AI Powered Traffic Management System

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Abstract*—Urban intersections increasingly struggle to handle rising traffic levels, particularly when traditional fixed-timer signals fail to respond to real-time conditions. To address this issue, this work proposes an adaptive traffic management system that integrates artificial intelligence with sensor-driven monitoring. A Raspberry Pi processes live camera footage through a YOLO-based detection model to identify vehicles and measure lane-wise density, enabling dynamic adjustment of signal timing. Alongside this, an ESP32 unit collects data from ultrasonic and infrared sensors and supports wireless communication for emergency-vehicle prioritization. By combining visual analytics with sensor validation, the system enhances reliability, reduces delays, and ensures rapid clearance for ambulances, offering a practical solution for smart-city environments.*

Index Terms*—Artificial Intelligence (AI), YOLO, Raspberry Pi, ESP32, Internet of Things (IoT), Smart Traffic Management, Ultrasonic Sensor, IR Sensor, Image Processing, Ambulance Priority System*

I. INTRODUCTION

The rapid growth of urban traffic has made congestion a persistent challenge, particularly at busy intersections where static signal patterns fail to reflect real-time vehicle flow. Predetermined signal cycles often result in unnecessary idling, long queues, and inefficient movement of vehicles—issues that become more severe during peak hours. Although manual traffic control is occasionally used to manage high-density periods, this approach relies heavily on human judgment and can be inconsistent.

Recent advances in artificial intelligence and IoT technologies create opportunities for developing more responsive and intelligent traffic systems. By integrating camera-based vehicle analysis with sensor-based feedback, it becomes possible to continuously assess traffic conditions and adjust signal durations according to current demand. In the proposed system, a Raspberry Pi running a YOLO detection model identifies vehicles and estimates traffic density, while an ESP32 module handles sensor inputs and emergency-vehicle signaling. Together, these components form a coordinated, adaptive platform aimed at reducing congestion and ensuring faster movement through critical routes.

II. LITERATURE SURVEY

Vision-based traffic monitoring has received significant research attention due to its ability to analyze real-time road conditions without relying on physical sensors. Sivaraman, Trivedi, and Lee [1] conducted an extensive review of vision-driven vehicle detection and tracking techniques. Their study highlighted the effectiveness of video analytics in understanding vehicle movement while also noting key limitations, such as reduced reliability during poor lighting, rainfall, shadows, and occlusions. These challenges indicate the need for more resilient models capable of handling dynamic urban environments.

The introduction of deep-learning-based detection models further advanced the field. Bochkovskiy, Wang, and Liao [2] developed YOLOv4, a highly optimized object-detection framework designed to achieve real-time performance with strong accuracy. Their work demonstrated that modern neural-network architectures can operate efficiently even on embedded computing devices. However, their focus remained on improving the detection algorithm rather than integrating it into a complete traffic-management ecosystem that includes IoT communication, multi-sensor fusion, or emergency-vehicle priority handling.

Manjunath, Hariprasad, and Raju [3] proposed a traffic-density control system built on Raspberry Pi using basic image-processing methods. Their results verified that embedded platforms can support adaptive signal control; however, the system's reliance on simple visual-processing techniques limited its accuracy in heavy traffic conditions and under varying environmental settings. Furthermore, their design lacked IoT connectivity and did not incorporate mechanisms for emergency-vehicle prioritization.

III. OBJECTIVES

1. To design an intelligent traffic regulation system that utilizes a Raspberry Pi, ESP32, infrared sensors, and ultrasonic sensors to continuously analyze traffic density and adjust signal durations based on real-time conditions.

2. To create an automated emergency-vehicle priority feature capable of identifying approaching ambulances and temporarily overriding standard signal behavior to establish a clear and uninterrupted travel path.

3. To combine data from multiple sensors with IoT-based communication between Raspberry Pi and ESP32 units, enabling coordinated intersection control aimed at minimizing traffic buildup and enhancing overall flow efficiency.

IV. METHODOLOGY

The system operates through a coordinated workflow involving live video processing, sensor input collection, decision-making logic, and emergency-priority handling. A camera positioned at the intersection streams video data to a Raspberry Pi, which runs a YOLO detection model to identify vehicles and determine lane-specific density levels. Based on the detected density, the system allocates green-light durations dynamically to balance overall traffic flow. In parallel, an ESP32 microcontroller receives readings from ultrasonic and infrared sensors that verify vehicle presence and measure proximity, offering redundancy when visual conditions are poor or obstructed.

The ESP32 also manages the emergency-override feature: when an ambulance transmits a signal through the IoT channel, the microcontroller forwards this information to the Raspberry Pi, prompting the system to immediately prioritize the relevant lane. All updates, including detected vehicles and signal changes, are displayed through an LCD or web interface and may be logged for further analysis.

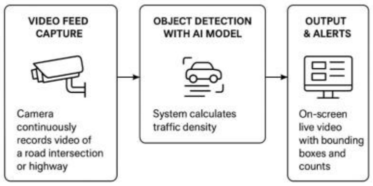

Fig. 1. Block diagram

V. RESULTS AND DISCUSSION

Figure 2 illustrates the complete workflow of the proposed system through a structured flowchart. It outlines each stage beginning from video acquisition, YOLOv5-based object detection, and traffic density assessment, followed by intelligent decision logic for managing traffic signals. The diagram clearly shows how data moves step-by-step through the pipeline, ensuring reliable and efficient traffic control. It also highlights the final output actions such as generating bounding boxes, displaying results on the web interface, and maintaining logs, showing that the system supports both real-time monitoring and record keeping.

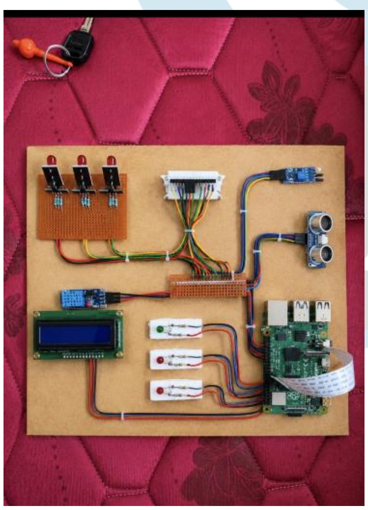

Fig. 2. Working Model of project

Figure 3 presents the hardware prototype assembled using components like the ESP32, IR sensors, ultrasonic sensor, LCD module, and traffic signal LEDs. The arrangement and wiring indicate that all devices are correctly interconnected on the testing setup. The LEDs display proper signal transitions, and the LCD confirms that sensor readings and decisions are being processed as intended. This prototype validates the practical implementation of the system and demonstrates that the IoT-based traffic control mechanism operates effectively under real-time conditions.

Figure 4 displays the ambulance detection output generated by the YOLOv5 model. The model successfully identifies the ambulance and assigns a high confidence score of 99%.

Fig. 3. Output by YOLO5 model

VI. CONCLUSION

The system presented in this work demonstrates how AI-driven video processing and sensor-based monitoring can be combined to create an adaptive and reliable traffic management solution. By using YOLO-based detection on a Raspberry Pi, the system continuously evaluates real-time traffic density and adjusts signal durations to minimize congestion. Additional sensor inputs from the ESP32 enhance accuracy, while the IoT-supported emergency-vehicle priority feature ensures ambulances receive timely clearance through intersections.

Overall, the integration of these technologies results in faster traffic movement, reduced waiting times, and improved safety. The approach is cost-effective, scalable, and well-suited for future smart-city applications, with potential for expansion into multi-junction coordination and predictive traffic modeling.

VII. ACKNOWLEDGEMENT

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