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A SMART MICROPROCESSOR-BASED FOUR WAY STOP ROAD TRAFFIC CONTROLLER

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ABSTRACT

Four-way stops are very common in African countries such as Botswana, South Africa, and many others. With the four-way stop concept, the first car to reach the intersection is supposed to proceed. There have been cases where this has proved to be inefficient and has also led to accidents due to the confusion of whose turn it is to proceed. During busy times with high traffic density, the system becomes inefficient and causes traffic congestion. This paper proposes a smart microcontroller based four-way stops traffic controller system that reduces confusion of whose turn it is to proceed, as well as reduces traffic congestion at four-way stops. In this work, the smart microcontroller-based road traffic controller system is designed using the Arduino microcontroller for the logic operation of the system, infrared (IR) sensors for detecting the presence and absence of the vehicles and also to sense if the traffic density is high or low by sensing the traffic approaching the intersection and light emitting diodes (LEDs) for displaying purposes. A prototype of the system was built and tested. The system was designed in the way that it uses the first come first served method whenever the traffic density is low, and when the traffic density is high, the lanes open for longer durations. The sensors are placed on the sides of the road to detect traffic, two sensors in each lane, one at the intersection and one away from the intersection.

KEYWORDS: *Arduino, Traffic Controller, Traffic Density, Microcontroller*

Article History

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INTRODUCTION

Four-way stops, also referred to as all-way stops, are intersections that are controlled by stop signs from all four sections of road that converge [1]. Four way stops are mostly found in small areas of towns and cities. Most accidents occur in instances where two or more vehicles reach the intersection at the same time and the drivers decide to proceed at the same time. According to the author in [2], when more than one driver reaches a four-way stop intersection, the first vehicle to reach the intersection first should proceed first. When two vehicles on different roadways arrive at a four-way stop intersection at the same time, the vehicle on the left should yield to the vehicle on the right. Normally there are no traffic lights in four-way stops, therefore drivers would just have to cooperate, whereby the first vehicle to arrive at the stop proceeds. This existing four-way stop system has also proved to be inadequate in high traffic density periods because it allows only one car per lane to pass at a time. The confusion at four-way stops, which operate on the principle of the first come, first pass, has resulted in accidents due to confusion and traffic congestion.

The accidents at four-way stop due to the confusion of whose turn it is to proceed, has been a worldwide problem. The drivers seem to be too negligent to the rules of four way stops and also get confused in instances where two or more vehicles reach the intersection at the same time because they may both want to claim to have reached the intersection before the other and then proceed at the same time and collide. According to a research done by researchers in [1,2], it has been shown that four-way stop accidents can be one of the most dangerous kind of traffic collisions. Four-way stops are the site of thousands of car accidents each year and are designated 'high crash areas' and drivers that fail to stop or are confused about four-way stop rules can easily cause a deadly accident. In 2014, in Botswana, 288 accidents resulted in deaths and most of the accidents happened in areas where there was no junction (76.3 percent), followed by those which happened at stop signs (9.8 percent) and those which happened even though traffic light signals were working (7.4 percent) [3]. With the statistics mentioned above, it proves the accidents occurring at four-way stops to be a major problem faced in different countries. This method of first come to firstpass, whereby only one car from a lane proceeds at a time is inefficient whenever the traffic density is high because it causes traffic congestion. In today's high-speed life, traffic congestion has become a very serious issue. This brings the productivity of individuals down and the community at large since time is wasted in the signals.

Some countries have tried to address this problem by placing police officers at busy times at these intersections to control traffic. Therefore, in order to get rid of these problems or at least reduce them to a significant level, new schemes need to be implemented. In this work we address these issues by using a microcontroller and sensors to detect traffic and traffic density.

RELATED WORK

A traffic light control system using switch sensors as the detecting unit was placed at the intersection on each lane to detect a vehicle was used developed and proposed in [4]. Light emitting diodes (LEDs) of three different colors were used as the displaying/output unit. A microcontroller, as a control unit, was designed to in a manner that it samples all the lanes to detect if there is a vehicle at any lane and therefore, added 15 seconds delay time. Once the system is high, the PIC coordinates the action by giving the lane with high input a passage immediately and indicates Red on the LED output of the three other lanes and if there is no high input on the other lane, the controller will pass the next turn on the same lane.

Authors in [5] proposed a multiple traffic light control and monitoring system that is based on a microcontroller and contained infrared (IR) sensors which were respectively mounted on each side of the road. IR sensors were to detect and count vehicles passing through them. The microcontroller controlled that system and updated the traffic light delays, according to the number of vehicles that were counted.

