Proposed Framework to Manage Traffic Signal Efficiently and Automatically

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ABSTRACT

The rising number of vehicles on road is leading to massive congestion and several hours of Traffic-Jams, especially in metropolitan cities. Congestion is a difficult issue to deal with as the commuters need to wait for traffic signal to go green. Therefore, a good traffic management is the immediate urge of the day. It is essential to have automatic traffic management signals that helps in organizing the flow of traffic on the roads, which will provide safety and assures smooth flow of traffic on the roads.

This paper has been written with the quest to find a solution to automate the traffic signals using Ultra-Sonic sensors. In this paper, the authors have demonstrated how using ultra-sonic sensors will help in evaluating the traffic density and managing the traffic signals. The sensors are used to map the traffic density and then automate it using a program which will automatically sort the data coming from the sensors in a descending order and based on the highest and lowest densities the lights will be allotted to the selective lanes. This will not only make it hassle free to manage traffic but also avoid massive traffic jams in the city. This will entirely work on the solar energy, making it cost efficient and energy saving for a green and smart city.

Keywords: *Ultra-sonic sensors; Traffic management system; Traffic efficiency*

1.0 Introduction

Initially, the traffic management was majorly handled by traffic police especially on the roads with peek pressure and no traffic light functioning due to power cut. After a proper training using signs, gestures and whistle the cop used to manage the traffic. Later traffic lights were connected with power backup to manage the power cuts. Now in various parts solar power is used to manage the traffic signals. The traffic signals now work 24*7 without fail; with proper power backup. Traffic signals are the control devices which alternately direct the traffic to stop or proceed at intersections using red (stop), green (go) and yellow (anticipation of red light, slow down for stoppage). [7]

1.1 Conventional traffic management system

The system used is semi-automatic i.e.: the police controller on the duty had to change the time limit manually every time there's a change in traffic density, or during a holiday the limit has to be set at a very minimum point.

The policemen also switch the system to standby mode at midnight in which the yellow light blinks so that the driver looks carefully and then pass, although this system is very prone to accidents.

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1.1.1 Classification of traffic signals- [14] [7]

The signals are classified into the following types:

- **Fixed Time Signals**-Depending upon the traffic intensities, the timings of each phase of the cycle is predetermined. The draw backs of this signal is, the cycle of red, yellow and green goes on irrespective whether on any road, there is any traffic or not. Traffic in the heavy stream has to stop at end phase.

- **Manually Operated signals**- In these types of signals, the traffic police watch the traffic demand from a suitable point during the peak hours at the intersection and varies the timings of these phases and cycle accordingly.

- **Traffic Actuated (automatic) Signals**- In these signals the timings of the phase and cycle are changed according to traffic demand. They use computer, called a "signal controller," which determines the timing and even the sequence of traffic movement for each phase and cycle, based on what vehicles or pedestrians are detected at the intersection.
    - In semi-actuated signals, the normal green phase of a traffic stream may be extended up to a certain period of time for allowing the vehicles to clear off the intersection.
    - In fully-actuated signals, computers assign the right of way for the traffic movement on turn basis of traffic flow demand.

- **Adaptive Signal Control Technology** (ASCT) adjusts the timing of red, yellow and green lights to accommodate changing traffic patterns, ease traffic congestion, and improve safety. [1] [2] [13] [16]

2.0 Related Work/ Review of Literature

Ultrasonic sensors work by emitting sound waves at a frequency too high for humans to hear. Then they wait for the sound to be reflected back, calculating distance based on the time taken. This is similar to how radar measures the time it takes a radio wave to return after hitting an object. [5]

While radar, or even light-based sensors, have a difficult time correctly processing clear plastic, ultrasonic sensors have no problem with this. In fact, they're unaffected by the color of the material they are sensing.

On the other hand, if an object is made out of a material that absorbs sound or is shaped in such a way that it reflects the sound waves away from the receiver, readings will be unreliable.

