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Smart Traffic Management System Using Vehicle Detection with ESP32 and Web-Based Control Interface

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Abstract: ***Urban traffic flow is suffering severe crisis due to the rapid increasing traffic volume and the limitation of fixed-time traffic signal coordination. This paper presents a smart traffic management system for improving traffic efficiency of three-lane intersection by real-time signal control based on vehicle density. This system uses video-based vehicle detection and ESP32 for signal control. Web interface is developed for signal countdown display through local IP address displayed on an in-built OLED display. Emergency control using RF with emergency switches to give priority to emergency vehicles is also incorporated . This system improves traffic flow, reduces stop time, and is an efficient and economic method for handling heavy traffic volume.***
Keywords: ESP32, Traffic Control, Vehicle Detection, RF Module, Web Interface

I. INTRODUCTION

Due to an increasing number of vehicles on the road and the limitations of the fixed time traffic signal system, traffic congestion has become one of the major problems in the urban areas. The situation worsens for those users who are unaware of a traffic signal system that employs set timings or actuations. In order to allow the implementation of embedded controllers and communication technologies, these problems must be overcome. A smart traffic management system for three lanes intersection using vehicle detection and ESP32-based control is presented here. Traffic lights shifting/changes as per the availability of traffic. It also provides a web interface for real-time monitoring and an RF-based emergency control feature to prioritize emergency vehicles. The traffic control system has undergone integration to boost efficiency.

II. LITERATURE REVIEW

A. Conventional Traffic Signal Systems

Starting at odd times, old-style signals just follow a set pattern regardless of how many cars show up. Though basic in design, they waste moments when roads sit empty or jammed alike. Waiting piles up because timing stays rigid even as crowds shift through the day.

B. Sensor-Based Traffic Management Systems

Sensor-based systems use technologies such as infrared, ultrasonic, and inductive loop sensors to detect vehicle presence. These systems improve automation but have limitations in accurately measuring traffic density and handling multiple vehicles simultaneously.

C. Vision-Based Traffic Monitoring Systems

Recent approaches use image processing and computer vision techniques to detect and count vehicles from video input. These systems provide better accuracy and adaptability compared to sensor-based systems, making them suitable for dynamic traffic control.

D. Embedded and IoT-Based Traffic Systems

Microcontrollers such as ESP32 are widely used in modern traffic systems due to their processing capability and built-in Wi-Fi features. IoT-based solutions allow real-time monitoring and remote access through web interfaces, improving system efficiency and control.

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E. Identified Research Gaps

One feature at a time - that is what most current setups prefer, whether it's spotting issues, managing responses, or keeping watch. Yet stitching these together - live traffic checks, crisis response, oversight from afar - into one working whole? That still feels missing.

III. PROJECT OBJECTIVES

Aiming to reshape how city lights respond, this effort builds a traffic system aware of current road activity. Instead it adjusts signal timing using live data flows across intersections. When urgent vehicles appear, response paths gain immediate clearance through coordinated changes. Focus stays on smoothing movement while giving critical needs faster passage.

1) To design a system that analyzes traffic density using prerecorded video input.
2) To implement a three-lane traffic signal control system using the ESP32 microcontroller.
3) When cars pile up, lights shift faster. As traffic builds, changes come quicker. If roads fill, response tightens. With more vehicles showing, flow adapts sooner. Once lanes get busy, timing reshapes itself.
4) To display system access information (IP address) on an OLED display
5) A live view of signal timing appears through a browser window. Web tools update the display as changes happen. This setup tracks countdown progress moment by moment. Updates flow without delays using standard internet connections.

IV. RESEARCH METHODOLOGY

A. Data Acquisition

Traffic data is obtained using prerecorded video sequences representing a three-lane road scenario. These videos are used as input to simulate real-time traffic conditions and analyze vehicle density in each lane.

B. Vehicle Detection and Density Analysis

The prerecorded video is processed on a computer system to detect and count vehicles present in each lane. Based on the number of vehicles detected, traffic density is estimated for all lanes. This information is used as input for decision-making.