According to researchers [6], past researchers went through different technology types. Wireless devices were mounted on each side of the road collecting data from active RFID tags. A monitoring station fetched data and responded to the corresponding traffic signal through GSM.

Researchers in [7] came up with a far infrared vehicle sensor system is a novel vehicle detector that detects vehicles based on temperature differences. Consuming less electrical power, it can be powered by a solar cell battery. Also, it can detect vehicles from oblique directions, and therefore it can be mounted on a shorter mounted arm and is more aesthetically acceptable. The far infrared vehicle sensor is used for a profile traffic signal control in Kanagawa prefecture and Ehime prefecture, Japan.

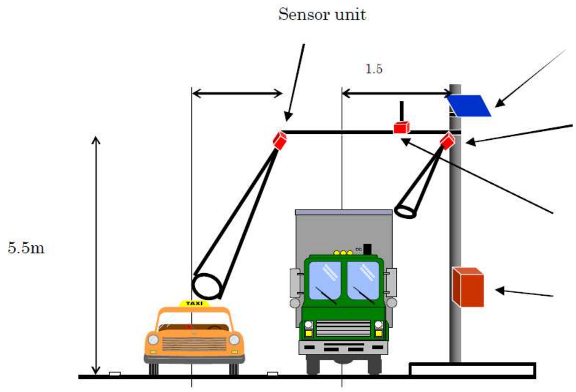

Figure 1: Structure of a Far Infrared Vehicle Sensor [7]

An inductive Loop Detector entails a coil of wire embedded into a groove in the road surface and sealed with a rubber. It detected a change in frequency and the inductor coil is connected to the detector that detected a change in resonant frequency of the coil loop, then controlled the triggering of the relay that triggered the traffic signals accordingly. It worked on the principle that whenever a car stepped over the inductor coil, the inductance of the coil decreased. The decreased inductance caused the oscillation or resonant frequency to increase then the electronics unit sent electric pulses, accordingly, to the control unit which to controlthe switching of traffic lights [8].

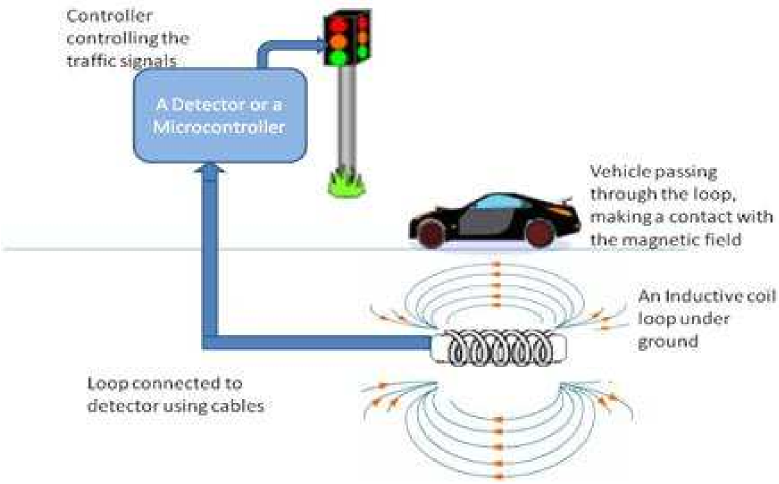

Figure 2: A Traffic Signal Control Using Inductive Loop Detector [8]

Researchers in [8] also implemented a system of sensors mounted on poles that can be a simple IRLED-Photodiode arrangement or a video detection unit which can detect the presence of vehicles. This works on the principle that when a car passes between the IR transmitter and IR receiver, the IR light is blocked and as the result the resistance of the photodiode increases. This change in resistance can be converted to electrical pulses, used to control the traffic lights [8].

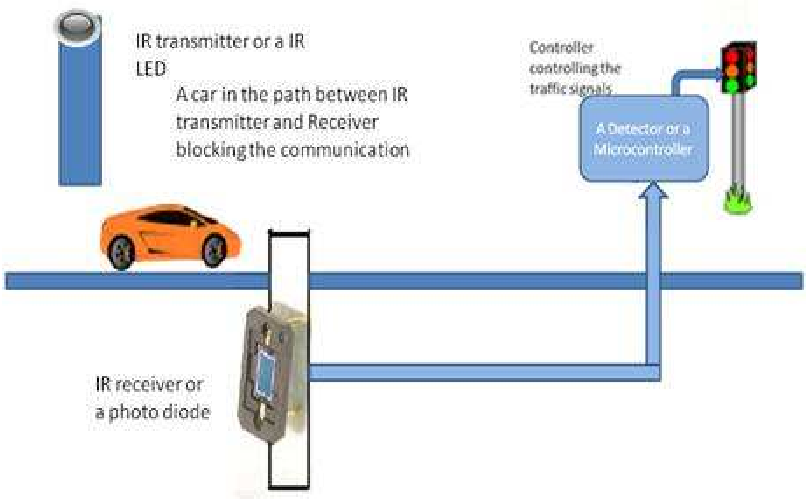

Figure 3: Traffic Signal Control uses Sensors Mounted on Poles [8]

