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Design and Development of a Traffic Density Detection and Signal Adjustment System

Dauda Elijah Mshelia, Abdulkadir Hamidu Alkali, Emmanuel Gbenga Dada & Kafilat Ismail

Department of Computer Engineering, University of Maiduguri, Maiduguri, Borno State, Nigeria.
Corresponding Email: daudamshelia@unimaid.edu.ng.com

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ABSTRACT

This research work uses an ultrasonic sensor and sound sensor to develop a traffic density detection and signal adjustment system to control traffic congestion in urban cities. During normal time the traffic signal timing changes automatically on sensing the traffic density at the junction by ultrasonic interruption method. But in the event of any emergency vehicles, priority is enabled from the feedback of the sound sensor and an override is provided by an instantaneous green signal in the desired direction by blocking the other lanes by red signal. Higher traffic density at one side of the junction demands longer green time as compared to specific allotted time. This traffic control system changes the traffic signal junction timings automatically to accommodate movement of vehicles smoothly to avoid unnecessary waiting time at the junction and also reduce noise pollution.

Keywords: Traffic, Density Detection, Signal Adjustment.

1. INTRODUCTION

The daily increase in population and vehicular movement in urban cities has brought about traffic congestion and dreadlocks on our roads and in particular major road intersections[1]. These traffic congestions reaches maximum during peak hours of the day. As a result, traffic bottlenecks occur, vehicles consume more fuel, sound pollution increases and emergency vehicles such as ambulances and fire service can't respond to emergencies promptly. The traffic control system proposed in this study provide an efficient alternative in solving the problems associated with traffic bottlenecks. It gives a cost effective solution in addition to being easy to implement.

The traffic control system automatically changes the timings of the traffic signaling based on the density of vehicles on a particular lane using a traffic detection unit and also gives priority to emergency vehicles with the help of a signal adjustment unit. A microcontroller is interfaced with the traffic detection unit and signal adjustment unit. The ultrasonic sensors serves as the traffic detection and density unit on a particular lane. The ultrasonic sensor works on the principle of the line-of-sight in detecting an object (car in this study). The sound sensors serves as the signal adjustment unit by detecting sound variation from preset threshold. If the recorded sound value from vehicle exceeds the preset value, or is continuously increasing over a chosen period of time, the system automatically detects an emergency vehicle and automates the signaling according to real time environment.

Most traffic intersections are of fixed type, utilizing constant timings for each cycle. Conventional traffic signal systems are time based and cannot be varied as per varying traffic density[2]. Existing traffic light systems have timers that are set at regular intervals. This leads to sound pollution and time wastage for rescue and emergency vehicles such as ambulance, fire service and police to get to their destinations in time [3].

It can be observed that, on a cross intersection, with traffic signal lights programmed for particular time intervals, traffic on adjacent or opposite road is predominantly more. In such a situation programming equal intervals of time for both traffics, attributes to congestion during hours of heavy traffic, making traffic delays on particular lane. Here we propose a system that generates the traffic light signals based on the vehicle density and signal to emergency vehicles, contrary to the norm of allotting the same time intervals to all lanes irrespective of their traffic density or emergency. This type of vehicular traffic signaling system is used in most urban societies [4] as a better solution of traffic bottleneck.

The aim of this research is to design and develop a traffic density detection and signal timing adjustment. The system is limited to a cross intersection (consisting of four roads at right angle to each other) for vehicles only. Also, it is aimed to provide a means of controlling traffic density and signal adjustment so as to change it from red(stop) to green(go) signal at the appropriate lanes for the approaching emergency vehicle. Due to traffic density on a given lane, the time allotted for the lane may be longer than others. Say for instance, during rush-hour to work, the lane leading to work places from residential area will experience higher density. The reverse would be the case at close of work. In such scenarios, it will be logical to allow longer passage time at the junction to depend on the density - the more the density, the longer the passage time. This is so because allocating same time on all lanes will result to congestion on the lane with higher density whereas the passage time on other lanes would be unutilized since there would be almost no vehicles to utilize all the time. To achieve this, a mechanism is implemented in which the time period for passage (indicated by green light) and for stopping (indicated by red light) is assigned on the basis of the density of the traffic present at that instance of time. It is however intended to produce a working traffic light system that can assign priority for more than one emergency vehicle approaching different lanes at the same time.

