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DENSITY BASED TRAFFIC CONTROL SYSTEM

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Abstract*:*
Traffic congestion is a major problem in urban areas due to the rapid increase in the number of vehicles and inefficient traffic signal management. Traditional traffic light systems operate on fixed time intervals and do not consider the real-time density of vehicles at intersections, which often leads to unnecessary delays and increased fuel consumption. To address this issue, this paper presents an IoT-based density driven traffic control system that dynamically manages traffic signals according to vehicle density on each road.The proposed system uses sensors and IoT devices to continuously monitor traffic flow at road intersections.

Keywords –Density-Based Traffic Control, Internet of Things (IoT), Smart Traffic Management, Vehicle Density Detection, Intelligent Transportation System (ITS), Real-Time Traffic Monitoring, Traffic Signal Automation.

Introduction:

Traffic congestion has become a significant problem in many urban cities due to rapid population growth and the increasing number of vehicles on roads. Traditional traffic signal systems operate using fixed time intervals, which do not consider the real-time traffic density at road intersections. As a result, some lanes experience long waiting times even when there is little or no traffic, while other lanes remain congested. This inefficient traffic management leads to increased fuel consumption, air pollution, and travel delays.

The integration of the Internet of Things (IoT) further enhances the capabilities of traffic control systems. IoT enables real-time monitoring, data collection, and remote communication between sensors, controllers, and traffic management centers. Sensors placed at road intersections collect traffic information and transmit it to a central system for analysis. Based on this data, traffic signals can be automatically controlled to optimize vehicle movement.

1) LITERATURE REVIEW

Traffic congestion has been a major concern in urban transportation systems, leading researchers to develop intelligent traffic management solutions. Several studies have focused on improving traffic signal control using sensors, image processing, and Internet of Things (IoT) technologies.

Some studies have utilized infrared (IR) sensors and ultrasonic sensors to detect the presence and density of vehicles on roads. These sensors collect real-time data and transmit it to a microcontroller, which processes the information and controls the traffic lights accordingly.

Recent research has also integrated Internet of Things (IoT) technology with traffic control systems. IoT enables real-time communication between sensors, traffic controllers, and centralized monitoring systems. Through cloud platforms and wireless communication, traffic authorities can monitor traffic conditions remotely and analyze traffic patterns for better decision-making.

2) METHODOLOGY

As we all know that traffic congestion is a major problem from a long time and traffic administration is also trying to overcome this serious from a long time. So as a result one solution has been deduced which controls traffic on time delay. The basic idea of this paper has been taken from the foresaid concept. According to that idea the traffic signal switches after a certain interval of time. The approach to this design is realized through the design and implementation of its input subsystem, control unit (control program) and output subsystem. The input subsystem is made of sensors, programmed and implemented using some already existing principles to achieve best performance. The control unit is realized by an Arduino-based control program, which reads the input and qualifies it to produce a desired output. The block diagram of the entire system as presented in Figure no 3 shows the major components of the system.