Researchers in [9] have done a simulation of VHDL design code in Quartus 3.1 and generate an optimized hardware of a traffic light controller at a four-way intersection project. The traffic light controller must handle a four-phase signal intersection. This intersection has two travel lanes in each direction; east, west, north, and south. This traffic light at the intersection of north-south (NS) and east-west (EW) streets goes through the following cycles of states: both red (5 sec), NS green (30 sec), NS yellow (5 s) -- both red (5s) EW green (30 sec) EW yellow (5sec). A 0.2 Hz clock signal is available for timing. Both streets are equipped with sensors that detect the presence of a car close to the intersection. Whenever there is a car close to the intersection on the street currently having its light red while there is no car approaching the intersection on the street with a green light, the switch over takes place and green light immediately turns to yellow.

A system called Dynamic Traffic Light Control (DTLC) was proposed in [10] which operate with Infrared Sensors mounted on the road to detect the frequency of the vehicles. The presence or absence of a vehicle is sensed by the sensor assembly mounted on each road, which is the input of the system. This input signal indicates the density of vehicles on each road. In this system the basic operations are implemented using Microcontroller89c51AT which is the heart of the system. For communicating with the external signals, additional ports like computer links and pull up array are used. The DTLC unit generates output signals for Red, Green and Yellow Signal and monitors their timings, taking into consideration the length of vehicles on each road. The information as input to microcontroller was given in the form of already prepared database entries for the typical model working, which would determine vehicle density on each lane. Therefore, the on and off signal time at the four junctions was calculated by the microcontroller.

It has been realized that all these systems have been designed to be intelligent using different microcontrollers and sensors. They have been designed in the past for different purposes that include reducing traffic congestion and accidents. None of them have been implemented for four way stops that operate on the first come, first pass principle and follows the rules mentioned in [2]. The main objective of our work is to develop a low cost system that solves the problem of congestion and minimizes the chances of accidents at four way stops.

SYSTEM ANALYSIS AND SYSTEM ARCHITECTURE

System Analysis

To detect the vehicles, we use sensors in our system. Infrared sensors and Ultrasonic Sensors can be used to detect objects. An infrared sensor is a sensor used to detect particular features of its surroundings by the emission and detection of infrared radiation [11]. An IR sensor has a transmitter and a receiver, IR transmitter looks like an LED. This IR transmitter always emits IR rays from it. IR receiver should be able to receive the IR rays, when power is given, the transmitted IR rays hit the object and reflect back to the IR receiver and as a result the resistance of the photodiode increases and is converted to electrical impulses to be used to control the LEDs [12]. Ultrasonic sensors use ultrasonic sound waves for sensing. Ultrasonic refers to inaudible sound waves above a frequency of 20 KHz. There are two parts in an ultrasonic sensor which are the transmitter and receiver. The transmitter transmits the ultrasonic waves towards the object to be detected. The receiver receives the echo from the target and determines its distance. Hence it is known as a distance sensor. After considering a few aspects including availability, costs and efficiency of the sensor, the infrared sensors were chosen because ultrasonic sensors are very sensitive to variation in the temperature and have more difficulties in reading reflections from soft, curved, thin and small objects.

Different microcontrollers, including arduino, beagle Bone black and raspberry pi were reviewed [14]. Arduino and Raspberry Pi and are very inexpensive. The Beagle Bone comes in at nearly the cost of three Arduino Unos. The Arduino comes with 32 KB of onboard storage, which is just enough to store the code that provides instructions for its current program [15]. Raspberry Pi and Beagle Bone both run the Linux operating system [16]. Beagle Bone and Raspberry Pi are powerful hardware, theirneeds continuous 5v power supply and it is difficult to run it on Batteries, while the Arduino needs less power can easily be powered using a battery pack. We chose the Arduino Mega microcontroller because it is very easy to interface analog sensors, motors and other electronic components, needs less power and can be easily powered using a battery pack and is less expensive compared to other microcontrollers. The Arduino MEGA 2560 is designed for projects that require more I/O lines, more sketch memory and more RAM compared to the Arduino UNO..

