engineering proceedings

MDPI

Proceeding Paper

Development of a Density-Based Traffic Light Signal System †

Umar Abubakar [1,*], Abdullahi Shuaibu [2], Zaharuddeen Haruna [1], Ajayi Ore-Ofe [1], Zainab Mukhtar Abubakar [1] and Risikat Folashade Adebiyi [1]

[1] Department of Computer Engineering, Ahmadu Bello University, Zaria 810107, Nigeria; mail1@email.com (Z.H.); email2@email.com (A.O.-O.); email3@email.com (Z.M.A.); email4@email.com (R.F.A.)
[2] Aerospace Engineering Department, Airforce Institute of Technology (AFIT), Kaduna 800282, Nigeria; email5@email.com
* Correspondence: abubakaru061010@gmail.com
† Presented at the 4th International Electronic Conference on Applied Sciences, 27 October–10 November 2023; Available online: https://asec2023.sciforum.net/.

Abstract: This paper presents a density-based traffic light signal system which has a timing signal that changes automatically based on the amount of traffic at each of its intersection. However, traffic congestion is a pertinent problem on all Ahmadu Bello university's (ABU) gates, it is time to advance from the traditional technique to an automated system which has self-decision capabilities. The current technique used on the traffic system is based on the traditional technique which works on time scheduling, this is inefficient in the case if one lane is operational while the others are not. 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 in which the time periods for 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. Arduino Uno Microcontroller was used for allocating the glowing period of green lights once density has been calculated. Sensors were used for monitoring the presence of vehicles and communicating information to the microcontroller, which determines the duration a signal will change or flank will remain open. Also displayed is the operating principle of the density-based traffic signal control system, which showed the prototype efficiency.

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

Citation: Abubakar, U.; Shuaibu, A.; Haruna, Z.; Ore-Ofe, A.; Abubakar, Z.M.; Adebiyi, R.F. Development of a Density-Based Traffic Light Signal System. *Eng. Proc.* **2023**, *52*, x. https://doi.org/10.3390/xxxxx

Academic Editor(s): Name

Published: date

1. Introduction

Traffic lights, has been in existence close to twenty (20) decades now, which are used as signaling devices. They are used to control traffic flows at street junctions, rail trains, 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 prevents any traffic from proceeding. Presently, there are quite a number of countries that are suffering from the negative consequences of traffic congestion, which in turn contributes negatively to the transportation system in urban areas and causes 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 increment in the volume of vehicles on the road and the ever-increasing number of street customers do not allow for 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 fractional arrangements [6,7]. However, the traffic problem is exceedingly 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; on the days of the week, with weekends showing the least congestion and Mondays and Fridays showing dense traffic arranged from urban areas to their edges and in event bearing separately; and time as holidays and summer vacations [8].

However, the 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 about 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 and breakdown of vehicles, all of which exacerbate traffic congestion. A critical issue is also highlighted with 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 inconveniences, reduction in waiting time and traffic volume, improve auto safety, reduce overall travel time, proficiency and expand the benefits in 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.

There are some researches done with respect to density-based traffic light signal system. Ref. [14] developed a traffic light system based on Arduino integrated development environment (IDE) which gives the traffic light priority to cars on the lanes with high density traffic. Also, an inventive prototype design was presented by [15] which was applied on a junctioned road. The research proposed the development of a density-based traffic signal system with automatic timing changes after the system has monitored the traffic density at the intersection. The scenario was developed using Arduino Uno. Also, a smart traffic system was designed in [16] which handles traffic satisfactorily. 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 which allocates time period for the various lights (green, red and yellow) that was based on the traffic density of the road at that particular instant of time. The technique was realized using Arduino Uno and IR sensors. Recently, IoT concepts were used for traffic management and regulation [19]. The traffic density problem in this research considered ambulances, which were given priority for in case of any issue.

The rest of the paper is organized as follows; the introduction is presented in section one, while section two gives the materials used in actualizing the traffic light system. The results and discussion of the system are presented in section three, and section four gives the conclusion.

2. Materials

This subsection presents the materials that has been used in actualizing the density-based traffic light system.

2.1. Arduino Uno Board

This is an open-source microncontroller board that is based on microship 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 (14) digital pins, six (6) analogue I/O pins

which are programmed through the Arduino IDE, and is powerd using 9V external battery or by USB cable [20]. Example of Arduino Uno Board is seen in the work of [20].

2.2. Infra-Red (IR) Sensors

This contains elements like the Op-ampp, a variable resistor, light emitting diode (LED), an IR transmitter and a receiver. The transmitter transmits lights in infrared frequency, while the receiver conducts when lights fall on it. The IR receiver's photodiode contains a reversed biased P-N junction semiconductor. The amount of current flow on the photodiode is proprtional 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 by 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 the work of [21].