C. Signal Control using ESP32

Inside the setup, the ESP32 chip runs everything like a brain. From it, signals go out via GPIO ports to manage the lights based on live traffic flow. When one road has more vehicles, that path gets faster green light changes.

D. System Integration

All modules, including vehicle detection, signal control, emergency handling, and web interface, are integrated to ensure smooth and synchronized operation.

V. BLOCK DIAGRAM

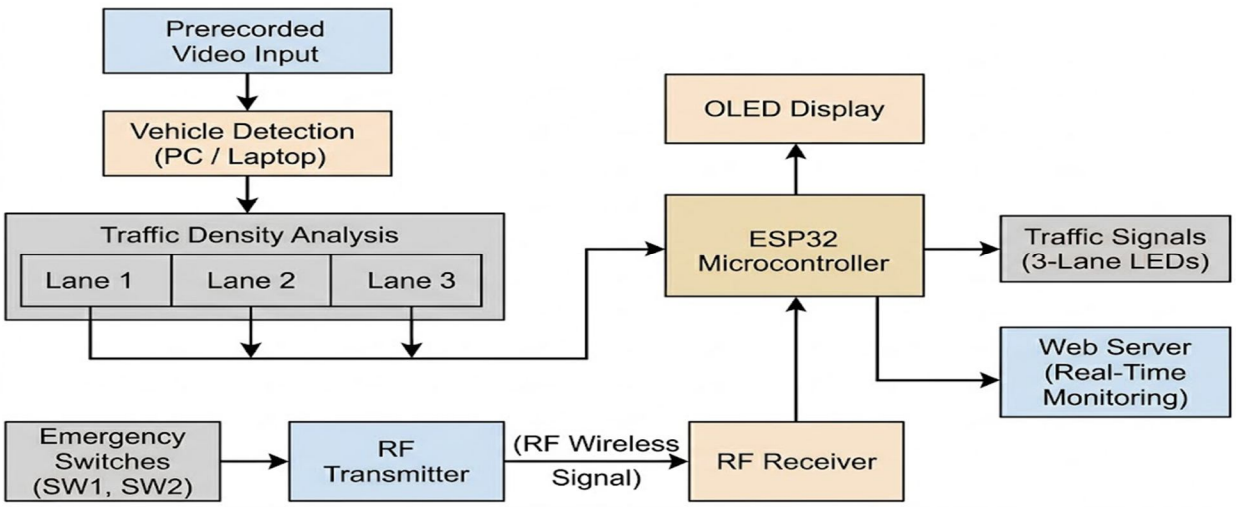


Figure 1: Block Diagram of Proposed Smart Traffic Management System

The system consists of the following blocks:

1) Prerecorded Video Input: Provides traffic video data used for analyzing vehicle movement in different lanes.
2) Vehicle Detection (PC/Laptop): Processes the prerecorded video to detect and count vehicles present in each lane.
3) Traffic Density Analysis: Calculates traffic density for Lane 1, Lane 2, and Lane 3 based on detected vehicles.
4) Microcontroller (ESP32): Acts as the main control unit that receives traffic data and controls signal operations.
5) Traffic Signals Three Lane LEDs: Displays red, yellow, and green signals for each lane based on control decisions.
6) OLED Display: Shows the IP address of the system, allowing access to the web interface.
7) Web Server: Provides real-time monitoring of signal countdown and system status through a browser.

