

Traffic Sign Recognition System with Voice Alerts Using IoT Technology

PRATIK LONKAR¹, PRATIBHA ADKAR²

^{1,2}*P.E. S's Modern College of Engineering, Pune, Maharashtra, India*

Abstract- The world is changing rapidly, and smart transportation technologies are evolving at a similar pace. Various technological advancements are being adopted for automotive safety and Advanced Driver Assistance Systems (ADAS). To address modern road safety threats and driver distraction, an advanced Internet of Things (IoT) equipped system is introduced, featuring real-time traffic sign recognition and voice alerts. The system utilises image processing technology and microcontrollers to detect road signs, immediately triggering hazardous warnings or navigational audio alerts. The device can also transmit real-time data to a cloud dashboard for traffic monitoring. By providing instant auditory feedback, the system ensures that drivers stay informed even if they momentarily take their eyes off the road. This setup specifically helps in reducing accidents caused by overlooked speed limits or stop signs in low-visibility conditions. The use of compact hardware makes it an affordable solution for older vehicles that lack built-in smart features. Furthermore, the cloud integration allows authorities to identify high-risk zones based on frequently detected warning signs. Ultimately, this project aims to create a safer driving environment by bridging the gap between manual driving and fully autonomous intelligence.

Keywords: *Traffic Sign Recognition, IoT, Voice Alerts, Raspberry Pi 5, Advanced Driver Assistance Systems (ADAS), Road Safety, Driver Distraction.*

I. INTRODUCTION

Road traffic injuries are a major problem worldwide, affecting millions of daily commuters and long-distance drivers. According to global health and transportation statistics, human error and driver distraction are leading causes of severe road accidents. Drivers frequently miss critical traffic signs—such as speed limits, stop signs, or school zones—due to fatigue, bad weather, or lack of attention. In today's fast-paced environment, there is an urgent need for effective strategies to combat road safety challenges. The current situation requires

intelligent, rapid, and automated responses to assist the driver without adding visual cognitive load. Considering these difficulties, an automatic traffic sign recognition system is designed using an ESP32-CAM microcontroller, a voice playback module, and an IoT framework as the main innovation. This system is built to meet specific vehicular requirements, providing functions such as real-time image capture, image classification, and auditory anti-collision warnings. This summary highlights the importance of this innovation in the current transportation security landscape and its critical role in reducing road risks and protecting lives.

II. LITERATURE REVIEW

Lina, et.al. (2018)

This paper presents a traffic sign detection and recognition method for driving assistance systems. The subsystem filters out irrelevant regions using colour information, followed by image segmentation and hierarchical grouping. For recognition, a Convolutional Neural Network (CNN) is employed to classify the candidate regions accurately.

Manawadu, et.al. (2021)

This study introduces a voice-assisted real-time traffic sign recognition system designed to aid drivers. It utilizes a trained CNN (YOLO architecture) for rapid sign detection and recognition. Once recognized, the specific traffic sign is narrated to the driver as a voice message using a text-to-speech engine.

Yeong, et.al. (2022)

The authors develop a real-time traffic sign detection and recognition system embedded in a Raspberry Pi 3 using the TensorFlow machine learning algorithm. Utilizing a Raspberry Pi camera NoIR, the system identifies signs and triggers alerts for the driver's

awareness. Testbed implementations demonstrate that the system performs with over 90% accuracy and an acceptable processing delay for city driving speeds.

Cardoso, et.al. (2022)

This paper describes the development of a digital image processing tool designed to detect pills for an oral medication self-monitoring system. It validates the system's accuracy in identifying medication to improve patient adherence tracking. The proposed tool aims to assist patients in managing their daily medication routines effectively and safely.

Xinyao, et.al. (2022)

This paper demonstrates a security vulnerability within the ARM TrustZone technology, which is widely used in modern IoT processors. The authors expose a cross-world covert channel attack leveraging the Performance Monitor Unit (PMU) to bypass hardware-isolated trusted execution environments. The study highlights potential risks to sensitive data and code running in supposedly secure processor areas.

