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Smart Traffic Light Control System

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Abstract: In recent years, road traffic has become a major global issue. Statistics reveal that an individual typically spends around 6-7 months of their lifetime simply waiting at traffic signals during travel. Generally, traffic management at city junctions is controlled either through fixed automated traffic light systems or manual intervention by traffic police. However, conventional fixed-time controlled traffic signals, which operate on preset intervals, are inefficient as they do not account for real-time traffic density. An economical densitybased traffic control system could therefore provide an effective solution. The proposed system operates with a timer set for a specific duration

Keywords: Pilot lamp, Arduino, Traffic control.

I.INTRODUCTION

Over the years, a shift in population from rural to urban areas has been observed due to factors like employment, business opportunities, and education. The increased urban population necessitates expanding infrastructure, including transportation systems, with more commuter vehicles like buses, cars, trucks, and other modes of transport. Globally, increased vehicle numbers have made traffic congestion a significant issue, causing inconvenience for urban commuters. Traffic control systems have therefore become essential to enable smooth transit [1]. These systems are a combination of signage at junctions and pedestrian crossings, and are now a vital part of city infrastructure. Initially, traffic was controlled by hand signals given by traffic police, but this method proved inadequate [2]. Today, a standard traffic signal consists of three lights—green for go, yellow for caution, and red for stop—arranged to regulate traffic flow. Most conventional systems, either semi-automated or manual operated, operate based on fixed-time cycles [2], making roads more organized and reducing accidents [3]. However, a fixed-time-based system does not adjust according to varying traffic densities. In many cases, green signals remain active even when no vehicles are present, which is inefficient. A system that detects real-time traffic density would make the signalling process more efficient, minimizing congestion. Traffic light systems can be designed using microcontrollers and microprocessors [1-4]. Recent technological advancements have introduced affordable and user-friendly options for traffic signal setups. This paper discusses the design and implementation of a density-sensitive Arduino-based traffic control system that automatically adjusts signals based on traffic density. Arduino was selected due to its simplicity and low cost.

II. LITERATURE REVIEW

Rongrong Tian, Xu Zhang [13] suggested to use the TRANSYT traffic modelling software to find the optimal fixed-time signal plan and VISSIM micro-simulation software to affirm and evaluate the TRANSYT model and to help assess the optimal signal plan; build an adaptive frame signal plan and refined and evaluated the plan using VISSIM with VS-PLUS emulator. Through micro-simulation, it was shown that delay in the adaptive signal control was shortened noticeably than that in the fixed time control. A genetic algorithm was developed to derive the model solution. A simulation control protocol embedded in PARAMICS software tool capable of conducting area-wide micro simulation is adopted to design the logic frame and function module of the areawide traffic signal control system. His results shown that mobility improvements are achieved after applying the proposed model along with the genetic algorithm for area-wide signal timing optimization, assessed by extended capacity ratio, and reductions in through and turning movement delays, as well as average and variance of travel time for unit distance of travel. Junchen Jin and Xiaoliang Ma [8] proposed a group based signal control approach capable of making decisions based on its understanding of traffic conditions at the intersection level. The control problem is formulated using a framework of stochastic optimal control for multi-agent system in which each signal group is modelled as an intelligent agent. The proposed system is designated to be compatible

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with the prevailing signal system. The parameters were off-line optimized using a genetic algorithm. Simulation results shown that the proposed adaptive group based control system outperforms the optimized GBVA control system mainly because of that's real-time adaptive learning capacity in response to the changes in traffic demand. Nasser R. Sabar et al

[11] controlled the movement of traffic on urban streets by determined the appropriate signal timing settings. Proposed algorithm was based on the so-called memetic algorithm that combines the strengths of the genetic algorithm and local search in an adaptive manner. In that used two important techniques for improving the performance of traditional memetic algorithms. In that used two important techniques for improving the performance of traditional memetic algorithms. First, a systematic neighbourhood based simple descent algorithm was employed as a local search to effectively exploit the search space. Second, an indicator scheme was proposed to control the local search application based on the quality and diversity of the search process. The proposed algorithm was coded in the commercial microscopic traffic simulator, AIMSUN, and tested on two difference real world case studies in Brisbane, Australia, and Plock, Poland. The results demonstrated that the proposed algorithm was better than genetic algorithms and fixed-time settings, indicated that the proposed algorithm was an effective solution method for traffic signal optimization problems.