SYSTEM ARCHITECTURE

The proposed system shown in figure 4 consists of display/output units, the detector/sensing units and the control/process unit. The data from the sensors is passed through to the microcontroller, which then decides the appropriate behaviors and give the feedback on which lane is to get green or red. The data from the microcontroller is sent to the LEDs to signal from which lane a vehicle is to proceed.

Figure 4: Signal Flow of the System

The detector unit entails of the arrangement of IR sensors to detect the presence and absence of vehicles and also detect the density of the traffic approaching a four way stop. Also Installation of infrared sensors does not require an invasive pavement procedure. Infrared sensors can transmit multiple beams for accurate measurement of vehicle position, speed and class. Multiple lane presence detection is available in side-looking models [21]. Only red and green LEDs will be used as the output unit because the system is going to give red for stopping and green for proceeding. A pole was mounted beside the road and bent to hang on top of the intersection to hold the two LEDs facing each direction and this was done on the prototype and will also be done in real life scenario. The sensors are placed on the sides of the road to detect traffic, two sensors in each lane, one at the intersection and one away from the intersection.In real life scenarios the sensors will be placed 40m away from the intersection and for the prototype a much smaller distance in centimeters will be used to represent the 40m. The 40m distance is just to demonstrate the concept and can be adjusted depending on the traffic conditions of a particular four way stop.

When the system is powered ON, all the sensors and time will be recorded once a sensor is HIGH and reset when it goes LOW. The sensors at the intersection are the ones that determine which loan is opened, if one of the sensors at the intersection is HIGH and any or all other 3sensors are also HIGH, their detection time will be compared and the lanes will be opened giving priority from the highest to the lowest time. When the green light glows, the away sensor in the lane is read and if it has been HIGH for more than 5seconds the green light will glow for 30 seconds but if not it will glow for only 3seconds. After that, there’s a 3seconds delay before another lane is opened. Otherwise, if only one sensor at the intersection is HIGH its lane will be opened straight away. In instances were 2 or more detection times are equal, the priority order is lane 1 followed by lane 2 then lane 3 then lastly lane 4. The placement of the sensors is shown in figure 5.

An algorithm was developed for implementing the microcontroller-based road traffic controller system design. Figure 6 shows the flow chart of the proposed system. The sensors are read and the lanes are opened according to the order of arrival of the cars and detect traffic congestion.

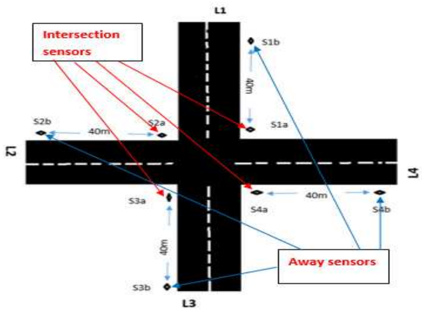

Figure 5: Placement of Sensors at the Intersection

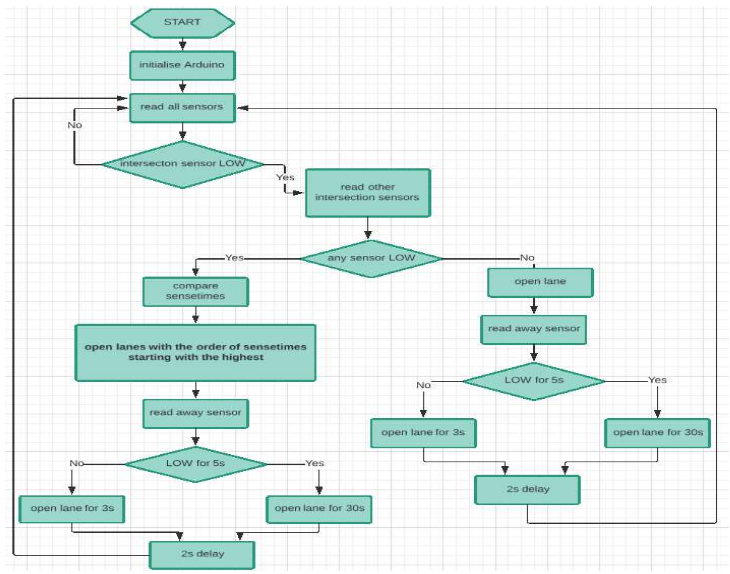

Figure 6: A Flow Chart of the Microcontroller-Based Road Traffic Controller System

METHODOLOGY

A schematic diagram for the circuit of the system is given in figure 7. Eight LEDs were connected to the Digital Input/ Output pins 2-9 of the Arduino. From these 8 LEDs, four are red and four are green. The LEDs have anodes and cathodes, the anodes were connected to the digital I/O pins and the cathodes to the ground (GND). These pins were declared in the code and the LEDs was declared as outputs. 220Ω resistors were connected between the anodes and the Digital I/O pins to limit the current that will enter the LEDs.

