected areas; personnel is allocated to sorting supplies that cannot be used; and space for storing HP supplies is overwhelmed. Holguin-Veras et al. [1] reported that more than 50% of relief supplies delivered to disaster areas are NP supplies. One of the reasons why a large volume of NP supplies is being delivered is competition among donors [7]. Donors are heterogeneous and have various motivations for donating supplies after a disaster occurs. Some may genuinely want to help the victims; some may want to gain a reputation by providing supplies; and some malicious companies or donors may see it as an opportunity for scavenger hunt, business, or tax deductions. A competition then arises, especially among those with the same motives.

In order to prevent material concentration problems, it is necessary to manage such a variety of donors with different motives, which is often the case in post-disaster humanitarian logistics. Among the few studies tackling material convergence problem, matching system (MS) has been proposed and implemented. AidMatrix or HELIOS are well-known systems. The author also has developed an MS [8, 9] and extended it to integrate with vehicle routing [10]. MS matches the information of donors' available supplies and recipients' desired supplies on a server. Appropriate matching of information can prevent mismatches between supply and demand and confusion at collection points.

Arnette et al. [6] reported that AidMatrix was not effectively used during the Colorado Flood of 2013. This does not mean there were no donors using the system, but they reported a large proportion of relief supplies were sent without using the system. To lessen the material convergence problem, we must understand why MSs were not used and what kind of algorithms and interfaces would enhance the usage of MS.

Regarding potential donors' incentives for using MS, the authors analyzed the relationship between the demand–supply balance of supplies and a realizing equilibrium state [11]. The potential donors are assumed to choose one of two behaviors:

"using MS" and "searching." This framework is similar to the buyers' choice of "auction" and "search" in the real estate market [12]. As a result, it is shown that for a certain item, when the demand exceeds the supply, an "M-equilibrium" occurs in which all donors use MS, and that when the supply exceeds the demands, an "S-equilibrium" occurs in which all donors directly search disaster victims to donate available supplies. Further, it is shown that multiple equilibria can hold when the quantities of available supplies and desired supplies are close to each other; in other words, both M-equilibrium and S-equilibrium coexist.

The above analysis supposed a simple case and analyzed potential users' behavior based on game theory. Although the supply–demand balance changes significantly over time after a disaster occurs, it did not consider the possibility of users learning about the supply–demand balance and the convenience of MS and their changing behavior.

In this study, we investigate whether the results of the above theoretical analysis hold through an economic experiment. The subjects of the experiment are divided into two groups: donor and recipient. The subjects belonging to the donor group can choose one of two alternative actions for donating supplies: "using MS" or "directly donating supplies." The subjects using MS input the information of available supplies into the matching system developed by the authors. If directly donating supplies, they make contact with a subject belonging to the recipient group through an online one-by-one chat system and make an offer of in-kind donation. Whether each subject of the donor group can succeed in donating supplies depends on the other subjects' choice and the supply–demand balance. Since the matching process is repeated for a certain number of rounds in an experiment, we can monitor how each subject changes his choice depending on the results of matching in the previous rounds and the information for the supply–demand balance.

We test two hypotheses. The first hypothesis is that "different equilibria arise for different supply–demand balances." In each round of the matching phase, we consider three different supply–demand balances for supplies: excess demand, excess supply, and balanced equilibrium. In actual disasters, the supply–demand balance changes daily for each type of supplies. Therefore, it is necessary to verify under which conditions the MS utilization rate changes. The second hypothesis is that "donors change their behavior, whether using MS or directly donating, depending on the matching results of previous rounds." If they had used MS but failed to donate, they might not use MS in the succeeding rounds. The results of these two hypotheses testing will provide insights into how to enhance the usage of MS.

2 Outline of Matching System

The framework of MS proposed by the authors is shown in Fig. 1. The MS developed by the authors makes an efficient assignment plan and a vehicle routing plan based on the information input into the system.

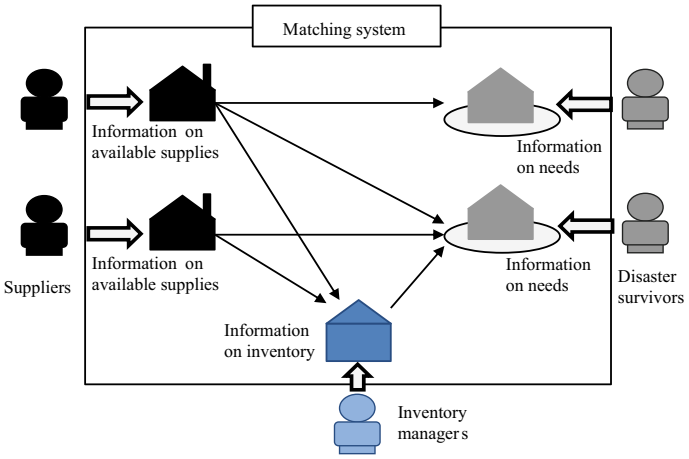

Fig. 1 Concept of the matching system

The system operates on the Internet twenty-four hours a day, and information can be input at any time. Donors and recipients of supplies input their own information, and the system is managed by a separate system administrator. Donors are assumed to be companies, organizations, or municipalities outside the disaster area, donors of supplies are assumed to be municipalities in the disaster area, and the system administrator is assumed to be a disaster response department of the central government, or a local government.

Donors enter the types and quantities of supplies that can be provided, the start date and time of availability, and the supplied deadline. The recipients enter the types and quantities of supplies in demand and the demand deadlines. The type of supplies can be selected from the primary, medium, and minor categories, and this makes it possible to standardize the information and improve the efficiency of matching. The size can be selected in the same way from the pull-down menu.

The system is to be launched by the system administrator charged with streamlining relief supply logistics. The matching system is designed for "pull-type delivery." The aim of such delivery is to recover the livelihood of disaster survivors (i.e., not intended to save survivors' lives). For these reasons, the matching system is intended to make assignment of almost any items of relief supplies; However, it is not intended to be used to match supplies critical to life, such as daily meals and medicines.

Four algorithms of matching are implemented. In this study, we use the demand satisfaction maximization algorithm.

3 Experimental Setting

The economic experiment is a sophisticated methodology to induce the rational behavior of subjects and empirically test the validity of economic theory [13]. In an experiment, the experimenter assigns tasks to the subjects. The subjects can get rewards proportional to the experimental scores from assigned tasks. In this study, we employ this methodology and test whether the potential users of MS have proper incentives to use it even though they can donate or receive supplies differently. The framework experiment is similar to the previous study [9]. The most crucial difference is that in this study, a donor can choose either or both, "using MS" or "directly donating supplies." In the previous study, each subject has no alternative choices.

The number of subjects participating in one experiment is twelve. At the beginning of the experiment, eight subjects were assigned to the donor group, and four subjects are assigned to the recipient group. Each subjects is seated in front of a computer terminal. They are not allowed to see the other subjects' terminal screens.

Each experiment consists of twelve rounds. In each round, supplies are matched. At the beginning of each round, subjects receive information on the supplies they can provide or the supplies they wish to receive. Next, the donor group inputs the information into the MS or directly offers a donation to a recipient. The offer is made through a one-on-one chat system. When a recipient subject receives a donation offer, he accepts the offer if the demand is not satisfied; then, a transaction concludes. If his demand is already fulfilled, he must refuse the offer. The donor can make offers repeatedly as long as he has available supplies. The recipient subjects may accept offers from multiple donors if the demand is not satisfied. After accepting some offers, each recipient subject inputs the remaining demand into the MS as long as all the demands are not fulfilled. The donor subjects also input information about the remaining available supplies into the MS if there are supplies that have yet to be donated, regardless of whether or not they made offers directly. At the end of each round, the MS outputs the matching result. All the donor subjects and all the recipient subjects record how many units of supplies they were able to provide and receive, respectively. This experiment used three types of supplies (water, blankets, and shirts.)

The information that subjects receive is described in more detail below. Each subject in the donor group is informed of the types and quantities of supplies he can provide (See Tables 1, 2, 3). In the same way, each subject in the recipient group is informed of the type and quantity of supplies he demands. This information is private, and each subject cannot know others' information. In addition to the above information, all subjects receive the same signal on the supply–demand balance in each round. The supply–demand balance is an index that synthesizes the difference between the total quantity available and the total quantity demanded, calculated for each type of supply. The signal is one of the following three: excess demand, supply–demand equilibrium, or excess supply.

Table 1 Available and demanded amount of supply 1

Round	Available amount (donor)								Demanded amount (recipient)				Total supply	Total demand	Excess demand	Balance
	D1	D2	D3	D4	D5	D6	D7	D8	R1	R2	R3	R4				
1	120	180	120	180	120	180	120	180	600	300	600	300	1200	1800	600	ED
2	150	150	150	150	150	150	150	150	300	600	300	600	1200	1800	600	ED
3	180	120	180	120	180	120	180	120	450	450	450	450	1200	1800	600	ED
4	120	180	120	180	120	180	120	180	600	300	600	300	1200	1800	600	ED
5	90	90	120	120	180	180	210	210	300	600	300	600	1200	1800	600	ED
6	180	120	180	120	180	120	180	120	450	450	450	450	1200	1800	600	ED
7	120	180	120	180	120	180	120	180	400	200	400	200	1200	1200	0	DS
8	90	90	120	120	180	180	210	210	200	400	200	400	1200	1200	0	DS
9	150	90	180	120	180	120	210	150	300	300	300	300	1200	1200	0	DS
10	150	210	120	180	120	180	90	150	400	200	400	200	1200	1200	0	DS
11	120	120	150	150	150	150	180	180	100	200	100	200	1200	600	−600	ES
12	150	90	180	120	180	120	210	150	150	150	150	150	1200	600	−600	ES

Table 2 Available and demanded amount of supply 2

Round	Available amount (donor)								Demanded amount (recipient)				Total supply	Total demand	Excess demand	Balance
	D1	D2	D3	D4	D5	D6	D7	D8	R1	R2	R3	R4				
1	15	15	15	15	15	15	15	15	30	60	30	60	120	180	60	ED
2	18	12	18	12	18	12	18	12	45	45	45	45	120	180	60	ED
3	12	18	12	18	12	18	12	18	60	30	60	30	120	180	60	ED
4	9	9	12	12	18	18	21	21	30	60	30	60	120	180	60	ED
5	18	12	18	12	18	12	18	12	30	30	30	30	120	120	0	BE
6	12	18	12	18	12	18	12	18	40	20	40	20	120	120	0	BE
7	9	9	12	12	18	18	21	21	20	40	20	40	120	120	0	BE
8	15	9	18	12	18	12	21	15	30	30	30	30	120	120	0	BE
9	12	18	12	18	12	18	12	18	20	10	20	10	120	60	−60	ES
10	12	12	15	15	15	15	18	18	10	20	10	20	120	60	−60	ES
11	15	9	18	12	18	12	21	15	15	15	15	15	120	60	−60	ES
12	15	21	12	18	12	18	9	15	20	10	20	10	120	60	−60	ES

