Smart traffic controller based on traffic density and prioritised emergency vehicle clearance.

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Abstract. Traffic lights play a key role in avoiding traffic congestion especially in cities in peak time. The traffic that built up in peak hours is the result of mismanagment of traffic in the off-peak hours is the bitter truth. In this paper, the application of the Ultrasonic sensors and micro controller prioritising the flow of traffic in the road based on vehicle density is widely discussed. The emergency vehicles are identified using RFID in the proposed prototype and given the top priority. Portable smart traffic management system is built as a prototype using inductive sensing elements, RF ID and Micro controller. The prototype of the smart traffic control system was built and tested in the controlled scenarios, comprehensive study was made and the results were thus obtained. The obtained results clearly shows that smart traffic controller is highly effective in clearing the traffic compared to the traditional traffic control system.

Keywords: Smart traffic controller, traffic density, micro controller, RF-ID

1 Introduction

The first traffic light system was designed by Lester Farnsworth and installed in salt lake city in 1912 [1]. Over these years, the traffic light system has undergone tremendous changes with the invention of microprocessor in late 1960s , and with the invention of the Light emitting diode in 1980s [1]. The idea of introducing smart traffic controllers to regulate the traffic flow within the city is not new as the engineers around the world are trying to simulate the best possible mechanism to effectively eliminate the traffic congestion. To deal with the dynamic changes in the logistics and considering the cost of implementation, smart traffic controller using microcontrollers and ultrasonic sensors are suggested. Traffic situation was observed around the two major junctions in Jaffna peninsula, Sri Lanka for about a month; hence peak and off peak times were determined. Then the data collection, experimental evaluation and analytics were performed to arrive at the conclusion. It was estimated in 2011 that 32 billion of LKR was lost due to traffic congestions in Sri Lanka which is 1.5% of GDP of the country [2]. Critical amount of resources can be conserved by concentrating on regulating traffic flow in major cities not in Sri Lanka but also around the world.