VI. .SYSTEM IMPLEMENTATION

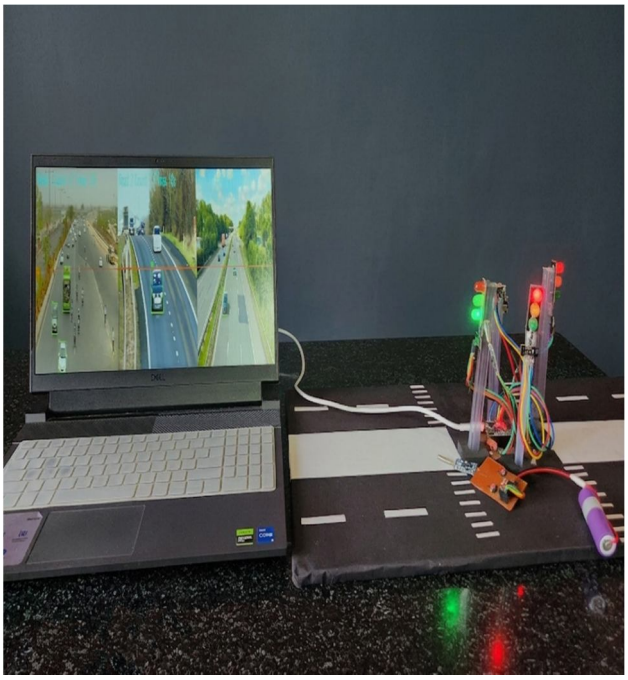


Figure 3: Hardware Implementation of Proposed System

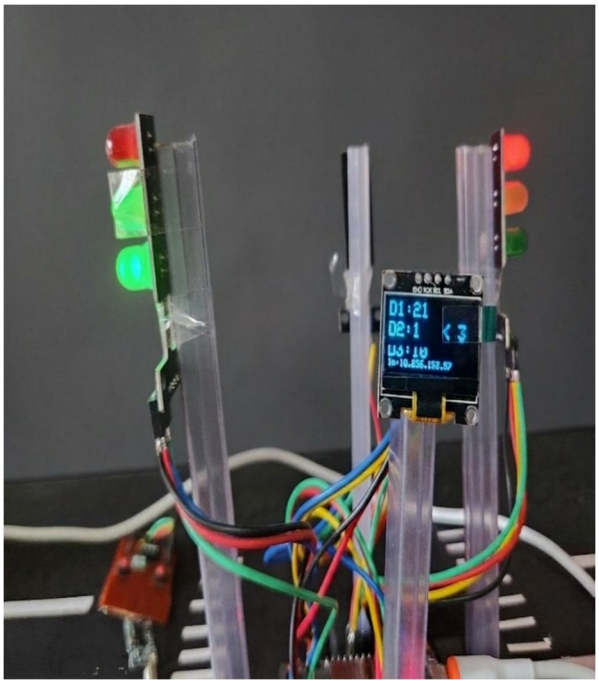


Figure 4: Close-up View of Traffic Signal and OLED Display

VII. FLOW CHART

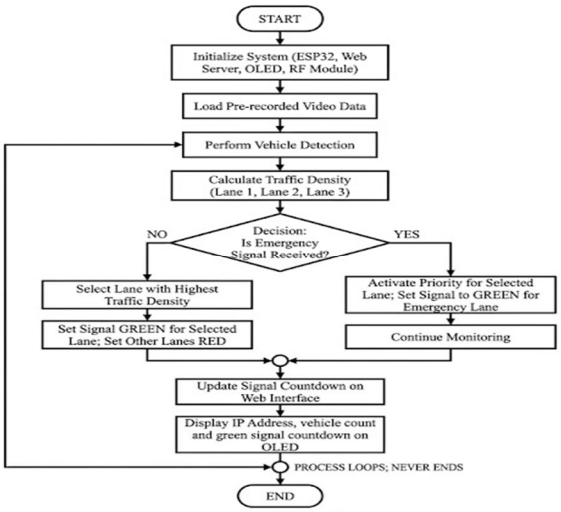


Figure 5: Flowchart of Proposed Smart Traffic Management System

VIII. RESULTS

The system successfully detected vehicles and adjusted signal timing based on traffic density. The web interface displayed real-time updates, and the RF module enabled emergency priority control. The system performed reliably under different traffic conditions.