Table 3 Available and demanded amount of supply 3

Round	Available amount (donor)								Demanded amount (recipient)				Total supply	Total demand	Excess demand	Balance
	D1	D2	D3	D4	D5	D6	D7	D8	R1	R2	R3	R4				
1	90	60	90	60	90	60	90	60	225	225	225	225	600	900	300	ED
2	60	90	60	90	60	90	60	90	300	150	300	150	600	900	300	ED
3	75	75	75	75	75	75	75	75	100	200	100	200	600	600	0	BE
4	90	60	90	60	90	60	90	60	150	150	150	150	600	600	0	BE
5	60	90	60	90	60	90	60	90	200	100	200	100	600	600	0	BE
6	45	45	60	60	90	90	105	105	100	200	100	200	600	600	0	BE
7	75	45	90	60	90	60	105	75	75	75	75	75	600	300	−300	ES
8	60	90	60	90	60	90	60	90	100	50	100	50	600	300	−300	ES
9	45	45	60	60	90	90	105	105	50	100	50	100	600	300	−300	ES
10	75	45	90	60	90	60	105	75	75	75	75	75	600	300	−300	ES
11	75	105	60	90	60	90	45	75	100	50	100	50	600	300	−300	ES
12	60	60	75	75	75	75	90	90	50	100	50	100	600	300	−300	ES

The first half of the twelve rounds corresponds mainly to the situation immediately after the occurrence of a disaster. In such a period, supplies are depleted in the affected area. In other words, demand in the disaster area is likely to exceed supply. As time passes, supplies arrive in the disaster area one after another. Demands in the disaster area become fulfilled, and the balance gradually changes. Eventually, the demand in the disaster area becomes small, leading to oversupply. The latter rounds mainly deal with such a situation.

After all the rounds are completed, the donors are paid an honorarium based on their performance in a total of twelve rounds of experiments. Points are awarded for a higher total quantity of supplies provided to the recipients, and points are deducted for a higher number of direct offers. The reason for the reduction in points based on the number of offers is the cost of searching for and contacting recipients, as well as the cost of transporting the supplies. If a donor uses only MS, other donors may have already directly offered to donate supplies, and the demand has been fulfilled, making his available supplies unmatched even after MS calculated the optimal matching. On the other hand, if the donor does not use MS and directly asks for donations, he can provide supplies if he finds a recipient who is willing to accept the offer. However, if he fails to find a recipient or if other donors have already provided supplies, the donor only bears the cost of searching for recipients and making direct offers. By making the reward dependent on the performance in the experiment, the subjects are given the incentive to conduct efficient transactions. As for the recipient subjects, the reward was fixed at a fixed amount since they only acted passively in response to the donor's offer.

We did four sessions of the above experiment in January 2019. The subjects were undergraduate and graduate students of Tohoku University. Each session took about three hours. The payments to the subjects, including a show-up fee of twenty dollars, varied from twenty to fifty dollars.

4 Results

4.1 Hypothesis 1

Hypothesis 1 is that "different equilibria occur in different supply–demand balances," with M-equilibrium in the case of excess demand (ED), S-equilibrium in the case of excess supply (ES), and multiple equilibria in the case of balanced equilibrium (BE). Figure 2 shows the MS utilization rates for each supply–demand balance cases.

We can see that M-equilibrium with a high MS utilization rate occurs when the supply–demand balance is excess demand (ED); S-equilibrium, in which the MS utilization rate drops significantly and MS is no longer used, occurs when the balance is excess supply (ES). The experimental results are consistent with the theoretical implication of the previous study. In excess-supply cases, many donors believe that other donors' direct donations would fulfill recipients' demand, and that they would

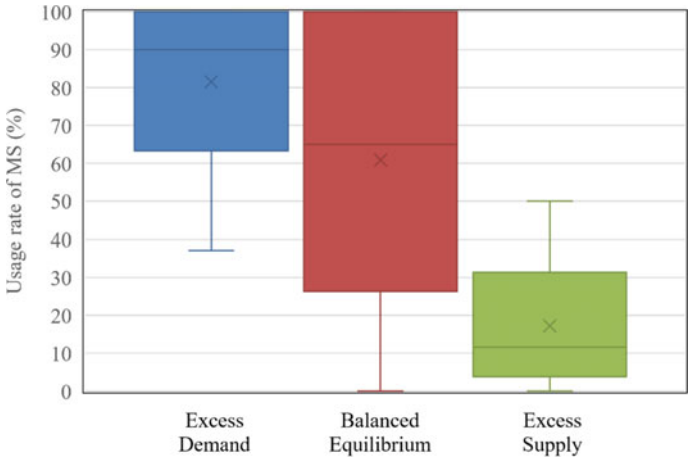

Fig. 2 Usage rate of MS

be unmatched even if inputting information on the available supplies for donation. This belief accelerates the direct donation.

In a balanced equilibrium (BE), we can see that the utilization rate of MS is dispersed. This result suggests that an intermediate state between M-equilibrium and S-equilibrium realizes rather than converges to one of the two extreme states, as predicted by the previous study. Once S-equilibrium realizes, it tends to be locked in. In other words, the recovery of the usage rate of MS and returning to the M-equilibrium state become more difficult. In the dispersed state, since S-equilibrium is not yet locked in, there may be room to restore the incentive of using MS. We will consider this again when we examine hypothesis 2 below.

4.2 Hypothesis 2

We can see that the null hypothesis that "the choice of directly donating is independent of the result of the direct donation offer in the previous round" is not rejected at a significance level of 5% or less (Table 4). This result means that there is no obvious suggestion that the failure of a direct donation offer reduces the likelihood of choosing it again in the next round. On the other hand, we can see that the null hypothesis that "the choice of using MS is independent of the result of the matching by MS in the previous round" is rejected at a significance level of <0.1% (Table 5). This result means that once a donor using MS is unmatched, he refrains from using MS again.

Let us look at the above result from another angle. The incentive for using MS can be maintained by matching as many donors as possible with the recipients. In this case, M-equilibrium may be sustained in the long run. Suppose that only a few large firms are matched with the recipients through MS; this may be efficient in

Table 4 Frequency of direct donation

Round T / Round T-1	Try direct donation	Not try direct donation
Try direct donation and succeed	59	13
Try direct donation and fail	347	41
Not try direct donation	99	497
p-value	$0.05 < p < 0.1$	

Table 5 Frequency of using MS

Round T / Round T-1	Using MS	Not using MS
Using MS and succeed	187	31
Using MS and fail	130	492
Not using MS	188	28
p-value	$p < 0.001$	

the short run in terms of transportation costs and other factors. However, it may be inefficient in the long run because the usage rate of MS declines quickly. We know that fairness is essential in distributing relief supplies among recipients. The above results suggest that fairness among donors in matching with recipients is also important in enhancing the incentives for using MS and achieving long-run efficiency in post-disaster humanitarian logistics.

5 Conclusion

In this study, we did an economic experiment to empirically verify the theoretical results of previous studies on the relationship between the usage rate of MS and the supply–demand balance of relief supplies. The experiment showed that when the supply–demand balance is in excess of demand and supply, there are M-equilibria with a low usage rate and S-equilibria with a high usage rate, respectively. This result is consistent with the theoretical results. On the other hand, when the supply–demand balance is in equilibrium, the results show that a state intermediate between the two is realized, unlike the theoretical conclusion that either M-equilibrium or S-equilibrium is realized.

Focusing on the factors affecting the usage of MS by individual donors, the probability that a donor will contact a recipient directly to offer supplies without using MS in the next round is significantly higher when unmatched in the previous round despite entering information on available supplies in the MS. If only a small number

of donors are successfully matched through MS, which may be cost efficient for transportation costs and other factors, the usage rate of MS tends to decline rapidly as many potential donors avoid using MS, and this leads to the increase of long-term costs. We must consider ways to increase the MS usage rate, such as devising allocation algorithms used in the matching.

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A Recent Review on Machine Learning Applications and Deep Learning Techniques for Handling Pandemics

Maha Zayoud, Soraia Oueida, and Rami Al-Hajj

Abstract Pandemics are defined as the widespread of different infectious diseases over large territories, such as influenza, SARS, and coronavirus. COVID-19, a severe contagious virus, has affected the daily life of every human on earth since 2019. It negatively impacted social life, the economy, the education sector, mental health, and many other aspects worldwide. Scientists envisioned the surge of using machine learning (ML) techniques and applying several artificial intelligent (AI) methods to tackle this issue. The main challenge that faces researchers and scholars when they suggest a particular solution is the selection of the best suitable algorithm to predict and classify the infection. In general, the examined virus may be detected by using either the available symptoms such as short breathing, dry cough, headache, loss of taste, and fever or by investigating available medical images. The aim of this work is to overview recent studies and proposed solutions that have been realized in the literature over the last three years. The result of the undertaken review is to identify, assess, and revise different methods of applying ML techniques on image-based and text-based COVID-19 data records and increase awareness of the need to consider such technology to alleviate the impact of any possible future pandemic. This will help in providing a comprehensive view of the current advances, limitations, and challenges in this field.

Keywords Artificial intelligence · COVID-19 · Deep learning · Machine learning · Pandemics · Prediction

M. Zayoud (✉) · S. Oueida · R. Al-Hajj
College of Engineering and Technology, American University of the Middle East, Egaila, Kuwait
e-mail: maha.zayoud@aum.edu.kw

S. Oueida
e-mail: soraia.oueida@aum.edu.kw

R. Al-Hajj
e-mail: rami.alhajj@aum.edu.kw

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1 Introduction

Coronavirus (COVID-19) is an infectious disease resulted from the SARS-CoV-2 virus. It was announced as a pandemic by the World Health Organization (WHO) in April 2020 causing a severe impact on every aspect of human life globally. Cases started to increase rapidly, and the number of deaths increased accordingly. The virus spreads by simply touching a contaminated surface and severely affects the immune system. Symptoms of the presence of COVID-19 include breathing problems, dry cough, body aches, sore throat, severe headache, and high fever [1], which have been illustrated in Fig. 1. Rapid testing kits were developed to detect if a person is infected by the virus or not. However, these antigen tests involve high costs and sometimes false results which makes them unfeasible in some cases. This urges the need to count on the advances in information technology as an alternative solution. Machine learning and deep learning (DL) models have been widely used for identification and prediction in many industrial sectors and particularly in healthcare [2]. For example, neural networks and various types of regression models can predict the future conditions of a certain patient for a specific disease [3]. Many researchers counted on data derived from medical images to classify a case to be either positive or negative. Others, like Tao et al., have studied the effect of social media on the virus spread and guiding methods for recovery. The authors used machine learning sentiment analysis (MLSA) to investigate the effectiveness of several available social media sources in the prediction process of population-level sentiment. Results of the neural network showed that Twitter is a better indicator of public sentiment [4]. They presented a short review on the importance of using ML and AI for predicting infectious cases during pandemics.

