

AUTOMATIC CAR CONTROLLER BASED ON SIGN BOARD USING AI

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Abstract

The continuous growth of intelligent computing and connected device technologies has accelerated the development of smart transportation solutions aimed at improving road safety and driving efficiency. This project introduces a real-time Traffic Sign Recognition (TSR) and Automatic Vehicle Control system that integrates a YOLO-based deep learning model, an ESP32 Wifi microcontroller, ultrasonic sensing, and Blynk-based cloud monitoring. In the proposed system, traffic signs are identified from live video streams using a trained YOLO object detection framework. The detected sign categories and their associated confidence values are analyzed by a decision-making module executed on a laptop. According to the recognized traffic sign, appropriate control commands are generated and transmitted to the ESP32 microcontroller. The microcontroller then adjusts the vehicle's speed by generating signals to control an L298N motor driver. For improved operational safety, an HC-SR04 ultrasonic sensor is employed to continuously measure the distance between the vehicle and potential obstacles. When an object is detected within a specified safety threshold, the system activates an immediate emergency braking response. Furthermore, integration with the Blynk cloud platform enables real-time monitoring, remote supervision, and visualization of system status through IoT-based communication. Overall, this project demonstrates a low-cost prototype of an Advanced Driver Assistance System (ADAS) that combines artificial intelligence, embedded system control, obstacle detection, and cloud-based monitoring to enhance autonomous driving capabilities.

Keywords: YOLO, ESP32, Traffic Sign Recognition, Ultrasonic Sensor, Blynk Cloud, Internet of Things (IoT), PWM Motor Control, Obstacle Detection.

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I. Introduction

The continuous advancement of Artificial Intelligence (AI), deep learning, and Internet of Things (IoT) technologies has accelerated the development of smart transportation systems. As vehicle density on roads continues to rise, improving driver safety and minimizing road accidents has become increasingly important. Advanced Driver Assistance Systems (ADAS) aim to support drivers by using real-time environmental data to enable informed and automated decision-making. Traffic Sign Recognition (TSR) plays a vital role in intelligent vehicle systems. It involves identifying and classifying road signs from live video input to help ensure adherence to traffic regulations and enhance overall road safety. Earlier approaches to traffic sign detection primarily relied on color segmentation and geometric shape analysis. However, these conventional methods often struggle under challenging real-world conditions such as poor illumination, shadows, partial obstruction, and motion blur, limiting their reliability in dynamic driving scenarios. With the

emergence of deep learning techniques, more robust and accurate object detection models have been developed. One of the most effective models for real-time applications is YOLO (You Only Look Once). Unlike traditional region-based detection algorithms that perform multiple processing steps, YOLO predicts object locations and classifications in a single pass through the neural network. This unified approach significantly improves detection speed, making it highly suitable for real-time vehicle safety applications. In this work, a YOLO-based object detection model is designed and trained using a custom-built traffic sign dataset containing 2,182 annotated images distributed across eight distinct categories. The trained model is implemented for real-time inference using frame-by-frame processing with OpenCV. Detected traffic signs, along with their confidence levels, are evaluated by a decision-making module running on a laptop system to determine the appropriate control action. The resulting control signals are transmitted wirelessly to an ESP32 WiFi-enabled microcontroller. The ESP32 manages vehicle movement by generating Pulse Width Modulation (PWM) signals to control an L298N motor driver. Based on the detected traffic sign—such as stop signs, speed limit indicators, or cautionary warnings—the system automatically adjusts the vehicle's speed or halts movement when required. To improve operational safety, an HC-SR04 ultrasonic sensor is incorporated to continuously measure the distance to objects in front of the vehicle. If an obstacle is detected within a predefined safety margin, the microcontroller triggers an immediate emergency stop to prevent potential collisions. Furthermore, the system integrates Blynk Cloud services to enable IoT-based monitoring and remote supervision. Both the laptop and ESP32 communicate with the cloud platform, allowing real-time visualization of detected traffic signs, vehicle behavior, and obstacle alerts through a connected interface. Overall, the proposed system demonstrates a compact and economical prototype of an intelligent vehicle assistance solution. By combining deep learning-based perception, embedded motor control, obstacle detection, and cloud connectivity, it establishes a practical foundation for future development of scalable semi-autonomous and smart transportation systems.