If one needs to measure the specific distance from your sensor, this can be calculated based on this formula:

Distance = ½ T x C

(T = Time and C = the speed of sound)

At 20°C (68°F), the speed of sound is 343 meters/second (1125 feet/second), but this varies depending on temperature and humidity. [3]

Specially adapted ultrasonic sensors can also be used underwater. The speed of sound, however, is 4.3 times as fast in water as in air, so this calculation must be adjusted significantly. [12]

Ultra-sonic sensors are used by traffic management system in numerous ways to manage traffic. For instance, it is used for parking, are also used to avoid accidents, in case of red light still any driver drives the car will lead to accident. Ultra-Sonic sensors with cameras are used for challan. [15]

Ultrasonic sensor functions originally to measure the distance and the speed of vehicles to determine the congestion on road. In general, ultrasonic sensors will fire ultrasonic waves into an area, after the waves touch the target surface, the target will reflect back the wave.

The solutions provided by many authors over the internet and in events such as hackathons include various other technologies to counter this traffic condition in cities,

The one which was awarded in the hackathon 2019 consist of camera modules in which the density was picture based and the footage of the traffic was sent to the servers which was then processed by the algorithm to detect vehicles and according to which estimating the density in each lane of the junction.

But this system has its own drawbacks such as: -

- Expensive to install and maintain
- Uses more energy due to many camera modules
- Cloud storage is expensive
- Has climatic restrictions such as visibility (in dense fog or heavy rains visibility decreases drastically)

The other solution proposed by a group of students was to use EMP (Electro-magnetic Pulse) which will run along each lane and emit a magnetic field in which if any metallic object (vehicles) approaches the magnetic field will be disrupted and it will be counted as an element for traffic and then the data will be mapped and the lights will be allotted accordingly, but this system has some fatal flaws: - [2][3][8]

- Electromagnetic pulses can damage or can permanently destroy electronics, which nowadays every vehicle is equipped with.
- Many people having metallic implants can also be affected by these magnetic pulses which is lethal.
- This system will consume too much electricity and will fall short of solar energy during rainy days or at night.
- Small metallic elements (debris) can be collected on the poles of the electromagnet which can be dangerous for the rubber tires and for general public too.

In 2019, The Smart India Hackathon hardware edition held at Reva university. The term for smart traffic system came into light by the winning team by using IOT (internet of things) and cameras to see what kind of vehicles are on the roads and the density of traffic. The whole idea was supported by the raspberry pie (Raspberry Pi is a series of small single-board computers developed in the United Kingdom by the Raspberry Pi Foundation in association with Broadcom). This collected data was to be uploaded to the cloud servers enabling smart communication.

This proposed system bagged the first place but this has some major drawbacks-

i. The estimated cost of installation and maintenance cost of cameras and servers was too much. In fact, 5 cameras per lane were to be used, which makes it 20 cameras per junction and installing them at such large scale looked very expensive.
ii. These cameras can easily be destroyed by the course of nature and had estimated life of 5 years or so maintain them will be a big task for the traffic department.
iii. The third and the most important one was the visibility, as fetching data from the visuals through the camera, weather can be a big problem for these cameras for e.g.: - during rainy days the visibility decreases and during winters fog can create total blind spots for these cameras resulting in inaccurate readings which may lead to mismanagement of the traffic again.

The proposed solution faced major drawbacks. It is not feasible and is not up to the mark when put through a practical approach.

i. Manual operation of traffic signal when there's a change in traffic density (including the info of the interview)
ii. Insufficient distribution of time across all lanes resulting in traffic jam
iii. Any technical issues in the traffic signals isn't reported and fixed for days resulting in accidents and manual policing to maintain the traffic flow.
iv. Proposal of installing camera-based traffic mismanagement system which uses much more storage and energy and is expensive to maintain and install.
v. drawbacks of the camera-based system (visibility, weather conditions, maintenance, installation cost)

3.0 Research Objective

i. To find gap in existing Traffic System
ii. To automate the traffic system which can handle the congestion and can adjust the traffic lights
iii. To propose a model or framework which will adjust the light signal according to the traffic density

4.0 Research Methodology

An interview with an on duty traffic police in Delhi, India, was conducted to know more about the existing traffic system. The interview was open-ended and this was brought to the notice that nothing is automated yet. The latest upgradation in Delhi traffic management was the addition of solar panels.

