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Smart Density Based Traffic Light Control System With (ESP32)

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ABSTRACT

Traffic congestion has become a major problem in urban areas due to the rapid growth in the number of vehicles. Traditional light traffic systems operate at fixed time intervals, which do not consider the actual traffic density on each road. This often leads to unnecessary waiting times and inefficient traffic flow. To overcome this limitation, a Smart Density Based Traffic Light Control System using the ESP32 microcontroller is proposed. The system uses sensors to detect the number of vehicles present on different lanes at an intersection. Based on the detected traffic density, the ESP32 processes the data and automatically adjusts the signal timing, giving priority to lanes with higher vehicle density. This dynamic control helps in reducing traffic congestion and improving the overall efficiency of traffic management. In addition, the ESP32's built-in Wi-Fi capability allows the system to be integrated with Internet of Things (IoT) platforms for remote monitoring and data analysis. The proposed system aims to optimize traffic flow, reduce fuel consumption, minimize waiting time, and contribute to the development of intelligent transportation systems in modern smart cities.

Keywords— ESP32 microcontroller, Traffic density, IOT, Ultrasonic Sensor, Resistor

1.INTRODUCTION

Traffic congestion has become a major challenge in modern urban areas due to the rapid increase in the number of vehicles. We have a solution to traffic congestion. Our project is to work on smart density-based traffic light control system. Conventional traffic light systems operate on fixed time intervals, which do not consider real-time traffic conditions. This often leads to unnecessary waiting times, increased fuel consumption, longer travel times, and higher levels of pollution. To address these challenges, a Smart Density Based Traffic Light Control System using ESP32 is proposed. This system is designed **to** monitor the traffic density on each lane of an intersection in real time and dynamically adjust the traffic signal durations accordingly. By giving priority to lanes with higher vehicle density, the system aims to optimize traffic flow, reduce congestion, and improve overall efficiency of the intersection. The system uses vehicle detection sensors, such as IR or ultrasonic sensors, to collect traffic data, which is processed by the ESP32 microcontroller. The ESP32 then controls the traffic lights (Red, Yellow, Green) based on the current traffic conditions. In addition, the ESP32's built-in Wi-Fi capabilities allow the system to be integrated with IoT platforms, enabling remote monitoring and analysis of traffic patterns. Overall, this project represents a step toward intelligent transportation systems (ITS) and smart city solutions, offering a cost-effective, scalable, and real-time solution for improving urban traffic management.

1.1 Design and implementation of a smart density-based traffic light control system

The system mainly consists of the following components - ESP32 Microcontroller main controller that processes sensor data and controls traffic lights, Ultrasonic sensors placed on each lane to detect vehicles, traffic light LEDs – Red, Yellow, and Green LEDs representing traffic signals. Power Supply provides power for ESP32 and other components. Wi-Fi Module (Built-in in ESP32) enables remote monitoring through IoT platforms. sensors are installed at a certain distance from the intersection on each road to detect incoming vehicles. When vehicles pass in front of the sensor, it sends a signal to the ESP32 indicating traffic density. The ESP32 reads sensor inputs and determines which lane has the highest vehicle density. Based on this information, it adjusts the duration of the green light for that lane. The system can be programmed using Arduino IDE with embedded C/C++.

Basic Algorithm

1. Start the system.
2. Read sensor values from each lane.

3. Compare vehicle density levels.
4. Assign priority to the lane with the highest density.
5. Turn Green light ON for that lane.
6. Turn Yellow light ON before switching.
7. Repeat the process continuously.

1.2 System Architecture

The system architecture describes how the different components of the smart traffic control system are connected and interact with each other. The architecture mainly consists of input units, processing units, and output units. The main components of the architecture are ESP32 Microcontroller, Resistors, Breadboard, connecting wires, Ultrasonic sensors placed on each road, power supply, USB cable, LEDs. These sensors detect the number of vehicles. ESP32 Microcontroller acts as a central processing unit and receives signals from the sensors, which received first priority. Traffic signal Module consists of Red, Yellow and Green Traffic Signals, The ESP32 controls these LEDs

1.3 Working principle

The working principle of the smart density-based traffic light system is based on real-time traffic density detection and dynamic signal control Step-by-Step Operation: Vehicle Detection Sensors installed on each lane detect vehicles approaching the traffic signal. When a vehicle passes in front of the sensor, the sensor sends a signal to the ESP32, and it collects the signal from the sensors then measures the traffic density for each lane from the sensors and compares density of all lanes. The lane includes higher vehicle it gives green signal with time to pass the whole vehicle. The ESP32 actively the green LED for the selected lane. When the green signal ends the yellow signal turns on for a short time, then the Red LED turns ON, and the signal moves to the next lane. The sensors continuously monitor traffic conditions, and the signal timing is dynamically adjusted according to real-time traffic density. Traffic data can be transmitted through Wi-Fi to a cloud server for monitoring and analysis

1.4 Hardware Components and System Integration

ESP32 Microcontroller is the main controller of the system. It processes data from sensors and controls the traffic lights accordingly and also it is built-in Wi-Fi and Bluetooth, allowing IoT connectivity and remote monitoring. Ultrasonic Sensors are used to detect vehicles on each road lane. When a vehicle passes in front of the sensor, it sends a signal to the ESP32 indicating traffic density. Multiple sensors can be placed at different lanes of the intersection. System integration refers to how all the hardware components are connected and work together to form a complete system. Ultrasonic sensors are placed on each road lane. Red, Yellow, and Green LEDs are connected to different GPIO output pins of the ESP32 through resistors. The ESP32 and sensors are powered using a stable power supply and proper grounding is required to ensure reliable operation.