2.3. Light Emitting Diode (LED)

An LED is a semiconductor light source which is used as an indicator lamp on various electirical devices. Early LEDs emitts low intensity red light, but newer versions of it emitts vissible, ultraviolet and infrared wavelengths with different degrees of light intensities. Most LEDs are designed to operates with a power range of 30-60 milliwats [22]. A typical LED can be seen in the work of [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 limits the value of current along the circuit. Resistors whose resitance can be varied precisley are called variable resistors or rheostats. A typical diagram of a resistor can be seen in the work of [23].

3. Results and Discussion

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

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

Figure 1. Signaling of Lane A.

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

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

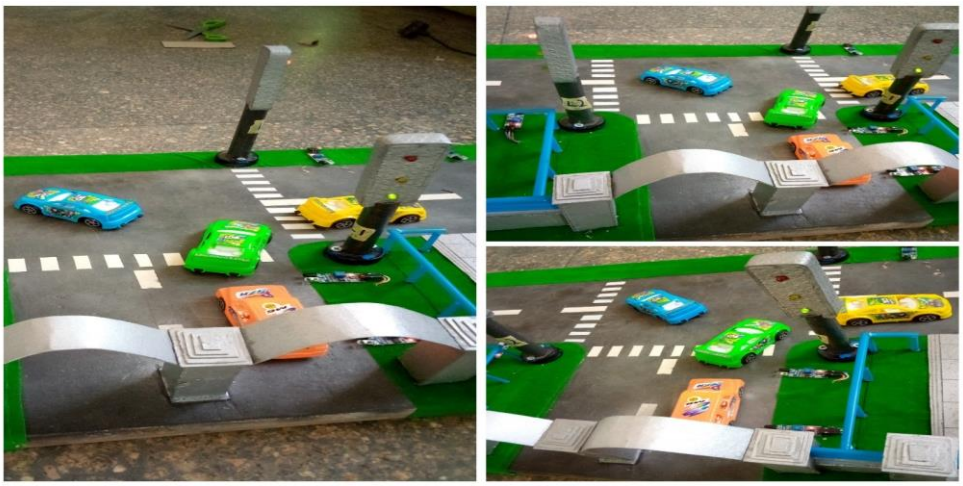

Figure 2. Signaling of Lane B.

From Figure 6, after 30 s, the green light on lane B turns OFF, while the yellow light on lane C and A turns ON.

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

Figure 3. Signaling of Lane C.

From Figure 7, after 30 s, the green light on lane C turns OFF, while the yellow light on lane B and A turns ON. This process goes on 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. The goal was to reduce the traffic congestion and jams inside the traffic control system. IR sensor with a power supply of 5 V were used on the Arduino. The research was able to detect the density of vehicles in each lane of the road concurrently using the IR sensor. The research was designed to combine the features from the hardware components used, and also 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 as compared to the fixed traffic signal used by previous

researchers. However, this technique has shown to be more efficient and has low production cost which can be extended for commercial purpose. Further research will focus on implementing this concept on real life scenario.

Authors Contribution: Conceptualization, U.A. and S.A.; methodology, U.A., S.A. and Z.H.; software, A.S., A.O.-O., Z.M.A. and R.F.A.; supervision, U.A. and Z.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research receives no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement:

Data Availability Statement: Not applicable.

Acknowledgments: The authors are grateful to the entire staffs and students of Computer Engineering Department ABU Zaria, towards the successful completion of this research article.

Conflicts of Interest:

References

1. Goel, S.; Bush, S.F.; Gershenson, C. Self-Organization in Traffic Lights: Evolution of Signal Control with Advances in Sensors and Communications. *arXiv* **2017**, arXiv:1708.07188.
2. Kayalvizhi, S.; Karthik, S. Labview Based Various Sensors Data Acquisition System for Smart City Management. In Proceedings of the 2023 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI), Chennai, India, 25–26 May 2023; pp. 1–5.
3. Fattah, M.A.; Morshed, S.R.; Kafy, A.-A. Insights into the Socio-Economic Impacts of Traffic Congestion in the Port and Industrial Areas of Chittagong City, Bangladesh. *Transp. Eng.* **2022**, *9*, 100122.
4. Prakash, N.; Udayakumar, E.; Kumareshan, N. Arduino Based Traffic Congestion Control with Automatic Signal Clearance for Emergency Vehicles and Stolen Vehicle Detection. In Proceedings of the 2020 International Conference on Computer Communication and Informatics (ICCCI), Coimbatore, India, 22–24 January 2020; pp. 1–6.
5. Wei, H.; Zheng, G.; Gayah, V.; Li, Z. A Survey on Traffic Signal Control Methods. *arXiv* **2019**, arXiv:1904.08117.
6. Smys, D.S.; Basar, D.A.; Wang, D.H. Artificial Neural Network Based Power Management for Smart Street Lighting Systems. *J. Artif. Intell. Capsul. Netw.* **2020**, *2*, 42–52.
7. Guo, Q.; Li, L.; Ban, X.J. Urban Traffic Signal Control with Connected and Automated Vehicles: A Survey. *Transp. Res. Part C Emerg. Technol.* **2019**, *101*, 313–334.
8. De Oliveira, L.F.P.; Manera, L.T.; Da Luz, P.D.G. Development of a Smart Traffic Light Control System with Real-Time Monitoring. *IEEE Internet Things J* **2020**, *8*, 3384–3393.
9. Wang, B.; Han, Y.; Wang, S.; Tian, D.; Cai, M.; Liu, M.; Wang, L. A Review of Intelligent Connected Vehicle Cooperative Driving Development. *Mathematics* **2022**, *10*, 3635.
10. Desai, V.; Degadwala, S.; Vyas, D. Multi-Categories Vehicle Detection for Urban Traffic Management. In Proceedings of the 2023 Second International Conference on Electronics and Renewable Systems (ICEARS), Tuticorin, India, 2–4 March 2023; pp. 1486–1490.
11. Adebiyi, R.F.; Abubilal, K.A.; Mu'azu, M.B.; Adebiyi, B.H. Development and Simulation of Adaptive Traffic Light Controller Using Artificial Bee Colony Algorithm. *Int. J. Intell. Syst. Appl.* **2018**, *10*, 68–74.
12. Slimani, I.; Zaarane, A.; Atouf, I. Traffic Monitoring System for Vehicle Detection in Day and Night Conditions. *Transp. Telecommun.* **2023**, *24*, 256–265.
13. Desai, K.; Gupta, P. Vehicle-Pedestrian Detection Methods for Urban Traffic Control System: A Survey. *NeuroQuantology* **2022**, *20*, 496.
14. Usikalu, M.R.; Okere, A.; Ayanbisi, O.; Adagunodo, T.A.; Babarimisa, I.O. Design and Construction of Density Based Traffic Control System. In *Proceedings of the IOP Conference Series: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2019; Volume 331, p. 012047.
15. Dzulkefli, N.N.S.N.; Rohafauzi, S.; Jaafar, A.N.; Abdullah, R.; Shafie, R.; Selamat, M.S.; Azman, N.S.; Muhammad, M.Z.Z. Density Based Traffic System via Ir Sensor. In *Proceedings of the Journal of Physics: Conference Series*; IOP Publishing: Bristol, UK, 2020; Volume 1529, p. 022061.
16. Firdous, A.; Niranjan, V. Smart Density Based Traffic Light System. In Proceedings of the 2020 8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), Noida, India, 4–5 June 2020; pp. 497–500.

17. Chanda, J. Density Based Traffic Control System Using Arduino. SSRN 3917889. 2021. Available online: https://ssrn.com/abstract=3917889 (accessed on).
18. Khan, F.; Shende, A.; Shende, P.; Sahare, R.; Hasan, T.U. Density Based Traffic Signal Control System Using Arduino. *Int. Res. J. Mod. Eng. Technol. Sci.* **2022**, *885*, 882.
19. Mohandass, M.P.; Kaliraj, I.; Maareeswari, R.; Vimalraj, R. IoT Based Traffic Management System for Emergency Vehicles. In Proceedings of the 2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 17–18 March 2023; Volume 1, pp. 1755–1759.
20. Haruna, S.H.; Umar, A.; Haruna, Z.; Ajayi, O.-O.; Zubairu, A.Y.; Rayyan, R. Development of an Autonomous Floor Mopping Robot Controller Using Android Application. In Proceedings of the 2022 5th Information Technology for Education and Development (ITED), Abuja, Nigeria, 1–3 November 2022; pp. 1–6.
21. Patel, D.; Rohilla, Y. Infrared Sensor Based Self–Adaptive Traffic Signal System Using Arduino Board. In Proceedings of the 2020 12th International Conference on Computational Intelligence and Communication Networks (CICN), Bhimtal, India, 25–26 September 2020; pp. 175–181.
22. Chen, Z.; Sivaparthipan, C.B.; Muthu, B. IoT Based Smart and Intelligent Smart City Energy Optimization. *Sustain. Energy Technol. Assess.* **2022**, *49*, 101724.
23. Poongodi, M.; Sharma, A.; Hamdi, M.; Maode, M.; Chilamkurti, N. Smart Healthcare in Smart Cities: Wireless Patient Monitoring System Using IoT. *J. Supercomput.* **2021**, *77*, 12230–12255.