The traffic police intimated that during the rush hours with change in traffic density, the man on duty has to manually change the time intervals of all the lanes for smooth flow of traffic. This manual feeding of the time intervals is still inappropriate and doesn't solve the problem of assigning the time according to the lane traffic. The roads having less traffic still gets the same interval, as the lane having much more traffic density which makes it difficult to manage the flow of traffic efficiently. These insufficient time gaps create traffic jams due to the lanes having heavy traffic density doesn't get enough time to be cleared.

Even if the there is any technical problems in these traffic signals the fixing and reporting takes at least 1 week to come into action and fix the problem. Which makes that region an accident-prone area when there's no policemen on duty or during late night hours when the traffic is less and people try to jump the signals, which make them prone to some accident.

In the conventional traffic management system, traffic signals are turned off after 1am or 2am because there's nobody to monitor the signals and there's very less traffic density at this hour of the day which is a major drawback of this system it needs to be monitored or else it doesn't adapt to the environment conditions.

5.0 Basic Terminology Used

5.1 Hardware/software

- Arduino

- Arduino is a single-board microcontroller for using electronics in multidisciplinary projects more accessible.
- The hardware consists of an open-source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM.
- The software consists of a standard programming language compiler and a boot loader that executes on the microcontroller.
- The open-source Arduino environment makes it easy to write code and upload it to the I/O board. It runs on Windows, Mac OS X, and Linux.

- The Arduino integrated development environment (IDE) is a cross-platform application written in Java programming, and is derived from the IDE for the Processing programming language and the wiring projects. [5][6]

➢ Proteus

- Proteus is a simulation and design software tool developed by Lab Center Electronics for Electrical and Electronic circuit design. It also possesses 2D CAD drawing feature.
- It is a software suite containing schematic, simulation as well as PCB designing. ISIS is the software used to draw schematics and simulate the circuits in real time. The simulation allows human access during run time, thus providing real time simulation. [9]

5.2 Hardware requirement

- Processor: intel dual core or above
- 2GB RAM
- Hard disk: 512MB
- Ultra-sonic sensors
- Arduino UNO circuit board

5.3 Software requirements

- Operating system: Windows 7, 8, 10
- Arduino IDE
- Proteus 8 (simulation software)

6.0 The Proposed System Design

Ultra-sonic sensors will be fitted into the roads starting from the red lights and till a 1 km stretch on the same road. These sensors emit ultra-sonic sound that cannot be heard by human ears, these sensors will be set at a range from how far they can emit signal and if any object is standing on it, the signal sent will return from a shorter distance which will trigger the program that a vehicle is standing above it and it will be counted as a traffic density element.

More the number of sensors showing a "positive" object detection more the density of that particular lane. This will work the same for the rest of the 3 red lights, combining the data of all these 4 red light's ultra-sonic sensors. The program for the **Arduino UNO** will take data every second from the sensors and then map the density according to the conditions predefined in the code itself. The program will automatically change the lights reading the data in real time. [5][6]

The time duration for green light will be also allotted according to the density of the lanes e.g.: the densest lane will get 90 seconds next dense will get 60 seconds and 3rd densest will get 40 and the least dense will get only 30 seconds. (time may vary according to the data fetched by the sensors and specified by the programmer).