2. DEVELOPMENT AND PERFORMANCE EVALUATION OF AN ESP32-BASED SMART DENSITY TRAFFIC LIGHT CONTROL SYSTEM

The development of the ESP32-based smart density traffic light control system involves designing the hardware setup, implementing the control algorithm, and integrating sensors with the ESP32 microcontroller. The goal is to create a system that dynamically controls traffic signals based on real-time vehicle density.

2.1 Hardware development

The ESP32 Microcontroller acts as the main processing unit and the Ultrasonic sensor detects the presence of vehicles on each lane. Traffic Signal LEDs Red, Yellow and Green represent the traffic lights. The resistors protect LEDs from excessive current. Breadboard and Jumper Wires are used for circuit connections. Power supply provides required voltage to the system. Sensors are placed at each lane of the intersection. Their outputs are connected to the GPIO pins of the ESP32, while the traffic light LEDs are connected to output pins.

2.2 Software development

The system software is programmed using ESP-ID. It reads vehicle detection data from sensors and determines traffic density on each lane it compares the density levels and assigns green signal priority to the lane with the highest vehicle density.

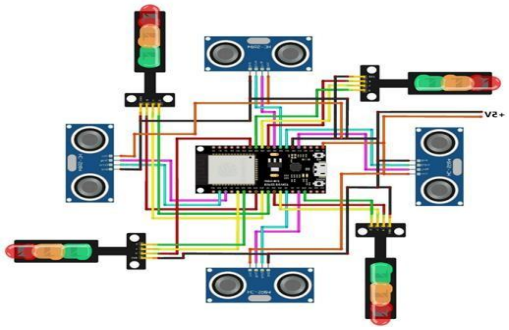

Fig -1 Circuit Diagram of Smart Density based Traffic Light Control System

3. SOFTWARE DESIGN AND CONTROL ALGORITHM

The software design defines how the system program is structured to control traffic signals based on real-time vehicle density. The ESP32 microcontroller is programmed using Arduino IDE with Embedded C/C++ to read sensor data and control the traffic lights. The software mainly consists of the following modules: This module initializes all hardware components when the system starts configuring GPIO pins for sensors and LEDs. This module evaluates the level of traffic density on each lane. The control algorithm determines how the traffic signals change based on sensor inputs. Step-by-Step Algorithm. Start the system. Initialize all components configure GPIO pins. Set all traffic lights to Red. Read sensor data and collect vehicle detection signals from all lanes. Switch to Red signal turn red light ON for that lane. Move to next lane, repeat the process for other lanes.

3.1 Real diagram of how project is assembled

The real assembly of the Smart Density Based Traffic Light Control System shows how all hardware components are connected on a breadboard with the microcontroller acting as the central controller.

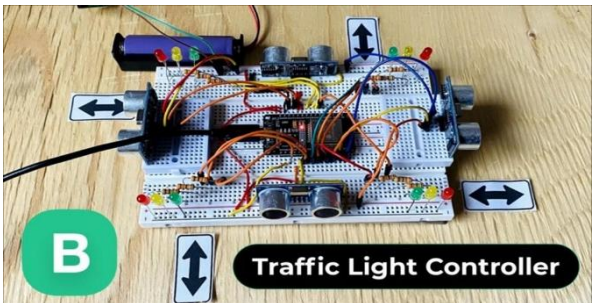

Fig -2 Project Assembly

4. CONCLUSION

The Smart Density Based Traffic Light Control System using ESP32 provides an efficient and intelligent solution for urban traffic management. Unlike conventional fixed-time traffic lights, this system dynamically adjusts signal durations based on real-time vehicle density, detected through sensors.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] B.R. Kiran, P. Anil Kumar, “Intelligent Traffic Control System Using ESP32 and Vehicle Density,” International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
[2] S. Gupta, R. Sharma, ESP32 Based Smart Traffic Light Control System,” International Journal of Computer Applications.
[3] R.S. Rajput, P. Singh, “ESP32 Based Smart Traffic Light Control System,” International Journal of Engineering Research & Technology.
[4] N.S. Patil, M. K. Chavan, “Density Based Traffic Light Control Using IR Sensors,” International Journal of Innovative Research in Science, Engineering and Technology.