Integrating Smart Traffic Management and Electric Energy Generation at Intersections

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Table of Contents

Abstract

Traffic congestion is one of the many issues that cities are facing as a result of the rapid population expansion and the migration of people from rural to urban areas. The duration of the green light in our suggested smart traffic system is adjusted based on the number of cars, which regulates traffic conditions at any intersection. We took into consideration the pedestrian push button option in this smart traffic system, which prioritizes pedestrians. Furthermore, we concentrated on generating electricity from moving cars on the road in order to employ renewable energy for the transportation industry. In order to reduce traffic congestion, our intelligent traffic technology addresses pressing issues including urban traffic management. Furthermore, using mechanical stress from moving cars on the road to create electricity is a very effective way to lessen dependency on fossil fuels and control energy costs in a sustainable manner.

Introduction

a. Problem Statement

Currently, 55% of people on Earth reside in cities, a number that is predicted to rise to 68% by 2050. According to projections, by 2050, there might be an additional 2.5 billion people living in urban areas due to urbanization—the progressive movement of people from rural to urban regions—and global population growth (United Nations, 2018). More moving vehicles must be accommodated over a certain amount of roadways and transportation facilities. The City of Calgary, Alberta, has implemented the Mobility Operations Centre (MOC), to monitor the traffic signals for proper operation and collect data on traffic flow, such as volumes and speeds from vehicle sensors at the intersections. However, it does not dynamically adapt green light durations based on real-time traffic conditions (The City of Calgary, n.d.). Additionally, the transportation sector requires a significant amount of energy to power street lamps, traffic lights, etc. Due to the growing energy needs, the non-renewable sources are getting depleted, and the focus has been shifted to renewables. During their service life, roads will absorb axle loadings from moving vehicles millions of times over, which will cause deformation and vibration. A significant amount of mechanical energy is lost in this operation (Yang et al., 2018). In this project, we are focusing on smart traffic systems and utilizing mechanical stress to generate useful electricity using piezoelectric technology.

b. Motivations:

Utilizing traffic lights based on road conditions is the driving force behind the creation of this smart traffic system. Put another way, intersection signals must be able to quickly adjust to changing traffic situations. This would lower the cost and inconvenience of travelling, as well as the carbon footprint of the cars by improving fuel economy and minimizing wear and tear from numerous pauses. Electricity is produced by harvesting mechanical energy that is already lost and assured to be available at all times through the use of piezoelectric technology. It is therefore more sustainable. In addition to reducing dependency on traditional sources, the energy produced in this way can power streetlights, traffic lights, and other devices.

c. **Research Questions:**

- How can intelligent traffic management by considering traffic density and pedestrians be good for traffic management at intersections in urban areas?
- How can energy generation improve urban transportation efficiency and lessen the environmental impact caused by traffic at intersections?

d. **Objectives:**

- To adjust the green light length according to the density of traffic at an intersection.
- To generate electricity from moving vehicles.

e. **Equipment List**

- UNO R3 Starter Kit.
- HC-SR04 Ultrasonic Distance Sensor Module.
- Piezoelectric Ceramic Vibration Sensor.

Methodology

1. At first, data (distance in this case) is measured for the vehicles using the ultrasonic sensor.
2. Based on the distance threshold value, the number of cars is counted. The vehicle counter is incremented if the sensor reads a value within the distance range.
3. The collected data is received by our traffic light controller, which is Arduino. Arduino manages the traffic light by switching between green, yellow, and red. We used a traffic light cycle (Ink, *Signal cycle lengths* 2015) with a period of 30 seconds for the green light, 6 seconds for the yellow light, and 10 seconds for the red light.
4. Then, the Arduino data (number of vehicles) is represented by the serial monitor.
5. After that, Arduino controls the green light duration according to the number of vehicles on the road. Several road conditions such as light, medium, moderate, and heavy are considered in this project. The approximate number of vehicles (Government of Canada, 2022) on each road condition is considered for the traffic density. So, if there is heavy traffic on the road the green light duration will be more than when there is medium traffic on the road. However, a maximum threshold of green light duration (30 seconds) is considered in the project.
6. In addition, we implemented a push-button option for pedestrian crossings. If the push button is pressed, the remaining green light time will be halved to give priority to pedestrians.
7. Finally, when vehicles apply mechanical stress is rectified from AC to DC using a full bridge rectifier, the voltage is generated across piezoelectric sensors.

Figure 1 demonstrates the workflow of the project.

