

AUTOMATIC ROAD SIGN RECOGNITION AND VISIBILITY ASSESSMENT USING YOLO

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ABSTRACT

Traffic accidents have been increasing as drivers are either failing to see traffic signs or are misinterpreting them in some of the most sensitive locations such as school zones, hospital zones, and speed zones. Driver distraction, harsh weather, lack of visibility, and human error contribute to drivers failing to recognize traffic signs in a timely manner, leading to speeding and other violations of traffic laws. Most vehicles today still depend on their driver's manual observations, which can be unreliable in fluid, dynamic road situations. In response to this problem, a camera will continuously capture images of the road while the use of deep learning technology will help to recognize and classify the traffic signs in real-time. The detected traffic signs and the level of confidence of detection will be displayed in real-time on a screen in front of the driver as a reference. After detection, the system will provide an audio notification indicating the name of the sign so that the driver is aware of it. Additionally, if the speed limit, school zone, or hospital zone sign is detected, the vehicle will automatically adjust and limit its speed to promote safe driving and compliance with traffic regulations.

Keywords: Road Safety, Sign Detection, Speed Control, Voice Alert, Deep Learning, YOLO.

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I. INTRODUCTION

Road safety is now one of the world's largest concerns due to the exponential growth of vehicles and the increase in traffic congestion. The majority of car accidents can be attributed to negligence on the part of drivers when it comes to observing, understanding, or responding to Traffic Signboards. Traffic Signboards that provide critical information to drivers include speed limits, school zones, hospital zones, pedestrian crossings and warning signs designed to help guide drivers in the execution of their duties and uphold traffic discipline. However, the drivers' ability to effectively observe, measure and respond to the information provided by Traffic Signboards may be impaired due to factors such as distraction, fatigue, poor visibility, adverse weather and/or obscured signboards leading to drivers speeding and subsequently responding late to a situation resulting in accidents or traffic violations.

Conventional driving mechanisms depend heavily on human perception. As a result of this type of system, many drivers may not see significant signage (e.g., stop lights) that are utilized by other drivers when they are travelling at high rates of speed, more commonly within urban areas. Other sensitive areas (such as schools and hospitals) require an immediate decrease in speed by drivers as they are approaching these types of areas, however, in many cases, either drivers will respond late or not comply at all with these requirements. Therefore, it is essential that there be an intelligent solution developed to detect road signs and provide assistance to drivers in "real-time." The proposed road sign detection and intelligent speed control systems are designed specifically to impact these issues by utilizing both computer vision and deep learning technology. The primary focus of the proposed systems is to utilize the on-board cameras located on vehicles to gather live images of the road and utilize advanced image processing algorithms and classification algorithms to immediately detect and/or classify traffic signage using the images collected. Once the system recognizes a sign, it

shows that sign along with the level of recognition of the sign on a live screen - in the car - and provides a clear visual indication to the driver. In addition to providing visual indications, it also generates an audio announcement indicating the name of the detected sign, (e.g., "School Zone Ahead" or "Hospital Zone - Slow Down"). The audio announcement provides the driver with an additional level of awareness without having to constantly look at the display. In addition, when it detects a speed limit sign or restricted zone sign, the system automatically adjusts the speed of the vehicle to comply with the speed limit, which supports the driver in following traffic regulations and improves overall safety on the road.

II. RELATED WORKS

Traffic sign recognition has become a major focus of many researchers because accurate traffic sign recognition is important to an intelligent transportation system or autonomous driving. Dagher and Makary [1] proposed a hybrid system for recognizing traffic signs that used both traditional image processing methods and deep learning models. They improved sign localization and classification using multiple types of feature extraction. The results showed that they were able to achieve improved robustness against different lighting and background conditions, indicating that hybrid architectures can be extremely effective for real-time traffic sign recognition.

Due to the critical importance of intelligent road sign recognition in the decision-making process of an autonomous vehicle, Janu et al. [2] introduced an intelligent road sign recognition system which is coupled to a vehicle's autonomous driving system. The authors focused on acquiring and classifying real-time images for quick responses by an autonomous vehicle to the changing conditions of the roadway when driving through roadway infrastructure. The experimental results from their experiments demonstrated that real-time processing of images for intelligent road sign recognition improved the recognition performance of signs in dynamic traffic situations and highlighted the criticality of real-time processing of images for the safe navigation of an automated vehicle.