III. SYSTEM DESCRIPTION

The proposed system consists of four major components: the power supply, sensing circuit, control circuit, and indicator lamps, as shown in Figure 1.

A. Power Supply

The power unit includes a rectifier to convert single-phase AC power into a 9V DC supply, energizing all system components. The indicator unit may be powered by either the main power unit or an external source, depending on the lamp's specifications.

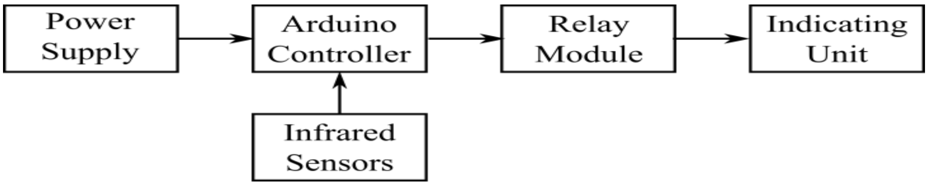

Fig. 1 Basic block diagram of the proposed system

B. Arduino Controller

The Arduino is a programmable electronic device that controls the circuit based on the program embedded in it. It's an open-source or open-hardware platform compatible with various languages like Java, MATLAB, and C+. Arduino is suitable for projects requiring automatic control and comes in several types, such as Arduino UNO, Arduino Mega, and Arduino Nano, each differing in inputs, outputs, and sensor compatibility.

Fig. 2. Arduino UNO Specifications of Arduino Uno:

- Microcontroller: Microchip ATmega328P Operating Voltage: 5 Volts
- Analog Input Pins: 6
- Digital I/O Pins: 14 (6 PWM outputs) DC Current per I/O Pin: 20 mA
- DC Current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB (0.5 KB used by bootloader) SRAM: 2 KB
- EEPROM: 1 KB

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Clock Speed: 16 MHz Weight: 25 g
Width: 53.4 mm
Length: 68.6 mm

C. IR Sensors

IR sensors are electronic devices powered by a DC supply, capable of emitting and receiving infrared signals. IR sensors generally contain a transmitter (IR LED) and a receiver (photodiode). The transmitter emits rays that reflect off objects, which the receiver then detects. In this project, a 3-pin IR sensor is used, consisting of Vcc, Ground, and Digital output.

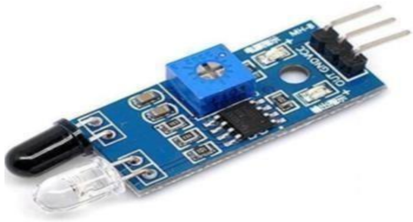

Fig. 3. IR sensor

1. Measures object heat and detects motion.
2. Emitter is an IR LED.
3. Detector is an IR photodiode.
4. Continuously transmits and receives IR signals to detect object presence.When the IR receiver module receives signal to the potential at the inverting input goes low.

C. 8-Relay Module

A relay functions as an electrical switch for controlling high-voltage circuits with a low-power signal. The 8-relay module used in this system can control various devices through a low-level trigger. When energized, it enables high-power device activation, controlled by the Arduino.

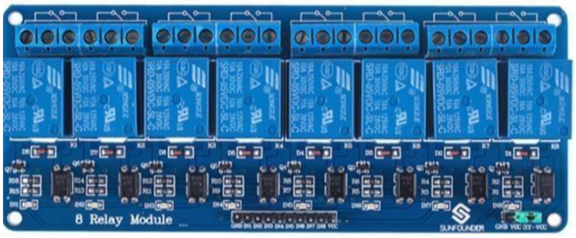

Figure 4. 8-Relay module

D. Pilot Lamps

Indicator lamps show circuit status (ON/OFF), typically using green for "ON," red for "OFF," and orange for faults. In this project, these lamps signal the traffic status to drivers, enhancing safety and clarity at intersections**.**

Fig. 5. Pilot Lamps

Any one of indicator lights glow whenever the suitable current applied to the circuit. These indicators are mainly used to indicate whether it’s ‘ON’ or ‘OFF’. In this project, the pilot lamps are used to indicate to the car driver about the state of each side whether road is passable or not. It is mandatory to avoid a situation where the lamp fails by which the unsafe or traffic misleading may occur.