Arduino IDE (integrated development environment) has been used for programming the circuit for the functioning of the sensors, data will be fetched every second from the sensors and 3 conditions will be proposed to the programmed IC

- Case 1: when A has more traffic elements than B
- Case 2: when B has more traffic elements than A
- Case 3: when A and B both have the same amount of traffic density elements

Let us discuss the Case 1, it will program the circuit to give the green light to the sensor A, as it has more traffic elements than B.

In Case 2, it will program the circuit to give the green light to the sensor B, as it has more traffic elements than A.

In Case 3, it will program the circuit to toggle between both sensors to given equal amount of time to both the lights so that there is no delay between the 2 lanes having equal amount of traffic elements.

These three cases will be implemented to all of the four lanes and their sensors respectively

creating a loop in which the sensor will fetch data in real time and the program will sort all of the lanes and address them with lights accordingly. This will increase the efficiency of red lights and will consistently decrease the chances of regular traffic jams in a city.

Fig 1.0 [ultra-sonic sensor]

In smart traffic management system three steps are involved in order for its functioning: -

i. The ultra-sonic sensors feed data to the algorithm.
ii. The algorithm maps the data fetched by the sensors in a descending order.
iii. Red/green lights to each lane is allotted according to that sorted data by the algorithm.

All of the above steps work simultaneously to make sure that the traffic lights get real time traffic density data and the time intervals between each lane is based on the density of traffic.

This system solves every problem that we face with the existing solution as well as with the conventional systems i.e.: -

i. It is totally automated and works in real time so it doesn't need any manual adjustments when traffic densities vary.
ii. It clearly works on the traffic density so it doesn't allot insufficient time intervals to the traffic lanes and the traffic is managed more efficiently.
iii. This system is feasible for both installation and maintenance and it doesn't require any storages to work and store the data it works in real time.
iv. Ultra-sonic sensors measure distance by emitting ultra-sonic sound waves (20 kHz or more) which is inaudible to human ears and hence isn't dependent on visuals like the camera-based traffic system.
v. Weather conditions doesn't affect the accuracy of the sensors they can work under water (1530m/s which is actually 4.3 times faster than that of air) and as well as in air(340m/s), unlike camera-based systems the fog and heavy rains cannot affect the functioning of these sensors.

6.1 Working of the smart traffic management system

The sensors installed on the roads will emit a high frequency sound and if an obstacle stand in its way the sound wave will be reflected and returned from a shorter distance which will be accounted for a traffic density element.

Sensors on each lane will send the data to the algorithm which will check for 3 conditions: -
CASE 1: - When both sensors show equal amount of traffic density the circuit toggle the green light between them in equal intervals of time. **(Fig 1.1, 1.2,1.3)**

Fig.1.1 [when both sensors show same density, green light is given to any one sensor]