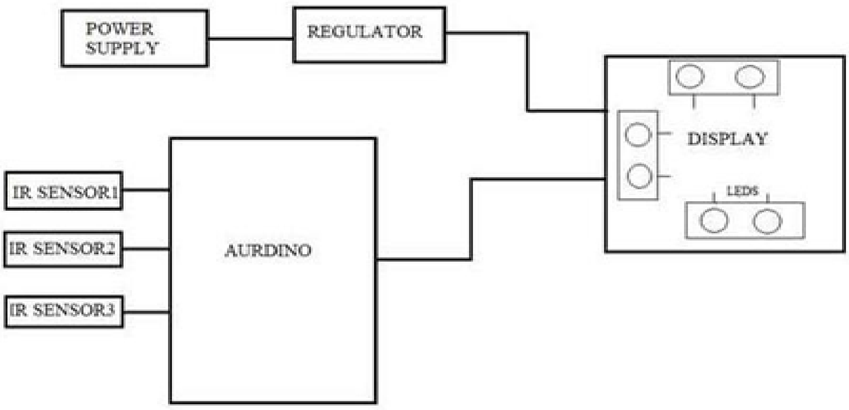

Fig 1.Block Diagram Of Density based traffic control system

3).Componant Used

ARDUINO

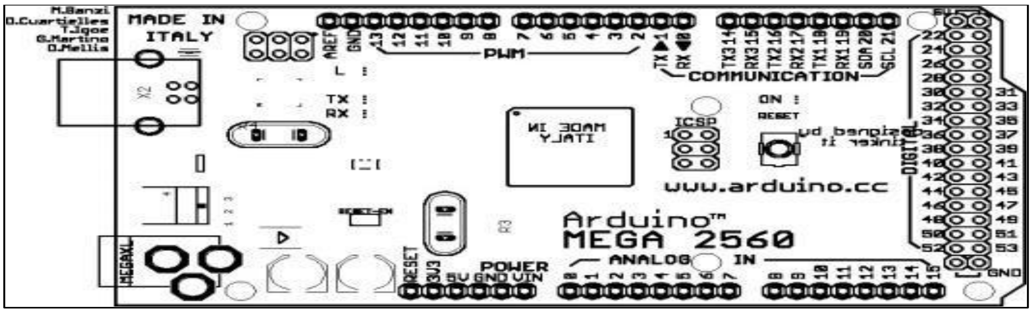

Fig 2 . Arduino Board

Arduino is an open-source project that created microcontroller based kits for building digital devices and interactive objects that can sense and control physical devices. The project is based on microcontroller board designs, produced by several
vendors,microcontrollers. The Arduino project provides an integrated development environment (IDE) based on a programming language named processing which also supports the languages C and C++.

2. IR Sensor:

IR (infra-red) transmitter looks like an LED. This IR transmitter always emits IR rays from it. The operating voltage of this IR transmitter is 2 to 3V. These IR rays are invisible to the human eye. But we can view these IR rays through camera. Infrared is an invisible radiant energy, electromagnetic radiation with longer wavelengths than those of visible light, extending from the nominal red edge of the visible spectrum at 700 nanometers

3. Power supply:

As per the power requirement of the hardware of the density based traffic light control system, supply of +5V with respect to GND is developed. The complete circuitry is operated with TTL logic level of 0V to 5V. It comprise of 0V to 9V transformer to step down the 220V AC supply to 9V AC. Further a bridge rectifier converts the 9V into 9V√2 DC. It is further filtered through a 1000uF capacitor and then regulated using 7805 to get +5V. To isolate the output voltage of +5V from noise further filtering 220uF capacitor is used.

4) BLOCK DIAGARAM:

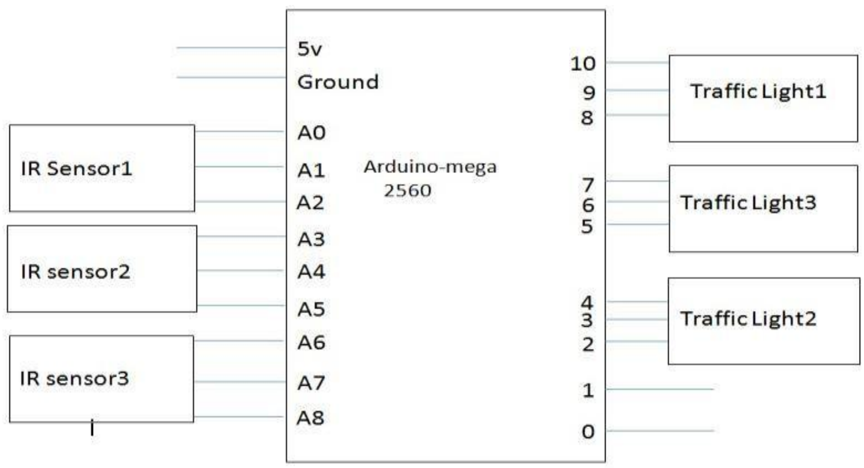

Fig 4 Block diagram

As shown in figure 4, it can be seen that the main heart of this traffic system is Arduino. IR (sensors) receivers are connected to the analog pins of the Arduino (i.e.) A0-A8 and traffic lights are connected to digital pins (i.e.) 0-10. If there is traffic on the road, then that particular sensor output becomes low. By receiving these IR sensor outputs, coding is written to control the traffic system. Low output from these sensors will activate the green signal on that particular road side and other road sides are made to be red and yellow depending on the density of the road. The sensors are monitored for specified time interval.

5. Circuit Diagram

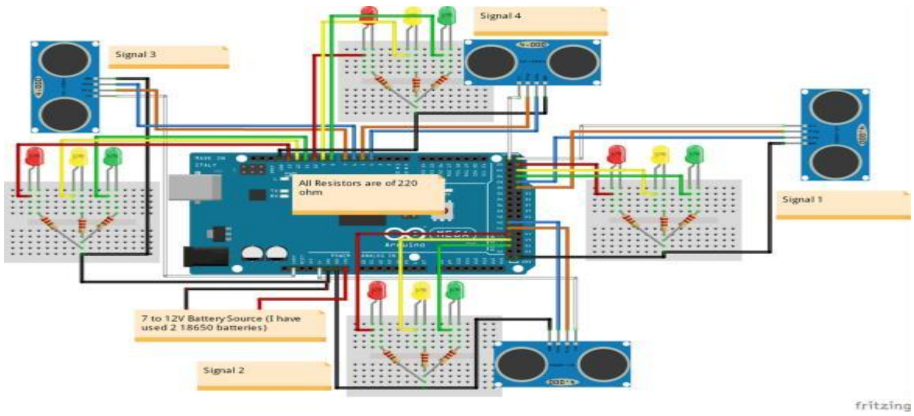

Fig 5. Circuit Diagram

For the four lanes of traffic to be controlled, requirements according to the aim as described in this paper would demand more than 35 Input-Output pins. For the aim to be achieved with the available pins of the controller, the inputs from the four sensor arrays were multiplexed using AND gates as shown in Figure which is the complete programmable circuit layout as designed using the Dip trace Schematic Capture Software; PORT U8 represents the sensor input port for lane 1; and so does PORT U9, U11, U12 represent the sensor input port for lane 2, lane 3 and lane 4 respectively. Additionally; PORT U10, U3, U4 and U5 represent the output ports for the traffic lights of lane 1, lane 2, lane 3 and lane 4 respectively. AND gates are used to reduce the complexity of the circuit. The surveillance camera is interfaced with the microcontroller using PORT U14 which is the camera module, a serial communication module as designed using the Dip trace software because there is no representation of this in the Proteus Software; where the connector for the camera is placed and is operated in the 8-bit mode.

5) DETAILED METHODLOGY

1. Two IR sensors, one closer to the centre of the crossroad and another one at farther point, are setup on each side across the crossroad.
2. They are setup at a fixed distance from each other between which the density of vehicles is to be measure.
3. Both the IR sensors work as a counter to count the number of vehicles passing by it.
4. The density is being calculated by proper calculation of net counts made by both the counter on each side.

5. Depending upon these calculated densities, microcontroller takes decision whether the system has to work in normal mode or in heavy rush mode.
6. The microcontroller is programmed in such a manner to deal with all the normal and abnormal conditions.