Triki, et.al. (2023)

The authors propose a real-time method combining a Haar cascade technique for detection and an attention-based deep Convolutional Neural Network for classification. The system is trained on the GTSRB dataset and successfully classifies various road sign categories. The developed solution is successfully evaluated and validated on a Raspberry Pi 4 embedded board.

Thevathayarajh, et.al. (2023)

This research focuses on developing a deep learning-based alert system tailored for the distinct traffic signs found in Sri Lanka. It uses the YOLOv5 model for efficient traffic sign detection and recognition. To enhance driver awareness, an auditory alert system generates real-time voice messages whenever a sign is detected.

Hushalictmy, et.al. (2024)

This paper develops a framework that uses a Convolutional Neural Network to recognize stop signs and other traffic congestion imagery. Upon recognition, the system provides a voice warning to the driver to assist with crucial decision-making. It

also alerts drivers about upcoming traffic signs based on stored GPS locations to ensure compliance with highway laws.

Drobiniak, et.al. (2025)

The research details a traffic sign recognition system that integrates colour segmentation, shape recognition, and neural network-based classification. It isolates signs using HSL/HSV colour models and employs a Region-based Convolutional Neural Network (RCNN) to accurately categorize them. The system operates with standard onboard cameras and provides robust performance under varying lighting conditions.

Ikharo, et.al. (2025)

This paper proposes a lightweight, real-time traffic sign recognition system built on Convolutional Neural Networks, optimized for embedded automotive platforms. Validated on the GTSRB dataset, the model strikes a balance between low-latency inference and high classification accuracy. The system operates at 22 frames per second on a Jetson Nano, demonstrating strong suitability for real-time ADAS applications.

Oloriegbe, et.al. (2025)

This study tackles traffic signal stop-line violations by designing an IoT-based intelligent detection system. It employs infrared (IR) sensors for vehicular detection and an ESP32 Camera to capture images of offending vehicles. The captured images are then transmitted to a server via notification bots, offering a 98% accuracy rate in detecting violations.

Chang, et.al. (2025)

This research details the design and implementation of an edge server system using the ESP32 microcontroller to perform object detection via deep learning. By integrating edge processing with a cloud server framework via MQTT protocols, the system significantly reduces bandwidth usage and classification latency. It effectively demonstrates how low-cost edge computing can alleviate the computational load on cloud servers.

Alzamzami, et.al. (2025)

The authors propose an intelligent traffic light management system named "Passable" that integrates

real-time incident detection and vehicle alerting. The system is designed to improve urban mobility and accessibility by dynamically adapting to road conditions and wirelessly warning drivers of nearby incidents. This approach leverages smart city infrastructure to enhance overall road safety and traffic flow efficiency.

III. RESEARCH GAP

Existing research primarily focuses on deploying traffic sign recognition models on older edge devices, where hardware limitations cause severe processing bottlenecks. While a few studies attempt to add basic audio warnings, they struggle to balance heavy object-detection algorithms with the instant feedback required for safe driving.

My project solves this by using the much faster Raspberry Pi 5, which completely removes that lag. Because of this upgrade, my system can spot a traffic sign and give an instant voice alert without any delay. The biggest advantage of adding this real-time voice feature is that drivers never have to take their eyes off the road to look at a screen, they just hear the warning immediately, making it a much safer and more practical solution than older systems.

IV. RELATED WORK

Early traffic sign detection relied on basic shapes and colours, which often failed in bad weather or poor lighting. While early machine learning methods improved things slightly, they still struggled to tell similar signs apart. Today, advanced neural networks can easily recognize signs even if they are blurry, tilted, or partially hidden. Building on this success, newer projects have added voice alerts that instantly read signs out loud, helping distracted drivers stay focused on the road. Now, the main goal is shrinking these heavy models so they can run efficiently on small devices like a Raspberry Pi. This allows the entire system to process instantly inside a moving car.