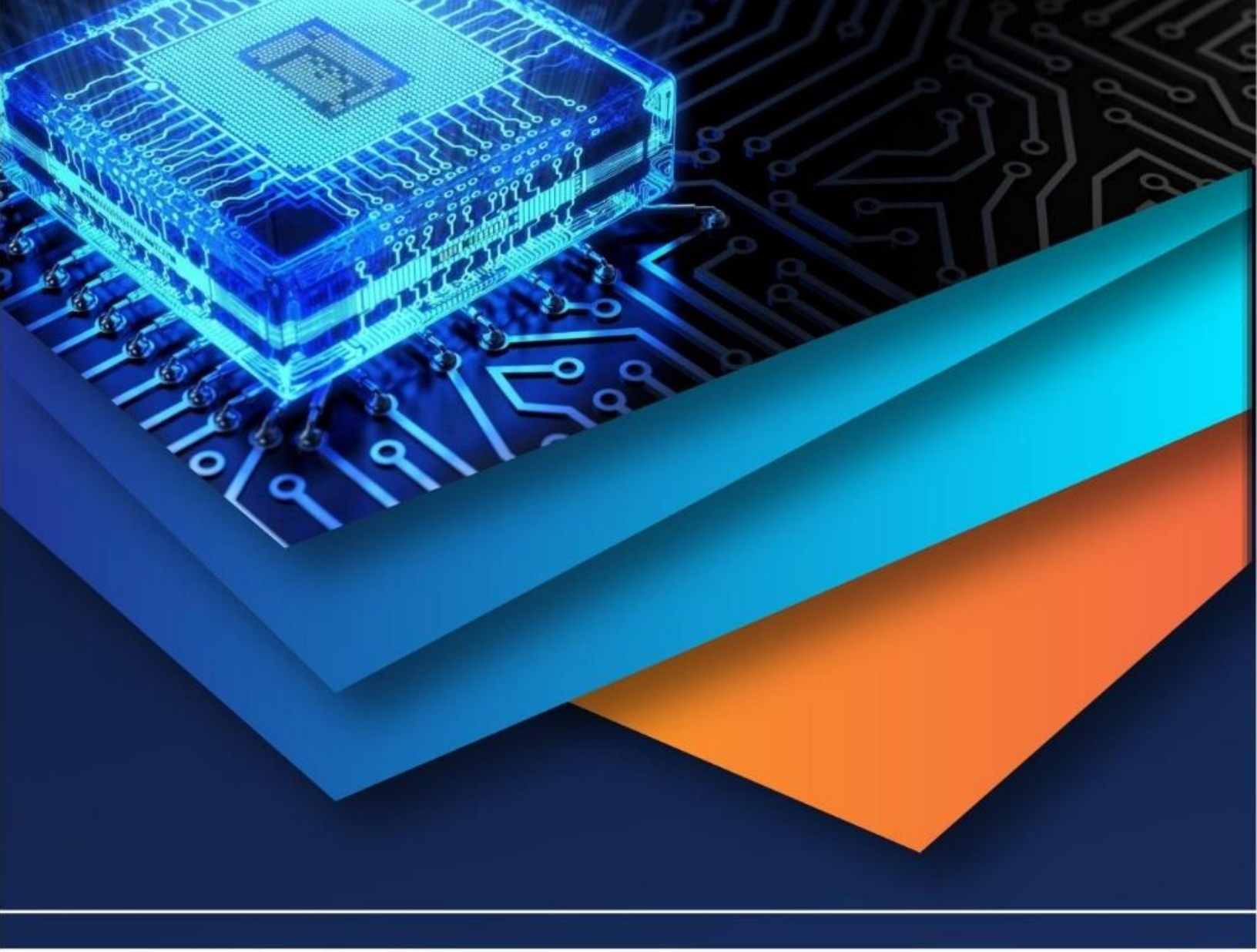
IX. CONCLUSION

A single idea stands out when watching cars move through a busy three-way crossing: timing matters. Instead of fixed lights, changes happen as needed, shaped by what the cameras see. Video clips recorded ahead of time help spot each vehicle. From there, signals shift based on flow, not schedules. An ESP32 chip runs the decisions, making adjustments live. Rules aren't static - they bend slightly with every passing minute.Right off, the online display lets everyone see what is happening at once. Not only that, radio signals give urgent transport a clear path when seconds matter. This setup runs without hiccups most days. The proposed system reduces waiting time and improves traffic efficiency

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