2. REVIEW OF RELATED WORKS

A programmable logic controller (PLC) based intelligent traffic control system was designed by[5]. The intelligent traffic control system senses the presence or absence of vehicles and reacts according to the sensors output. In this system, the PLC takes data from sensors and checks the priorities. After that, the PLC provides signals as the traffic signals. The intelligent traffic control system works in four different modes as either normal flow, peak time, off time and manual operation. Peak time and off time modes are dependent on the sensors outputs then change the status. The intelligent traffic control system totally depend on the sensors output to take decisions and there is no room for emergency vehicles.

Rotake et al [6], implemented an intelligent traffic signal control (ITSC) system using an embedded system. The ITSC system consist of an AVR-32 microcontroller with inbuilt 8-channel ADC to receive IR-input from IR-transmitter which is embedded in the emergence vehicle. The 8-IR sensors are used to detect the emergence vehicle and open the divider gate to pass emergency vehicle and there after closed the gate. This system used the genetic algorithm to find the traffic flow information at signalized intersection using previous data. Genetic algorithm calculates the green light time for signal depending on the three factors namely: demands, densities, and flow. The transmitter has to be mounted on the vehicle which could be dislodged. The system cannot be used for congestion control.

Basavarajuet al [4], designed a vehicle density sensor system to manage traffic. It was implemented by calculating the density of traffic measured by several sensors along the way. These sensors are placed on either or both sides of the road. The sensors output is fed to a microcontroller which is then sent to a computer for digitization through a serial communication cable. Thus, depending on density of traffic, the timing of traffic lights are appropriately set. The traffic administrator can remotely control the system including updating the timings of traffic light delays through the microcontroller or requesting recorded data for monitoring. The traffic administrator can also remotely erase previous recorded data after analysis. Whenever any obstacle like a vehicle passes between IR transmitter and IR sensor, microcontroller detects and increase number of vehicle count in a recording interval for particular traffic light. The system does not give priority to emergency vehicles.

Gayathri et al. [3], designed a solar powered traffic control system based on traffic density with emergency vehicle alert. The system uses photodiodes and IR sensors which are placed in line of sight configuration across the lanes. The emergency vehicle alert is triggered by RF transmitters which are in the emergency vehicle and the RF receiver is placed at the traffic junction. The circuit uses solar energy in order to keep the traffic lights operating at all times. The major setback of this system is that RF transmitters need to be installed on all emergency vehicles which makes it expensive and unachievable.

Another approach by Udoakah et al. [7], designed a density based traffic light control with a surveillance system. It uses IR sensors at a cross junction to determine the traffic density on each lane. Based on the computed traffic density, time for the traffic to flow on each lane was determined. The limitation of this system was that it accorded priority to lanes with higher traffic density thereby causing more traffic jams in the other lanes. Priority for emergency vehicles is not catered for this in system. The system also uses a surveillance camera was used to capture of vehicle plate numbers of traffic defaulters for storage and law enforcement purposes. The camera uses loop detection methods which are inaccurate and time consuming. Video based monitoring needs more maintenance while loop detection reliability is very low.

K. Shekar et al. [8], implemented a power saver street lighting and automatic traffic management system. To control the traffic, IR sensors are connected on either side of the road of the cross junction. the traffic density is determined and processed by a FPGA and priority is accorded to the higher traffic density lane. If the traffic density is the same on four lanes, then a set of conditions is followed to allocate priority. A power saving mechanisms is achieved by using light dependent resistors (LDR) to detect the absence of sunlight and activation of street lights based on the presence of traffic. Unfortunately, this system doesn't incorporate priority for emergency vehicles.