2 Literature review

It is very much obvious that conventional traffic control system in the modern world also contribute to the traffic congestion in cities and hence need to be replaced with smart and intelligent traffic control system that can take decisions depending on the on-the-spot situations. Advantages of smart traffic system for the developing countries which are struggling with traffic congestion are clearly described by Ranjith.A et al. He points out that emergency vehicle clearance in traffic congestion is a major struggle even in developed countries and suggest that these issues can be overcome by smart traffic control system [3]. But, the cost of such smart traffic control system and requirement of skilled people for the operation and maintenance becomes the downside of the smart traffic control system. In a view to overcome the downsides of smart traffic control system, Mohit Dev Srivastava et al. presented the preliminary steps in the application of a smart traffic light control system based on Programmable Logic Controller (PLC) technology. The density of vehicles is measured using total weight of the vehicles. From the total weight, number of vehicles on the road were obtained [4]. This method is far from being efficient and it is also problematic for a traffic police to observer the whole situation within a stipulated time. Later, Xu Li, et.al in their paper used mobile sensing networks to identify traffic situation of the road and take decision based on the signals transmitted back from those sensing networks [5]. But this method can be slow depending on the process time and mobile network. This system wss also affected by the weather changes. Poor signal level also cause further delay in signal transmission. The complication of this system requires high installation and maintenance cost and a lot of hardware implementations. In an attempt to solve this, C Barz et al presents the smart traffic control system that can function with PLC using various sensors [6]. The entire traffic control system coordinates the traffic flow, providing a path which depends on coordination of combination of sensors and functions of radar to inform the traffic situation. But using radar for smart traffic control in every junction is practically impossible in developing countries. To overcome this challenge, Ashit S Chitta et al proposed a design of smart traffic system using ARM LPC 2148 microcontroller. CC2500 RF tags is used to identify the emergency vehicles. GSM module is used to communicate with controller through mobile networks. In the conventional traffic control system, congestion can be caused by large delay in red-light. The ARM microcontroller-based traffic control system propose a traffic light control and monitoring system that can reduce the traffic congestions, caused by traffic lights. This system works based on IoT and is controlled by ARM7 micro controller [7]. At the same time, Roxanne Hawi et al describes about insufficient space and resources to build new roads with the increase in number of vehicles. But in developing countries, it is difficult to accomodate growing demands of vehicles within limited resources, so some solutions are required to avoid traffic congestion [8]. One such upcoming solution is to involve smart traffic control systems (STCS) to make traffic congestions pretty less. These systems use real time data to eliminate traffic congestions and improve traffic management. Nikhil R.Chitragar et al, in their paper, mentioned that traffic signals are the most suitable method of regulating traffic in a junction. Current traffic system fails to control the traffic congestions effectively. When a particular road has got more traffic congestions than the other roads, the Smart Traffic Control using PLC calculates the vehicle density in a particular road and then the system decides to control the signal depending on the priority.The above proposed method has number of flaws including sensors positioning and lack of planning for emergency vehicle clearnce system [9]. Rajeswari S et al in their research work proposed installing RFID to every vehicles therby counting the number of vehicles that passes the junction and therby determing which lane to be given priority. Ambulance also tagged wiith RFID and detected by the controller yet the biggest drawback is installing RFID to billion of vehicles is ideal for a prototype but is not feasable and also complicate the controlling process [10].Priyanka sharma et al in their paper proposed to reduce the traffic congestion on the road by traffic diversion system based on weighted data [11]. This work is done based on weight sensing sensors whose output will be feed to a PLC, which in turn will control the traffic light switching decision. According to this method, measuring the weight along the road is not possible. Only a short distance of the road can be measured. At the same time, weight measurement technique of vehicle is very complicated because of the measuring mechanism and high initial cost. Hence, Muhammad Arshad Khattak in his paper describes about the use of photo electric sensors to measure the density of vehicles [12]. If the number of vehicles are high, the density of light is low. But this idea of measuring the light density is inaccurate, since the sensor works properly only if it is close to the vehicle and this system will not work in the night time. This system is also affected by the climatic changes. Sultane Shubham et al describe about the manually operated emergency vehicle clearance system which may results in number of human errors [13]. So, an automatic system that can identify the emergency vehicles and clear the path for emergency vehicles need to be identified. In the mean time, Wei-Hsun lee and Chi-yi Chiu described about building a cloud based advanced traffic controller for a smart city using emergency vehicle signal pre-emption (EVSP), Public transport signal priority (TSP), Adaptive traffic signal control (ATSC), eco-driving supporting and message broadcasting [14]. However, this system is very complex. Integrating this proposed system with IoT and exisiting systems in developing countries like Sri Lanka is almost impossible. Similarly, Hitiyaremye et al, in their research work accept the failure of the traditional traffic light system and agree the need of smart traffic system to eliminate the delays and traffic congestions. They propose a system in which vehicles communicate with each other using Vehicle to infrastructure V2I, vehicle-to-vehicle V2V and vehicle-to-Device V2D communication protocols [15]. The proposed system as described is complicated and does not comply with the existing infrastructure available in Sri Lanka. In an attempt to improve the efficiency of smart traffic controller, Roxanne hawi et al, describe about involving fuzzy expert system FES and artifical neural network ANN [16]. The proposed system feed the vehicle counts obtained using RFID to the system. The decision to operate the traffic lights is obtained based on the output of the processed data using the FES and ANN algorithms. At the same time, Sakuna prontri et al, in an attempt to solve the existing traffic congestion in the smart cities proposed fuzzy learning vector quantization FLVQ and Fuzzy learning quantization particle swarm optimization FLVQ-PSO based smart traffic controller [17]. The proposed algiorithms learn and then forecast the traffic flows in the streets and make decisions based on the predicted outcomes. The proposed algorithm is fexible to the changing environment and hence proved to be effective. Yet, the fuzzy and neural algorithms are complex to design and implement. Khaled kamel et al in their research work described the importance of the effective parking management system, lack of which also contribute significantly for chaos and congestions in the city traffic. This paper describes about parking slot identification using mobile-net classifier which is a light weight deep neural network [18]. Subarna shakya in his research work analyse the novelty about integrating the transportation using edge computing to establish collobrative services and preserving individual privacy. The concept of integrating the services in a smart city is also a good way to reduce traffic in a city [19]. The existing methods discussed in the literature are constructed using artifical algorithms (Fuzzy logic, FLVQ and ANN) and PLC, which are complex to design and implement in developing countries with limited resoureces and technical expertise.

The proposed method in this current research work though utilises autonomus algorithm, it is implemented using simple and easily available micro controller AT mega 328p-pu. It detects the density of the vehicle using ultra sonic sensors placed at regular intervals and the emergency vehicles are identified using RF ID implemented in paticular vehicles. It aims at providing a smart, simple solution by develping a system that can be integrated with the existing infrastructure.