The advancement of deep learning has resulted in considerable growth within street sign recognition in complicated city areas. The research completed by Ruprah et al. [3] developed an artificial intelligence model based on deep learning techniques for recognizing and classifying street signs in complex urban environments with regards to occlusion of signs, changing brightness, and clutter of background objects. This study concluded that the use of convolutional neural networks to detect traffic signs is much more consistent when detecting the same street signs in an urban traffic environment making it possible to interpret road signs with a high degree of accuracy.

Recognizing a traffic sign as we get to it in real-time necessitates high-speed detection algorithms for determining its presence accurately. J. et al. have developed an intelligent

traffic sign recognition system based on the YOLOv8 detection algorithm that can be used for autonomous driving applications, specifically for recognizing traffic signs. In their application, they have utilized YOLOv8's rapid object detection capability to provide fast and accurate recognition of traffic signs. Their results demonstrated that the single-stage object detection networks are capable of being integrated into vehicles in real-time; therefore, providing a quick and reliable vehicle recognition of traffic signs.

Federated learning is emerging as an ideal approach for a wide variety of distributed solutions across traffic sign detection and has demonstrated success through work by Shahria et al. [5], which developed an enhanced federated solution for traffic sign detection with greater generalisation in the overall recognition model and data privacy protection. The research from Shahria et al. [5] was primarily based upon the collaborative training of models across multiple electronic devices without the need for the models to have access to centralised datasets. Their results indicate that federated learning has the capacity to be both robust and scalable while providing significant potential for developing federated privacy-preserving methods for intelligent transportation systems through distributed learning methods that are based upon privacy perspective.

Early research into traffic sign detection systems has created the foundation for today's systems. An early example of traffic sign detection was presented by Chen et al [6], who developed a method of detecting and recognizing traffic signs in an intelligent vehicle through classical vision techniques. Feature extraction and classification strategies were established for accurate sign localization from the sign on the vehicle. Results showed that the method could reliably detect traffic signs in any structured environment (e.g., city, highway). Initially, this initial study created a base from which new deep-learning techniques could evolve.

The fusion model allows for increased dependability through research. A recently introduced detection and recognition model by Yu, et al. [7], used the YOLO and VGG networks in order to perform multiple image analyses of roadway signs. In addition to increasing detection accuracy by combining object detection with deep-feet extraction, they discovered that fusing architectures results in an increase in recognition rate when applied to dissimilar roadway situations.

Object detection has proven to be challenging due to the effects of adverse weather on detection of objects. Ahmed and colleagues (2018) developed a robust approach for deep transfer learning to predict whether traffic signs can be seen in challenging weather (e.g., rain and fog). The findings of their study show that their new methods for feature extraction produce consistent prediction results across all weather types, resulting in greater robustness than traditional techniques. This work highlights the importance of developing more adaptive algorithms to deal with the variability of environmental conditions.

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In haze conditions, the recognition of traffic signs is greatly affected by the degradation of visibility due to haze. Hu et al. proposed a new method for detecting traffic signs that considers the principles behind determination of the sight distance available while driving in haze conditions to improve reliability of detection. The study concluded that there was improved detection performance in low visibility environments compared with previous published results. Ultimately, this research emphasizes the need for environmental considerations when designing detection systems.

When considering how to categorize objects in space, it is essential to realize there are many different types of objects that have their own unique classifications, and each type of object will require its own method for finding a suitable location or identifying where it could ideally be placed within the space. Researchers Min et al.'s study from 2005 developed an experimental approach that explored how using the complete area around an object could provide a means of identifying traffic signs; specifically, they looked at two participants (vegetables v.s. fruits). The conclusion drawn from this study is that neither participant will experience a negative effect on performance if either is allowed to supplement his/her data with additional information outside of the specific object, which will improve the ability of either participant to recognize objects located within a complex environment (e.g., seeing a motorcyclist riding through a city).

III. PROPOSED SYSTEM

This project aims to create a real-time traffic sign detection and intelligent speed regulation framework to support drivers in making safer travel choices. Using an onboard camera mounted to the vehicle, the system collects images of the road as the vehicle drives. A model based upon deep learning technology will analyze each photo from the camera to detect and recognize different types of traffic signs, and classify each sign according to the environmental conditions at the time it was captured. The system will utilize advanced techniques for extracting features and detecting objects to accurately detect and classify traffic signs in all types of cities, highways, and low-light conditions. A picture of the detected traffic signs (with the output value of detection confidence) will be displayed on an onboard display for immediate visual feedback to the driver when they are driving.