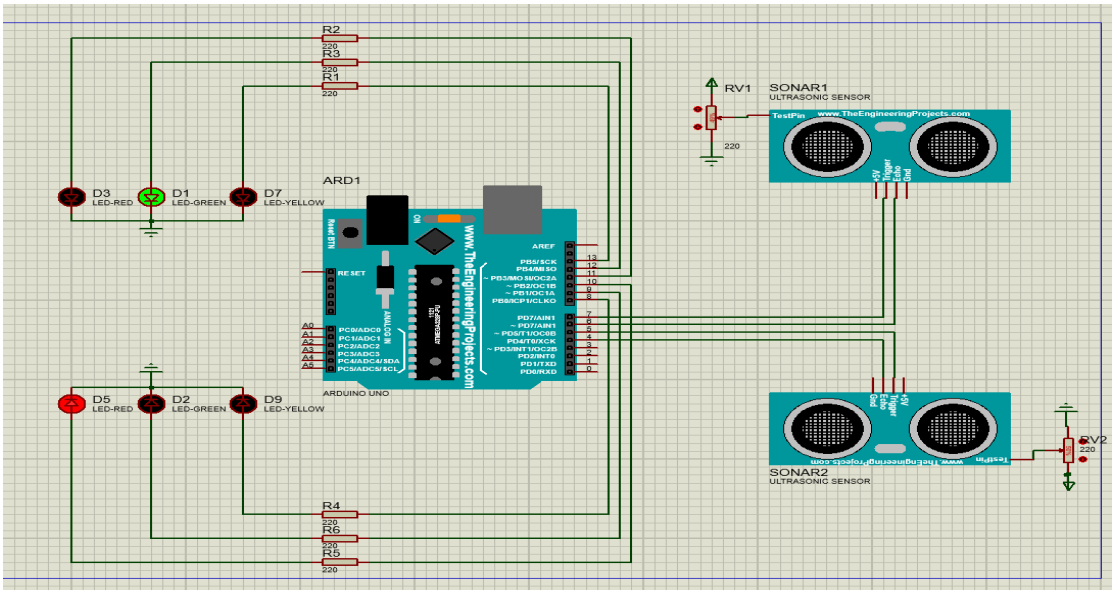


Fig1.2 [then the system toggles between the two sensors.]

