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Development of a Density-Based Traffic Light Signal System †

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Abstract: This paper presents a density-based traffic light signal system that performs timing signal that changes automatically based on the amount of traffic at each of its intersections. However, as traffic congestion is a pertinent problem on all of Ahmadu Bello University's (ABU) gates, it is time to advance from the traditional technique to an automated system that has self-decision capabilities. The current technique used on the traffic system is based on the traditional technique, which works based on time scheduling; this system is inefficient if one lane is operational while the others are not operational. The intelligent traffic control was prototyped in order to solve this perennial problem of ABU's gate. When there is a high density on one lane of the intersection, it causes a longer waiting time on the other lanes than the regular permitted time. As a result, a process was designed through which the time periods for the green and red lights were assigned based on the traffic densities on each of the lanes at that time. Infrared (IR) sensors were used to perform this task. The Arduino Uno Microcontroller was used for allocating the glowing period of green lights once density had been calculated. Sensors were used for monitoring the presence of vehicles and communicating information to the microcontroller, which determines the duration for which a signal will change or a flank will remain open. Also displayed is the operating principle of the density-based traffic signal control system, which shows the prototype's efficiency.

Keywords: traffic light; congestion; microcontroller; Arduino Uno; infrared sensors

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1. Introduction

Traffic lights have been in existence for close to twenty decades now, and they are used as signaling devices. They are used to control traffic flows at street junctions, rail crossings, pedestrian intersections and other locations [1,2]. The green light allows traffic to continue on the indicated path, the yellow light warns motorists to prepare for a brief halt and the red light forbids any traffic from proceeding. Presently, quite a few countries are suffering from the negative consequences of traffic congestion, which, in turn, negatively contribute to the transportation system in urban areas and cause serious problems [3]. Regardless of whether the traffic authorities and the flagmen are replaced with programmed traffic systems, the repair of the overburdened road is still insufficient to alleviate traffic congestion and time delays [4].

The progressive rise in the volume of vehicles on the road and the ever-increasing number of street users do not allow for the creation of advanced systems with sufficient resources [5]. The development of new streets, the execution of flyovers and street, the creation of rings and the recovery of streets were all options for creating fractional arrangements [6,7]. However, the traffic problem is extremely complicated due to the incorporation of several elements. The traffic stream is dependent on time, with peak traffic hours generally occurring in the first half of the day and toward the evening; the day of the week, with weekends showing the least congestion and Mondays and Fridays showing dense traffic traveling from urban areas to their edges in specific events; and time of year, such as holidays and summer vacations [8].

However, a state-of-the-art traffic light system is composed of hard-coded defers, which ensure that light change vacancies are consistent and do not depend on the flow of traffic. The third point is concerned with the state of one light at a crossing point, which has an impact on traffic flow at surrounding intersections [9]. Similarly, the traditional traffic system ignores the possibility of accidents, construction issues and the breakdown of vehicles, all of which exacerbate traffic congestion. A critical issue is also highlighted with regard to the smooth flow of crisis vehicles with higher needs, such as ambulances, and rescue on foot, which cross the pathways and adopt the traffic system [10,11].

The standard traffic system should be improved and modified to better understand the serious traffic congestion, reduce transportation inconvenience, reduce waiting times and traffic volume, improve automotive safety, reduce overall travel times, and expand benefits related to health, economics and the environment [12,13]. This article presents a simple, low-effort and continuous traffic light control system that aims to eliminate a variety of flaws and improve traffic management. The device is powered by an Arduino Uno Microcontroller with infrared sensors that monitors the density of traffic and adjusts the lighting progress as needed.