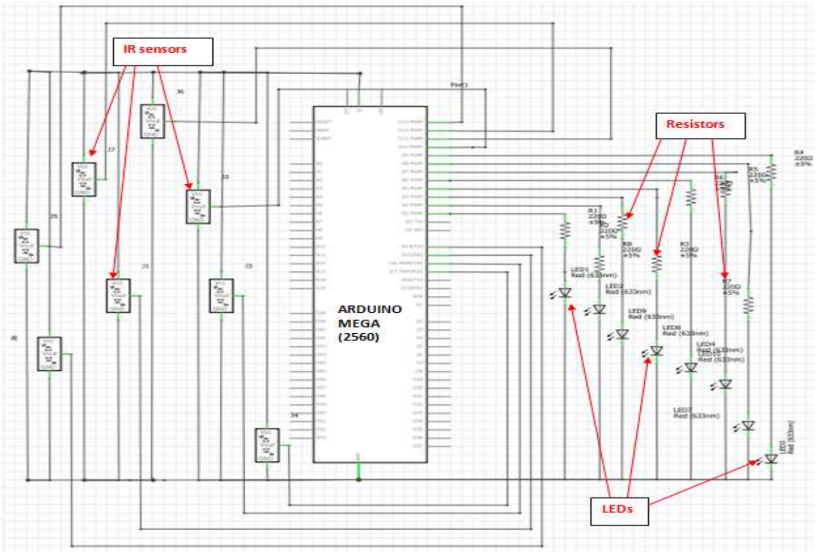

Figure 7: A Schematic Diagram of the Microcontroller-Based Road Traffic Controller System

Eight Infrared sensors connect to the Arduino as well, the sensors have 3pins each, the signal was connected to the digital input pins (10-17) of the microcontroller, the ground pin was connected to the ground (GND) and V_{cc} was connected to the 5V power pin on theArduino. The overview of the procedure followed to develop this system is shown in figure 8. was followed during the implementation of the system and the following chart shows the following of the procedure.

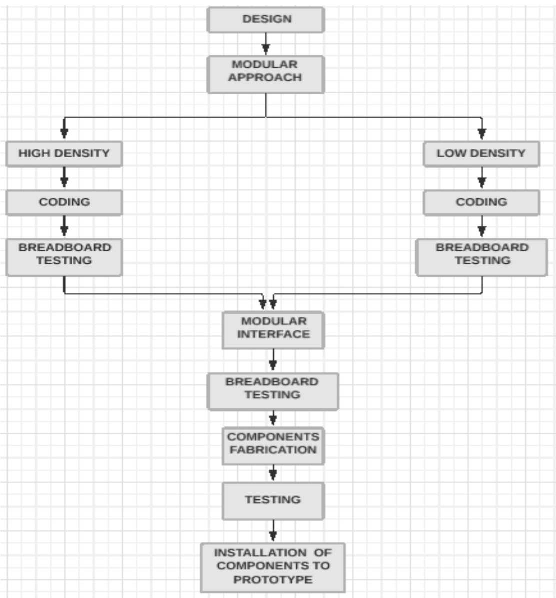

Figure 8: Methodology Followed

In section 3, the system design was presented. The design was divided into two modules, the high density and the low density module and the codes for the modules were initially written separately and then combined. All the 8 sensors were then connected to the circuit on the breadboard and the final testing was done. Obstacles were put in front of the sensors when testing.

TESTING AND RESULTS

In this section we present an overview of the Arduino code as well as the tests that were carried out to test the system.

Code Overview

int state1 = digital Read(10);

The code initialized integers called ‘state1-8’ and then set the values of the states to be the values of the digital pins 10-17. The digital Read statement reads the state of the digital pin within the parenthesis and returns it to the integer assigned it to. The value can be checked in the state to see if the has detected an obstacle or not.