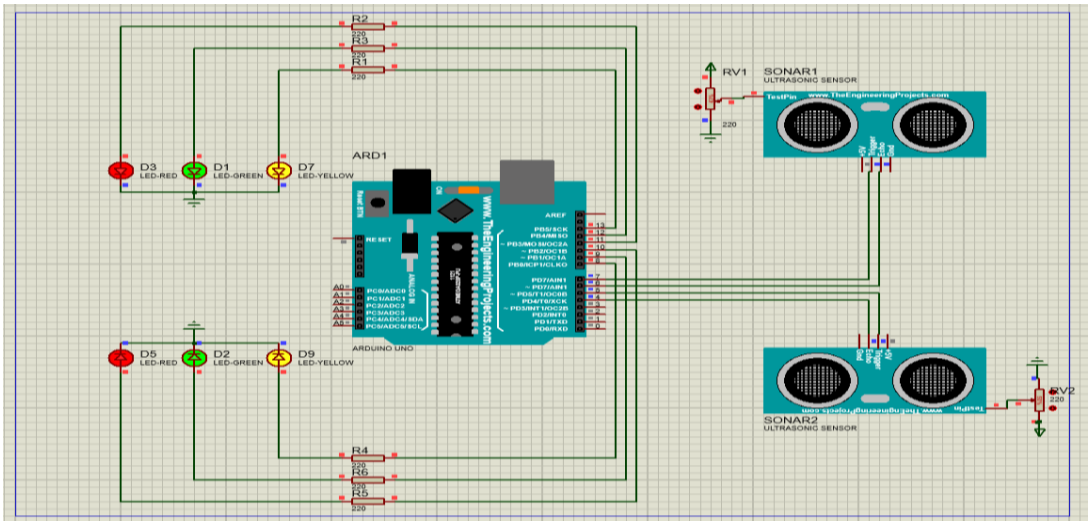
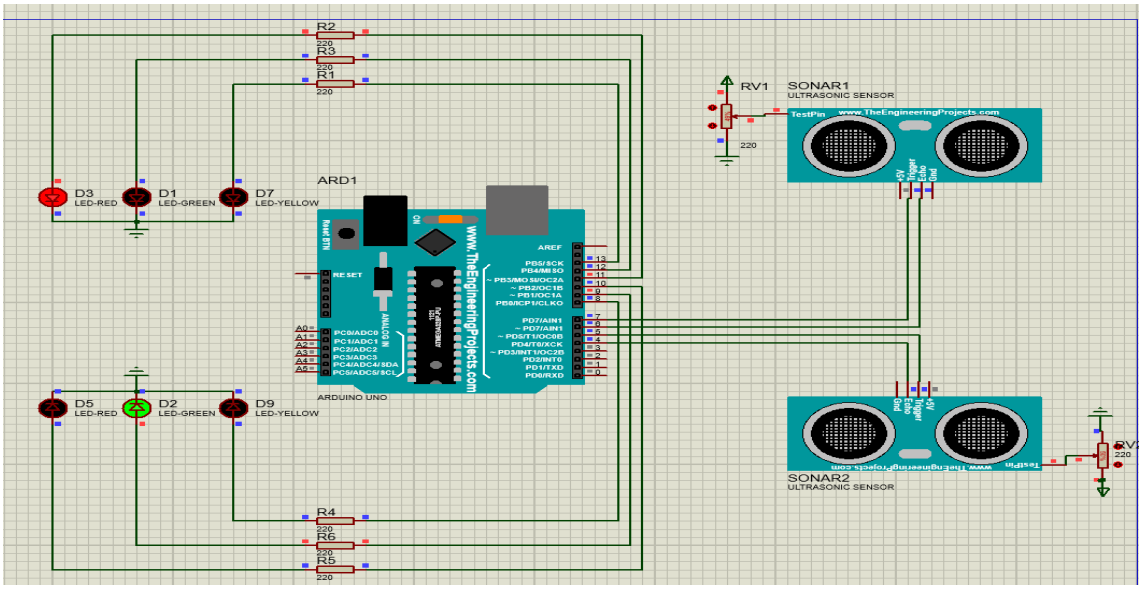


