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Smart Real-Time Traffic Signal System Using Sensor-Based Vehicle Detection

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ABSTRACT

This project proposes an intelligent traffic signal control system that adapts to vehicle density in real-time using infrared sensors. The system monitors traffic at intersections and dynamically adjusts signal timings to minimize delays and reduce congestion. A microcontroller processes sensor data and manages the signal flow using an adaptive algorithm. The proposed setup improves traffic throughput and efficiency, offering a low-cost, scalable solution for modern cities. Simulation results indicate reduced average waiting times and fuel consumption compared to conventional fixed-timing systems.

Keywords: Traffic optimization, IR sensors, real-time traffic control, adaptive signals, smart transportation.

1. Introduction

Traffic congestion is an escalating concern in cities due to the growing number of vehicles and fixed-time traffic signals. These outdated systems fail to adapt to changing traffic volumes, causing delays, fuel wastage, and pollution.

This paper introduces a sensor-based traffic management system that detects real-time vehicle presence and regulates signal durations accordingly. Infrared sensors count the vehicles in each lane, and a microcontroller processes the data to dynamically manage signal timings. Priority is given to high-density lanes, improving traffic flow and minimizing wait times.

By integrating such smart control systems, urban areas can achieve smoother mobility, reduce idle emissions, and move closer to intelligent transportation infrastructure.

2. Literature Review

Several researchers have explored methods to address traffic congestion using sensor and vision-based techniques:

- Somefun et al. proposed an IR-sensor-based system for vehicle counting and speed monitoring, achieving significant reduction in intersection delays.

- Zhang et al. developed a real-time system using computer vision and Raspberry Pi to evaluate vehicle flow and adjust signal cycles dynamically.

- Singh et al. used traffic density analysis for optimizing signal timings and demonstrated improvements in urban traffic management through simulation. These studies validate the need for adaptive systems that respond to real-time traffic data to enhance road efficiency and safety.

3. Proposed Methodology

The system architecture includes the following components:

- Sensor Setup: IR sensors installed at four lanes (North, South, East, West) detect vehicle count.

- Data Processing: A microcontroller (e.g., Arduino Nano) collects data from sensors and calculates traffic density.

- Signal Control: Based on the density, the controller dynamically assigns green light durations.

- Emergency Handling: Optional integration with RFID or sound detection modules can allow priority passage for ambulances and fire trucks.

- Visualization: A 16x2 LCD connected via I2C displays traffic status in real-time.

This methodology ensures longer green time for heavily crowded lanes and optimizes signal cycles efficiently.

4. Block Diagram Overview

The system consists of:

- IR Sensors → Input signals to Arduino

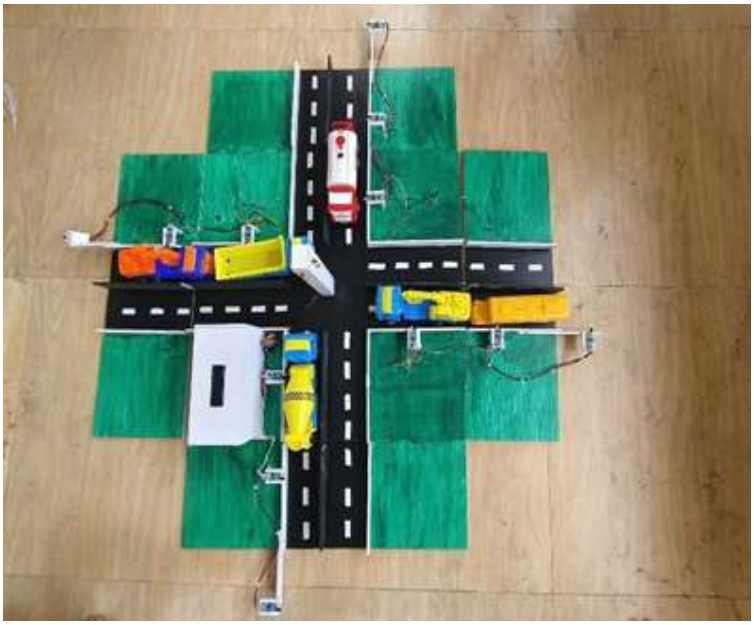
- Arduino Nano → Processing Unit

- I2C Module + 16x2 LCD → Display vehicle count and active lane

- LEDs → Represent traffic lights

- 12V 2A Adapter → Power supply

5. Result



A working model was developed and tested under controlled conditions. The system responded correctly to varying vehicle densities by adjusting the green signal timing. In scenarios with uneven traffic, the lane with higher density was granted extended passage time, reducing total waiting duration and improving flow.

6. Conclusion

The smart traffic signal system effectively minimizes congestion by adapting to real-time traffic conditions. It offers a cost-effective solution using widely available components like IR sensors and microcontrollers. The system is easily replicable and supports integration with emergency detection and IoT features. It demonstrates notable improvements in traffic flow, fuel efficiency, and pollution reduction.

7. Future Scope

- IoT & Cloud Integration: Real-time data can be uploaded for centralized traffic management.

- Camera-Based Detection: Use AI with computer vision for better accuracy and license plate reading.

- Emergency Vehicle Tracking: GPS and RFID-based priority signal control for ambulances and VIPs.

- Mobile App Interface: For commuters to receive real-time traffic alerts and route suggestions.

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