Integrating Smart Traffic Management and Electric Energy Generation at Intersections

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, a significant amount of energy is required by the transportation sector 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 smart traffic systems and utilizing mechanical stress to generate useful electricity using piezoelectric technology.

Motivation

An efficient part of making the streets smarter is utilizing traffic signals. Stated differently, intersection signals need to possess the capability to instantly adapt to changing traffic conditions. This would not only reduce the inconvenience and expense of commuting but also lessen the transportation vehicles' carbon footprint by increasing fuel efficiency and reducing wear and tear caused by frequent stops. Through piezoelectric technology, mechanical energy that is already lost and is guaranteed to be in constant supply is harvested to generate electricity. This makes it more sustainable. Energy thus generated reduces reliance on conventional sources and can be used to power traffic lights, streetlights, etc.

Research Question

1. How can the Internet of Things (IoT) be used to implement intelligent traffic management?
2. How can energy generation improve urban transportation efficiency and lessen environmental impact caused by traffic at intersections?

Proposed Solution

Our proposed solution is utilizing a network of intelligent ultrasonic sensors placed in the intersection to monitor, analyze traffic density and adjust green light durations accordingly. This system aims to optimize traffic flow by extending green lights during peak traffic hours and reducing them during low-traffic periods. Simultaneously, we will consider the pedestrian crossing with the green light timing.

We will embed piezoelectric sensors beneath the road surface at the intersection so that when vehicles pass over them, the mechanical stress applied to the sensors can be converted to electricity. The elastic piezoelectric crystal material deforms in response to pressure or force, which results in the development of charge between them.

Planned Methodology

1. Firstly, we will collect data (such as distance) from our car counting sensor used in the project.
2. Based on the threshold value of distance, we will count the number of cars. The car counter is incremented if the sensor reads a value within the distance range.
3. The collected data will be received by our traffic light controller, that is Arduino. Arduino manages the traffic light by switching among green, yellow and red.
4. Then, the Arduino sends data to our local server.
5. From local server, data is sent to the cloud server. Here, we will calculate the average green light timing for any intersection. The current actual time the green light is on is then compared to this computed green light time. The server then makes a decision: it decides to increase the green light time if the current actual green time is less than the estimated time, and it decides to lower it otherwise.
6. In addition, we will keep a push button for pedestrian crossings. If the push button is pressed, the average green light timing will be minimized to give priority to pedestrians.
7. Then the data will be visualized using a cloud platform.
8. After that, the voltage generated across piezolelectric sensors, when vehicles apply mechanical stress will be rectified from AC to DC using a full bridge rectifier.
9. The output of the rectifier will be connected to a capacitor, where the voltage gets stored.
10. Finally, this stored voltage can then be used to light the street light represented by an LED.

Engineering Significance

1. Efficient urban mobility:

This project uses Internet of Things technology to tackle urgent problems like urban traffic management that will help to minimize traffic congestion .

2. Sustainable roadways:

Utilization of an already existing input (mechanical stress by vehicles on roads) to generate electricity is highly efficient, reduces reliance on fossil fuels and curbs down energy costs in a sustainable manner.

References

1. United Nations. (2018, May 16). 68% of the world population projected to live in urban areas by 2050, says UN | UN DESA | United Nations Department of Economic and Social Affairs. the United Nations. Retrieved January 23, 2024, from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html
2. The City of Calgary. (n.d.). Traffic signal management. The City of Calgary. Retrieved January 20, 2024, from https://www.calgary.ca/roads/traffic-signal-management.html
3. Yang, H., Wang, L., Zhou, B., Wei, Y., & Zhao, Q. (2018). A preliminary study on the highway piezoelectric power supply system. *International Journal of Pavement Research and Technology*, *11*(2), 168–175. https://doi.org/10.1016/j.ijprt.2017.08.006