This research paper is written in a way that, section one introduces the current traffic scenario, section two as the detailed literature review of the steps taken by different authors to solve the traffic congestion issue. Section three describes the current system designed and developed in this research work to solve the above mentioned issue. Section four explains the working methodology of the developed system, section five analyse the results obtained and the last section metion about the conclusion of this research work.

3 System description

At thirunelveli junction and ariyakulam junction, Jaffna, Srilanka, usually in peak hours following scenario was observed for a long time. These are the two crucial junctions which expereience maximum traffic in Jaffna Peninsula always. The usual fixed time intervals of traffic lights cause long queues and finally to traffic jam. Based on the data shown in Table 1 and 2, there are some irrelevant patterns were identified. These data proved the need of smart traffic control system in high traffic roads.

The following data is collected for a week in the city of Jaffna on high rush week-days average is taken, projection is obtained for the month and verified. Jaffna town, being a regional hub comprises of number of schools, banks, government and pri-vate offices draws huge amount of people on weekdays. Weekends usually record less traffic and hence ignored in general. When one observing the data given in table 1 and 2 closely, the problem with the existing system can be captured. For example, in Table 1, for day 5, when 27 vehicles are waiting in road 1 for 72 seconds, the green light is on for 15 seconds just for 11 vehicles in road 4.

Table 1. Average of vehicle density per rotation of signal light at thirunelveli junction, Jaffna, Sri Lnka.

	Duration for which lights are on	Number of vehicles				
		Dav 1	Day 2	Day 3	Day 4	Day 5
Road 1	72s (Red)	13	16	29	18	27
Road 2	52s (Red)	4	11	18	5	7
Road 3	32s (Red)	12	6	7	4	3
Road 4	15s (Green)	11	25	30	9	11

Table 2. Average of vehicle density per rotation of signal light at ariyakulam junction, Jaffna, Sri Lanka.

	Duration for which lights are on	Number of vehicles				
		Day 1	Day 2	Day 3	Day 4	Day 5
Road 1	72s (Red)	27	42	19	22	27
Road 2	52s (Red)	10	17	39	16	9
Road 3	32s (Red)	2	6	21	7	11
Road 4	15s (Green)	6	3	6	11	7

Same pattern can be observed in Table 2; day2. When 42 vehicles are waiting in road 1 for 72 seconds, the green light is on for 15 seconds just for 3 vehicles in road 4. This set up need to be revised considering the rush created by number of vehicles. It is discussed in detail in this paper.

4. Research Methodology

Fig. 1 shows the selected 4-way junctions taken for study (thirunelvely junction and ariyakulam junction). These two were the junctions where traffic lights were installed at the initial stage when traffic lights were introduced to Jaffna population. This shows the importance and rush on these particular juctions. Fig.2. shows the flow chart of the operation of proposed smart traffic controller. The switching decisions namely normal mode (time based control), auto mode (densıty based control) and emergency mode are made based on the output of the sensors as depicted in the flow diagram. Fig. 3 illustrates the block diagram of proposed density based smart traffic control system using ultra sonic sensors and RFID as input elements and micro controllers as controlling element. The block diagram of traffic controlling system is designed for a four-way junction. This system has the following add on features comprising of four parts namely compilers & ultrasonic sensors (for vehicle density measurement), microcontrollers & RF ID modules (for emergency vehicle identification), control unit and traffic signal lights. Vehicle density measurement system has controlling micro controllers one for each road. The working principle of vehicle density measurement system is as follows. Each micro controller circuit has 2 ultrasonic sensors whose arrangement is in one side of the junction and these two sensors are decided to be fit at 20 m distance. If the queue of vehicles is in the range of 0 – 20 m, then one ultrasonic sensor will be activated and will be fed to the micro controllers.

