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Creation of a Traffic Signal System Based on Density

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ABSTRACT

This document introduces an innovative traffic signal system centered on density, dynamically adjusting signal timing based on traffic volume at each intersection. With congestion persisting at all entry points of Ahmadu Bello University (ABU), a shift from conventional scheduling methods to a self-decision automated system is imperative. The existing system relies on scheduled time intervals, proving inefficient when only one lane is operational while others remain inactive. To address ABU's gateway challenges, an intelligent traffic control prototype was developed. High density in one lane causes extended waiting times in other lanes beyond the usual allotted periods. To counter this issue, a methodology was devised, assigning green and red light durations based on real-time traffic densities using Infrared (IR) sensors. The Arduino Uno Microcontroller facilitated the allocation of green light periods once density calculations were determined. Sensors monitored vehicle presence, relaying information to the microcontroller, which then dictated signal change durations and flank openness. This paper also elucidates the operational principles of the density-based traffic signal control system, showcasing the prototype's efficacy.

Keywords: *traffic signal; congestion; microcontroller; Arduino Uno; infrared sensors*

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Creación de un Sistema de Señalización de Tráfico Basado en la Densidad

RESUMEN

Este documento presenta un innovador sistema de señalización de tráfico centrado en la densidad, ajustando dinámicamente el tiempo de señalización según el volumen de tráfico en cada intersección. Con la congestión persistente en todos los puntos de entrada de la Universidad Ahmadu Bello (ABU), es imperativo pasar de los métodos convencionales de programación a un sistema automatizado de toma de decisiones propia. El sistema existente se basa en intervalos de tiempo programados, demostrando ser ineficiente cuando solo un carril está operativo mientras que otros permanecen inactivos. Para abordar los desafíos en la entrada de ABU, se desarrolló un prototipo de control de tráfico inteligente. La alta densidad en un carril provoca tiempos de espera prolongados en otros carriles más allá de los períodos habituales asignados. Para contrarrestar este problema, se ideó una metodología que asigna las duraciones de las luces verde y roja según las densidades de tráfico en tiempo real utilizando sensores infrarrojos (IR). El microcontrolador Arduino Uno facilitó la asignación de períodos de luz verde una vez que se calcularon las densidades. Los sensores monitorearon la presencia de vehículos, transmitiendo información al microcontrolador, que luego dictaba las duraciones de cambio de señal y la apertura de flancos. Este documento también aclara los principios operativos del sistema de control de señalización de tráfico basado en la densidad, mostrando la eficacia del prototipo.

Palabras clave: *señal de tráfico; congestión; microcontrolador; Arduino Uno; sensores infrarrojos*

INTRODUCTION

For nearly two centuries, traffic lights have served as crucial signaling devices, orchestrating traffic flow at street intersections, rail crossings, pedestrian walkways, and various locations. The green light authorizes the continuation of traffic, the yellow cautions motorists to prepare for a brief pause, and the red prohibits any further movement. Many countries currently grapple with the adverse effects of traffic congestion, significantly impacting urban transportation systems and causing serious issues. Even with the potential replacement of traffic authorities and flagmen with automated systems, simply repairing overloaded roads proves insufficient to alleviate congestion and time delays.

The continual surge in vehicle numbers and the growing population of road users pose challenges in developing advanced systems with ample resources. Although options like constructing new roads, implementing flyovers, creating ring roads, and rehabilitating existing streets offer partial solutions, the complexity of the traffic problem persists due to multiple factors. Traffic patterns are time-dependent, with peak hours generally occurring in the morning and evening, weekdays exhibiting varying congestion levels, and certain times of the year, such as holidays and summer vacations, impacting traffic flow.

However, contemporary traffic light systems employ hardcoded delays, ensuring consistency in light changes regardless of traffic flow. The third issue revolves around the status of a light at an intersection, affecting traffic at adjacent intersections. Moreover, traditional traffic systems overlook potential accidents, construction-related challenges, and vehicle breakdowns, all of which exacerbate congestion. A crucial concern is also raised regarding the smooth passage of emergency vehicles, such as ambulances, which cross pathways and interact with the traffic system.

To address these challenges, there is a need to enhance and adapt the standard traffic system, comprehending severe congestion, minimizing transportation inconveniences, reducing waiting times and traffic volume, enhancing automotive safety, cutting overall travel times, and maximizing benefits in health, economics, and the environment. This article introduces a straightforward, cost-effective, and continuous traffic

light control system aimed at rectifying various shortcomings and improving traffic management. Powered by an Arduino Uno Microcontroller and equipped with infrared sensors monitoring traffic density, the system adjusts lighting sequences as required.

Several studies have explored density-based traffic light signal systems. Reference crafted a traffic light system based on the Arduino Integrated Development Environment (IDE), prioritizing lanes with high-density traffic. Additionally, presented an inventive prototype for a junction road, proposing a density-based traffic signal system with automatic timing adjustments based on monitored traffic density. Another smart traffic system, utilizing Arduino ATMega328 and IR sensors, effectively managed traffic by detecting vehicles on the lane. In, an Arduino Uno was employed to develop a density-based traffic controller system using IR sensors for signal transmission. Reference introduced a technique allocating time periods for green, red, and yellow lights based on real-time traffic density, realized through Arduino Uno and IR sensors. Recently, IoT concepts were integrated for traffic management, prioritizing ambulances in case of issues.