This paper is organized as follows: Sect. 2 presents a literature review on the available machine learning algorithms and deep learning techniques that can be of interest when dealing with pandemics. An analysis of the studied articles is presented in Sect. 3. Section 4 offers resultant recommendations that can help researchers and scholars. Limitations and challenges are presented in Sect. 5. Finally, Sect. 6 concludes the paper and discusses the potential perspectives in the near future.

2 Literature Review

Artificial intelligence refers to the algorithms that enable computer systems to predict and make decisions after being trained. Research about the applications of AI and ML in the healthcare sector is extensively presented in the literature. Several researchers have employed ML and particularly DL techniques for detecting COVID-19. In this section, we discuss different ML and DL algorithms that have been recently applied (between 2020 and 2022 inclusive) for the diagnosis and prediction of COVID-19. A comparison among the applied algorithms is presented in Sect. 3.

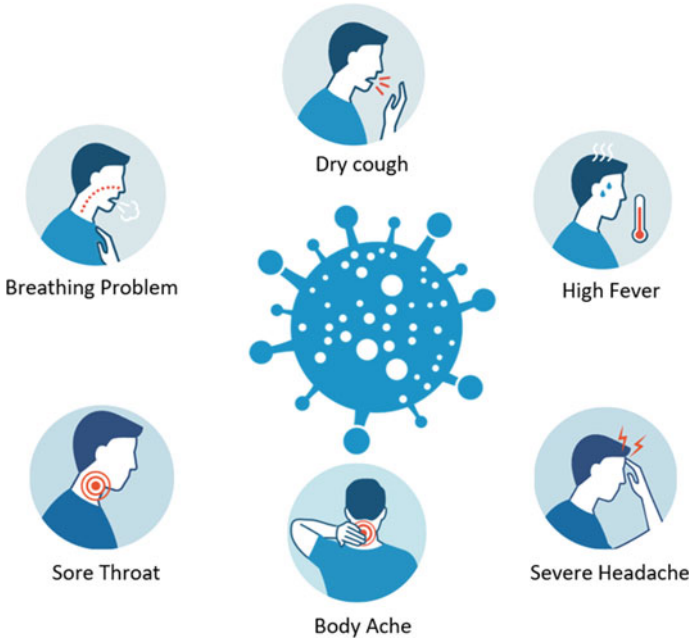

Fig. 1 Symptoms of COVID-19

2.1 Machine Learning for Detecting COVID-19

Regression and classification are two categories of problems that can be approached by supervised ML algorithms. Supervised learning is a technique that maps a predictive relationship between features and outcomes. In general, the main difference between classification and regression is the type of prediction where the first predicts discrete class labels, whereas the second one predicts continuous quantities. A prediction problem is usually formulated to be a regression task where a wide range of ML regression algorithms is applied. Authors in [5] examined several ML algorithms, e.g., support vector machine (SVM), logistic regression (LR), decision tree (DT), Gaussian Naive Bayes (GNB), and random forest (RF) for prediction. They particularly applied the ensemble voting to combine the outcomes of the several trained models and as a result improve the overall prediction process. The ensemble model consists of aggregating the responses of a parallel set of ML models to improve the prediction performance in a complex classification/regression problem. The proposed approach showed promising results with approximately 99% accuracy [6]. Begum et al. combined three regression methods: polynomial regression, simple linear regression, and multivariate regression to predict positive cases along with the degree of spread. The authors claimed that the main advantage of their approach is its ability to perform legitimate arrangements when dealing with potential future waves of the virus. The reported results showed accuracy percentages for the case of

China equal 62.1%, 96.2%, and 98.8%, respectively, for the three different regression methods used. While for the United States case, the reported precision values were 65.01%, 98.82%, and 99.47%, respectively [7]. Regression ML models have been also applied to the datasets of several affected countries to predict the number of patients that can be recovered in those regions as in [8]. In this context, Chitturi et al. proposed a model based on different ML algorithms. The purpose of this model is to study parameters, identify patterns within the collected data, and therefore predict whether the corresponding patient is infected or not. Random forest outperformed all other algorithms with an accuracy of 99.03% [9]. Logistic regression was used by Dharani as a classification model to classify the inspection results by means of patients infected by COVID-19 or not infected and to predict which symptom is more probable to cause a positive test result. The probability of contamination had only 66.89% accuracy, and therefore, the model was fine-tuned to provide better results and increase accuracy by applying artificial neural networks (ANN) [10].

Due to the latest technological advancements, several monitoring devices have been developed to follow up on patients' medical status and arrange the collected information in time series records. These medical records, such as body temperature, heart rate, respiration rate, and more, if collected in real-time and analyzed properly, can play a crucial role in predicting COVID-19 cases. Since early detection can limit the spread of the virus, Skibinska et al. proposed a model that not only detects COVID-19 but can also be useful for detecting, at the earliest stages, the presence of any viral disease and thus limiting its spread. The authors used SVM, XGBoost, K-nearest neighbor (KNN), DT, RF, and LR for classification. The model inputs data were collected by wearable electronic devices [11]. The examined dataset consists of the readings that are received by those wearable devices. Three steps were performed in their study including pre-processing of data signals, training of the machine learning model, and evaluation of the results' accuracy to validate the overall performance. Many other researchers also investigated the use of wearable devices in this field such as Mishra et al. [12]. Hence, researchers during pandemics focused on estimating the number of infected patients. Rustam et al. conducted research to demonstrate the capability of different ML algorithms in forecasting COVID-19 based on datasets containing details about newly infected patients, the number of recoveries, and the number of fatalities. The results of the proposed model are promising and lead to efficient management of any infectious disease like COVID-19. To train the model, supervised ML methods were applied such as SVM, least absolute shrinkage and selection operator (LASSO), exponential smoothing (ES), and LR counting on datasets from the Johns Hopkins University [13]. Anggreainy et al. [14] also analyzed future possible COVID-19 cases using supervised ML methods like linear regression and ES. The examined approach yields an 81.6% training accuracy, which is a promising output; therefore, the approach can be trusted and used for future forecasting [15]. It is important to highlight the work done in [14], where authors used complete blood count (CBC) records to assist doctors in effectively managing medical cases, increasing patient satisfaction, and optimizing the process without wasting resources. Early prediction of mortality risks associated with this virus is the key, leading to urgent support to patients considered as severe and thus

minimizing the mortality rate. The authors developed a scoring tool based on ML and CBC records to classify patients under three risk categories: high, moderate, and low. The multivariate logistic regression-based model along with the scoring tool helped in identifying, predicting, and minimizing mortality risk with an important degree of precision. High accuracy levels were achieved. The concept of accuracy refers here to the probability of correctly classifying all patients by the ML model. Based on the accuracy criterion's values and many other values, it can be said that the models KNN, locally weighted learning (LWL), GNB, and K-means clustering are more accurate than other models when it comes to detecting the severely infected cases. Over 87% of the trained models in this study could accurately identify both severe and moderate COVID-19 patients. The model input data were based on information collected by hospitals' receptionists at the patient arrival stage. This data contained routine blood values (RBV) and patient's age acquired to identify severe and slightly infected COVID-19 patients. An effective feature dataset for the illness prognosis was generated through a sequence of data pre-processing steps and has been clinically validated. Following some data preparation steps, a feature dataset was created that has been clinically shown to be useful for the prediction stage [16]. It can be said here that ML could be used to extract important information from large datasets and build prediction models for the medical industry based on the key characteristics of a specific virus such as COVID-19. However, many platforms that are built especially to detect COVID-19 virus are established based on the concepts of data collection, pre-processing, extraction of features, and machine learning.

A novel model established by Panthakkan et al. to detect COVID-19 from lung X-ray pictures at an early stage [17]. It is based on a deep learning algorithm that correctly predicted the illness in both the training and testing phases with approximately 99% accuracy. The transfer learning (TL)-based approach improved the overall performance and correctly predicted the illness in both the training and testing phases with an accuracy of almost 99% and 98.5%, respectively. Also, the dimensional reduction of features was applied by the authors to assist the ML models. The final phase of the approach involves a voting technique that combines SVM, GNB, and RF. A neural network model was proposed with chest X-ray images of affected patients. The accuracy of the neural network-based model outperformed all other models [17].

2.2 Deep Learning for Detecting COVID-19

DL models consist of deep layers of neural networks that help in obtaining high-level abstract features, which leads to consistent performance and highly accurate results. Authors in [6] implemented an AI model to predict COVID-19 based on CT scans. As a first step, they applied a pre-processing on the collected scans. They used normalization and image reshaping to make images readable. As a next step, a convolutional neural networks (CNNs) model was trained to extract the prominent features from the pre-processed images. CNN is widely used for the classification and regression analysis of one-dimensional data specifically for image recognition.

A novel deep learning method was suggested in [18] to predict COVID-19 using medical images. They proposed a model that is based on two separate CNNs; one to extract features from CT images and another one to extract features from X-ray images. Before the classification step, the proposed model concatenates the extracted features from the two different networks into one layer. They achieved an accuracy of 99%.

Since coronavirus is basically affecting the lungs, lungs X-ray scans were mainly used for prediction. Those X-rays were helping radiologists to classify patients as either COVID-19 infected or COVID-19 free. In the novel model in [19], 20% of the total 2000 lung X-ray images utilized in the trial was essential for testing the proposed deep learning model, while the remaining 80% were used for training. According to Panthakkan et al., the proposed DL approach is aimed at the detection of COVID-19 at an early stage. The model was based on lung X-ray images, for a given sample size of around 2000 X-rays, a suggested binary classification and normalization techniques, and using a well-known TL model. The X-ray images are resized to an appropriate size without removing important characteristics or affecting the classification's precision as in [19]. The suggested system could help radiologists in diagnosing COVID-19 quickly. As a result, a new DL algorithm for early detection using lung X-ray images was proposed [19]. The coronavirus epidemic has sparked a gigantic upheaval across the planet. Therefore, authors in [20] aimed to integrate AI techniques with medical science to develop a classification tool that is able to recognize COVID-19 infection and other lung ailments. In this study, they evaluated four conditions, namely non-COVID-19 pneumonia, COVID-19 pneumonia, pneumonia, and clear lungs. The suggested AI solution consists of two stages. The first one classifies chest X-ray volumes into two categories pneumonia and non-pneumonia. In stage 2, if the lungs X-ray is related to pneumonia class, then it classifies it into either COVID-19 positive or COVID-19 negative. The authors evaluated their method on a dataset of 1300 images with an accuracy of 89.60%. In other words, the identification of pneumonia is made in the first step; the differentiation between pneumonia and COVID-19 is done in the second one; the identification of the COVID-19 area in the lungs is accomplished in the final step. With the use of AI and ML, research in medical databases has transformed into a productive concentration on everything. X-rays have aided the initial phases of COVID-19 screening and diagnosis of patients. Albawi et al. discussed their framework as follows: Stage 1 divides the X-rays into normal and pneumonia-affected cases, and stage 2 applies the CNN to classify the pneumonia-affected cases into COVID-19 positive and COVID-19 negative [21]. The complete image dataset consists of around 1800 X-ray scans, 570 of the total scans are pneumonia-affected, and the remaining 630 are not. The training data were appropriately pre-processed to exclude severely deteriorated images that might reduce the trained model's accuracy. A new architecture called CovAI-Net is proposed by Mishra et al. to categorize the input data into necessary classes [20]. It is a 2D CNN that detects potential COVID-19 infected patients using their chest X-ray images. This architecture predicts COVID-19 potential patients in two steps. Pneumonia and non-pneumonia X-rays datasets were used to train the architecture for stage 1 of classification. The architecture has been also trained using a dataset

of x-rays for both positive and negative COVID-19 cases for stage 2 to categorize the pneumonia X-rays as either positive or negative. Better hyperparameters could be available for the suggested architecture to enable a more precise classification of the X-ray volumes. Even though there have been several works on the prediction of COVID-19 based on CT volumes, the authors of this work were planning to use CT volumes to train CovAI-Net to predict lung illnesses [20].