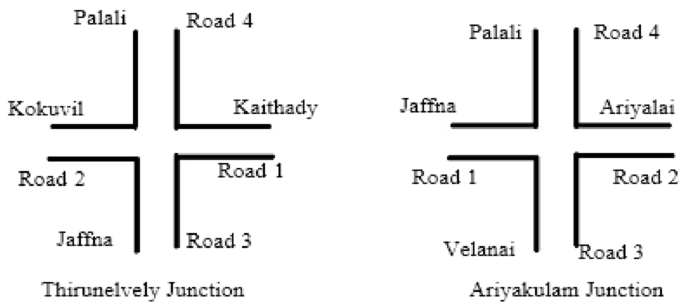

Fig. 1. Selected four-way junction for study

But if the queue of vehicles exceeds 20 m, then both ultrasonic sensors will be activated and will be fed to the micro controllers. In this case, Micro controller works as AND gate. If both signals are logical 1 then compiler will generate logical 1 as a signal and send the signal to Control system. Through the relay the micro controller output signal is stepped up from 5V DC to 24V DC since the output signal of the compiler is 5V and input signal of selection micro controller is 24V and also the relay work as a switch. If both signals are not logical 1, then compiler will give

logical 0 as signal to the selection micro controller through the relay and at this situation the relay will not step up the output signal from 0V to 24V. In this situation, micro controller will not receive logical 1 as signal so the micro controller will not trigger to auto mode. If it triggers only, it will change the signals based on 64 combinations. In this manner, if the queue of vehicles exceeds 20 m, that road would be given priority to green signal. Once the range of queue of vehicles decreases below 20 m, the next road which have the queue of vehicles above 20 m would be given priority. If no road has length of queue of vehicles above 20 m, then the signal system works normally without consulting this newly introduced system. Higher priority is expected to be given to emergency vehicles, if there is one entering into the range. Briefly the operation of traffic controller under auto mode can be explained as, when the vehicle density is identified using the ultra-sonic sensors, it would be fed into the system. The controller decides which road to be given priority and duration of green signal for that particular road is more, until the traffic is cleared up to the threshold level. Once the density of that road falls below the threshold level, the road with second highest density would get the next priority and gets the chance to open up. Fig. 6 shows the circuit diagram of ultrasonic sensor in section 4.3, the algorithm for the above mentioned scenario is shown in section 4.4 and the hardware componets utilized in the prototype building is listed in table 3.