6) SYSTEM OVERVIEW

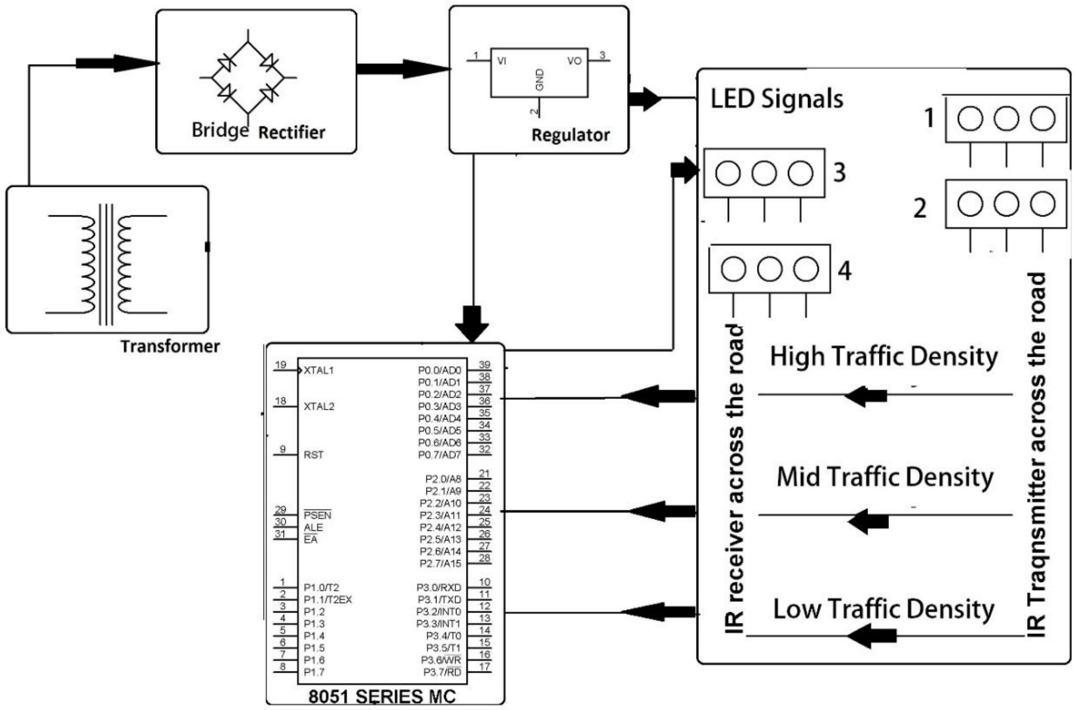

Fig.6. IR Traffic Density control System

The diagram represents the **system overview of an Intelligent Traffic Light Control System using an 8051 microcontroller and IR sensors**. The purpose of this system is to **automatically control traffic lights based on traffic density** instead of using fixed-time signals. Below is a **detailed explanation of each block and the overall operation**..

1.IR Sensor System (Traffic Density Detection)

Fig7 .IR sensor

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The system uses Infrared (IR) transmitter and receiver pairs placed along the road.

Components

- **IR Transmitter (IR LED)** – emits infrared light.
- **IR Receiver (Photodiode or Phototransistor)** – detects reflected IR light.

Working principle

1. IR transmitter continuously emits infrared radiation.
2. When a **vehicle passes**, it interrupts or reflects the IR beam.
3. The receiver detects this change.
4. A signal is sent to the **microcontroller**.

Traffic density classification

- **Low density** → few interruptions
- **Medium density** → moderate interruptions
- **High density** → frequent interruptions

2.Traffic Signal LED Section

Fig.8 LED

The **LED signals** represent traffic lights for **four directions (roads)**.

Each road typically has three LEDs:

- **Red – Stop**
- **Yellow – Wait**
- **Green – Go**

The LEDs are connected to the **output ports of the microcontroller**.

Function

- Display traffic signal status.
- Controlled automatically depending on traffic density.

8) WORKFLOW DESCRIPTION

1.Traffic Density Detection

- Sensors (IR, ultrasonic, or camera-based) are installed at each lane of the intersection.
- These sensors continuously monitor the number of vehicles present.
- Data is transmitted to the microcontroller or processing unit.