The main issues of pandemics are the rapid change of the virus type and the amount of different data that is generated due to its impacts on different aspects of health. As discussed before, DL refers to artificial neural networks with multiple hidden layers that ensure the extraction of abstract high-level features. Nowadays, DL is considered to be one of the most powerful tools to solve complex problems in classification and regression because of its ability to handle data of high dimensions and to acquire complex behavior from various input types, such as images, audio signals, or text. The expanding use of deep neural networks in the electronic medical field, in which the analysis of predictive trends is of utmost significance, has been hampered by its mystery's nature. The authors in [22] chose a few cutting-edge techniques that performed well on COVID-19 picture categorization. Their suggested approach could produce a positive prediction and concentrate on the most exclusionary region of the picture, which may be located as the lesion area. They highlighted the super-pixels for each pair of photos that were helpful in the prognosis, and locations with lesions are emphasized for the prognosis. The study was done for COVID-19 investigations, but it might also be applied to other picture modalities and clinical inquiries. The experiments had shown that their XAI augmented classifier model can produce reliable and acceptable classification results and a compelling justification for different outcomes. This work inspires other researchers to innovate new methods, technologies, and platforms to detect the new virus and all their variants, in addition to defeating these viruses in different ways. Authors in [23] used technological advances to screen COVID-19 patients. They established a model based on AI and other technologies to assist in virus diagnosis. Their system consists of three parts: a training model, the use of AI basic algorithms to classify the COVID-19 CT images, and the design and then implementation of the system based on modeling, training, and deployment. The authors were able to build a system that involves a complete process of modeling-training-validation-deployment activities for COVID-19. The positive outcomes of this model allowed researchers and more than 100 hospitals worldwide to defeat the epidemic. This novel framework can be considered as a reference for possible similar future events.

The spread of COVID-19 caused a tremendous influence on people's daily lives and health all around the world that affected their social and mental development as well. Hence, many researches focused on COVID-19 impacts on mental health and used ML with DL techniques to propose new methods to predict and overcome these impacts. The study in [24] is based on ML algorithms that analyze the hidden pattern of mental health data and classify them into different levels during pandemics. This paper investigates the performances of recently suggested approaches and algorithms for evaluating psychological impact during pandemics. This study was based on an online survey and consists of responses that are based on questions

that can detect the level of general anxiety disorder (GAD-7) and many other mental problems. However, among the classifiers, ANN showcased the highest accuracy of 95.45%, whereas logistic regression, linear kernel support vector machine, and Gaussian process exhibited accuracy levels of more than 90% as discussed in [24].

3 Discussion and Analysis

Different machine learning and deep learning models have been used for the early detection and prediction of COVID-19. The majority of the studies in the domain of ML have used classification and regression models, namely the SVM, LR, DT, RF, GNB, KNN, ANN, and XGBoost for the detection and prediction of COVID-19 using image and non-image datasets. Whereas, the majority of the studies in the domain of deep learning have used CNN, VGG16, VGG19, MobileNetV1, CovAI-Net, and TL for early detection and prediction of COVID-19 using patient data collected in real-time, such as CT scans and X-ray images. With the broad deployment of smart medical information systems along with the advances in ML and the increase of medical data records, data-driven medical systems against pandemics are booming. However, there are still numerous issues and limitations including the necessity of enough amount of historical data over extended periods to train DL models in predicting and detecting infected cases. Besides, unified metrics to evaluate the performance of newly suggested approaches will definitely help in comparing those approaches and increase the benefits of their combination. Furthermore, TL may play a key role in advancing modern DL-based systems for predicting and detecting pandemics,

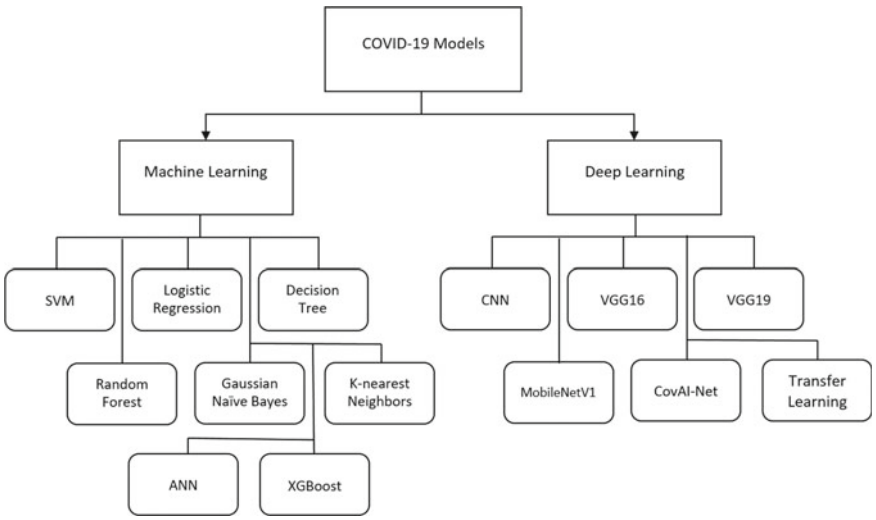

Fig. 2 Reviewed machine learning and deep learning algorithms

especially in newly examined communities where historical data are limited. In general, the findings of the suggested DL-based approaches are promising in improving modern healthcare systems to defeat pandemics. In this review, we surveyed several machine learning and deep learning-based approaches for defeating COVID-19, and they are illustrated in Fig. 2.

Table 1 lists the significant techniques discussed in this review along with their advantages, disadvantages, limitations, and dataset type. This table helps in increasing awareness of the positive impact of deploying ML and DL techniques to predict and defeat severe viruses during pandemics such as COVID-19.

4 The Resultant Recommendations

After reviewing the most recent studies on pandemics, especially COVID-19, it can be concluded that wearable medical devices, biosensor technology, and AI-powered data processing can be helpful in remote health monitoring. Fog cloud-based Internet of medical things devices can provide remote patient surveillance for proactive illness identification and health administration as discussed in [25]. Important data may be collected by medical equipment, connected sensors, and the Web of medical things. This may help in making the remote treatment and illuminating symptoms quite easy. Using wearable medical devices with AI capabilities and automated diagnostic systems based on ML, real-time patient monitoring and massive biological data can be used to determine illness prognosis and diagnosis and assist a clinical decision. Due to the COVID-19 crisis' increased demand for intensive unit-level treatment and ventilator support, AI can offer diagnostic speed and accuracy while lowering exposure time to a highly virulent pathogen [25]. However, wearable sensors coupled with other connected computers can generate data that helps with care process automation, user engagement, and medicine efficiency optimization. In the Internet of things-enabled healthcare context, researchers estimated real-time patient monitoring and large amounts of biological data. Hospitals are being compelled to constantly implement new models and innovations due to the COVID-19 epidemic, pushing the fast uptake of remote clinical services. Rapid innovation was required to address the pandemic's effects, and the way healthcare facilities are planned and constructed will never be the same. Using real-time medical data analytics, diagnostics, clinical decision-support systems, cordless medical and biological sensing devices, and AI-powered solutions are essential for diagnosing and screening COVID-19. Smart IoT devices are networked to collect multi-model patient records via remote health surveillance and test equipment backed by ML [25].

Table 1 Significant techniques with high impact on handling COVID-19

Technique	Advantages	Disadvantages	Limitations	Dataset type
Minimum-redundancy-maximum-relevance (MRMR)	Ability to identify severe and mild COVID-19 cases using patient admission data	Sensitivity to outpatients	The comorbidity of patients and inpatients/outpatients follow-up are missing in the dataset	Blood test
Binary classification	i. Reduced X-ray input image ii. Less computational complexity iii. Simplified model iv. High classification accuracy	Data requirement is high	Applicable to huge amount of data	X-ray
Real-time medical data analytic	i. Remote health monitoring ii. Time-saving	Error susceptible in small data	i. Cross-sectional data ii. Size of the sample is limited	Biosensors
Deep learning	i. Anomaly detection ii. Read 3D images iii. Diseased regions in radiology iv. Automatically detect important features without human intervention	i. Massive data requirement ii. High processing power iii. Struggle with real-life data	Requires massive amount of labeled data	X-ray
Deep learning (CovAI-Net)	i. Accuracy ii. High processing power	Massive data requirement	i. Unable to access data ii. Collect more data	X-ray
State-of-the-art (Deep learning XAI)	i. Read out complex patterns from data ii. Error-prone iii. Black-box reading	i. High cost ii. Non-specificity	i. Non-specific ii. Subtle and difficult manifestation	Scanner (CT Scan)
Artificial Neural Network	i. Accuracy ii. Time-saving iii. Information available on entire network iv. Flexibility to operate with insufficient knowledge v. High tolerance rate vi. Distributed-memory vii. Efficient for model training viii. Ability of parallel processing	i. Require lots of computational power ii. Hard to explain iii. Require lots of data iv. Careful attention to data preparation	i. Fixed size input ii. Training is required to operate	Computer Software
Modeling-training-validation-deployment	i. Cost reduction ii. Quality results	Time-taking	Separation of samples	Scanner
Voting classification	i. Accurate and highly specific ii. Categorize data into different clusters	i. Time-taking process ii. False negative, false positive	i. Variation in dataset ii. Size of dataset	X-Ray

5 Limitations

As for the limitations that we faced in this work, we can mention the following:

1. Not all the works published in the literature reveal the improvements provided by the application of their ML models.
2. The limitation of comparative analysis in the literature that may help scholars to conclude the cons and pros of each proposed approach.
3. The limitation of computing resources and available datasets that prevents authors from validating some particular results in the reviewed works.