R. Ghosh et al. [9], designed an auto density sensing traffic control system using an AT89S52. The design was to control the traffic depending upon the traffic density by placing an IR transmitter receivers at both ends of the lanes. The AT89S52 triggers the green light to glow for the lane with higher density. As observed, the system doesn't follow the conventional sequence of traffic lights i.e. red, amber(yellow), green but allocates only red and green. Emergency vehicles are not accommodated for in this traffic system.

According to [10] , traffic density detection can be identified using IR sensors which are placed in particular distances along a lane while sound sensors are used in identifying the amount of sound in an area to help in identifying emergency vehicles. Furthermore, the data obtained from the sensors are stored in a cloud database and a visual graphical visualization of the data is provided to the vehicle user. This is to assist the vehicle user to take alternate routes.

3. MATERIALS AND METHOD

The following sections describe the research process as well as the implementation of Traffic Density Detention and Signal Adjustment. The units include the following:

- ✓ Power supply unit
- ✓ Traffic density detection unit
- ✓ Signal adjustment unit
- ✓ Microcontroller unit
- ✓ Display unit

The block diagram of the design is shown in fig.3.1 below.

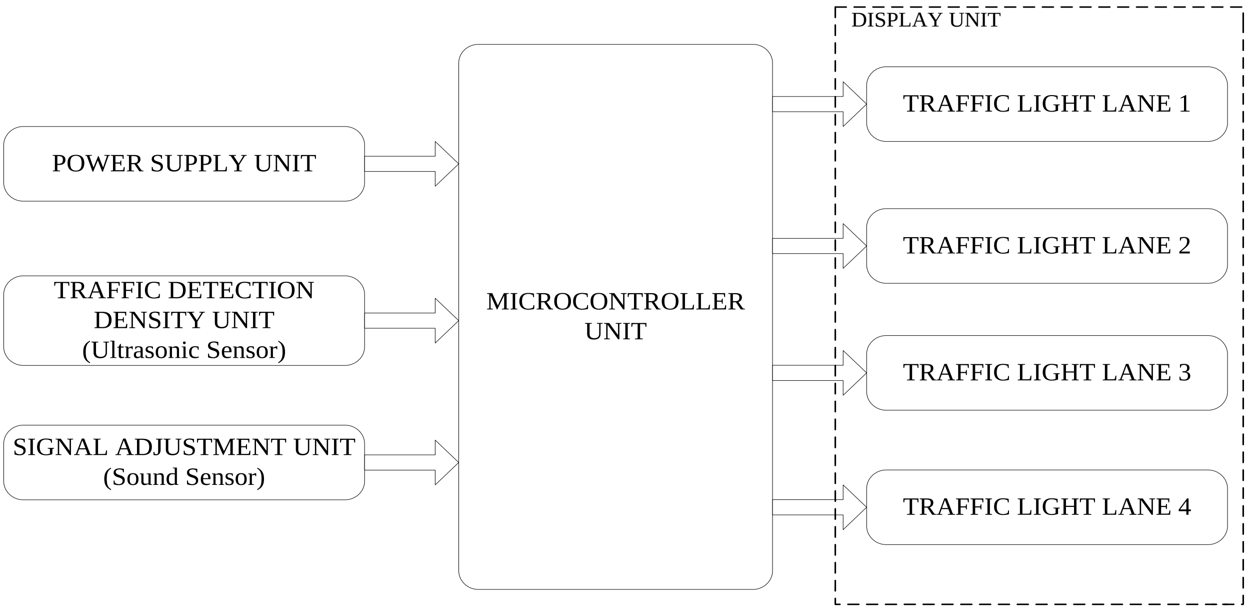

Fig. 3.1: Block Diagram

As shown in figure 3.1, the power supply section supplies electrical energy with a potential difference of 5V to the microcontroller unit and display unit. The traffic density detection unit and signal adjustment unit feed the microcontroller with information via the ultrasonic and sound sensors respectively. The display unit gives out the traffic lights for the four(4) lanes. The road junction layout and possible movement of vehicles for the design is shown in figure 3.2.