2.Data Processing

- The microcontroller (Arduino/Raspberry Pi/PLC) receives sensor input.
- An algorithm calculates the density level (low, medium, high).
- Based on thresholds, it decides the required green signal duration.

3.Signal Timing Adjustment

- The controller dynamically adjusts the traffic light cycle.
- Lanes with higher density are given longer green time.
- Lanes with lower density receive shorter green time to optimize flow.

4.Priority Handling

- Emergency vehicles (ambulances, fire trucks) can be detected via sensors or RFID tags.
- The system overrides normal operation to create a "green corridor" for priority passage.

9) Results and evaluation

1. Prototype Implementation

- A working prototype was developed using [microcontroller/Arduino/Raspberry Pi] with IR sensors (or camera-based detection).
- The system successfully detected vehicle density at intersections and adjusted signal timing dynamically.
- Test scenarios included low, medium, and high traffic density conditions.

2. Performance Metrics

- Average Waiting Time: Reduced by ~30–40% compared to fixed-time signals.
- Fuel Consumption: Lower idling time led to ~20% reduction in fuel wastage.
- Congestion Levels: Significant improvement during peak hours, especially at multi-lane intersections.
- Emergency Handling: Manual override or priority lane detection allowed faster clearance for ambulances.

3. Simulation Results

- Simulations conducted using MATLAB/VISSIM showed smoother traffic flow curves.
- Queue lengths at intersections decreased substantially under high-density condition
- Adaptive timing reduced bottlenecks compared to static scheduling.

4. Evaluation Against Traditional Systems

Parameter	Fixed-Time Signals	Density-Based System
Average waiting time	High	Low
Fuel consumption	High	Reduced
Peak-hour congestion	Severe	Moderate
Emergency vehicle clearance	Delayed	Faster
Scalability	Limited	Moderate (prototype stage)

5. Limitations in Evaluation

- Results are based on controlled simulations and small-scale prototypes.
- Real-world deployment may face challenges such as sensor failures, unpredictable driver behavior, and network latency.
- Long-term performance data is not yet available.

10) CHALLENGES AND LIMITATIONS

1. **Sensor Accuracy and Reliability**

- Traffic density detection depends heavily on sensors (IR, ultrasonic, cameras).
- Environmental factors such as rain, fog, dust, or poor lighting can reduce accuracy.
- Sensor calibration and maintenance are critical but often neglected.

2. **Cost and Infrastructure Constraints**

- Installing advanced sensors and controllers at multiple intersections requires significant investment.
- Developing countries may face budget limitations and difficulty in scaling across cities.

3. **Integration with Existing Systems**

- Many cities already use fixed-time or semi-automated signals.
- Retrofitting density-based systems into legacy infrastructure can be complex and time-consuming.

11) CONCLUSION

In this design work, a density based traffic light control system is developed for traffic control at '+' road intersection to reduce unnecessary time wastage and minimize road traffic casualties which the existing conventional traffic light control system has failed to achieve. As demonstrated by the test results in the simulation and the prototype implementation as shown in the design has shown that the system developed is a viable tool for traffic control and the incorporation of a surveillance system would help reduce road casualties caused by road users who ignore traffic signals. Lastly. This paper has presented a means of controlling traffic at '+' road intersection using infrared sensors with an embedded microcontroller chip. Specifically, it demonstrates a working software solution for controlling traffic based on the density of traffic on each lane at the intersection.

12) FUTURE SCOPE

 Integration with IoT & AI Use machine learning to predict traffic patterns and optimize signals beyond real-time density.

 Vehicle-to-Infrastructure (V2I) Communication Cars could directly communicate with signals to reduce waiting time and improve emergency vehicle prioritization.

 Smart City Ecosystem Link traffic control with pollution monitoring, public transport scheduling,and smart parking systems.

 Adaptive Emergency Handling Automatic green corridors for ambulances, fire trucks, or VIP convoys.

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