6 Conclusion and Future Work

In this study, we conducted a review of the application of ML and DL for defeating COVID-19. We discussed the advantages of applying these models for early diagnosis and prediction of the virus. The majority of the studies used datasets from China and USA to implement different machine learning techniques such as SVM, LR, RF, DT, and ANN for predicting COVID-19. Whereas, some of the authors collected COVID-19 data in real time. Different new deep learning models are also proposed or used such as CNN, VGG16, VGG19, MobileNetV1, and CovAI-Net for detecting COVID-19 at an early stage. The majority of the researchers based their studies on CT scans and X-ray images as essential datasets for their models. All ML and DL models yielded to promising results in terms of performance. It was found that ML and DL have great potential, and they can be effectively used to detect and defeat COVID-19, especially in its early stages. In summary, this review aims to concentrate on increasing awareness and highlighting the importance of using AI and ML during pandemics and the surge of adopting this technology to prevent such future possible events. As a future work, we aim to study the reasons behind the lack of actual deployment of AI and ML in real-life especially in healthcare and conduct a survey to investigate the level of awareness of medical resources about AI techniques.

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A Systematic Review of Platforms for Reconfiguration of Industrial Process Based on IEC-61499 and Multi-agents

Marcos Salinas-Escobar, Gustavo Caiza, Paulina Ayala, and Marcelo V. Garcia

Abstract Industrial progress experienced a before and after with the 4.0 revolution. To comply with the new rules created by Industry 4.0, it was necessary for industries to modernize their processes through the use of technology, as well as maintain both their infrastructure and the knowledge of their employees. This article presents a systematic review of the literature on the dynamic reconfiguration of the automatic control of an industrial process based on IEC-61499 and multi-agent, developed using the PRISMA methodology. First, 309 articles were collected from major databases such as IEEE XPLORE, MDPI, SpringerLink, SCOPUS, and TAYLOR and FRANCIS, resulting in a final sample of 40 articles. Here, the different industrial processes in which dynamic reconfiguration is used, the different platforms using the IEC-61499 standard, and the multi-agents are analyzed. The findings show that the IEC-61499 standard and multi-agents are used in dynamic reconfiguration and in industry 4.0, which is currently developing a breakthrough for companies, allowing greater efficiency and quality in production.

Keywords Systematic review · IEC-61499 · Multi-agents · Industry 4.0 (I4.0) · Digitization · Digital technologies

M. Salinas-Escobar (✉) · P. Ayala · M. V. Garcia
FISEI, Universidad Tecnica de Ambato, UTA, Ambato 180206, Ecuador
e-mail: msalinas4774@uta.edu.ec

P. Ayala
e-mail: ep.ayala@uta.edu.ec

M. V. Garcia
e-mail: mv.garcia@uta.edu.ec; mgarcia294@ehu.es

G. Caiza
Universidad Politecnica Salesiana, UPS, 170146 Quito, Ecuador
e-mail: gcaiza@ups.edu.ec

M. V. Garcia
DISA, University of the Basque Country, EHU/UPV, 48013 Bilbao, Spain

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1 Introduction

The current and Fourth Industrial Revolution has led to important changes on numerous fields which cannot be seen as the traditional changes in the previous Industrial Revolutions [1]. This Industrial Revolution (4IR) is characterized by the fusion of the digital, biological, and physical worlds, as well as the growth of ICT technologies such as artificial intelligence, cloud computing, robotics, 3D printing, the Internet of things, and advanced wireless technologies, among others. Compared with the previous industrial revolutions, the Fourth is evolving at an exponential rather than a linear pace. Moreover, it is disrupting almost every industry in every country, transforming entire production, management, and governance systems. Summing up, the Fourth Industrial Revolution(4IR) has transformed many industries and has introduced engineering standardization. Fields like security, law, education, the job market, science, research, social systems, and many others are being reinvented [6]. The industrial automation field is no exception, and it is continuously growing and developing.

IEC-61499 can be seen as a way of modeling control applications using the function block concept because it allows encapsulating components and viewing the relationships between them. According to the required level of detail, this makes it possible to see the system from several levels of abstraction. The developed model will be deployed and executed immediately, but at the same time, this architecture is also a control implementation [3, 4].

In the digital era, industries use technologies created as part of Industry 4.0. These technologies, along with the IEC-61499 standard and the dynamic reconfiguration, allow performing operations that were formerly manual resulting in shorter completion times of several tasks [2]. Within this context, this paper presents a systematic literature review related to IEC-61499-based platforms and multi-agents for the dynamic reconfiguration of the automation of industrial processes. This work focuses on the studies that have considered the use of these technologies in the industry and in the environment.

The paper is structured into five sections. The introduction is presented in Sect. 1. Next, Sect. 2 presents the methodology followed for selecting the final sample of scientific papers. Section 3 presents the results, the bibliometrics, and citation analysis. Section 4 responds to and discusses the research questions previously introduced in Sect. 2. Finally, Sect. 5 presents the conclusions.

2 Metodology

In this section, the preferred reporting items for systematic reviews and meta-analysis (PRISMA) methodology had been applied to the written scientific articles [3], to achieve this systematic review appropriate to the proposed topic. The steps that were followed: (i) research questions, (ii) information sources, (iii) search strategy, (iv) eligibility criteria, (v) risk of bias, (vi) data extraction [5].

Table 1 Research questions

Number	Investigation questions	Motivation
P11	In what types of industrial processes have dynamic reconfiguration been applied?	Identify the industrial processes in which it can be applied
P12	What types of platforms are dynamic reconfiguration used for?	Identify the platforms to consider using with dynamic reconfiguration
P13	What types of platforms are the IEC-61499 standard and multi-agents used?	Identify the different platforms to consider using with the IEC-61499 standard and multi-agents
P14	Have companies used the IEC-61499 standard and multi-agents for dynamic reconfiguration?	Identify the objective of IEC-61499 and multi-agents for dynamic reconfiguration

2.1 Research Questions

There were four research-related inquiries, which supported the proposed systematic analysis to verify the usefulness of the IEC-61499 standard and multi-agents in the dynamic reconfiguration platform. These questions were framed in two points of view: The applicability of dynamic reconfiguration in industry 4.0; and the objective of the IEC-61499 standard and multi-agents. It includes the suggested questions in Table 1.

2.2 Information Sources

A bibliographic search of articles published in journals was carried out. A time range from 2018 to 2022 was selected because this is the precise timing in which to evaluate the advancement of technology. The research for these studies was carried out using the following resources: international academic publishers SPRINGER AND TAYLOR & FRANCIS, the academic research databases IEEE Xplore and SCOPUS, the online scientific research services SCIENCE DIRECT, and WEB OF SCIENCE, where DOI-bearing research was indexed and could be accessed to track documents more efficiently. It is worth mentioning that research in different digital media focuses on using specific terms according to the perspectives or points of view (PV) described by: PV1 “dynamic reconfiguration” AND (“platforms” OR “industrial processes” OR “architecture”, OR “IEC-61499”). The search for information from a second point of view was done by the combination of the keywords; PV2 industry 4.0 AND (“industrial control” OR “automatic control” OR “manufacturing systems”). In the same way for a third point, specific terms were used; PV3 IEC-61499 AND (“dynamic reconfiguration” OR “multi-agent” OR “industry 4.0”), based on keywords, title, or abstract of the papers analyzed in detail.

Table 2 Criteria used in the inclusion and exclusion

Title 1	Title 2	Title 3
C1	Articles related to the dynamic reconfiguration of automatic control of an industrial process based on IEC-61499 and multi-agents	Duplicates from different bibliographic sourcesa
C2	Articles published from 2018 to 2022	Articles not related to the main topic
C3	Articles in English	Books and theses
C4	Articles based on the application of the IEC-61499 and multi-agent standards	Publications based on other topics that do not influence
C5	Dynamic reconfiguration related articles	Article review

2.3 Article Selection

This section focuses on three important parts in order to choose the most relevant references. Firstly, the inclusion and exclusion criteria were applied, since the language of the articles, the date of publication, and the number of subjects were considered. Secondly, a focus on the body of each writing such as perspective, summary title, and keyword, was used. Finally, the introduction and conclusions had to be checked in order to address the questions that had been previously given. Table 2 shows the criteria used.

The PRISMA flowchart is shown in Fig. 1, which starts from the selected articles and shows the reduction according to the previously reviewed criteria.

2.4 Data Extraction

The total of final articles was 40, since according to the proposed criteria and objectively all the works found at the beginning were excluded. Figure 1 details all the main items for the resolution of each question, since it was based on the application, use and processes that govern the dynamic reconfiguration of automatic control of an industrial process based on IEC-61499 and multi-agents.

2.5 Bibliometric Analysis

Respectively to the development of the results for the investigation, one of the studies elaborated was the bibliometric analysis, which included the quantitative analysis of the publications, which allowed for the state of the art of the subject to be known.

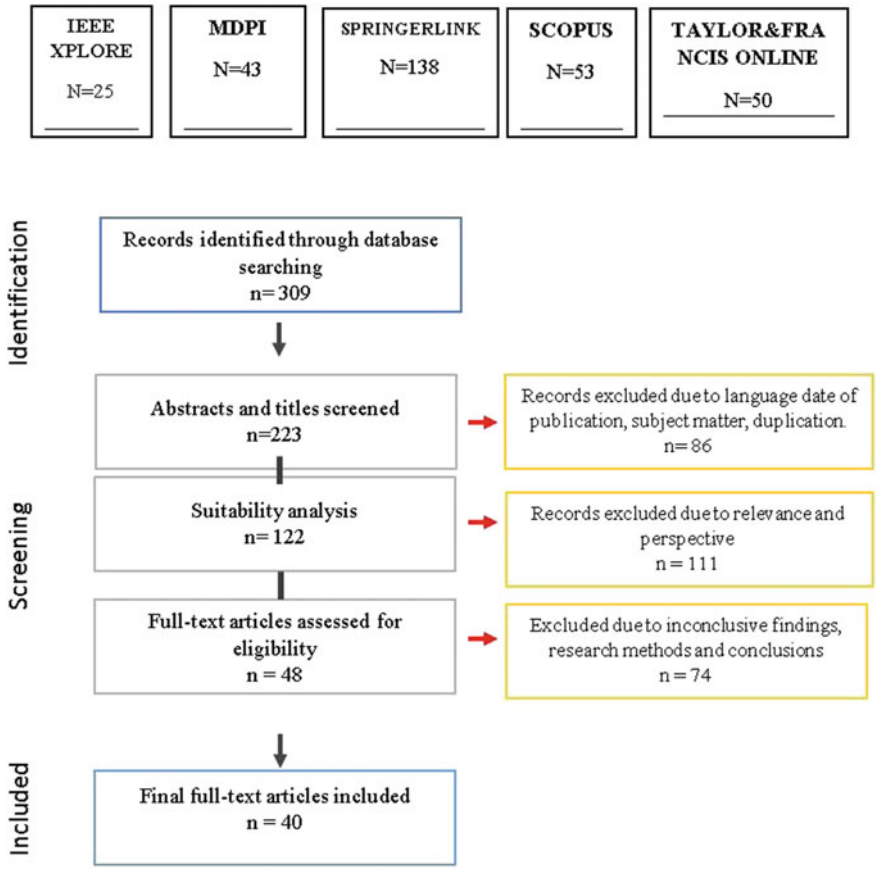

Fig. 1 PRISMA flow diagram

Consequently, the identification of the output of the scientific community and the assessment of significant trends in a particular field comprise a bibliometric analysis.