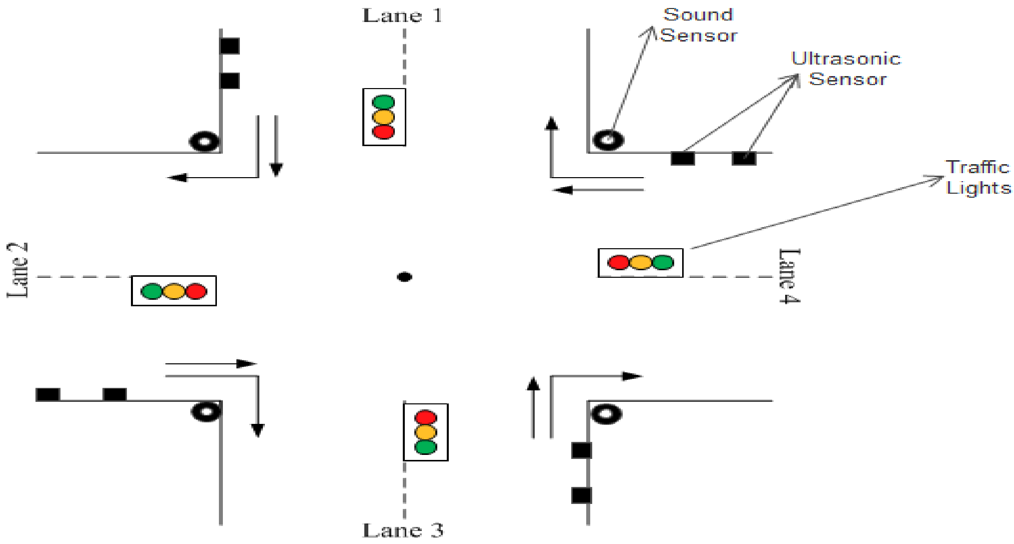

Fig. 3.2: Road junction layout and possible movement of vehicles

3.1 Traffic Density Detection Unit

Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function serves as the traffic density detection unit. It has a ranging accuracy that can reach 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. Figure 3.3 shows an ultrasonic sensor module. It comes with three pins or four pins from which two are for power and ground that are connected directly to the microcontroller and so also the other two are the trigger(transmitter) and echo(receiver) which are also connected to the microcontroller(for three pins the trigger and echo are replaced by a pin called short for signal). The ultrasonic sensor measures an object distance using the equation:

$$\text{distance (m)} = \text{speed (of sound)} \times \frac{\text{time}}{2} \quad \text{...(1)}$$

where speed of sound is 340 m/s.

Fig. 3.3: Ultrasonic Sensor Module

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3.2 Signal Adjustment Unit

The signal adjustment unit consists of a sound sensor used to detect sound from the emergency vehicles. When a sound is being detected on a particular lane, the microcontroller will pay attention to the lane and shut all other lanes for the emergency vehicles to pass. Sound sensor can detect the sound intensity of the environment. The main component of the module is a simple microphone, which is based on the LM386 amplifier and an electric microphone. This is depicted in fig.3.4.

Fig.3.4: Sound Sensor Module

3.3 Display Unit

The display unit is divided into 4 equal units with each unit representing the traffic light for the four(4) lanes. Each unit is made up of common cathode 7-Segment display. It is a Light Emitting Diode(LED) which is a solid state optical pn-junction diode which emits light energy in the form of photons. Fig. 3.5 shows a common cathode 7-segment display.