V. PROBLEM STATEMENT

Every day, numerous road accidents occur because drivers miss critical traffic signs due to distraction,

heavy traffic, or poor visibility. While modern luxury vehicles feature built-in Advanced Driver Assistance Systems (ADAS) to read road signs, these technologies remain far too expensive for the vast majority of standard and older cars. Relying solely on human concentration is no longer sufficient in fast-changing driving environments, creating a strong need for an accessible, retrofittable safety device. This project addresses that critical gap by developing a low-cost, IoT-enabled system that uses a compact camera to recognize traffic signs in real-time. By instantly delivering clear voice alerts, the system acts as a second pair of eyes, ensuring drivers safely stay informed of road rules without ever having to look away from the road.

VI. PROPOSED METHODOLOGY

1. Capturing Live Video (Input)

A camera continuously watches ahead and sends that live video straight to the system. This ensures that every passing object on the road is captured the moment it comes into view.

2. Recognizing the Sign (Processing)

The "brain" of the project (the Raspberry Pi 5) instantly scans the video frames. It spots a traffic sign and figure out exactly what it means (like "STOP" or "Speed Limit 50"). Because the Raspberry Pi 5 is so powerful, this heavy computing happens in a split second.

3. Showing the Results (Visual Display), The system immediately shows the recognized sign on a main screen, while a small LCD display prints out the text of the sign so it can be read quickly. This double-display method makes sure the driver or passengers can easily verify exactly what the system saw.

4. Playing the Voice Alert (Audio Warning)

At the exact same time, a speaker plays a clear voice message telling the driver what the sign says. This ensures the driver gets the warning without ever taking their eyes off the road. It acts like an ever-present co-pilot, greatly improving safety by preventing you from missing important road rules.

5. Continuous Scanning (Loop)

The moment the sign is out of view, the system instantly resets the screen to say "NO SIGN" and keeps scanning for the next object without any delay. This fast reset prevents old alerts from confusing the driver and keeps the system completely ready for whatever sign is coming up next.

VII. SYSTEM ARCHITECTURE

The proposed system architecture operates on a highly efficient edge-computing model, ensuring that all data acquisition, processing, and output occur locally. The system is initiated by the Input Module, where a camera continuously captures real-time video frames of the traffic environment and feeds this raw visual data directly to the core processing unit.

The central hub of the system is a Raspberry Pi 5, which instantly captures and preprocess the incoming video, detect traffic signs, and classify them accurately. Once a sign is identified, it immediately translates the classified text into an audio signal.

Concurrently, the Output Module delivers immediate dual feedback to the user: a main monitor displays the live video feed complete with a bounding box around the detected sign, a 16x2 LCD screen prints the exact text of the sign for quick, distraction-free reading, and external speakers broadcast the real-time voice alert. This seamless integration ensures the driver receives instant visual and auditory warnings while the system instantly resets to scan for the next object without delay.

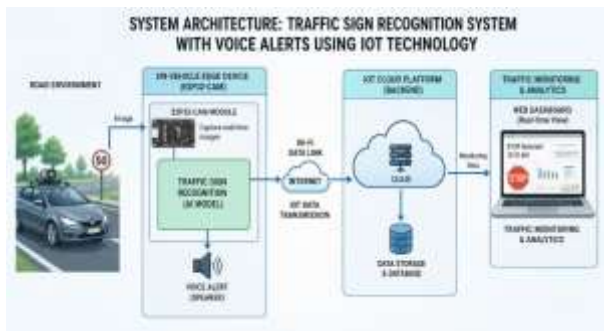


fig.1 System Architecture

Experimental Setup
 Hardware Configuration: -
 Raspberry Pi 5 (4GB)

USB Mini Camera Module (5megapixels)
 Speaker for voice output (6 watts)
 Screen for displaying the image output
 LED screen for image text output
 Software Configuration: -
 Raspberry Pi OS
 Python