The analysis was based on articles collected in a systematic review of the literature. These references were compiled as RIS spreadsheets using the VOSviewer software from data obtained from the Scopus database. Scopus was chosen because it indexes more than 95 press directories, and the publications not indexed in this database are manually retrieved and incorporated into the information. The analysis included the distribution of articles by year, the principal authors whose articles had been published, and the main journals where articles on a given topic had been published. VOSviewer software was used to conduct an analysis of article citations, a country analysis, and a keyword analysis.

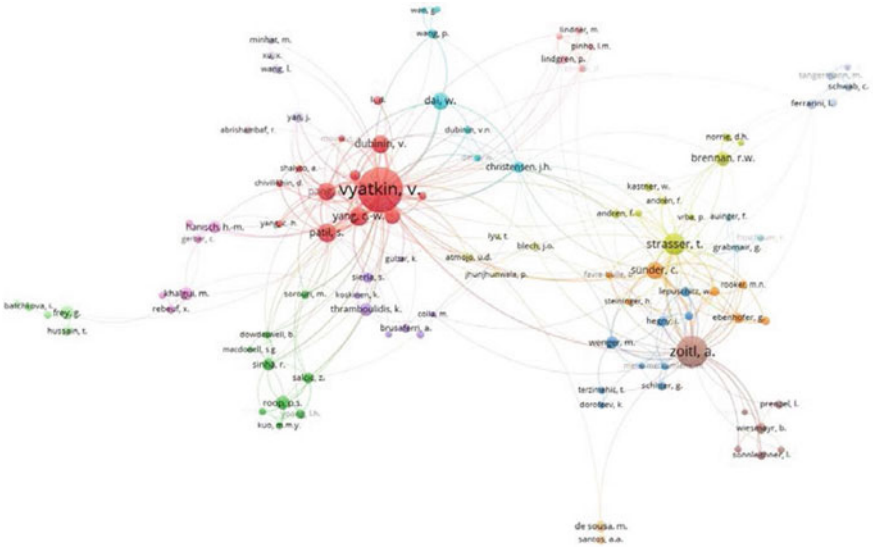

Fig. 2 Relevance of the authors

3 Results

3.1 Bibliometric Analysis

The authors' citation network is shown in Fig. 2, as a result of the analysis of the most frequently cited articles using the VOSviewer software, which shows the relevance of the authors in the citations received, in which 1025 studies were found in the Scopus database. It can be observed the network formed by the clusters in relation to the authors, in which Vyatkin V, was found as the main axis of the network with a link strength of 405 and around 230 documents, followed by Zoitl A. with a link strength of 225 and about 113 documents. In the same way, a smaller group of authors with a lower amount of relevance in the selected documents was formed.

Respectively in Fig. 3, the VOSviewer was used to perform a keyword co-occurrence analysis for each document to understand which terms were identified and were the most relevant to each article. The most important buzzwords were the term IEC-61499, which is represented in the orange figure. It was identified as the most important due to the connections that this cluster presented. The second most representative word was "industry 4.0" or 4.0 industry. This is the cluster represented in green, the same color that was associated with the Internet of things, manufacturing systems, and control processes. The network was built to have at least five occurrences for each keyword and thus be able to generate a network that provides the facilities to identify the relationship strength that existed between them in the dif-

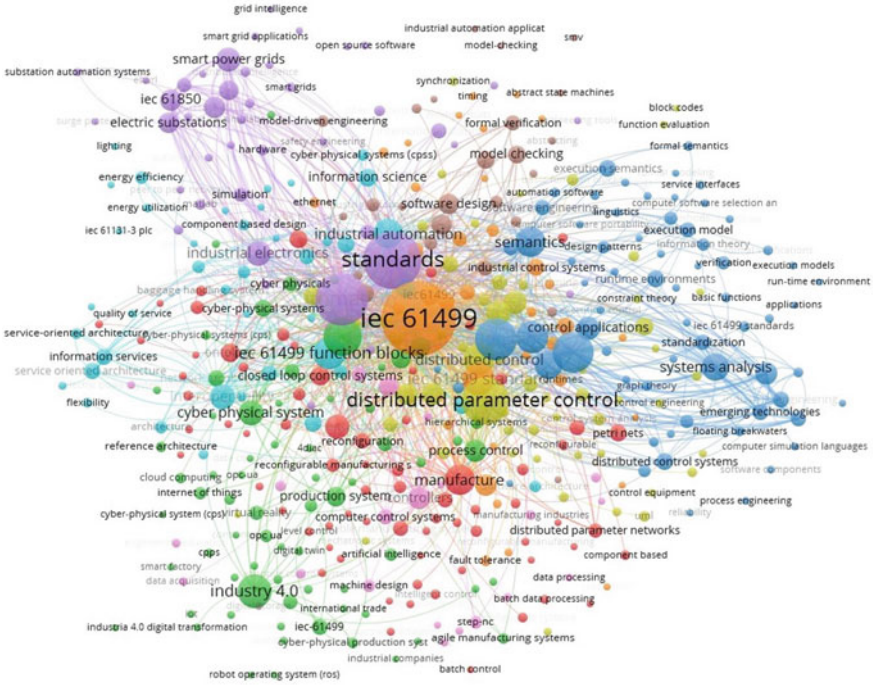

Fig. 3 Co-occurrence of key words

ferent articles analyzed. As observed in Fig. 3, the highlighted words were connected to each other providing an affinity of the works studied with the research topics.

On the other hand, an analysis of the countries was prepared in VOSviewer, to which the most notable authors on the importance and use of dynamic reconfiguration, industry 4.0, and the IEC-61499 standard were linked. A minimum number of five documents per country was found for this study.

In the same way, there was also a requirement of two citations per country. There is a green cluster where 17 is the total strength of the bond, corresponding to Sweden, which brings together the most authors in this scientific field. The cluster of Germany represented in red color is the country that had the second highest number of relevant investigations in the 4.0 industry, standard IEC-61499, and dynamic reconfiguration currently with a total link strength of 7. Adding to the above, there were smaller clusters that represented various countries such as the United States, Portugal, Brazil, China, Austria, and Finland that had a significant amount of research for this topic of study. See Fig. 4.

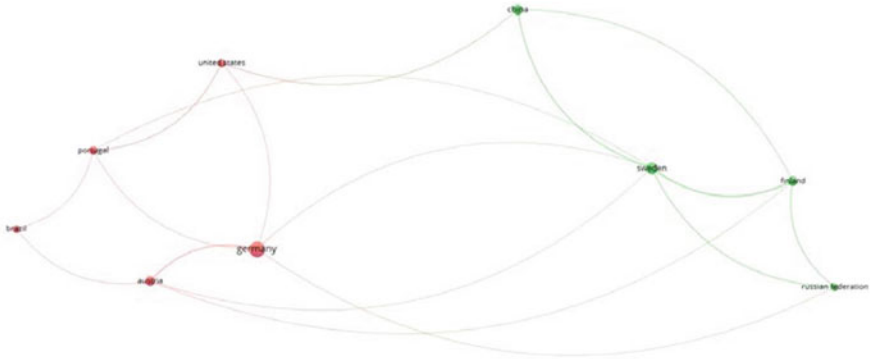

Fig. 4 Affiliation countries

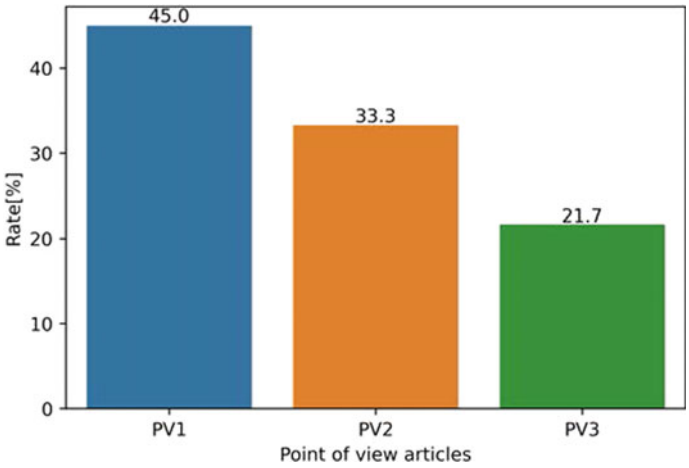

Fig. 5 Classification of selected articles according to points of view

3.2 Document Selection

Most of the articles included the presentation of technological advances that allowed companies to innovate and prosper in an environment where technology advances by leaps and bounds. With the literary review of scientific articles, the research questions raised in this document could be answered. Co-responding to industrial processes that had applied dynamic reconfiguration, the identification of platforms that used dynamic reconfiguration, the types of platforms that used the IEC-64199 standard and multi-agents, in addition to identifying where and how the IEC-61499 standard and multi-agents had been used for the dynamic reconfiguration of automatic control of an industrial process.

In Fig. 5, it can be seen that, of the 40 selected articles, 45% corresponded to point of view 1 (dynamic reconfiguration), 33.33% focused on point of view 2 (industry 4.0) and finally 21 .67% concentrated on point of view 3 (IEC-61499).

4 Discussion

4.1 Investigation Questions

This section will give a specific answer to each question proposed in section two of the document. Since industrial training will be understood from another point of view, together with the IEC-61499 and multi-agent standards as well as its dynamic reconfiguration.

PI1: In what types of industrial processes have dynamic reconfiguration been applied?

In the industrial field, dynamic reconfiguration is focused on several multifaceted issues, especially in the area of technology and communication. In this bibliographical analysis, it was identified that this type of technical application is applied in the 4.0 industrial field.

Currently, 4.0 industry and computer systems maintain coherence and recover from events that affect operations without interrupting execution. Typically, these systems must adhere to the time constraints of real-time systems. Control systems have taken advantage of distributed systems to gain flexibility and adaptability, which has led to the implementation of distributed control strategies. These strategies propose dividing the system into separate entities that perform parts of the control cycle.