Results and Discussions

The integration of our intelligent traffic system with intersection-based electricity generation produced excellent results. We successfully controlled traffic flow at crossings by dynamically modifying green light durations in response to current traffic circumstances. Smooth traffic flow was ensured by the Arduino-based traffic light controller, which effectively controlled the changeover between green, yellow, and red lights. Moreover, push-button pedestrian alternatives prioritize pedestrian crossings when necessary, which further improves safety and efficiency. After pressing the push button the remaining green light timing will be halved and then changed to yellow and red to ensure the fastest and safest pedestrian crossing.The technology showed that it could respond to the needs of both automotive and pedestrian traffic by cutting in half the amount of time that the green light would remain on when a pedestrian activated it.

Figure 2 represents the traffic status and its green light durations based on road conditions and pedestrian push-buttons for our smart traffic system.

Furthermore, the use of piezoelectric technology to produce power from moving cars illustrated a sustainable method of producing energy. In addition to lowering reliance on fossil fuels, this sustainable strategy will provide a workable way to power traffic signals and other intersection infrastructure.
Figure 3 represents the circuit diagram of the project.

Through data analysis and experimentation, we found that this may greatly increase energy sustainability and traffic management efficiency. Our system's ability to react to changing conditions will undoubtedly result in fewer traffic jams, more efficient traffic flow, and lower carbon emissions. Including renewable energy generation also lessens the need for conventional energy sources, which supports environmental preservation initiatives.

Figure 4 demonstrates the actual working model with smart traffic and piezoelectric electricity generation.

Conclusion and Future Work

In conclusion, there is a lot of promise for resolving urban transportation issues with the combination of smart traffic management and power energy generation at intersections. Our experiment proved that a system like this is both feasible and efficient in enhancing traffic flow and sustainability.

Still, there are several directions for additional development and improvement:

1. Cloud Platform Implementation: Real-time data analysis and optimization may be possible if our system is integrated with a cloud-based platform. We can improve our traffic management system's scalability, adaptability, and intelligence by utilizing cloud computing capabilities. Our next target is to implement it on a real-time IoT platform such as ThinkSpeak to make it more

efficient.

2. Energy Storage Options: The search for efficient methods for storing the electricity generated by piezoelectric technology is of utmost importance. When traffic is light, battery storage systems or other energy storage technologies can be used to guarantee a steady supply of electricity for a variety of infrastructural needs.

3. Real-Time Application: We must continue to improve our smart traffic system in order to implement adaptive control mechanisms and make necessary real-time modifications. Advanced sensors, machine learning methods, and artificial intelligence algorithms can all be used to produce a traffic management system that is genuinely adaptable and responsive, able to optimize traffic flow in real time.

Our smart traffic system's scalability and real-time monitoring capabilities could be improved by implementing cloud-based platforms, opening the door to more dynamic and individualized traffic management solutions. By investigating more sophisticated energy storage alternatives for piezoelectric generation, it may be possible to increase the efficiency and dependability of electricity harvesting and guarantee a steady and uninterrupted supply of power for traffic infrastructure. Ultimately, more investigation into real-time traffic prediction and decision-making algorithms may improve our smart traffic system's efficacy and responsiveness, allowing for proactive modifications to signal timings and traffic flow optimization.

Urban traffic congestion, energy sustainability, and pedestrian safety can all be effectively addressed by integrating smart traffic control and electricity generation at intersections. Our technology exhibits great potential to enhance urban mobility and lessen environmental effects through energy generation technologies and adaptive traffic signal regulation. Upcoming studies focused on improving energy storage, scalability, and real-time applications will propel the industry forward and help build more sustainable and efficient cities.