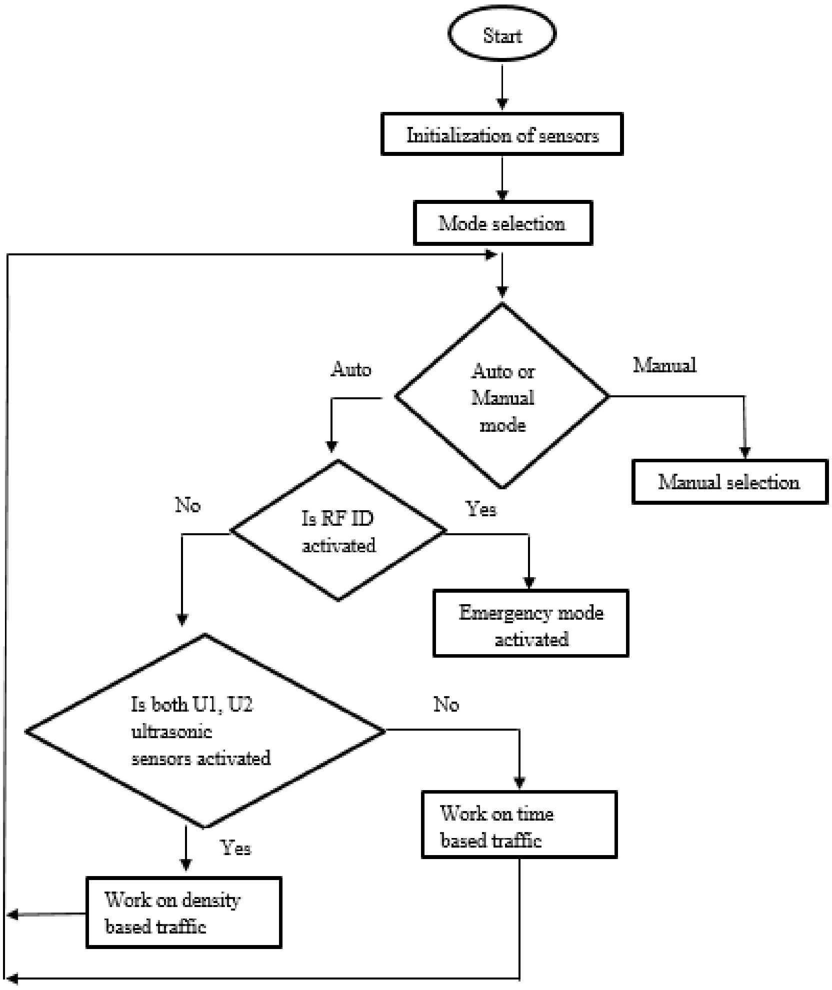

Fig. 2. Flow chart showing the operation of proposed smart traffic controller

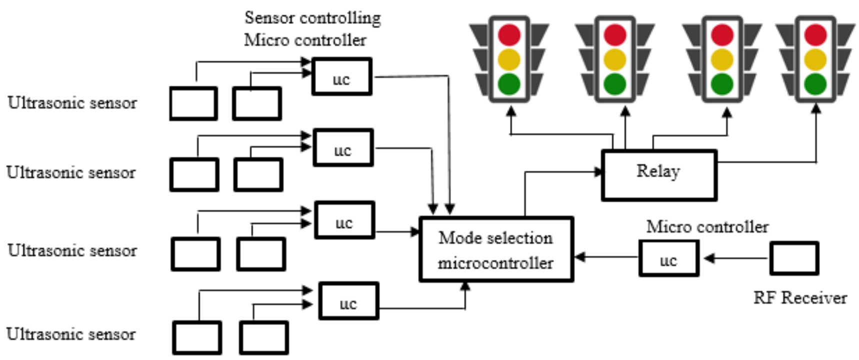

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Fig. 3. Block diagram of overall function

Table. 3. Specifications of hardware components utilized in the proposed system

Hardware components used	Specification
AT mega 328p-pu micro controller	28-pin AVR Microcontroller Flash program memory: 32 Kbytes EEPROM data memory: 1 Kbytes SRAM data memory: 2Kbytes I/O pins: 23 Timer: Two 8-bit / one 16-bit
Ultra sonic sensor HC-SR04	Working voltage : DC 5V Working current : 15mA Working frequency : 40 Hz Max Range : 4m Min Range :2cm
RF ID sensor and tag MFRC-522	Operating voltage : 2.5 V to 3.3 V Communication protocols : I2C, SPI,UART Data rate : 10 Mbps Range : 5cm

controller works in the emergency mode; the operations take place as follows. RFID, according to this research work, fixed to the emergency vehicles are activated when the emergency vehicles enter the junction. The RF Receiver shown in fig 4 and fig 5, pick up the signal and the following algorithm gets activated to give priority to the emergency vehicles. The emergency vehicles include ambulance, fire brigade and VIP vehicles.

4.1 RFID Circuit Diagram

RFID circuit used for prioritizing the emergency vehicle clearance along with the algorithm is shown in Fig. 4. Fig. 5 shows the hardware of the RFID system.

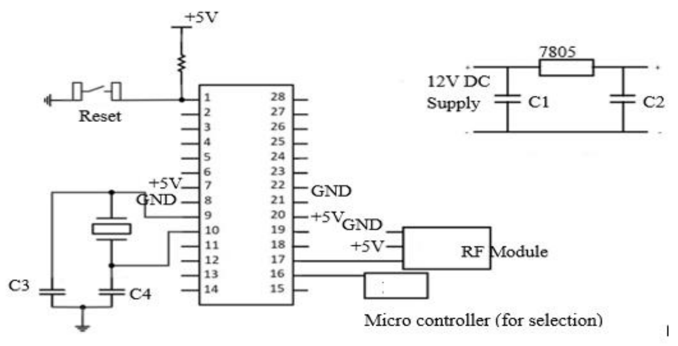

Fig. 4. RFID sensor circuit diagram

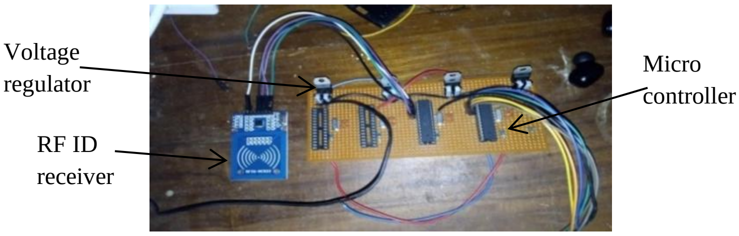

Fig. 5. RFID Hardware implementation

4.2 Algorithm when RFID is activated by an emergency vehicle on road-1

When RFID receiver is activated by the emergency vehicle approaching the junction on road 1, and if green light is ON on road 1, it'll remain green till the emergency vehicle leave the range of RFID. Otherwise, in order to give priority to road 1, green lights on all other roads than road-1 turns to yellow in order to switch to red, while red light on road 1 turns to yellow in order to switch to green.