Some studies have been conducted with respect to density-based traffic light signal systems. Ref. [14] developed a traffic light system based on the Arduino Integrated Development Environment (IDE), which gives priority to cars on the lanes with high-density traffic. Also, an inventive prototype design was presented by [15], which was applied on a junction road. This study proposed the development of a density-based traffic signal system with automatic timing changes after the system monitored the traffic density at the intersection. The scenario was developed using Arduino Uno. Also, a smart traffic system was designed in [16] that satisfactorily handles traffic. The traffic light system was developed using Arduino ATMega328 and IR sensors. These sensors were used to detect the vehicles on the lane. Also, Arduino Uno was used for developing a density-based traffic controller system in [17]. The system contained IR sensors for transmitting and receiving signals from the sensors on the traffic based on the vehicles that are on the lane. In [18], the authors developed a technique that allocates time periods for the various lights (green, red and yellow) that was based on the traffic density of the road at that particular point in time. The technique was realized using Arduino Uno and IR sensors. Recently, IoT concepts were used for traffic management and regulation in [19]. The traffic density problem in this study considered ambulances, which were given priority in case of any issue.

The rest of the paper is organized as follows: the introduction is presented in Section 1, while Section 2 outlines the methods used in actualizing the traffic light system. The results and discussion of the system are presented in Section 3, and Section 4 outlines the conclusion.

2. Materials

This subsection presents the methods that have been used for actualizing the density-based traffic light system.

2.1. Arduino Uno Board

This is an open-source microcontroller board that is based on microchip ATMega328 microcontroller. The board is equipped with different sets of digital and analogue input/output (I/O) pins, which are used for interfacing with the different expansion boards (shield) and circuits. It contains fourteen digital pins and six analogue I/O pins, which are programmed through the Arduino IDE, and it is powered using a 9V external battery or via a USB cable [20]. An example of an Arduino Uno Board is seen in [20].

2.2. Infrared (IR) Sensors

This contains elements like the Op-amp, a variable resistor, a light-emitting diode (LED), an IR transmitter and a receiver. The transmitter transmits lights in infrared frequency, while the receiver conducts light when light falls on it. The IR receiver's photodiode contains a reverse-biased P-N junction semiconductor. The amount of current flow on the photodiode is proportional to the amount of light absorbed on the receiver. The IR sensor contains three pins, which are the O/P, VCC and GND. The O/P provides the output signal, as sensed via the sensor to the Arduino Uno, while the VCC supplies the power to the sensor. The Arduino GND is connected to the GND of the sensor [21]. A typical IR sensor can be seen in [21].

2.3. Light-Emitting Diode (LED)

An LED is a semiconductor light source that is used as an indicator lamp in various electrical devices. Early LEDs emitted low-intensity red light, but newer versions of it emit visible, ultraviolet and infrared wavelengths with different light intensities. Most LEDs are designed to operates with a power range of 30–60 milliwatts [22]. A typical LED can be seen in [22].

2.4. Resitor

This is a passive component that allows the flow of electrons through it and precisely drops the applied voltage across it, which tries to limit the value of the current along the circuit. Resistors whose resistance can be precisely varied are called variable resistors or rheostats. A typical diagram of a resistor can be seen in [23].

3. Results and Discussion

This subsection presents the results that were extracted from this study, ranging from the stage of fabrication to the testing of the results when the complete components were coupled together to produce the prototype and its operation principle.

When the system is in operation, it works based on the principle of a traffic light system, and the lanes were divided into lane A, lane B and lane C, respectively. Firstly, lights on lane A turn green for 30 s, while the other lanes are red. Vehicles coming from lane A can travel straight on, turn right or take a U-turn, as shown in Figure 1.