The paper's structure is as follows: Section 1 presents the introduction, Section outlines the methods used in implementing the traffic light system, Section presents the results and discussion of the system, and Section outlines the conclusion.

MATERIALS

This section outlines the techniques employed in implementing the density-based traffic light system.

Arduino Uno Board

The Arduino Uno Board, an open-source microcontroller board based on the microchip ATMega328, serves as the core component. Equipped with various digital and analog input/output (I/O) pins, it interfaces with expansion boards (shields) and circuits. Featuring fourteen digital pins and six analog I/O pins, it is programmed through the Arduino IDE and powered by a 9V external battery or USB cable [20]. An illustration of an Arduino Uno Board can be found in [20].

Infrared (IR) Sensors

Comprising components like the Op-amp, a variable resistor, a light-emitting diode (LED), an IR transmitter, and a receiver, the IR sensor operates in the infrared frequency. The transmitter emits infrared light, and the receiver conducts light when illuminated. The IR receiver's photodiode, with a reverse-biased P-N junction semiconductor, registers current flow proportional to absorbed light. The sensor has three pins - O/P, VCC, and GND. O/P provides the output signal to the Arduino Uno, while VCC supplies power. The Arduino GND connects to the sensor's GND [21]. A typical IR sensor is depicted in [21].

Light-Emitting Diode (LED)

An LED, a semiconductor light source used as an indicator lamp in electrical devices, emits visible, ultraviolet, and infrared wavelengths with varying intensities. While early LEDs emitted low-intensity red light, contemporary versions operate within a power range of 30–60 milliwatts [22]. A standard LED is shown in [22].

Resistor

The resistor, a passive component, allows electron flow, precisely dropping applied voltage to limit current along the circuit. Variable resistors or rheostats feature adjustable resistance. A typical resistor diagram is presented in [23].

RESULTS AND DISCUSSION

This section showcases results extracted from the study, spanning from fabrication to testing when assembling components to create the prototype and understand its operational principles.

When operational, the system follows traffic light principles, dividing lanes into A, B, and C. Initially, lights on lane A turn green for 30 seconds, with other lanes displaying red signals. Vehicles from lane A can proceed straight, turn right, or execute a U-turn, as illustrated in

Figure 1: Lane A Signaling.

In Figure 1, following a 30-second interval, the green light on lane A deactivates, and concurrently, the yellow lights on lanes B and C activate.

On lane B, the green lights persist, but after 30 seconds, the yellow lights on lanes A and C activate. This is depicted in Figure 2.

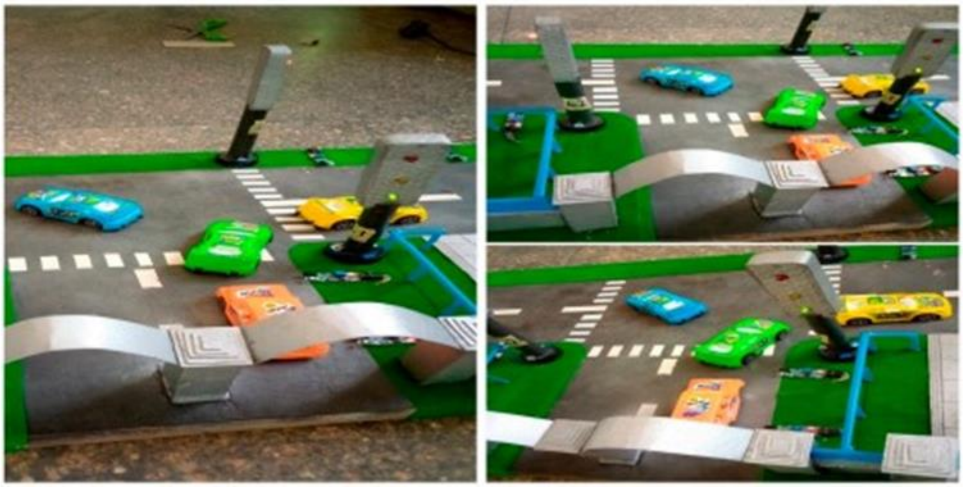

Figure 2: Lane B Signaling

In Figure 2, following a 30-second interval, the green light on lane B deactivates, and simultaneously, the yellow lights on lanes C and A illuminate.

On lane C, the green lights persist, but after 30 seconds, the yellow lights on lanes A and B activate. This is illustrated in Figure 3.

Figure 3: Lane C Signaling

In Figure 3, after 30 seconds, the green light on lane C deactivates, while the yellow light on lanes B and A illuminates. This cyclic process continues, and simultaneously, vehicle riders observe the red laser light at the front of the stop lane road.

CONCLUSION

The presented density-based traffic light signal system aims to alleviate congestion and traffic jams within the traffic control system. Utilizing IR sensors with a 5 V power supply on the Arduino, this study successfully detected vehicle density in each road lane simultaneously. The design seamlessly integrates hardware components, leveraging both modern integrated circuits and advancing technology. The prototype effectively portrayed the challenging scenario of the T-junction in front of the North gate of Ahmadu Bello University, Zaria, Nigeria. Results indicate a reduction in traffic congestion compared to the fixed traffic signal utilized by previous researchers. Importantly, this technique demonstrates enhanced efficiency and boasts a cost-effective production, making it viable for potential commercial applications. Future research endeavors will concentrate on implementing this concept in a real-world scenario.

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