Figures

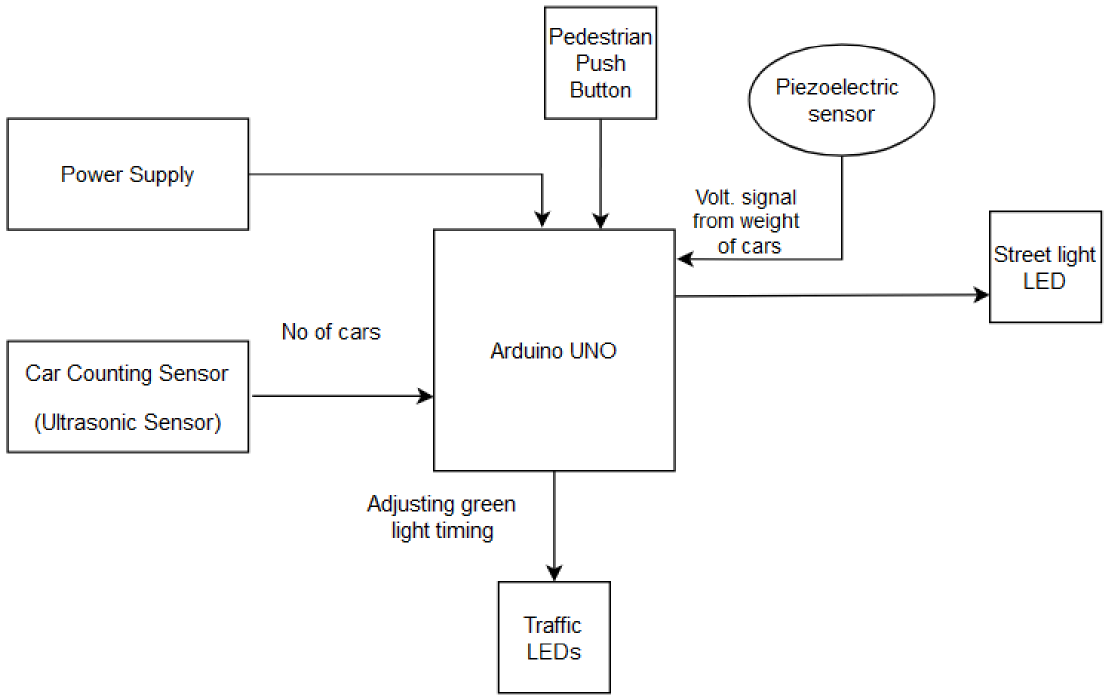

Figure 1:Methodology

Traffic Status	No. of vehicles		Green light duration (in sec.)	
	Actual density	Scaled down density	Pedestrian button not pushed	Pedestrian button pushed
Light traffic	0 to 5	0 to 2	5	Remaining time is halved
Medium traffic	6 to 10	3 to 6	10	
Moderate traffic	11 to 20	7 to 9	20	
Heavy traffic	21 to 35	more than 9	30	