The automated traffic sign identification system automatically announces an audible alert of each traffic sign once a sign has been detected by the system. This audible announcement is intended to increase the level of awareness by the driver about the vehicle's position relative to the detected traffic sign, while not causing any distraction for the driver. When there is a detected speed limit sign, or a detected school zone sign, or a detected hospital zone sign, the vehicle will automatically control and limit the speed of the vehicle to comply with the established speed limit for that type of area. The controlling of the vehicle's speed will occur in conjunction with the stability of driving for the driver's continued driving. This integrated system will provide a

combination of vision-based detection, audio assistance, and intelligent control to enable driving that is safer and will comply with all traffic laws and regulations.

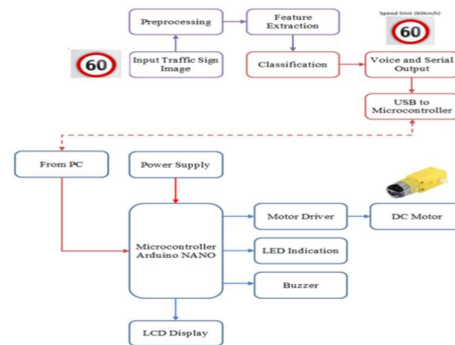


Figure 1: Proposed Block Diagram

The block diagram depicts the whole process of functioning of the Traffic Sign Detection and Intelligent Speed Control System. The first step of this system is to take an image of a traffic sign and then send this image through a preprocessing stage where it is enhanced and noise is extracted from it. The next step is to execute a feature extraction of the image to find significant features of the sign. The next step after this is a classification step where the system determines what kind of traffic signs exist, and how to classify them (e.g., speed limit signs, school zone signs, etc.) so that when they have been identified via classification, the system can announce the identified traffic signs and send this information via USB communication to a microcontroller.

In this case, the Arduino Nano microcontroller serves as the primary controller of the hardware component of the system. It will control the speed of the DC motor using a Motor Driver based on sign information received from either cameras or other sensors. It is also used to turn on the LED indicators and provide visual signals (lights), activate the buzzer alarms and provide audible signals (sound), and display the sign information on the LCD display. Therefore, all three devices (motor driver, alarm, and display) will be powered from the same power supply to eliminate issues with simultaneous performance. This system is an integration of image processing and hardware to provide automation of speed regulation/traffic control and increased road safety.

IV. METHODOLOGY

To create the Road Sign Detection and Intelligent Speed Control System, a structured methodology will be utilized for the system design and execution. This technology will constantly observe road conditions through continuous updates to the roadway; detect traffic signage in real-time; and automatically adjust vehicle speed in order to improve safety. This system will combine computer vision, deep learning classification, microcontroller control, and automated alert systems into one integrated Driver Assistance System. Identifying traffic signs at an early

enough time point will provide adequate notice for the driver and allow for compliance with traffic laws without having to rely on the driver's decision-making ability to make a timely response.

A. System Architecture

The The proposed system's architecture consists of two fundamental components: a Vision Processing Layer and a Control & Actuation Layer (Figure). The camera module captures real-time images of the street and connects to the Processing Unit (PC or embedded). These images will then be processed through various deep learning algorithms in order to detect and classify traffic signs. Once sign information has been recognised, it will be transmitted from the processing unit to the Microcontroller via serial (USB) communication. The Control and Actuation layer consists of the following elements: Arduino Nano, Motor Driver, DC Motor, LCD, LED indicators and a Buzzer. The Control and Actuation layer will be used to control speed and generate alerts based on detected signs.

B. Image Data Acquisition

The camera captures images of the roadway on a regular basis, with new images being taken at regular intervals (e.g., every 10 seconds). Each image captured with the camera is compared to images taken in previous locations for the purpose of identifying the presence of traffic signage. In the majority of cases, the image will not contain any relevant traffic signage. In the infrequent case that an image does contain traffic signage, the program will isolate the relevant area and process it further.

The captured image model is represented as:

$$I_m(x,y) = I(x,y) + n(x,y)$$

where $n(x,y)$ represents noise caused by lighting variations, shadows, and environmental disturbances.

C. Preprocessing and Feature Extraction

Before classification begins, the captured image undergoes several pre-processing treatments: resizing the image, normalising the image, contrast enhancement of the image, noise filtering, and maximising the ability to correctly detect traffic signs so as to allow for accurate detection regardless of changing conditions such as varying levels of light or weather. After pre-processing comes feature extraction which determines the features of the traffic signs, such as edges, shapes, colours and structure. The features that were extracted from the traffic signs are used to provide input to the classification model which allows for the correct classification of the traffic signs.

D. Deep Learning–Based Sign Classification and Communication

A deep learning algorithm processes the detected features from the camera using various labelled traffic signs, determining their classification based on pre-defined categories including 'speed limit' or 'school zone' or 'hospital zone.' The name of the detected sign along with the confidence level are displayed on the screen after the identification process.