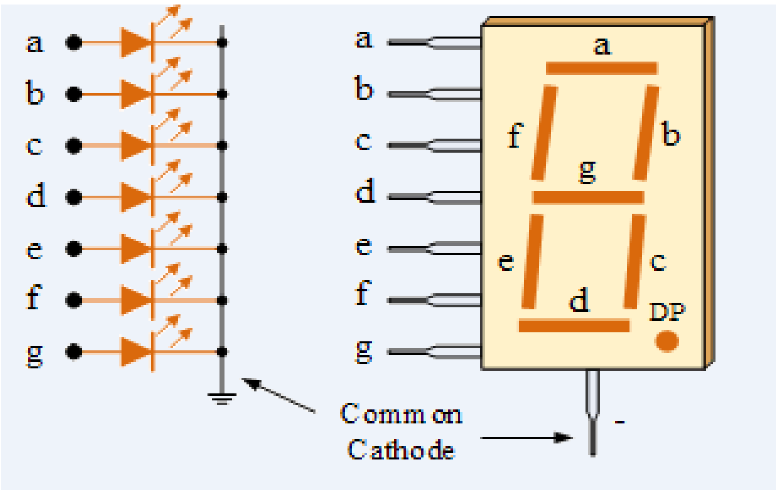

Figure 3.5: Common Cathode 7-Segment Display [11]

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3.4 Overall Circuit Diagram

Overall circuit diagram is a visual display of an electrical circuit using either basic images of parts or industry standard symbol and taking everything into account. The diagram in fig. 3.6 shows the full circuit diagram of traffic density detection and signal adjustment.