Unsigned long t1a;

The code above stores the value of detection time for each sensor so they can be compared and lanes opened according to the results

int state1 = digital Read(s1a);

The code above showed in the void loop where the system operation begins and all the sensors are read to know which one detected a car and which one did not.

if (state1==HIGH){

t1a=0;

This code shows the conditions where a sensor has not detected any car, or after the car has left. The sensors reset the detection time in that case.

```
if(state1 == LOW){
 //car detected
t1a=millis();//count milliseconds
//check if any other sensor has detected a car
  if(state2 == LOW || state3 == LOW || state4 == LOW){

 //compare their detection times
 if(t1a >= t2a && t1a >= t3a && t1a >= t4a){
        //t1a was assigned first
        //open lane 1
```

In the code above a car is detected in one lane and time is recorded and the others sensors are checked to see if they have also detected cars or not. The detection times are compared and the highest gets priority. ‘&&’ means Logical AND and ‘||’ means Logical OR. The figure above shows the flow of the system as per the code above.

```
/* check if sensor has detected a car and it is
over 5 seconds since it has */
 if ((millis() - tlb) > 5000){
  if(state5 == LOW){
  delay(30000);
    }
 }
   else{
  delay(3000);
  }
 digitalWrite (2,LOW);
digitalWrite (3,HIGH);
delay(2000); //delay 2seconds before changing to another lane
```

After opening for a lane the sensor that is away from the intersection in the same lane is checked if it has detected a car for more than 5 seconds and if it has the lane is open for 30seconds but if not the lane opens for 3 seconds to allow only one car to pass.

```
    else {
  digitalWrite (2,HIGH);
digitalWrite (3,LOW);
digitalWrite (4,LOW);
digitalWrite (5,HIGH);
digitalWrite(6,LOW);
digitalWrite (7,HIGH);
digitalWrite (8,LOW);
digitalWrite (9,HIGH);
 if ((millis() - tlb) > 5000){
  if(state5 == LOW){
  delay(30000);
    }
 }
   else{
  delay(3000);
  }
 digitalWrite (2,LOW);
digitalWrite (3,HIGH);
delay(2000);
      }
```

From the above code, if none other sensors have detected a car, the lane with the only one that has will be opened right away. There will also be a delay of 2 seconds before the system opens for another lane.

Test Scenarios

Scenarios were created to low and high density. These scenarios were used to test the system. A brief of the scenarios is presented in this section and shown in figures 9, 10 and 11. Figure 12 shows the prototype used for testing the system. Scenario 1 shows a scenario where a car from lane 3 came at the intersection first and the traffic congestion is also detected in the lane which means it will be opened for 30 seconds. Scenario 2 shows a car in lane 1 reaching the intersection while there are no cars at the detected at the intersection which mean the lane is opened straight away. The scenario above can happen for each lane. Scenario 3 shows a scenario were 4 cars from all different lanes have arrived at the same time. The car in lane 1 is given the first priority, followed by the car from lane 2 then from lane 3 and lastly lane 4. The lane is open for only 3 seconds.

