Title: Smart Traffic Signal Control System Using IoT

Abstract:
In urban areas, traffic congestion at roundabouts and intersections is a major issue, leading to increased commute times, fuel consumption, and air pollution. Traditional traffic signal systems operate on fixed timers, irrespective of real-time traffic conditions. This approach results in inefficiencies such as prolonged wait times for vehicles in high-traffic lanes and unnecessary green-light durations for low-traffic lanes. This project aims to develop a smart traffic signal control system using IoT and cameras technology to dynamically adjust signal durations based on real-time traffic density. The system integrates cameras, and an ESP32 microcontroller to collect and process traffic data, optimizing signal timings for improved traffic flow and reduced congestion.

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1. Introduction
Traffic congestion is a major issue in urban areas, significantly impacting travel efficiency and environmental sustainability. Traditional traffic signal systems operate on pre-defined timers without considering real-time traffic variations. We will enhance traffic management by employing IoT-based solutions that dynamically adjust signal timings based on real-time traffic density estimation using camera-based vehicle detection.

2. Objectives

- To develop an IoT-based smart traffic signal system that dynamically adjusts green light durations based on real-time traffic density.
- To integrate computer vision techniques for accurate vehicle detection and queue estimation.
- To optimize traffic flow, reducing unnecessary wait times and improving urban mobility.
- To implement a scalable system that can be deployed at various intersections.

3. Methodology

3.1 Data Collection

- Traffic cameras capture images, which are processed using OpenCV to count the number of vehicles.

3.2 Traffic Density Estimation

- The extent of vehicle queues is analysed using Cameras data to calculate the traffic density area for each lane.
- Lanes with larger areas are identified as having higher traffic density.
- The presence of larger vehicles is factored into the density calculation since they take longer to clear the lane.

3.3 Decision-Making

- The collected and processed data is sent to the ESP32 microcontroller.

- The microcontroller dynamically adjusts the green light duration based on real-time traffic density.
    - Lanes with higher traffic density receive longer green light durations.
    - Lanes with lower traffic density receive shorter green light durations.

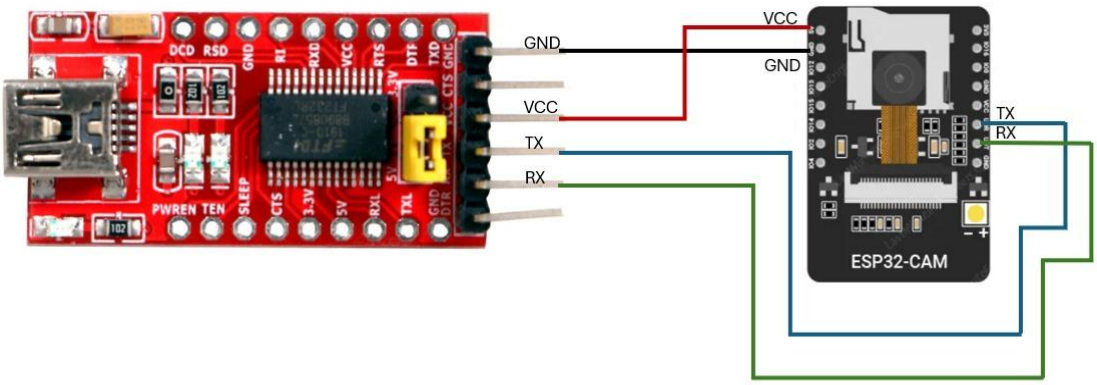
4. System Components

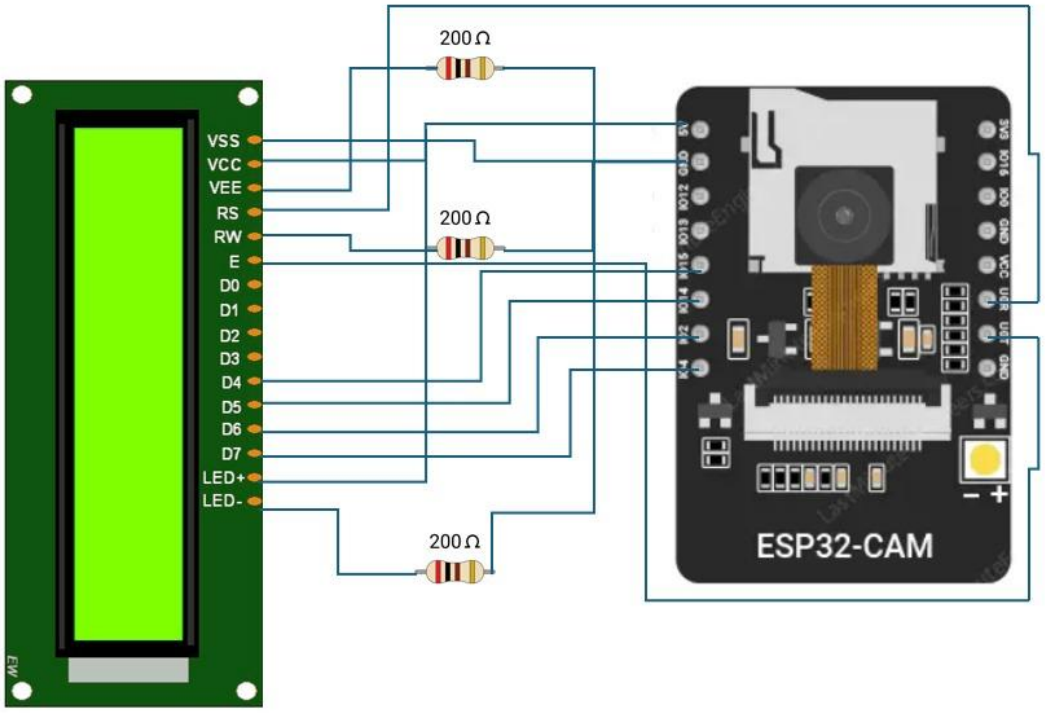
- **Hardware:**
    - Traffic cameras for image-based vehicle counting
    - ESP32 microcontroller for processing and decision-making
- **Software:**
    - PTV VISSIM for traffic flow modeling and simulation
    - OpenCV for image processing and vehicle detection
    - Microcontroller programming for traffic light control