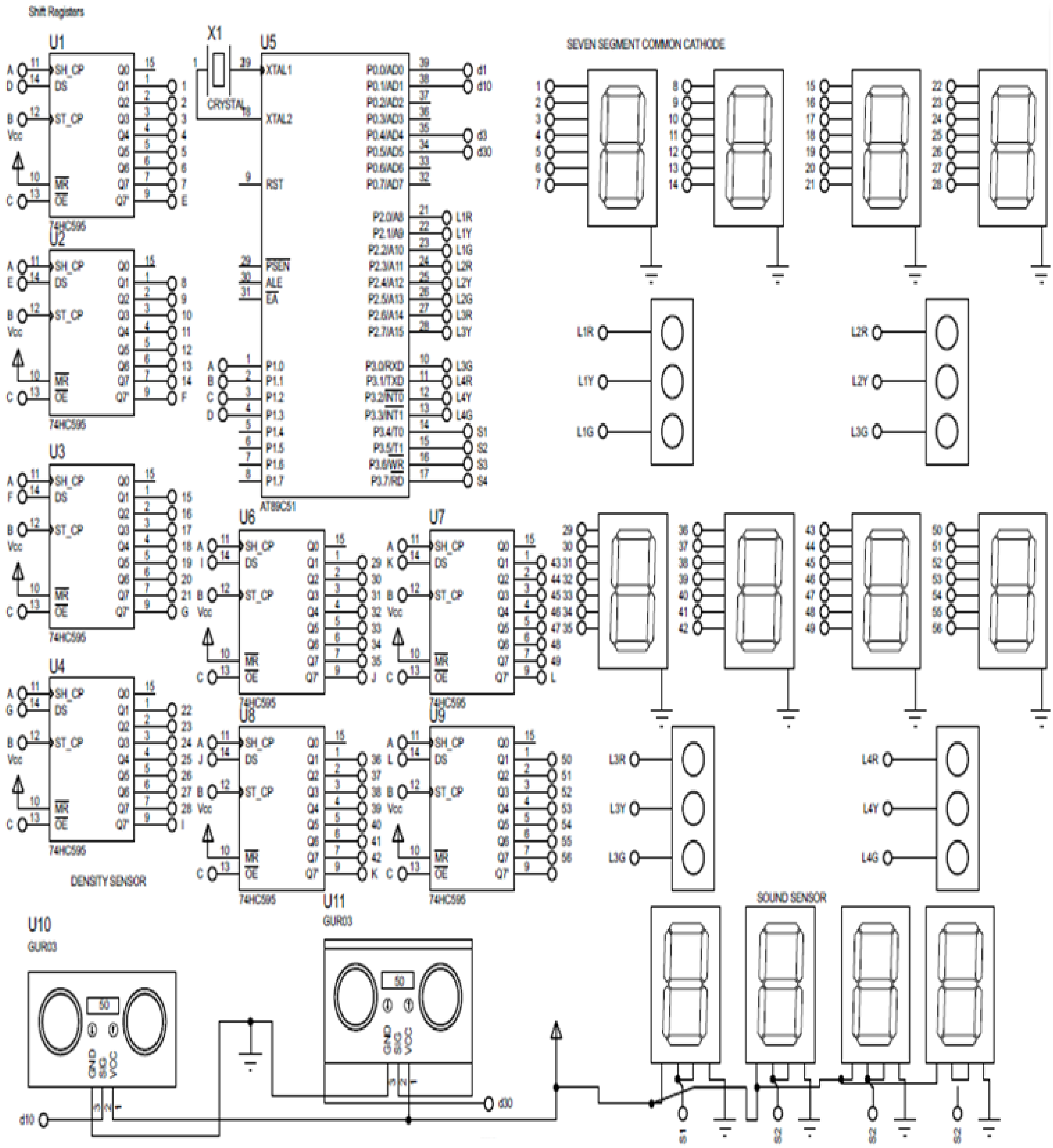

Fig. 3.6: Circuit Diagram of a Traffic Density Detection and Signal Adjustment System

3.5 Flowchart

A flowchart is a diagram that represent algorithm, workflow or process. Fig. 3.7 shows the visual representation of sequence of steps and decisions needed to perform the process.