PI2: What types of platforms are dynamic reconfiguration used for?

The transistor densities allowed in electronic devices today are so high that it is already possible to integrate an entirely digital system into an integrated circuit, the so-called system-on-chip or SoC. To reduce development time and be able to successfully address this type of design, they are usually organized into modules or cores. Due to their complexity, these modules usually contain one or more processors, which is why there are multiprocessor systems.

Specifically, Xilinx provides tools for creating drivers, running simulations, and software debugging (XMD) through the EDK development environment. Xilinx uses the GNU tool (gcc) for this. The code is compiled for each application. These tools are designed to run on personal computers, thus preventing the reconfiguration process from taking place in an embedded environment. Therefore, there is a need to design software and hardware tools that can perform the partial reconstruction process autonomously.

PI3: What types of platforms are the IEC-61499 standard and multi-agents used?

Today's industrial automation systems must meet the challenges of trying to meet the demands of a highly competitive marketplace. A new generation of automated

systems built on what are known as cyber-physical production systems (CPPS) are used as a result of these difficulties. To extract information and enhance the overall performance of production systems, CPPS enables the integration of established data acquisition systems with cutting-edge intelligent data processing systems. To do this, the gap between the control system and the higher levels has to be closed.

Applications built on the IEC-61499 standard and using multiple agents for data transfer between the plant level and higher layers use the OPC-UA industry standard. OPC-UA communication provides a subscription mechanism that allows easy and efficient integration of resources located on different devices. In addition, since the OPC-UA architecture also allows for execution on embedded devices. The proposals provided in this article will allow designs based on hardware-independent components of the platform used, using a low-cost architecture. It is worth mentioning that the development and programming environments that are compatible with commercial products or are available as open source for IEC-61499. This is especially true for 4DIAC and FBDK since they are the most used at an academic level.

PI4: Have companies used the IEC-61499 standard and multi-agents for dynamic reconfiguration?

In this case, it is necessary to design a software tool capable of converting the meta-model into an XML file, which contains information to create an FB with information components using OPC-UA servers when developing the configuration file for the meta-model to create applications that can be downloaded in runtimes in accordance with the IEC-61499 standard. This software tool is responsible for configuring all the required information, as well as guaranteeing the correct behavior of the distributed control application. For these cloud environments, other than IEC-61499 standards, this change becomes difficult as applications (or managed modules) may need to be moved between supported cloud providers. SeaClouds supports the migration of application modules from one provider to another. But this function is not built in an adaptive way that responds to runtime problems, because knowing which modules should go where is not an easy task.

5 Conclusions

This study has discussed a systematic review of the literature of the platform for dynamic reconfiguration of autonomous control of an industrial process based on IEC-61499. It has summarized the information from the last five years on what types of industrial processes have been used for dynamic reconfiguration. An analysis was made of the types of platforms used for dynamic reconfiguration at the industrial level and implemented in an appropriate way for the new era better known as industry 4.0. The types of platforms that use the IEC-61499 standard and multi-agents have been identified, allowing for better and broader structuring at the industrial level. Such multi-agents are used in dynamic reconfiguration in industry.

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Analyzing Malware from System Calls by Using Machine Learning

Tazkia Tasnim Bahar Audry, Puja Ghosh, Sumaiya Akter, Arnisha Akter, and Md. Motaharul Islam

Abstract The popular open-source operating system Android is quite vulnerable to malware threats. To identify malicious programs, researchers have created machine-learning models that learn from features retrieved using static or dynamic techniques. Due to the inclusion of noisy features generated from traditional feature selection techniques, these models have a low detection accuracy. Therefore, to increase malware apps' identification and precise categorization, the traditional feature selectors such as ML, GSS, and DFS are employed and initially carried out giving each system call a binary score. Machine learning models can be applied to handle this. By using machine learning methods such as Random Forest, Support Vector Machine, Decision Tree, Naive Bayes Classifier, Extreme Gradient Boosting, K-Nearest Neighbors, and Adaptive Boosting, we have proposed a method of analyzing the Android Malware Detector using these binary scores of system calls. Additionally, the models' performance was evaluated using the metrics accuracy, precision, recall, and F1 score by examining the learning rate where Decision Tree outperformed with 98.5% accuracy.

Keywords Android malware detection · Smartphone security · System calls · Malware classification · Machine learning

T. T. B. Audry · P. Ghosh · S. Akter · A. Akter · Md. M. Islam (✉)
United International University, United City, Madani Avenue, Badda, Dhaka 1212, Bangladesh
e-mail: motaharul@cse.uiu.ac.bd

T. T. B. Audry
e-mail: taudry191189@bscse.uiu.ac.bd

P. Ghosh
e-mail: pghosh191116@bscse.uiu.ac.bd

S. Akter
e-mail: sakter191180@bscse.uiu.ac.bd

A. Akter
e-mail: aakter191194@bscse.uiu.ac.bd

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1 Introduction

Android is one of the most widely used operating systems for smartphones, which are becoming increasingly important in our lives because of its open-source architecture. There are different applications and fundamental features of Android OS, often trusted by app users to protect data, yet research has proven that Android is more unstable and prone to security issues. Malware detection for the Android OS is now a hot research topic. Malicious software that specifically targets Android devices is known as Android malware. Malware can be of various types as shown in Fig. 1 and can grow in an environment made less secure by Android's infrastructure, which includes its Play Store where users can download programs and side-load content from the internet. The integrity of user data may be compromised by malicious apps in order to exploit software and hardware features.

The malicious or trusted applications can be detected by the system call traces. As we know, a system call is a programmable approach in computing by which a computer application requests the kernels of the computer system on which it is running as a service and allows the applications to connect with the operating system. When a computer application requests anything from the kernel of the operating system, it performs a system call. Application Programming Interfaces (APIs) are implemented by system calls to provide operating system functionality to user programs (API). It functions as a point of communication between programs and the operating system, offering user-level programs to request support from the operating system. The kernel system can only be accessed using system calls. Any applications that require resources need to use system calls. And the detection of malware and trusted applications can be detected from an android can be done by using the required system call traces.

In this paper, we analyze the existing works and propose android malware detection methods based on following system calls, all of which we classify the applications into two classes (i.e., trusted applications and malware applications) by using machine learning models. Our contributions to this paper are as follows:

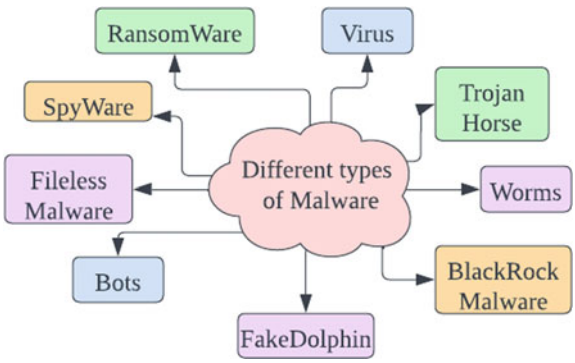


Fig. 1 Different types of malware

- Analyzed the detection of malware applications from system calls.
- Measured the malware and trusted applications using machine learning algorithms.
- Developed a Decision Tree with GINI index model with an average accuracy of 98.5%.

The remainder of the paper is structured as follows. In Sect. 2, the related and existing works in the field of android malware detection are provided. Section 3 presents the methodology where we have discussed about dataset and machine learning algorithms. The experimental setup and result analysis of the models are presented in Sect. 4. In Sect. 5, we have discussed our limitations and future works. Finally, Sect. 6 brings the article to a conclusion.

2 Related Works

Zhang et al. [1] have built an Android malware detection method where they have used malicious and benign Android applications to build a dataset for system call traces and analyzed the dataset to enhance the effectiveness of host intrusion detection systems(HIDSs), machine learning (ML) approaches. System calls were analyzed using N-gram and TF-IDF models and for the malware detection system, six machine learning algorithms like DT, RF, K-Nearest Neighbors, Naive Bayes, SVM, and Multi-layer Perceptron were trained. SAILS, feature selection method is suggested by Ananya et al. [2] in their study. In addition, weighted feature selection, a unique approach to global feature selection, is proposed which compares various machine learning models like LR, CART, RF, XGBoost, and Deep Neural Networks. Again, Chaba et al. [3] concentrated on tracking the behavior of malware software when it is really operating on a host system in their work. They looked at each program's system call log and used that dataset to determine if an unknown application was malicious or benign. In this article [4], researchers have used four tree-based machine learning methods, together with a substring-based feature selection technique for the classifiers to identify Android malware.

Several methods for identifying fraudulent Android applications were assessed on the repository level in this work by Dimja Sevi et al. [5]. Their chosen algorithms automatically classify apps, running in a sandbox environment based on tracking system calls and put into practice with the MALINE tool. Whereas, Omer et al. [6] have examined the different factors being used for malware detection in Android applications and discussed different techniques for detecting malware. Abderrahmane et al. [7] suggested a behavioral dynamic study of the apps that are more likely to include malignancy. Through an interface, the program was directed toward a faraway server which will be installed and put into operation using a simulation of human use. After the evaluation of apps, the Linux kernel generates a number of system calls, which are gathered, processed, and sent to the neural network model to determine the software. The model CNN was developed and improved, and they have used a matrix representation of the gathered system calls and input to the CNN model.

3 Methodology

In this section, our proposed system is presented. The pipeline diagram in Fig. 2 describes the framework and the functioning of our system. In the below sections, a clear description of the identification of malware samples and analysis of the performance of various models of machine learning on identifying malware are discussed.

3.1 Dataset

The data we use for our proposed system involves the selection of two types of Android application data, i.e., trusted applications and malware applications. The dataset consists of a total of 4949 samples (2475 trusted and 2474 malware applications) [8]. In order to gain more accuracy, we have normalized the data and preprocessed by extracting the conventional feature selectors such as Mutual Information (MI) [27], Greedy Step-wise Search (GSS) [28], and Discriminative Feature Selection (DFS) [29]. After preprocessing the data, we generate new samples into a ratio of 2:1 of the trusted and malware applications. The preprocessed dataset has 15036 samples consisting of 9476 trusted and 5560 malware applications. The distribution of applications before and after is illustrated in Table 1.

After the preprocessing of the dataset is concluded, we proceed to train the dataset and apply different ML models. Later, we supply test samples to the trained models. We have used the train–test split method with 80% train data and the rest 20% test samples. Furthermore, the performance of the ML models is evaluated under the metrics, i.e., accuracy, precision, recall, and $F1$ score.