II. Motivation

The primary motivation behind this project is to contribute to improved road safety through intelligent and automated vehicle assistance technologies. With the rapid increase in the number of vehicles worldwide, traffic accidents caused by human error—such as missed traffic signs, delayed reactions, and driver fatigue—remain a major concern. Developing systems that can assist drivers in recognizing traffic signs and responding appropriately can significantly reduce such risks. Another key motivation is the growing accessibility of Artificial Intelligence, deep learning, and IoT technologies. Modern object detection models like YOLO enable accurate real-time perception, while low-cost microcontrollers such as the ESP32 make embedded automation affordable and practical. By combining these technologies, it is possible to design a compact and cost-effective prototype that demonstrates the core principles of Advanced Driver Assistance Systems (ADAS). This project is also motivated by the need to bridge the gap between software-based intelligence and real-world hardware control. Integrating deep learning-based traffic sign detection with motor control, obstacle sensing, and cloud monitoring provides hands-on experience in building a complete intelligent transportation framework. Ultimately, the goal is to create a scalable foundation for future semi-autonomous and smart vehicle systems that enhance safety, efficiency, and reliability in modern transportation environments.

III. Objectives

- To develop a real-time Traffic Sign Recognition system using a YOLO-based deep learning model for accurate detection and classification of traffic signs.
- To design a decision-making module that interprets detected traffic signs and generates appropriate vehicle control actions.
- To implement automatic vehicle speed control using an ESP32 microcontroller and PWM-based control of an L298N motor driver.
- To integrate an ultrasonic sensor for obstacle detection and implement an emergency stop mechanism to enhance safety.
- To establish reliable communication between the laptop and ESP32 for real-time transmission of control commands.
- To enable IoT-based monitoring by integrating the Blynk cloud platform for remote visualization of system status, detected signs, and obstacle alerts.
- To develop a cost-effective prototype that demonstrates the practical integration of artificial intelligence, embedded systems, and IoT technologies for intelligent transportation application.

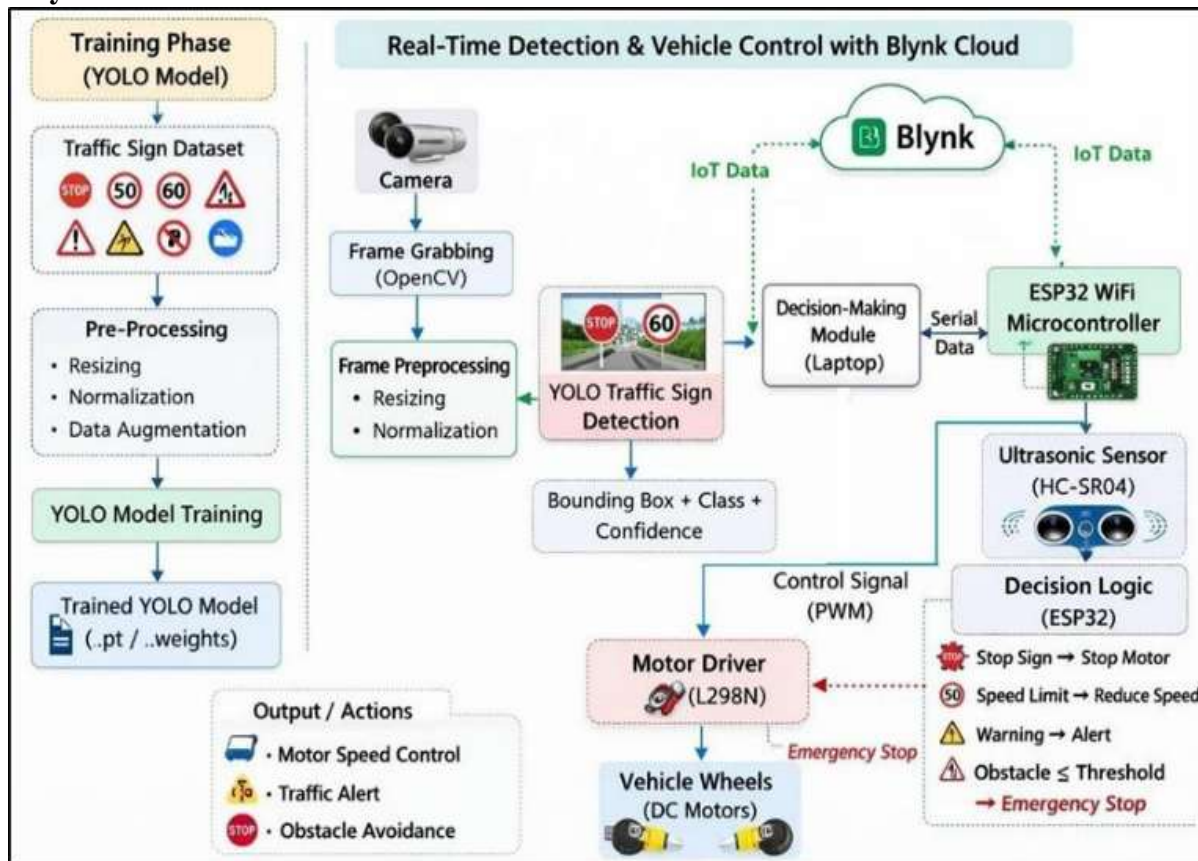
IV. Implementation

The implementation stage consisted of several structured development steps:

Collecting and labeling a traffic sign dataset for model training.