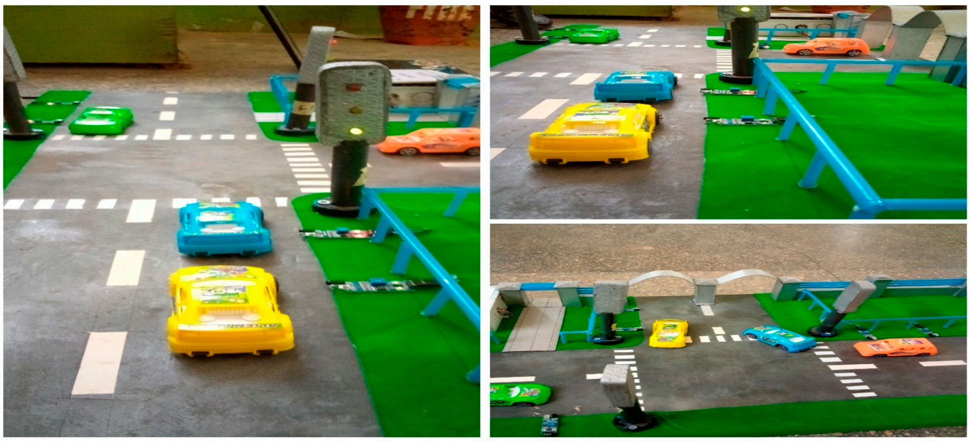

Figure 1. Signaling on Lane A.

In Figure 1, after 30 s, the green light on lane A turns OFF, while the yellow lights on lanes B and C turns ON.

On lane B, green lights continue to remain ON, but after 30 s, the yellow lights on lane A and C turn ON. This is shown in Figure 2.

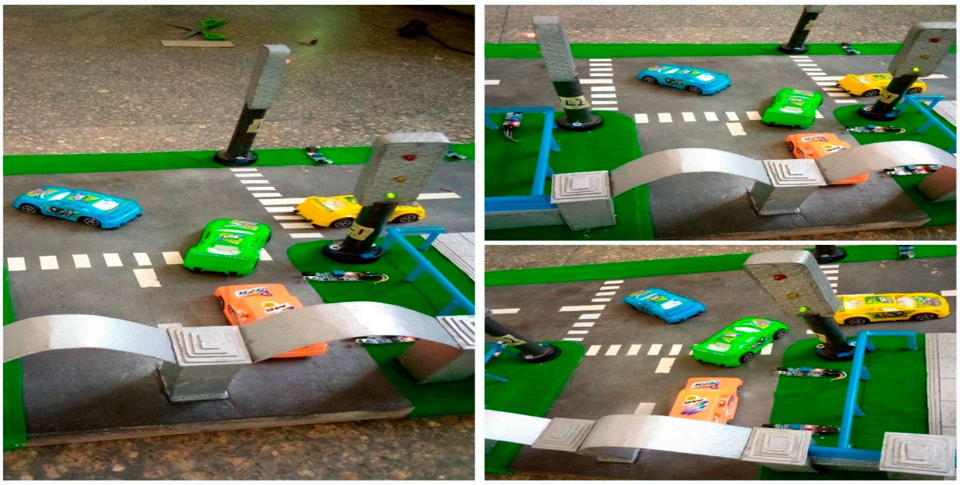

Figure 2. Signaling on Lane B.

From Figure 2, after 30 s, the green light on lane B turns OFF, while the yellow lights on lane C and A turns ON.

On lane C, green lights remain ON, but after 30 s, the yellow lights on lane A and B turn ON. This is shown in Figure 3.

Figure 3. Signaling on Lane C.

In Figure 3, after 30 s, the green light on lane C turns OFF, while the yellow light on lane B and A turns ON. This process occurs continuously, while vehicle riders also see the red laser light from the front of the stop lane road.

4. Conclusions

The density-based traffic light signal system has been presented. Our goal was to reduce the congestion and traffic jams inside the traffic control system. IR sensors with a power supply of 5 V were used on the Arduino. This study was able to detect the density of vehicles in each lane of the road concurrently using the IR sensor. This study was designed to combine the features of the hardware components used, and the idea was effectively implemented using both modern integrated circuits and growing technology. The prototype was used to depict the challenging scenario of the T-junction in front of the North gate of Ahmadu Bello University, Zaria, Nigeria. The results showed that the traffic congestion was reduced compared to the fixed traffic signal used by previous researchers. However, this technique has been shown to be more efficient and has a low production cost, which can be extended for commercial purposes. Further research will focus on implementing this concept in a real-life scenario.

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