Fig1.3 [and then green light is given to the other sensor in equal time]



CASE 2: - When Sensor A shows more traffic density than sensor B, green light is automatically allotted to the sensor A. (**Fig1.4)**
CASE 3: - When Sensor B shows more traffic density than sensor A, green light is automatically allotted to the sensor B. **(Fig 1.5)**

Fig1.4 [When sensor A shows traffic density, green light is given to sensor A]

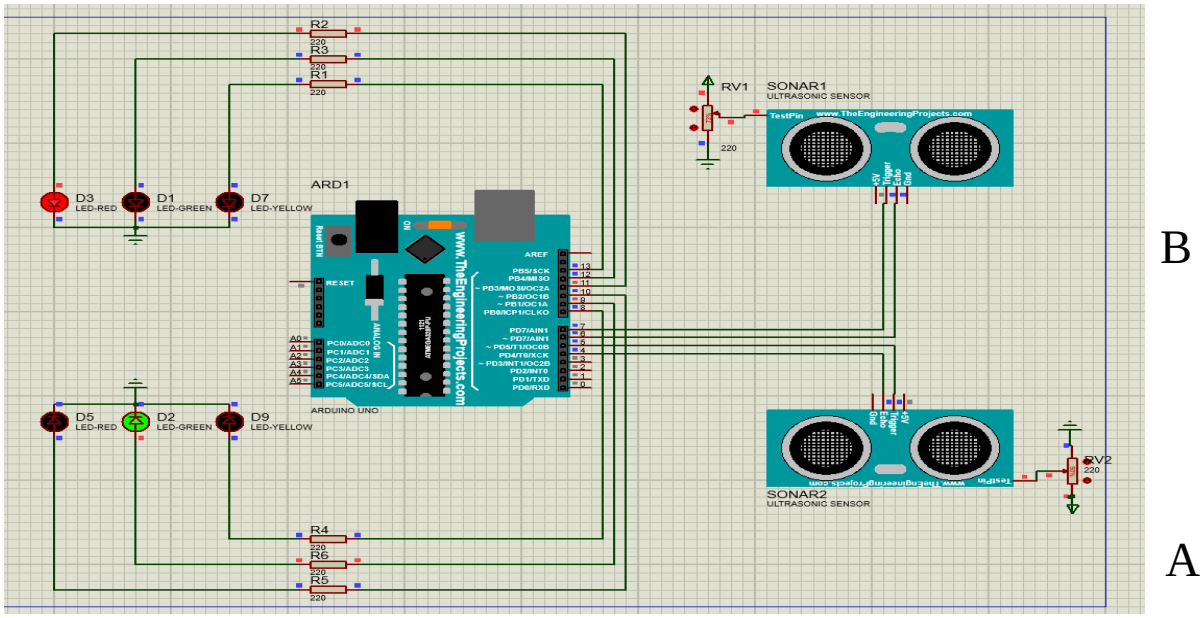
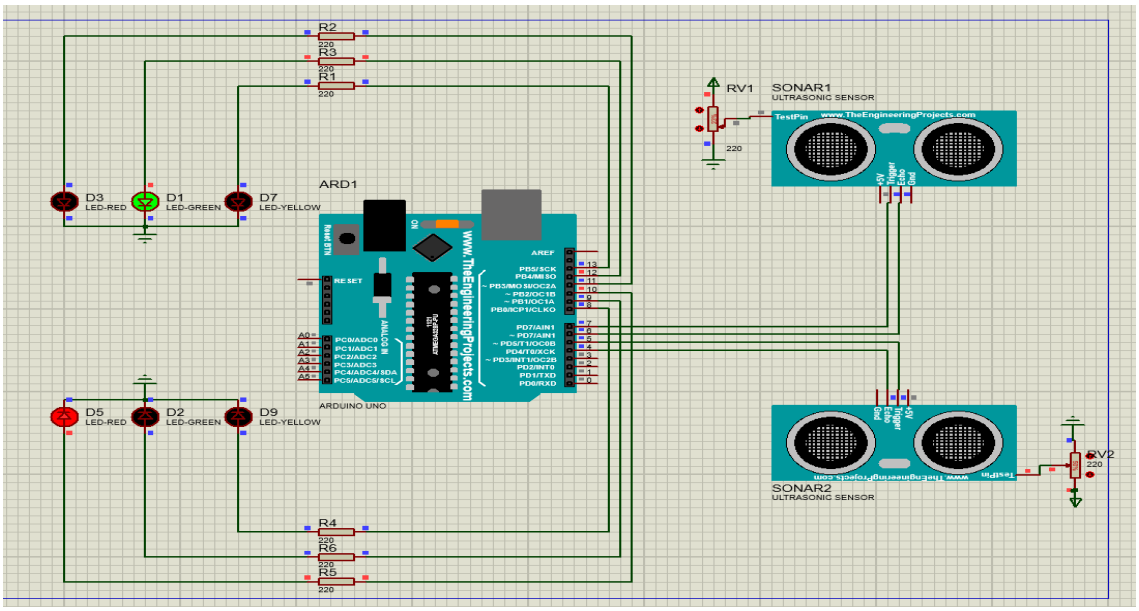


Fig1.5 [when sensor B shows traffic density, green light is given to sensor B]



Based on these conditions the red/green lights will be allotted to the lanes. It will work in a loop which will ensure its real time nature of functioning.

7.0 Conclusion

The use of sensors and automation will take the traffic management system to another level, this technology is better than the existing ones in a very practical way.

The ease of installing this system and implementation is very cost effective and environment friendly, it has more advantages than the other solutions provided by various other authors. The system is able to cover most of the weaknesses of other traffic management systems.

Commuters who had been suffering due to massive traffic jams and failed signal systems will get a big relief, casualties will be reduced by large number. The route that emergency vehicles follow will be cleared in no time. It'll be far more efficient than the conventional timed traffic signal which creates a lot of delay between each green light thus having increased chances of massive traffic jams in cities during working hours.

The ultra-sonic signal control is best suited to improve the efficiency in all the scenarios, when traffic demand is unpredictable, in low volume or during peak hours, when traffic demand is high and predictable. Traffic Management using Ultra-sonic sensors performed better.

8.0 Future Scope

Future research could aim to implement Artificial intelligence for more precise and accurate data mapping and density analysis, it will also benefit the emergency vehicles which can be identified by the system from a distance.

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