IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received May 29, 2021, accepted July 6, 2021, date of publication July 19, 2021, date of current version July 23, 2021.

*Digital Object Identifier 10.1109/ACCESS.2021.3097969*

# Evaluation Method of Deep Learning-Based Embedded Systems for Traffic Sign Detection

**MIGUEL LOPEZ-MONTIEL[1], ULISES OROZCO-ROSAS[2], (Member, IEEE), MOISÉS SÁNCHEZ-ADAME[1], KENIA PICOS[2], AND OSCAR HUMBERTO MONTIEL ROSS[1], (Senior Member, IEEE)**

[1]Instituto Politécnico Nacional, CITEDI-IPN, Tijuana, Baja California 22435, México
[2]CETYS Universidad, Centro de Innovación y Diseño (CEID), Tijuana, Baja California 22210, México

Corresponding author: Ulises Orozco-Rosas (ulises.orozco@cetys.mx)

This work was supported in part by the Coordinación Institucional de Investigación of Centro de Enseñanza Técnica y Superior (CETYS Universidad), and in part by the Consejo Nacional de Ciencia y Tecnología (CONACYT).

**ABSTRACT** Traffic Sign Detection (TSD) is a complex and fundamental task for developing autonomous vehicles; it is one of the most critical visual perception problems since failing in this task may cause accidents. This task is fundamental in decision-making and involves different internal conditions such as the internal processing system or external conditions such as weather, illumination, and complex backgrounds. At present, several works are focused on the development of algorithms based on deep learning; however, there is no information on a methodology based on descriptive statistical analysis with results from a solid experimental framework, which helps to make decisions to choose the appropriate algorithms and hardware. This work intends to cover that gap. We have implemented some combinations of deep learning models (MobileNet v1 and ResNet50 v1) in a combination of the Single Shot Multibox Detector (SSD) algorithm and the Feature Pyramid Network (FPN) component for TSD in a standardized dataset (LISA), and we have tested it on different hardware architectures (CPU, GPU, TPU, and Embedded System). We propose a methodology and the evaluation method to measure two types of performance. The results show that the use of TPU allows achieving a processing training time 16.3 times faster than GPU and better results in terms of precision detection for one combination.

**INDEX TERMS** Traffic sign detection, deep learning, hardware acceleration, computer vision, autonomous vehicles, embedded systems, digital systems.

## I. INTRODUCTION

Nowadays, there has been a rapid emergence in the development of Deep Learning (DL) algorithms focused on vision problems for autonomous vehicles. These algorithms have been evolving throughout the years, having different applications such as robotics, object recognition, self-driving cars, among others [1]. Within the applications of autonomous vehicles, different tasks exist to attain vehicle autonomy. One of those is computer vision. One of the main tasks to achieve in computer vision is Traffic Sign Detection (TSD).

The vision problem of traffic sign detection started decades ago with some research that focused on classical computer vision algorithms [2], [3], where image processing was used through geometric characteristics. However, these algorithms were not robust enough to obtain the desired results. This is because they faced different challenges [4], such as the internal and external conditions of the traffic sign's environment. External conditions are variables that cannot be controlled, such as lighting conditions, weather conditions, complex backgrounds, physical degradation of traffic signs, among others. On the other hand, the internal conditions are the variables that can be controlled by the algorithm, such as response time, precision in detection, adaptability, and hardware dependency, among others [5]. These challenges of improving precision, reducing complexity, and hardware dependence have encouraged the development of more robust algorithms that allowed the adaptation and improvement in recent results. Through the years, intelligent algorithms began to be used in state-of-the-art, specifically, machine learning [6], [7]. The expected results were improved due

The associate editor coordinating the review of this manuscript and approving it for publication was Marco Martalo.


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