System Screens

1. Sign name: - Speed Limit 50



fig.2

Image detected by camera: -



fig.3

Text output on LED Screen:-



fig.4

2. Sign name: - No Entry



fig.5

Image detected by camera: -



fig.6

Text output on LED Screen: -



fig.7

3. Sign name: - Roadwork



fig.8

Image detected by camera: -



fig.9

Text output on LED Screen: -



fig.10

VIII. RESULTS AND DISCUSSION

Based on the integration of camera processing and audio feedback, the proposed model features seamless alert delivery. The system successfully identifies standard signs (Speed Limit, Stop, No Parking, etc) and plays the corresponding auditory warning with minimal latency. The proposed work will significantly reduce driving risks on highways and city roads where the high risk of missing hidden or obscured traffic signs causes accidents. Using IoT, the acquired data can be visualized by traffic authorities to identify areas where signs are frequently ignored, allowing for better urban planning and feedback.

IX. ADVANTAGES

1. Instant Voice Warnings for Maximum Safety: The biggest benefit of your project is the real-time audio alert. Drivers never have to take their eyes off the road to look at a dashboard or screen; they simply hear the warning immediately, which drastically reduces driving distractions.
2. Clear Double Display: It provides two simultaneous ways to visually check the results—a main screen showing the live video with a target box, and a dedicated 16x2 LCD screen printing the exact text. This makes the system incredibly reliable and easy to read at a glance.
3. Smart Auto-Reset: The moment a traffic sign passes out of the camera's view, your system instantly resets to say "NO SIGN." This fast continuous loop prevents old, outdated warnings from lingering and confusing the driver.
4. Cost-Effective Safety Upgrade: Instead of needing to buy an expensive, brand-new luxury car to get smart driving assistance, your project uses affordable, easy-to-find hardware (like the Raspberry Pi). This allows anyone to add high-tech safety features to older, standard vehicles at a very low cost.
5. Compact and Easy to Install: The entire "brain" of the project is built around the small footprint of the Raspberry Pi. This means the system takes up very little space on a dashboard, won't block the driver's view, and can easily be moved from one car to another.
6. Reduces Driving Stress and Fatigue: Constantly scanning for and reading every single sign on a long

road trip or in an unfamiliar, busy city can be mentally exhausting. Having a system that automatically reads the important rules out loud acts like a helpful co-pilot, keeping the driver relaxed and focused.

7. Easily Upgradable for the Future: Because the core of the project is software-based, the system isn't stuck exactly as it is today. In the future, you can easily update the code to recognize new types of signs, or even change the text-to-speech engine to speak in different languages, all without having to build new hardware.

X. LIMITATIONS

1. Struggles in Bad Weather: It can be blinded by environmental factors like heavy rain or thick fog can prevent the system from capturing a clear enough image to recognize the sign.

2. Limited to Its Training Data: If the camera captures a heavily vandalized sign or a brand-new type of street sign that was not included in its original training pictures, the system will not be able to identify it.

XI. FUTURE WORK

1. In the future, the system can be expanded using more advanced deep learning models and using infrared (IR) or low light camera to operate in extremely low-light or foggy conditions, rainy weather and dark night vision

2. The machine learning model could be trained on a specialized dataset of blurry or rain-covered or snow-covered signs so it can still alert drivers in poor weather conditions.

3. Right now, it likely speaks in standard English language. A highly useful future enhancement would be adding a language-selection feature. By adding more regional languages like Hindi or Marathi, makes the technology accessible to a much wider range of local drivers.

4. Future versions of this project could include a companion smartphone app connected via Bluetooth. While the main system runs offline to avoid lag, it could silently send a log of all detected signs to the driver's phone.

XII. CONCLUSION

The automatic traffic sign recognition system with voice alerts promises a highly effective initiative toward technological enhancements in road safety. Utilizing an embedded camera and audio network provides an efficient alert mechanism that notifies the user of critical road rules without causing visual distraction. The added advantage of IoT integration allows for real-time traffic condition monitoring, making it a highly scalable solution for modern smart vehicles.

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