- Training a YOLO-based deep learning model for accurate sign detection.
 - Implementing real-time video processing and detection using OpenCV.
 - Programming the ESP32 microcontroller to generate PWM signals for motor speed control.
 - Integrating an ultrasonic sensor to enable front-obstacle distance measurement.
 - Establishing reliable serial communication between the laptop and the ESP32 for command transmission.
 - Setting up the Blynk cloud platform to enable IoT-based monitoring and system visualization.
- Each component was designed, tested, and validated separately to ensure proper functionality before being combined into the complete integrated system.

V. System Overview



VI. Result

The developed YOLO-based Traffic Sign Recognition system combined with an ESP32-based vehicle control mechanism was successfully designed, implemented, and evaluated in controlled real-time conditions. The system effectively integrates deep learning-based object detection, embedded motor control, ultrasonic obstacle sensing, and IoT cloud monitoring into a unified prototype platform.

• Traffic Sign Detection Performance:

The YOLO model was trained using a custom dataset containing 2,182 annotated images representing eight distinct traffic sign categories. After the training phase, the model achieved strong detection performance under standard lighting conditions.

Key observations from experimental testing include:

- Accurate detection of traffic signs with clearly defined bounding boxes and confidence scores.
- Real-time processing suitable for prototype vehicle applications
- Capability to detect multiple traffic signs simultaneously
- Reliable performance under moderate occlusion and visually complex backgrounds

During real-time evaluation:

- Stop signs triggered an immediate halt of the vehicle
- Speed limit signs dynamically adjusted the motor speed.
- Warning signs generated alert notifications.

The average inference time per frame was sufficiently low to support real-time vehicle control without noticeable delay.

- **Vehicle Speed Control:**

The ESP32 microcontroller successfully received detection results from the laptop through serial communication.

Based on predefined decision logic:

- PWM signals were generated to regulate motor speed.
- The L298N motor driver controlled DC motor rotation.
- Speed adjustments and stop commands were executed accurately.

The time delay between sign detection and motor response was minimal, enabling smooth and responsive vehicle operation.

- **Obstacle Detection and Emergency Braking:**

The ultrasonic sensor (HC-SR04) continuously measured the distance between the vehicle and nearby obstacles to enhance operational safety.

Test results demonstrated:

- When distance > predefined threshold → Normal vehicle movement
- When distance ≤ threshold → Immediate emergency stop.

The emergency braking mechanism successfully disabled motor power upon detecting close-range obstacles, preventing potential collisions during testing. This module significantly improved overall system safety and reliability.

- **IoT Cloud Integration (Blynk Platform):**

The system was integrated with the Blynk IoT Cloud platform, enabling remote monitoring capabilities. Both the laptop and ESP32 were connected to the cloud infrastructure.

Through the Blynk interface:

- Real-time vehicle status was monitored.
- Detected traffic sign information was displayed.
- Obstacle alerts were visualized.
- Overall system performance could be remotely observed.

This integration enhanced the prototype by adding IoT-based monitoring, data visualization, and remote supervision functionality.

VII. Conclusion

This project describes the development and practical implementation of a Traffic Sign Recognition system based on the YOLO deep learning model, combined with an ESP32-driven automatic vehicle control mechanism. The system also incorporates ultrasonic-based obstacle detection and cloud-based monitoring through the Blynk IoT platform.

The developed system is capable of:

- Identifying traffic signs in real time using a trained YOLO object detection model.
- Analyzing detection outputs through a dedicated decision-making module.
- Regulating vehicle motion using an ESP32 microcontroller and an L298N motor driver with PWM speed control.
- Activating an immediate stop function when obstacles are detected within a predefined safety range using an ultrasonic sensor.
- Enabling live system monitoring and status visualization through Blynk cloud integration.

By combining deep learning techniques, embedded hardware control, and IoT-based communication, the proposed solution serves as an affordable prototype of an Advanced Driver Assistance System (ADAS). Experimental evaluation under controlled conditions demonstrated stable and dependable performance, highlighting its potential for future intelligent transportation and semi-autonomous vehicle applications.

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