5. Expected Outcomes

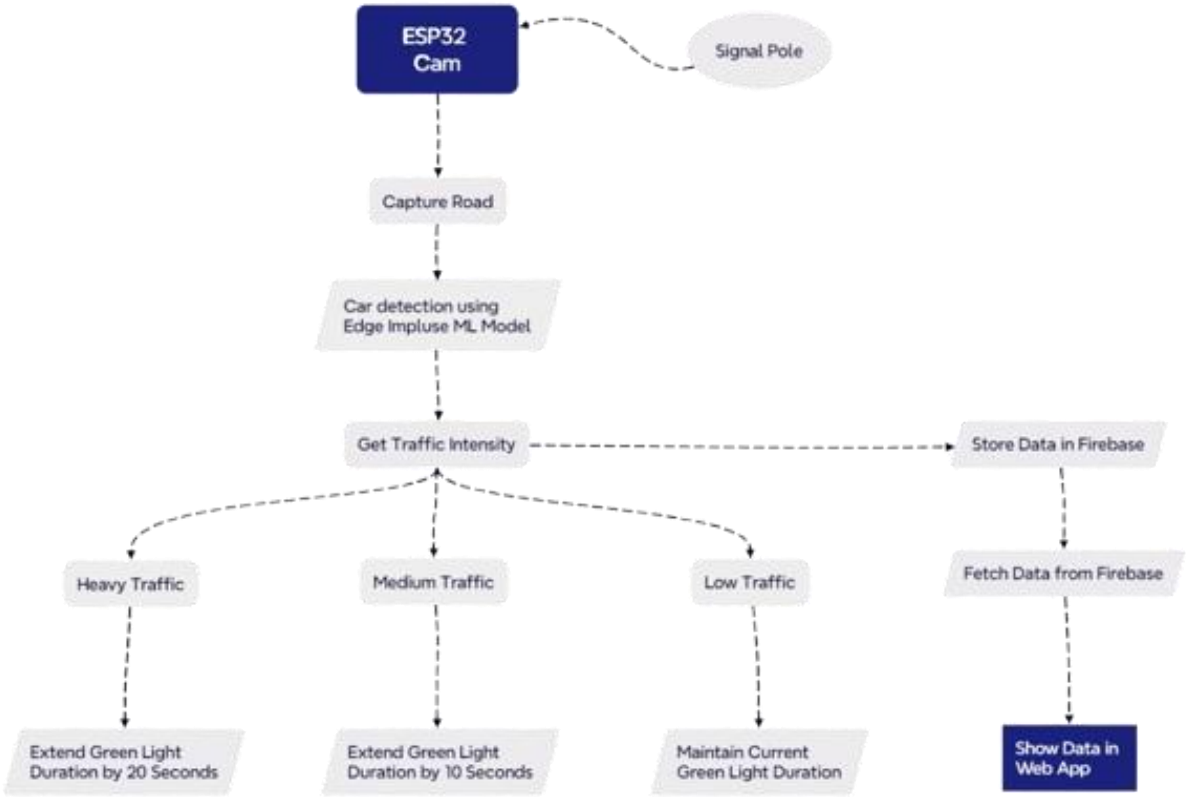
- A functional prototype demonstrating real-time adaptive traffic signal control.
- Improved traffic flow efficiency by reducing congestion and wait times.
- A scalable solution that can be implemented at multiple intersections for better urban traffic management.

6. Circuit Diagrams





7. Block Diagram



8. Future Innovations

- **Vehicle-to-Infrastructure (V2I) Communication**: Enabling vehicles to communicate with traffic signals for smarter coordination.
- **Edge Computing with ESP32**: Local processing of camera data using microcontrollers to reduce delay and bandwidth usage.
- **Emergency & Priority Vehicle Detection**: Automatic recognition and prioritization of ambulances, fire trucks, etc., in traffic signals.

7. Conclusion

This project aims to address urban traffic congestion by implementing an intelligent, real-time traffic signal control system. By leveraging IoT, cameras and computer vision, the system dynamically adjusts traffic light durations based on real-time traffic density, optimizing flow and reducing delays. PTV VISSIM integrates with the system for simulation, and the ESP32 microcontroller controls it, ensuring a practical and scalable solution to modern traffic management challenges.