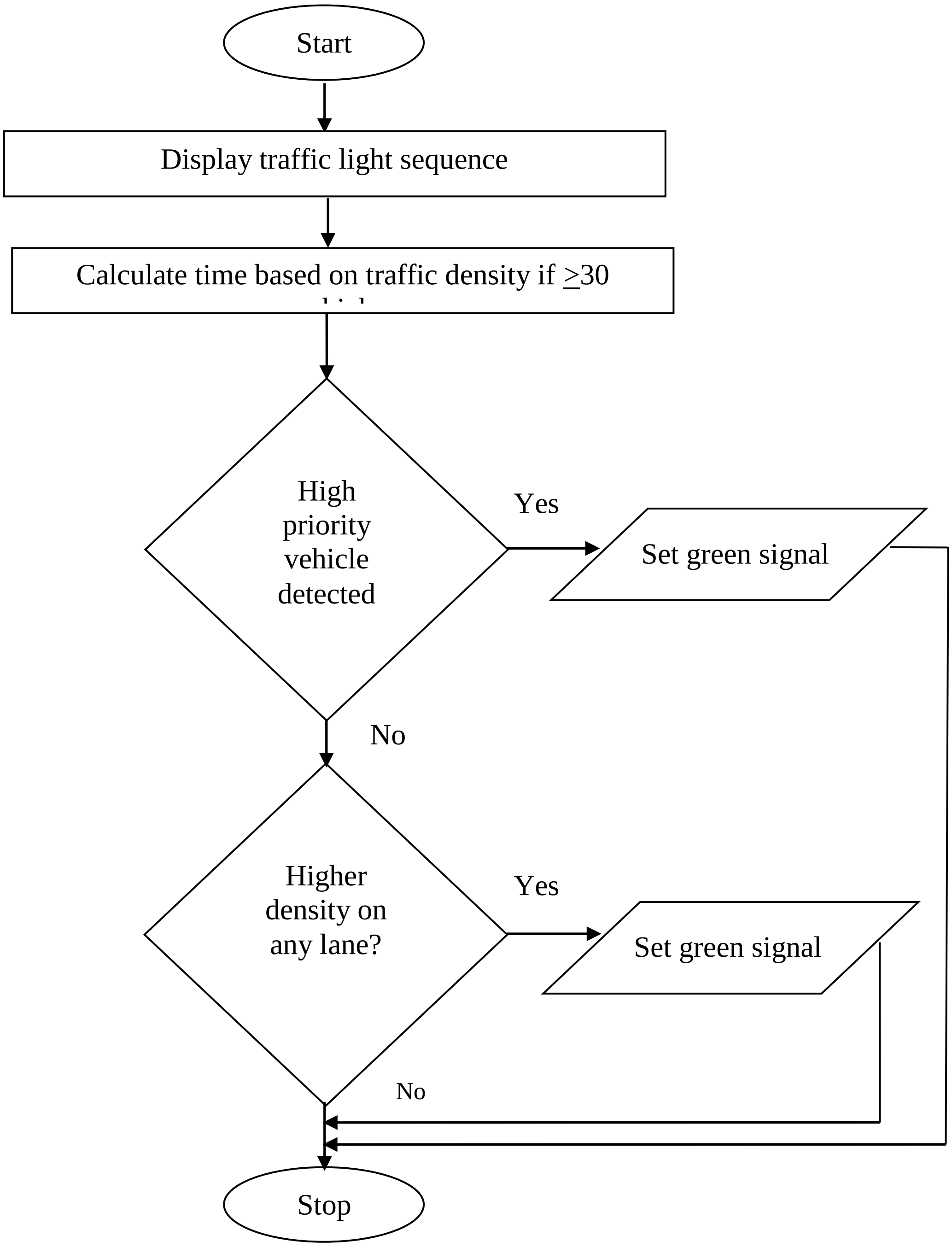

Fig. 3.7: Flowchart of the traffic density detection and signal adjustment

4 RESULTS AND DISCUSSION

4.1 Results

The ultrasonic sensor and sound sensor were tested for sensitivity by using a multimeter and the output is shown in Table 4.1 and Table 4.2 respectively.

Table 4.1: Sensitivity result of the ultrasonic sensor

S/N	Distance (cm)	Vehicle detected
1	0.0	No
2	5.0	Yes
3	10.0	Yes
4	20.0	Yes
5	40.0	Yes
6	50.0	Yes

Table 4.2: Sensitivity result of the sound sensor

S/N	Voltage Level	Sound detected
1	High voltage	Yes
2	Low voltage	No

Furthermore, table 4.3, table 4.4, table 4.5 and table 4.6 show traffic light sequences and traffic light sequence states on lane 1&3 and 2&4 respectively. Table 4.7, table 4.8, table 4.9 and table 5.0 shows traffic light sequence for emergency cases and traffic light sequence states for emergency cases on lane 1&3 and 2&4 respectively.

Table 4.3: Traffic light sequence on lane 1&3

State	TRAFFIC LIGHT LANE 1			TRAFFIC LIGHT LANE 2			TRAFFIC LIGHT LANE 3			TRAFFIC LIGHT LANE 4		
	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green
1	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF
2	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON

As shown from table 4.3, state 1 shows lane 1&3 are the lanes allowed to move while lane 2&4 are on red. Subsequently after state 2 is activated allowing traffic to move on lane 2&4 while lane 1&3 are stopped.

Table 4.4: Traffic light sequence state on lane 1&3

State	TRAFFIC LIGHT LANE 1			TRAFFIC LIGHT LANE 2			TRAFFIC LIGHT LANE 3			TRAFFIC LIGHT LANE 4		
	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green
1	0	0	1	1	1	0	0	0	1	1	1	0
2	1	1	0	0	0	1	1	1	0	0	0	1

Table 4.4 shows the traffic light sequence state of table 4.3 where OFF = 0 and ON = 1.

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Table 4.5: Traffic light sequence on lane 2&4

State	TRAFFIC LIGHT LANE 1			TRAFFIC LIGHT LANE 2			TRAFFIC LIGHT LANE 3			TRAFFIC LIGHT LANE 4		
	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green
1	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON
2	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF

The table above shows the traffic situation when lane 2&4 are on the go and lane 1&3 are stopped while state 2 indicates traffic flow on lane 1&3 immediately after lane 2&4 are red.