Output: Green light on the road 1
    If (green light already on in road 1)
    Continue (green light until emergency input is on)
    Else
    Change (red in road 1 to yellow)
    Change (green in any other road to yellow)
    Turn on (green light on road 1 & red light in all the other roads)
End

4.3 Ultasonic sensor circuit diagram

Ultrasonic sensor circuit diagram used for prioritizing the road depedning on the traffic density is shown in fig. 6 and the algorithm is shown in section 4.4.

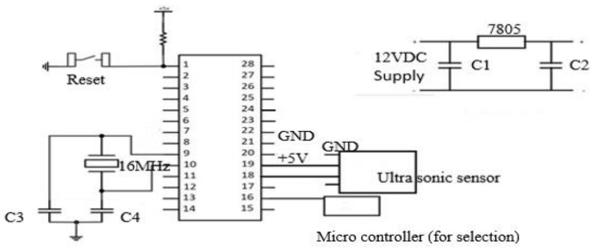

Fig.6. Ultrasonic sensor circuit diagram

4.4 Algorithm for the working of Selection micro controller based on the output from the ultrasonic sensors

```
    duration = pulseIn(echoPin, HIGH);
    distance M = (duration * 0.0340 / 2)/1000;
    if (distance M&lt; 3)
    {digital Write (pin, LOW);
    }
    else
    {Digital Write (pin, HIGH);
    }

    Input: ultrasonic distance is less than 3m
    Output: Green light on the road 1
    If (green light already on road 1)
    Continue (green light until emergency input is on)
    Else
    Change (yellow to other roads than road 1)
    Turn on (green light on road 1 & red light on other roads)
End
```

Thus the signal lights are switched on based on to the selected mode by mode selection micro controller and is shown in Fig. 8. These data are shown in Table 4 briefly.

5. Results and discussion

1. In case if there is no emergency vehicles in the proximity of the junction and none of the ultrasonic sensors are activated, then no outputs can be obtained from the sensors to be fed to the controller, none of the roads will get the priority and the system continue to work as the time based traffic control system.

2. In case no emergency vehicles enter the junction and only one ultra sonic sensor is activated , still no roads will be given any priority. The traffic control system will continue to function as time based traffic control.

3. In case, both the ultra sonic sensors are activated simultaneously and no emergency vehicles are in the proximity, then time based traffic control system is interrupted and priority of clearing the traffic is given to the particular road which has high traffic density.

4. Incase emergency vehicles are near the junctions, time based traffic control system and priority based traffic clearance are interupted and priority is given to the road with the emergency vehicles.

Table.4. Functioning of the proposed system

Range of Vehicle	Emergency vehicle	Sensors activated	Sensor controlling Microcontroller	Mode selection Microcontroller	Road priority
0 -20 m	No	0	0	0	No
0 – 20m	No	1	0	0	No
0 – 20m	No	2	1	1	Road get High priority
0 – 20m	Yes	0	0	1	Road with emergency vehicle get high priority