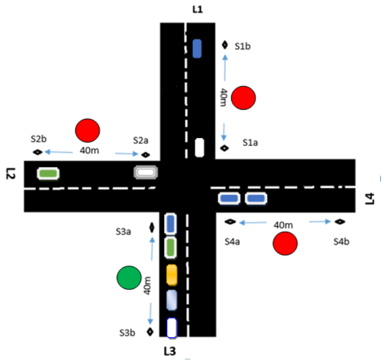

Figure 9: Scenario 1

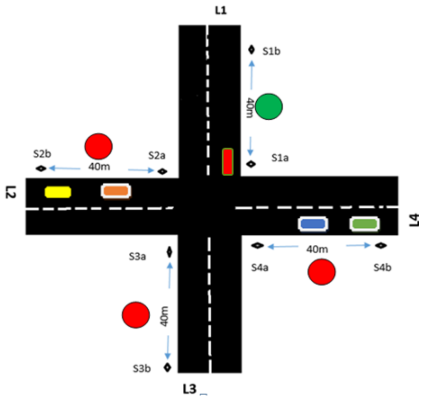

Figure 10: Scenario 2

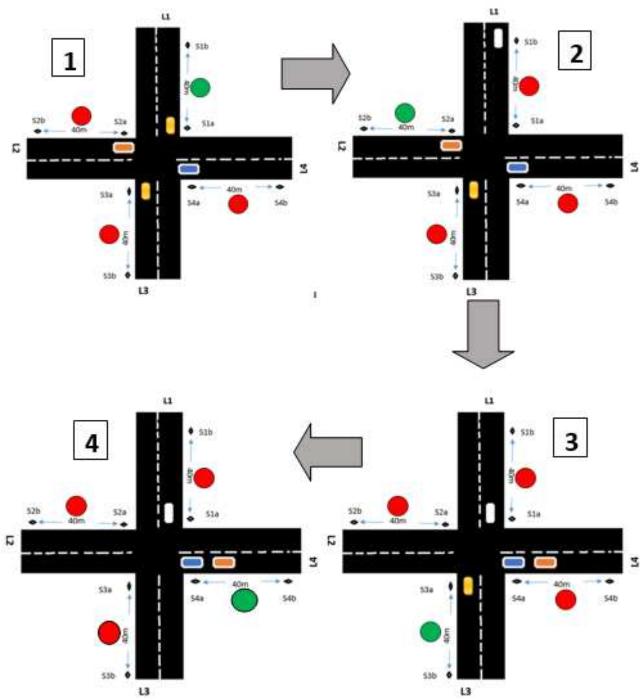

Figure 11: Scenario 3

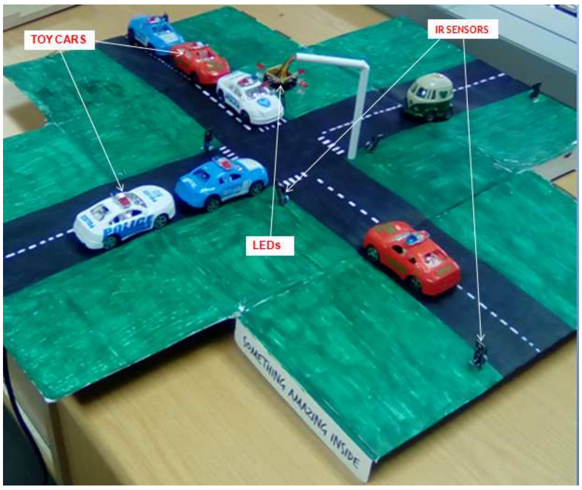

Figure 12: System Prototype

DISCUSSIONS

The IR sensors cannot calculate the length of a car that has stopped at the intersection, therefore the 3 seconddelay used in this project for the low density case is just to demonstrate the concept of the project to allow only one car to proceed. The best way would be in the lane to be opened until the car leaves the vicinity of the sensor, and the best function for the scenario would be “delay (state==LOW;)”, unfortunately it is unsupported the Arduino because when it is used, the lights from the different lanes conflict and more than one lane could be opened at the same time hence accidents being caused. Other microcontrollers would be considered hoping they will support such a function in, however, it would be written or executed. In this case, ultrasonic sensors could be used because they can measure the length of a car.

The average length of a car is 4.8m which is approximately 5.0m. Therefore according to the author of this work, more than 6 cars queuing in one lane at a four-way stop reaching 40m distance from the intersection, is considered traffic congestion. This value can be changed for different implementations. The lane should be opened for a long time, which was set in this project to be 30 seconds and that means 10 plus or minus two cars will be able to proceed, depending on their lengths, if they go at an average speed 10km/h because they would be picking up from rest.

The existing systems for controlling traffic density used IR sensors for counting cars approaching the intersection, but in this project the sensors have to detect a car for 5seconds that’s how it can tell the traffic is congested. The mechanism of counting cars is very irrelevant because cars have different lengths. The 5 seconds proposed for this project was set looking at the fact that the average speed for cars approaching traffic lights is 60km/h, therefore it is not likely for a car, despite its length, to be in the vicinity of the sensor for more than 5seconds unless is traffic that has stopped in front of it.

There is an abundance of sunlight in many countries, therefore, solar energy would be best converted to electrical energy and used to supply traffic lights with power. It is very advantageous to use solar-powered systems because they do not need external power sources and require less maintenance since they possess no moving parts.

CONCLUSIONS AND FUTURE WORK

The proposed system is designed to reduce accidents due to the confusion at four-way stops by signaling whose turn it is to proceed and also reducing traffic congestion whenever the traffic density is high. The system is hoped to result in a smooth traffic follow at four-way stops. The concept has been designed and tested on a prototype. The system is still to be tested in a real-life implementation. This system can be enhanced in different ways in the future. It can be connected to the internet through a Wi-Fi Module for operational monitoring. The system is a low-cost system and suitable for implementations where traffic lights are a higher cost option. Also, the system can be integrated with traffic lights. When the traffic lights become faulty, this system can come on and operate. Usually, when traffic lights are not working, the traffic operates as a four-way stop.