The identified sign will then send data to the Arduino Nano via a USB communications interface where the delay in communications can be represented using:

$$T_{total} = T_{processing} + T_{transmission}$$

where $T_{processing}$ is image processing time and $T_{transmission}$ is serial communication delay.

E. Speed Control and Alert Mechanism

The microcontroller starts the proper action after receiving sign information. A voice module is used to announce the sign that has been detected to make drivers more aware of their surroundings. If a speed limit or restricted zone sign is detected, the Arduino Nano will send control signals to the motor driver so that the DC motor can run at the speed prescribed by the sign. There are also warning signals using LED indicators and a buzzer; and real-time information about signs and system conditions is provided through the use of an LCD display.

F. Data Logging and System Performance Analysis

The detection of all event occurrence logs and responses from systems are used to evaluate these systems' performance. Continuous monitoring allows for analysis of frequency of detections, time delays in response, and system stability. A response index according to frequency can be calculated as follows:

$$R_{avg} = (1/N) \sum R_i$$

R_i denotes individual instance of response.

The performance analysis assures; quick-reliability of system to provide speed enhancements in road safety at the same time as providing promptness of vehicle operation.

IV. RESULT & DISCUSSION:

This section focuses on the system's operational performance in detecting traffic signals and displaying the level of accuracy in displayed vehicle speeds. All experimental evaluations have shown that the systems can be tested for detection accuracy and can generate audio alerts if necessary to provide automated vehicle controller functionality. Integrating deep learning technology with microcontroller based control will create and operate with real-time speeds while enhancing driver safety.

A. Traffic Sign Detection and Accuracy Results

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In real-time, the system can identify objects, including traffic signs, throughout various weather and light conditions through the analysis of images taken along the roadways. For example, when the system accurately and effectively identifies traffic signs, it will then show the object with its corresponding identification info including the level of accuracy of that identification, as well as a reference point to help the driver navigate safely on the roadway.

The experimental results indicate that the proposed system has all of the essential components needed to achieve real-time detection, visually indicate the accuracy of detection, notify the operator verbally when there is a detection, and to intelligently manage the speed of the vehicle under control. Showing the level of accuracy improves the transparency and credibility of the system. The automatic speed management system reduces the risk of exceeding the speed limit in sensitive locations. As a whole, the system is designed to enhance driver assistance and promote adherence to traffic regulations, and to provide a meaningful and direct contribution toward increasing roadway safety.

Table I. Traffic Sign Detection and Accuracy Display

Condition	Sign Type	Detection Status	Displayed Accuracy
Normal Road	None	Not Detected	—
Speed Limit 60	Present	Detected	94%
School Zone	Present	Detected	96%
Hospital Zone	Present	Detected	95%

High confidence and consistency were displayed by the results through accurate detection, thus giving a dependable level of certainty for classifications of the test items.

B. Speed Control and Alert Performance

Upon verification of a valid traffic sign the system automatically generates an audible voice alert indicating what type of traffic sign is present. In restricted areas, such as schools and hospitals, there was a buzzer activated and an LED warning system activated corresponding to the detected speed limit for enhancing driver safety. An Arduino Nano was used to receive the classification results and control the motor driver of a DC motor to automatically change its speed according to the speed limit indicated by the detected traffic sign.

Table II. Speed Control and Alert Response Analysis

Sign Type	Alert Generated	Speed Control Action	Average Response Time (s)
Speed Limit 60	Voice Alert	Speed Limited to 60	1.8
School Zone	Voice + Buzzer Alert	Speed Automatically Reduced	2.0
Hospital Zone	Voice + LED Alert	Speed Automatically Reduced	2.1
No Sign	No Alert	No Speed Change	—

Based on the findings, all three functions (detection, alert creation, and speed control) operate effectively through a nearly instantaneous connection.

C. Discussion

IV. CONCLUSION

The Intelligent Speed Control System and Road Sign Detection and Accuracy Display offer a powerful, effective solution for improving road safety. The system utilizes deep learning to recognize traffic signs in real-time while providing on-screen accuracy display. This provides transparency of the system's performance in detecting traffic signs and creating voice alerts that inform drivers of their surroundings to raise awareness while driving in high-risk areas, such as schools or hospitals. Automatic speed regulation is also provided based on the detected speed limit signs to reduce overspeeding and therefore reduce the risk of accidents. The experimental results show stable detection, a response time that is short, and a smooth matching of the software and hardware components. The system is ultimately a means to assist drivers through intelligent driver assistance and to promote safer, compliance with regulations, driving.

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