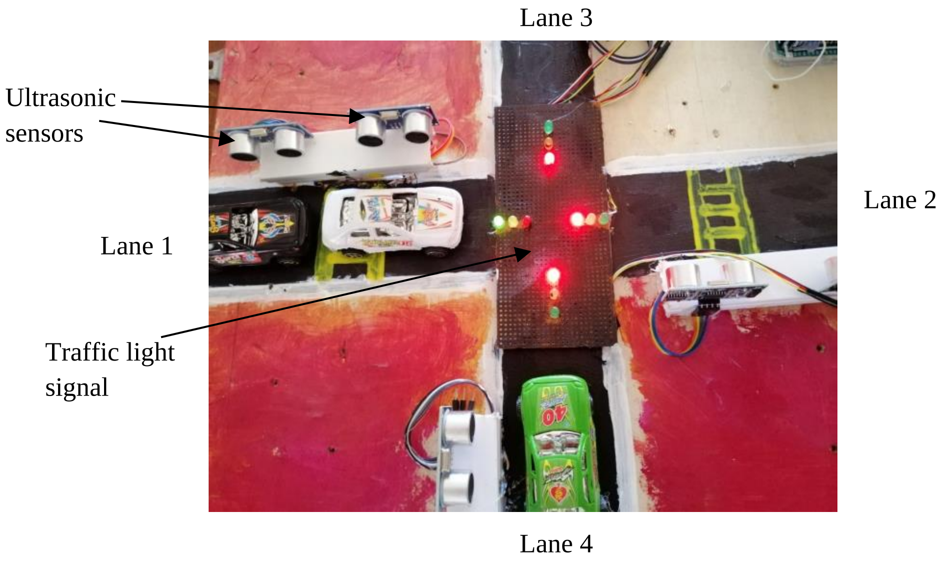

Fig. 7. Working example

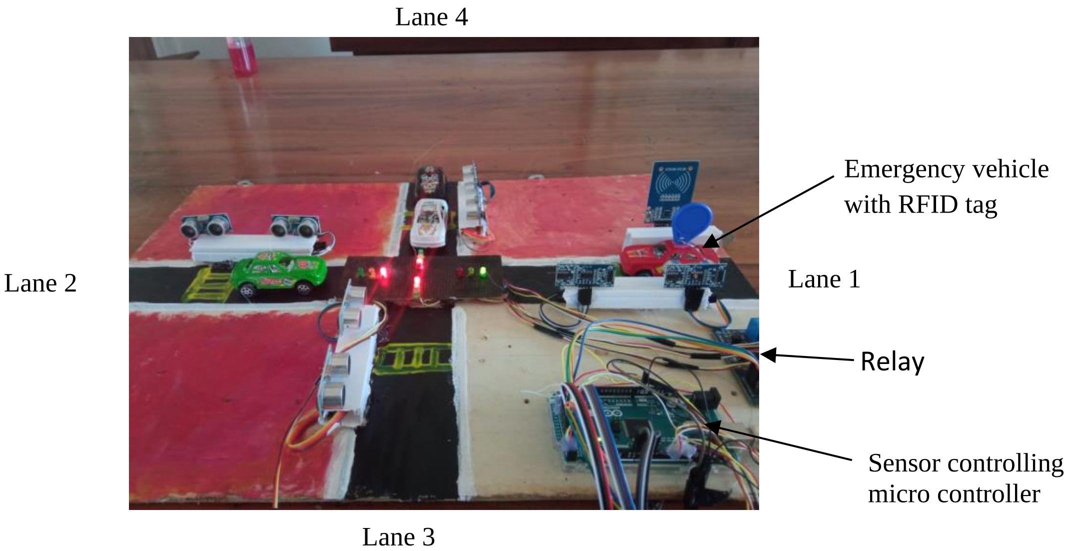

Fig. 8. Working example

6. Conclusion and Future Scope

The prototype of smart traffic light system was designed as shown in Fig. 7, in which if both sensors are activated by the line of vehicles then that particular lane gets the highest priority than other lane, as in other lanes the traffic density is comparatively less. In practical application the two sensors are kept 20m apart and depeding upon the requirement more number of sensors can be incorporated in between. When an emergency vehicle having RFID installed in it approaches within the detectable range of the sensor as shown in Fig 8, that particular lane gets the top priority irrespective of the traffic density in the other lanes. Once the emergency vehicle passes the junction, again the controller would be switched to the density based operation. Thus the above protype tested internally in the electrical laboratory and redundancy that occurs when using time based algorithm is effectively eliminated and therby incresing the efficiency to a greater extent.Yet the real efficiency can be derived only from real time application by incorporating the proposed prototype in the existing traffic light controller. The sensor unit is synchronized with micro controller to enhance its endurance and performance. This prototype of smart traffic controller can easily be attached with any real time four-way traffic signal system simply disengaing the existing controller and connecting the proposed smart controller with ultra sonic sensors placed on proper intervals on the road. The controller is designed as a prototype to synchronize with the existing models. Ultra sonic sensor was used to provide better output while identifying the density of vehicles. Increasing the number of sensors may help to improve the identification of accurate density of vehicles. Another added enhancement of this system is emergency vehicle identification. The Emergency mode of operation is designed using RF ID for robust and unique identification of emergency vehicles. Using the proposed method of controlling traffic, based on the traffic density proves to be smart and effective way to avoid traffic congestion.

However, permission to test the prototype on the real time system is yet to be approved and hence it is included in the future scope. Smart traffic control system will include the break down mode in the future to ensure regular flow of traffic even if the traffic control signal failed to operate properly due to various reasons including power failure. Synchronising the smart traffic controller over the IoT might allow different smart traffic controllers interact with each other for communication and further effective control.

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