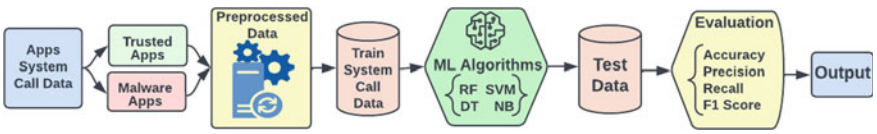


Fig. 2 Detailed pipeline of malware detection

Table 1 Distribution of applications before and after preprocessing

Applications	No. of samples	
	Before preprocessing	After preprocessing
Trusted application	2475	9476
Malware application	2474	5560

3.2 Machine Learning Algorithms

We develop classical and ensemble models like Random Forest (RF), Support Vector Machine (SVM), Decision Tree (DT), Naive Bayes Classifier (NB), eXtreme Gradient Boosting (XGBoost), K-Nearest Neighbors (KNN) and Adaptive Boosting (AdaBoost) to detect the rate of malware applications from the input training dataset of two type of applications that we have already trained and compare the performances to find out the best performing model.
RF: Random Forest are a selection of tree predictors where each tree is determined by the values of a randomized variable and provides internal estimates for error and correlation significance [9]. It employs bagging and feature randomness to build an uncorrelated forest of decision trees [10].
SVM: Support Vector Machine uses classifiers for binary classification to maximize the prediction accuracy by averting the over-fitting [11]. To train an SVM decision function, a consistent hyperplane optimizing the distance between the support vectors of the two class labels must be identified [12].
DT: The Decision Tree [13] classifiers are a tree-like structure, a predictive model that explores large and convoluted datasets to find useful patterns. The data is classified starting at the Decision Tree's root node and continuing iteratively until it reaches the leaf node with class labels. The GINI index is used to compute the contaminant value in split test outcomes [14].
NB Classifier: Naive Bayes classifiers [15] are the probabilistic classifiers that can achieve high accuracy by assuming that an attribute value is conditionally independent of the values of the other attributes. Based on the hypothesis, the NB classifier indicates that minimizing the attributes optimizes the classification's accuracy [16].
XGBoost: XGBoost is applied to identify the calculated accuracy comparison between the variables used as leaves and nodes [24]. It integrates regularization to the loss function and optimizes the new tree-reducing over-fitting [25]. **KNN**: KNN, a supervised learning classifier, uses proximity to predict how a particular data point will be classified [23]. The algorithm will determine the k-nearest neighbors of the dataset for a given value of k and then classify the class to the data predicated with the most data points among the K neighbors.
AdaBoost: AdaBoost is a machine learning ensemble method that optimizes classifier accuracy by combining different classifiers. It combines classifiers having accuracy relatively improved to get indefinitely accurate predictions. We intend Decision Tree (DT) as our baseline classifier for Adaboost [26].

4 Experimental Analysis

We conduct the experiments and execute Python code in Google Colab, also known as 'Collaboratory' which allows combining executable code. With Google Colab and Python 3.10, we implement the classifiers and execute our python code on the cloud.

Python emphasizes the readability of the code and supports a number of programming paradigms [17]. We use the library named SciKit Learn, for our ml algorithms for classification, regression, and clustering [18]. We evaluate the performance of the classifiers using the following evaluation metrics.

Accuracy This metric shows the ratio of the number of accurate predictions to the total sample size. For balanced data, accuracy produces better performance results [19]. The equation to measure accuracy is:

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}} \tag{1}$$

Precision In the multi-class classification problem, precision can be measured. In general, the proportion of test samples among all samples with positive outcomes is provided to measure precision [20]. The equation outlines the formula for calculating precision.

$$\text{precision} = \frac{\text{TP}}{\text{TP} + \text{FP}} \tag{2}$$

Recall By Recall, the ratio between the total sample size and the number of correct predictions is shown. It determines accuracy and displays the prediction precisely for balanced data [21]. The equation is as follows:

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}} \tag{3}$$

***F*1 Score** By calculating their harmonic means, the $F1$ score is used to compare multiple classifiers on a broad level. It represents the balance of precision and recall, which ranges from 0 to 1 [22]. The equation to calculate $F1$ score is given below:

$$F1 \text{ Score} = \frac{2 \cdot \text{precision} \cdot \text{recall}}{\text{precision} + \text{recall}} \tag{4}$$

4.1 Results

Table 2 illustrates the comparative performance of the proposed classifiers, i.e., RF, SVM, DT, NB classifiers, XGBoost, KNN, and AdaBoost under the evaluation metrics, i.e., accuracy, precision, recall, and F1 score. Among the classifiers, in terms of all the metrics, the Decision Tree performs the best with an average accuracy of 98.5%. The other classifiers, XGBoost and AdaBoost, performed similar on average with an accuracy of 96.7%, and KNN Classifier performed a slightly better with an accuracy of 97.5%. Furthermore, SVM performed with an accuracy of 71.9%, and lastly, NB Classifier performed lowest compared to all the proposed classifiers with an accuracy of 69.7%.

Table 2 Performance table on preprocessed data

Name of classifiers	Evaluation metrics			
	Accuracy	Precision	Recall	*F*1 score
RF	0.944	0.947	0.931	0.937
SVM	0.719	0.772	0.777	0.719
DT	**0.985**	**0.986**	0.982	**0.984**
NB	0.697	0.768	0.759	0.699
XGBoost	0.967	0.977	0.961	0.959
KNN	0.975	0.972	0.969	0.978
AdaBoost	0.967	0.974	0.965	0.967

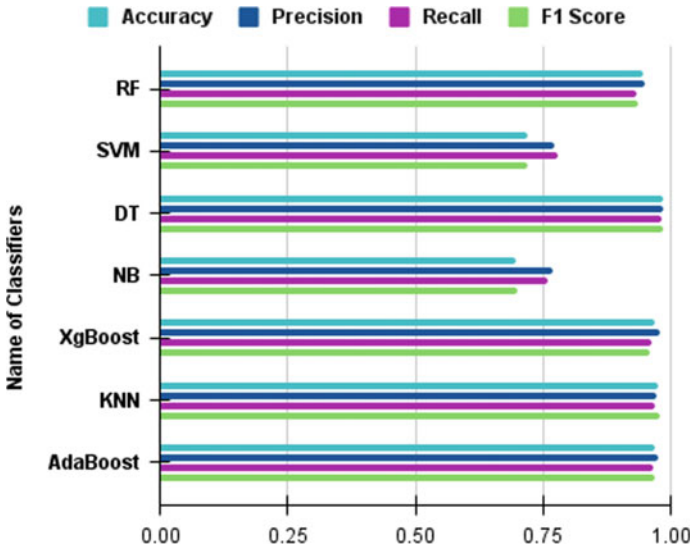
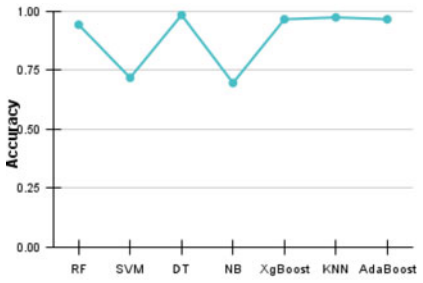
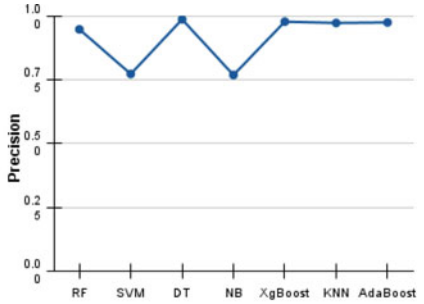


Fig. 3 Model-wise performance measure

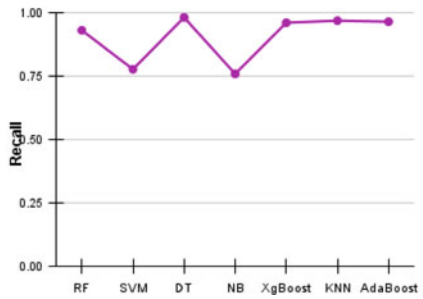
Apart from the average accuracy of the classifiers, in the Table 2, under the evaluation metrics, precision, recall, and F1 score, the performance comparison for the classifiers, RF, KNN are 94.7%, 93.1%, 93.7% and 97.2%, 96.9%, 97.8% respectively. The classifiers XGBoost and AdaBoost performed quite similarly with precision, recall, and F1 scores of 97.7%, 96.1%, 95.9% and 97.4%, 96.5%, and 96.7% respectively. The other two classifiers, SVM and NB classifier, performed poorly compared under the metrics precision, recall, and F1 score with 77.2%, 77.7%, 71.9% and 76.8%, 75.9%, and 69.9% respectively. In Fig. 3, the overall comparison of the classifiers on the performance metrics is represented in a chart-like structure and from the bar-chart too, we can say that Decision Tree performed better than the other classifiers, i.e., RF, SVM, NB, XGBoost, KNN, and AdaBoost.



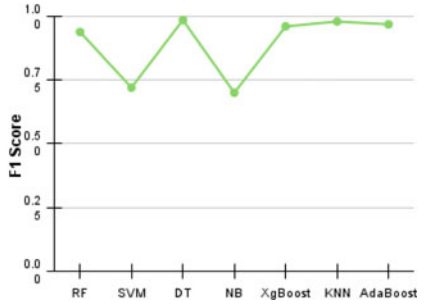
Class-wise Accuracy on different classifiers



Class-wise Precision on different classifiers



Class-wise Recall on different classifiers



Class-wise F1 score on different classifiers

Fig. 4 Visualization of evaluation results

An illustrative comparison of the performance of the classifiers is given in Fig. 4, and we show the performance of the classifiers under the metrics, accuracy, precision, recall, and F1 score. We can say that after all four classifiers are evaluated under each performance metric, Decision Tree performed better. And thus, among all the classifiers, namely RF, SVM, NB classifier, XGBoost, KNN, and AdaBoost, Decision Tree outperforms in the comparability of class-wise accuracy, precision, recall, and F1 score with 98.5%, 98.6%, 98.2%, and 98.4% respectively.

5 Limitations and Future Works

In this work, we have used a built-in dataset generated from android applications. For future research, we plan to create and use a malware applications dataset created on the Linux kernel and Android platforms. Additionally, as a guide for future research, we want to propose the MALINE environment for evolving malware detec-

tion in Android, which is open-source and free. This environment will provide a large amount of information about the structure of implementation executions, the effects of various machine learning methods, and the kind and size of input data for dynamic evaluations.

6 Conclusion

Android apps must create at least one system call in order to perform any operation. This system calls' generation enables one to see and comprehend the behavior of Android applications. The use of a machine learning methodology is attractive since controlling these prolonged processes in a precise way is quite challenging. Selecting the best learning algorithm is an important first step. For that, on a collection of malware and trusted apps, we applied RF, SVM, DT, NB Classifiers, XGBoost, KNN, and AdaBoost classifier algorithms. We used a dataset to analyze system call traces from both malware and trusted android apps. The Decision Tree classifier outperformed with a weighted accuracy for system calls of 98.5 compared to other classifiers.

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