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IV. CONCEPT OF CODING

The coding process begins with variable declarations corresponding to each component in the model. Variables can be called upon as needed, with traffic lights set as output components and IR sensors as input. Commands are sent from the sensors to the Arduino controller, instructing it to switch traffic lights based on density or default timing if no density is detected. The coding sequence is illustrated in Figure 6.

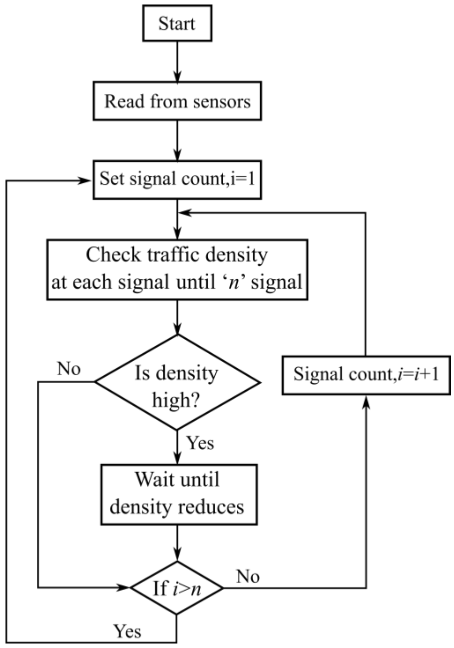

Fig 6. Flow chart of density based traffic control

V. OPERATION AND DISCUSSION

This density-based traffic light control system optimizes signal timings based on the real-time traffic density at each section of an intersection. Equipped with eight infrared (IR) sensors—two for each road segment—the system identifies traffic density by detecting vehicles as they pass. The IR sensors are positioned on opposite sides of each lane, allowing them to monitor the density effectively in both directions.

Once a vehicle crosses an IR sensor, it sends a signal to an Arduino microcontroller, which processes the data and determines the density level on each road. Based on this analysis, the Arduino automatically adjusts the duration of the green signal for each segment. This approach allows roads with heavier traffic to receive a longer green light, helping to clear congestion faster and reduce wait times.

Each road segment has three LEDs—red, yellow, and green—indicating when drivers should stop, proceed with caution, or go, respectively. Under normal, low-density conditions, the system follows a fixed timing cycle where each green light remains active for 10 seconds, allowing traffic flow in that direction, followed by a yellow caution light for 4 seconds before transitioning to red. This sequence ensures a smooth, orderly flow of vehicles while reducing idle time when fewer cars are on the road.

When the traffic density increases, the IR sensors notify the Arduino, which overrides the standard timings, allowing roads with more vehicles to have a longer green light phase. The system cycles through the four segments in sequence, ensuring only one lane has a green light at any time to avoid intersection conflicts. This setup provides a responsive, real-time solution that efficiently manages traffic flow, minimizing congestion and wait times, especially during peak hours. By automating traffic management, this system addresses the inefficiencies of fixed-timed lights, offering an adaptable and cost-effective traffic control solution for urban intersections.

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TABLE II. TRAFFIC SIGNAL OUTPUT

First Lane	Second Lane	Third Lane	Forth Lane
Green	Red	Red	Red
Yellow	Yellow	Red	Red
Red	Green	Red	Red
Red	Yellow	Yellow	Red
Red	Red	Green	Red
Red	Red	Yellow	Yellow
Red	Red	Red	Green

VI. CONCLUSION

This system effectively reduces congestion by adapting signal times to real-time traffic density, using a low-cost Arduino setup. "Density Based Traffic Control System" is therefore suitable for commercial use. This setup integrates hardware and software to manage traffic control effectively, offering flexible programming for future system expansions or improvements.

This density-based traffic control system addresses congestion by dynamically adjusting signal intervals in response to actual traffic flow, enhancing efficiency at intersections. Unlike traditional fixed-time signals, this system leverages real-time data from IR sensors to determine the density of vehicles on each road, thereby optimizing green light durations where traffic is heaviest. By employing a cost-effective and accessible Arduino microcontroller, this setup provides a viable solution suitable for commercial deployment in urban areas facing frequent traffic bottlenecks.
The integration of both hardware and software allows for seamless management of signal changes without requiring constant manual oversight. Additionally, the system's modular design and adaptable programming offer potential for future scalability and upgrades, such as adding more sensors or integrating it with IoT networks for centralized traffic management. This adaptable approach makes it highly practical for evolving traffic needs, setting a foundation for enhanced urban mobility and reducing delays caused by inefficient signal timing**.**

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