Figure 2: Traffic Light Controller

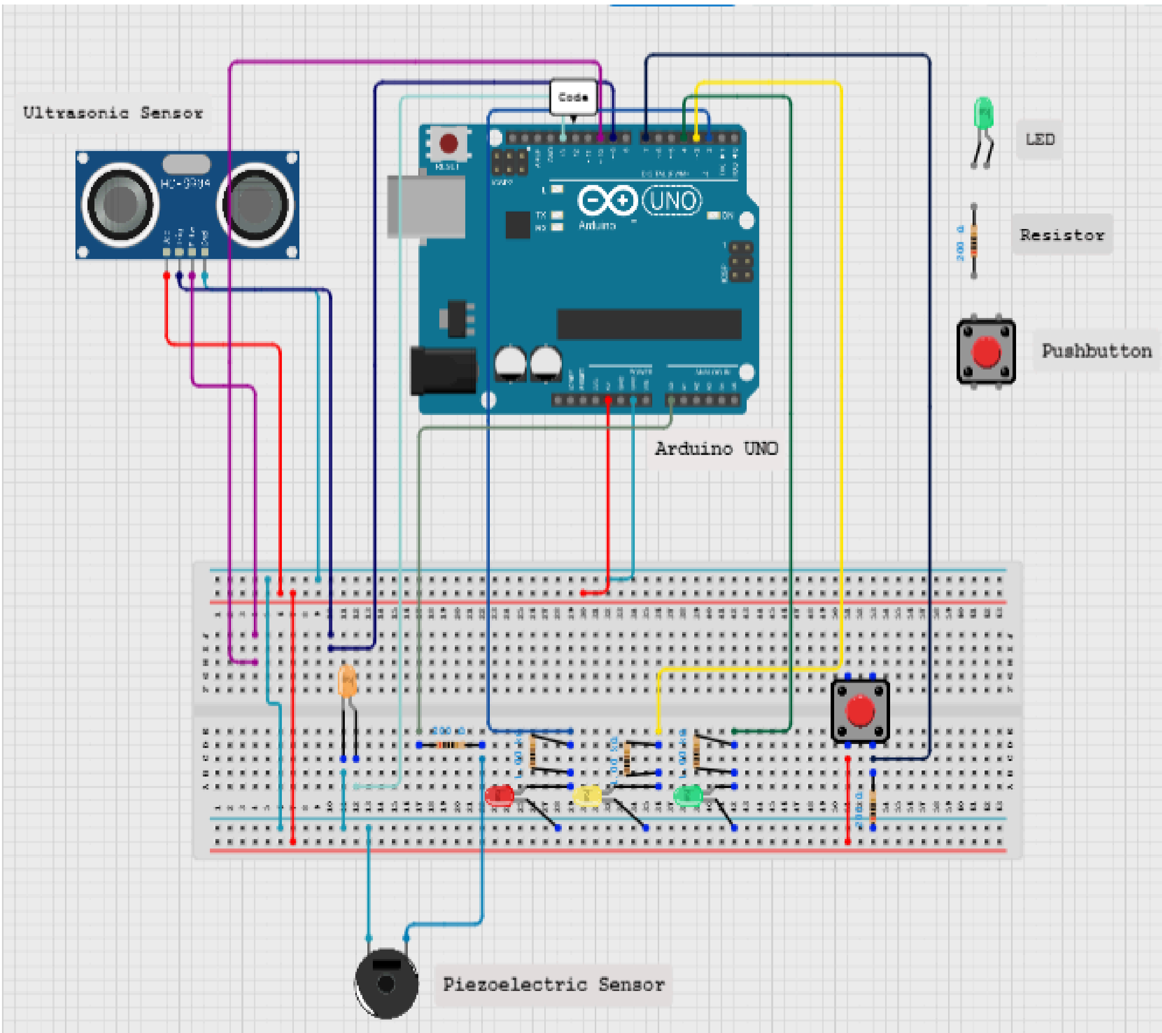

Figure 3:Circuit Diagram

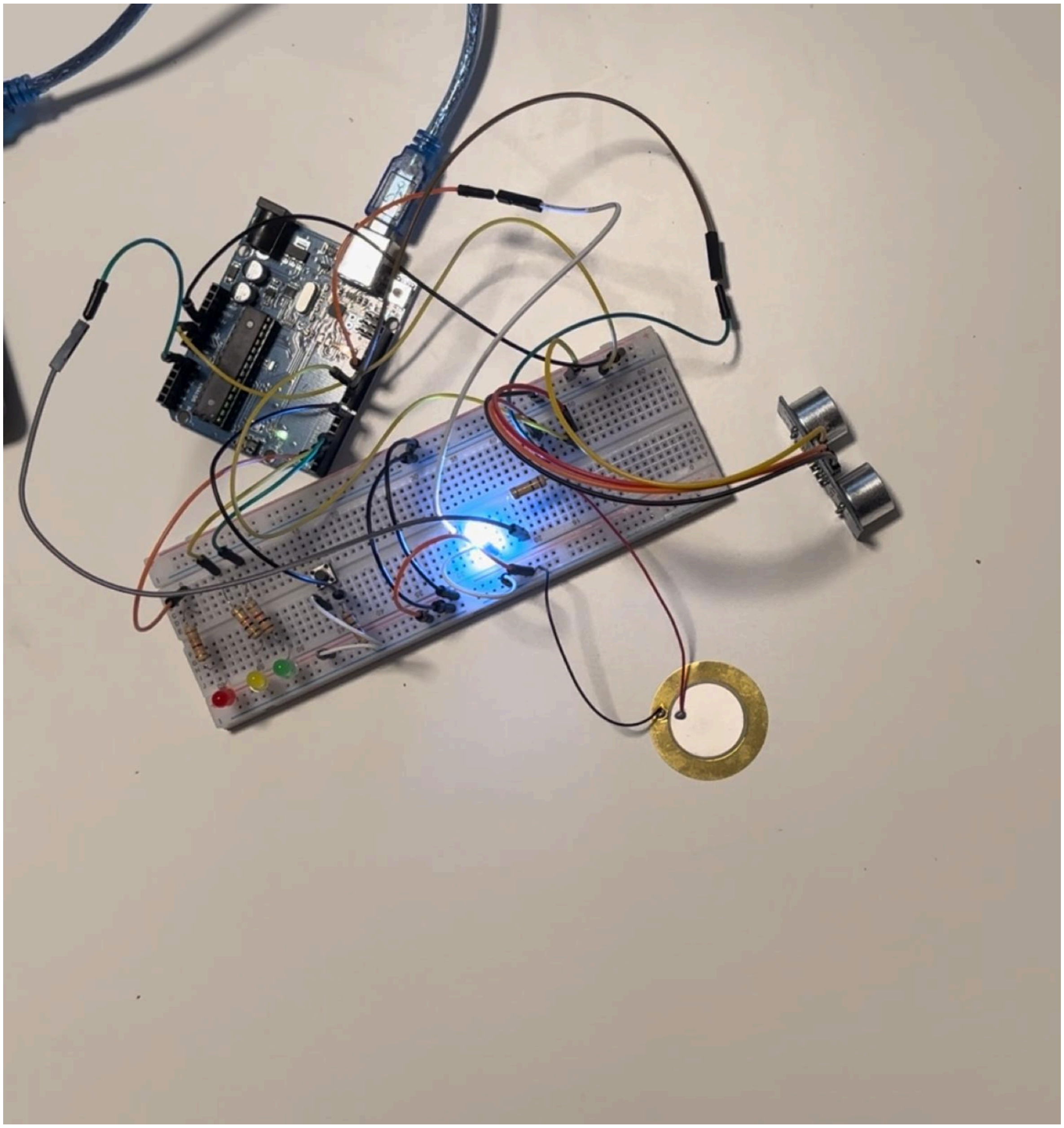

Figure 4: Working Model

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