Table 4.6: Traffic light sequence state on lane 2&4

State	TRAFFIC LIGHT LANE 1			TRAFFIC LIGHT LANE 2			TRAFFIC LIGHT LANE 3			TRAFFIC LIGHT LANE 4		
	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green
1	1	1	0	0	0	1	1	1	0	0	0	1
2	0	0	0	1	1	0	0	0	1	1	1	0

Here, the traffic light sequence state is shown where OFF = 0 and ON = 1.

Table 4.7: Traffic light sequence for emergency case at lane 1&3

State	TRAFFIC LIGHT LANE 1			TRAFFIC LIGHT LANE 2			TRAFFIC LIGHT LANE 3			TRAFFIC LIGHT LANE 4		
	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green
1	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON
2	OFF	ON	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	OFF
3	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON

In the case of emergency vehicles coming through on lane 1&3 when lane 2&4 are on the go as shown in state 1 in table 4.7, the traffic system immediately changes to state 2 to allow traffic flow for the emergency vehicles and comes back to the former state as state 1 but in this case is state 3.

NOTE: Priority is given to emergency vehicles which arrive at the same time based on the order of the lanes i.e. 1, 2, 3, and 4.

Table 4.8: Traffic light sequence state for emergency case at lane 1&3

State	TRAFFIC LIGHT LANE 1			TRAFFIC LIGHT LANE 2			TRAFFIC LIGHT LANE 3			TRAFFIC LIGHT LANE 4		
	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green
1	1	1	0	0	0	1	1	1	0	0	0	1
2	0	1	1	1	1	0	0	1	1	1	1	0
3	1	1	0	0	0	1	1	1	0	0	0	1

The traffic light sequence state for table 4.7 is given in table 4.8 where OFF = 0 and ON = 1.

Table 4.9: Traffic light sequence for emergency case at lane 2&4

State	TRAFFIC LIGHT LANE 1			TRAFFIC LIGHT LANE 2			TRAFFIC LIGHT LANE 3			TRAFFIC LIGHT LANE 4		
	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green
1	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF
2	ON	ON	OFF	OFF	ON	ON	ON	ON	OFF	OFF	ON	ON
3	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF

In the case of emergency vehicles coming through lane on 2&4 when lane 1&3 are on the go as shown in state 1 in table 4.9, the traffic system immediately changes to state 2 to allow traffic flow for the emergency vehicles and comes back to the former state as state 1 but in this case is state 3.

Table 5.0: Traffic light sequence state for emergency case at lane 2&4

State	TRAFFIC LIGHT LANE 1			TRAFFIC LIGHT LANE 2			TRAFFIC LIGHT LANE 3			TRAFFIC LIGHT LANE 4		
	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green	Red	Yellow	Green
1	0	0	1	1	1	0	0	0	1	1	1	0
2	1	1	0	0	1	1	1	1	0	0	1	1
3	0	0	1	1	0	0	0	0	1	1	0	0

The result here shows the traffic light sequence state for table 5.0 where OFF = 0 and ON = 1.

4.2 Discussion

From the tests and results obtained, the design and development a traffic density detection and signal adjustment is equipped with a sound sensor, ultrasonic sensor, seven segment display, produces a mechanism that gives priority to emergency vehicles whenever it detects emergency vehicle sounds and also detect the density of a vehicles using

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ultrasonic sensor. The proposed system overcomes the problem of traffic jam, noise and delay at intersections as the traffic signal system is introduced. Here the first objective is achieved by developing priority based signaling which helps to give priority to emergency vehicles in the road. Secondly it determines the density of vehicles on each lane and hence calculates the time given for each lane for vehicles to pass for traffic to move smoothly without congestion.

5. CONCLUSION

This paper designed and developed a traffic density detection and signal adjustment using AT89S52 microcontroller as the traffic controller for a cross junction with four(4) lanes. The paper aimed at setting a signal for the traffic lights based on density of vehicles and also triggers a detection unit to adjusts the traffic lights when emergency vehicles approach.

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