REFERENCES

1. *C. Davis, "Davis law group," Davis law group, 07 August 2016. [Online]. Available: https://www.injurytriallawyer.com/library/four-way-stop-accident-stop-sign-controlled-intersection-collisions.cfm. [Accessed 26 August 2017].*
2. *J. White, "Intensive English Institute," 19 august 2016. [Online]. Available: http://www.iei.illinois.edu/assets/documents/rules-of-road.pdf. [Accessed 24 August 2017].*
3. *M. K, "Transport and Infrastructure statistics report 2014," October 2015. [Online]. Available: www.cso.gov.bw. [Accessed 01 September 2017].*
4. *Lalitha, K., and G. KEVIN Ruther. "Road traffic accident." International Journal of Research in Humanities, Arts and Literature 2.3 (2014): 83-84.*
5. *O. Ganiyu R, "Development of a Microcontroller-Based Traffic Light System for Road Intersection Control," International Journal of Science & Technology Research, vol. 3, no. 5, p. 5, 2014.*

A. *S. Ms Promila, "Intelligent traffic light and density controller using IR sensors and microcontroller," International Journal of Advanced Technology & Engineering Research, vol. 3, no. 2, p. 5, 2012.*

6. *S. S. Mishra, "Density Based Intelligent Traffic Controller Using IR Sensors," vol. 3, no. 3, p. 5, 2016.*
7. *T. M. Koji Hayama, "A far intrared vehicle sensor for a traffic signal control," vol. 3, no. 2, p. 4, 2006.*

A. *Tarun, "Dynamic road traffic signal control system," vol. 4, no. 3, p. 5, 2013.*

8. *V. P. Faizan Mansuri, "Four-Way Traffic Light Controller Designing with VHDL," Romeo, Ahmedabad,Gujarat,India, 2016.*
9. *S. S, P. D, R. G and G. B, "Design of Dynamic Traffic Signal Control System," International Journal of Engineering Research & Technology (IJERT), vol. 3, no. 1, p. 6, 2014.*
10. *Sodikov, Jamshid. "Road Traffic Accident Data Analysis And Visualization In R."*
11. *J. A, "AzoSensors," 21 august 2014. [Online]. Available: www.azosensors.com/Article.aspx. [Accessed 2017 september 17].*
12. *L. Davidson, "Electronics Hub," 7 october 2015. [Online]. Available: http://www.electronicshub.org/density-based-traffic-signal-system-using-microcontroller/. [Accessed 18 september 2017].*
13. *Henry, "Henry's Bench," World Press, 2013. [Online]. Available: http://henrysbench.capnfatz.com/henrys-bench/arduino-sensors-and-input/arduino-ir-obstacle-sensor-tutorial-and-manual/. [Accessed 19 April 2018].*

14. M. Roger, "The Monday Jolt," 24 october 2012. [Online]. Available: https://makezine.com/2013/04/15/arduino-uno-vs-beaglebone-vs-raspberry-pi/. [Accessed 06 September 2017].
15. D. Albright, "Beebom," Beebom Media Private Limited, 2016 september 2016. [Online]. Available: https://beebom.com/arduino-vs-raspberry-pi/. [Accessed 19 September 2017].
16. Kithion, "learniot," 14 april 2016. [Online]. Available: https://learniot.wordpress.com/2016/04/14/arduino-vs-raspberry-pi-vs-beaglebone-which-one-to-choose-for-iot/. [Accessed 19 September 2017].
17. Prakash, "VILROS," 13 AUGUST 2016. [Online]. Available: https://www.vilros.com/learn/getting-started/raspberry-pi-vs-arduino-vs-beaglebone-whats-difference/. [Accessed 19 September 2017].
18. R. Santos, "Random Nerd Tutorials," 5 DECEMBER 2013. [Online]. Available: http://randomnerdtutorials.com/arduino-vs-raspberry-pi-vs-beaglebone-vs-pcduino/. [Accessed 19 September 2017].
19. L. Robert, "Dspace," 01 may 2016. [Online]. Available: https://dspace.cvut.cz/bitstream/handle/10467/65602/F2-BP-2016-Lexmann-Robert-priloha-4-ArduinoMega2560.pdf?sequence=4. [Accessed 27 April 2018].
20. P. Jackson, "FeaturePics," API, 14 april 2017. [Online]. Available: https://www.featurepics.com. [Accessed 14 september 2017].
21. L. A. K. Luz Elena Y. Mimbela, "A Summary of Vehicle Detection and Surveillance Technologies used in Intelligent Transportation Systems," Federal Highway Administration's Intelligent Transportation Systems Joint Program Office, 2000.
22. Øyvind Nydal, "buildelectroniccircuits," Dahl Technology, 22 august 2014. [Online]. Available: https://www.build-electronic-circuits.com/what-is-a-microcontroller. [Accessed 17 august 2017].