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Automated Traffic Signaling System for Ambulance Crossing using IOT

Pattabiraman V[1], Parvathi.R[2], Jai Ganesh C[3], Kaushal C[4] and Mohnish Kumaar D[5]
[1-5]Vellore Institute of Technology, School of Computer Science and Engineering, Chennai, India
Email: pattabiraman.v@vit.ac.in,parvathi.r@vit.ac.in

***Abstract*—The research aims to improve traffic management and response time of emergency vehicles, specifically ambulances, at four-lane traffic junctions. The primary objectives are to detect the presence of emergency vehicles, reduce traffic congestion, and design an efficient traffic management system. The proposed solution combines radio frequency (RF) technology and sound sensing for emergency vehicle detection, along with density-based traffic regulation using ultrasonic sensors. The methods employed include installing RF transmitters in ambulances and RF receivers with sound sensors at traffic junctions, interfaced with an Arduino microcontroller. The project's outcomes are expected to include more efficient traffic flow, faster passage for emergency vehicles, and overall reduced traffic congestion. As a result, the response time of emergency services will be improved, contributing to saving lives and promoting sustainable urban transportation infrastructure. The scope of this project will include traffic management in urban environments, specifically at four-lane traffic junctions. The proposed system has the potential to be scaled up and adapted for larger or more complex traffic networks, as well as integrated with other smart city technologies, enhancing traffic management and emergency response efficiency in various urban settings.**

***Index Terms*— Traffic Management, Emergency Vehicle Detection, Radio Frequency Technology, Ultrasonic Sensors and Sustainable Urban Transportation.**

I. INTRODUCTION

An increasing number of vehicles on the road have led to an increase in delays, as well as an increase in pollution and a reduction in the efficiency of the transportation system [13]. The problem of traffic congestion in urban areas has become an urgent problem [12]. The timely passage of emergency vehicles like ambulances, which play an essential part in the process of saving lives, is one of the most important but also one of the most challenging aspects of traffic management [11]. Congestion is especially likely to occur at intersections with four lanes of traffic, which makes it difficult for emergency vehicles to move through the traffic in a timely manner [13]. Therefore, it is essential to develop a traffic management system that is able to detect the presence of emergency vehicles and adapt to varying traffic densities [12]. This will allow for traffic flow that is smoother, and will reduce congestion [15]. This work proposes a hybrid system that combines radio frequency (RF) technology and sound sensing for emergency vehicle detection [11]. Additionally, density-based traffic regulation utilizing ultrasonic sensors will be implemented as part of this hybrid system [12]. The goal of this project is to optimize traffic flow at four-lane junctions [13]. By utilizing these technologies, the system intends to enhance traffic management, thereby reducing congestion and making it easier for emergency vehicles to pass

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through, which will, in the end, contribute to the saving of lives and the promotion of sustainable urban transportation infrastructure [12]. The implementation of this intelligent traffic management system will not only reduce the amount of time it takes for emergency services to arrive at a scene, but it will also improve the flow of traffic overall at intersections with four lanes [14]. In addition, the adaptability of the solution that has been proposed makes it appropriate for integration with other smart city technologies, thereby paving the way for more extensive applications in a variety of urban settings [15]. This paper will continue our discussion of the project's methodologies, including those used for the detection of emergency vehicles and the regulation of traffic based on density, as well as its architecture, explanation, proposed works, and the results we get after putting this project into action [11, 12, 13]. The first part of this research combines ambulance siren detection with traffic light management to create a smart traffic control system that prioritizes emergency vehicles. This could significantly improve response times in urban areas, potentially saving lives in critical situations.The second part of this project combines vehicle detection with adaptive traffic light management to create a smart traffic control system that optimizes traffic flow based on the presence of vehicles in each lane. This could significantly improve traffic flow in urban areas, reducing waiting times and potentially decreasing congestion.

II. LITERATURE SURVEY

Gour Karmakar et al. [1] proposed an Emergency Vehicle Priority System, a system that assigns priority to Emergency Vehicles (EVs) based on the type and severity of the incident, while considering the impact of signal interventions on traffic in the surrounding areas. The authors propose a new algorithm to estimate the necessary number of signal interventions, and a simulation model is developed in SUMO using real traffic data from Melbourne, Australia.The advantage of this article is to ensure that the most critical emergencies receive the quickest response times. The system considers the impact of signal interventions on traffic in the surrounding areas, reducing the overall impact of emergency responses on other on-road traffic. The use of a simulation model allows for testing and evaluation of the system in a controlled environment. Disadvantage of this article is the system relies on the availability and accuracy of real-time traffic data from various sensors, which may not always be available or accurate. The system may require significant infrastructure changes and upgrades to implement, which can be costly. The simulation model may not fully replicate the complexities and nuances of real-world traffic patterns and behavior. Shajnush Amir et al. [2] describe an automated traffic control system with emergency vehicle control. The system has the ability to detect an emergency signal and give priority to the corresponding road by giving it a green light as long as the emergency signal is high. Once the emergency signal becomes low, the system instantly returns to the normal sequence. The system is designed using PLC ladder logic program and tested in a simulated and hardware environment. Some advantages are Improved emergency response, Improved traffic flow, cost effective, easy to implement. The disadvantages of these papers include Dependence on RFID, Limited scalability, Lack of human intervention, Vulnerability to cyber-attacks. Tejas Naik et al. [3] proposed solution is an RFID-based system that manages and regulates traffic signals at intersections when an emergency vehicle approaches, allowing for an easy passage out of traffic congestions. The proposed system is modeled using an experimental setup with Arduino and LED displays to simulate a real-time traffic scenario. The simulation results show that the proposed system performs better in terms of detection and management of emergency vehicles, providing a passage out of traffic congestions during peak hours. This system has the potential to save lives by allowing emergency vehicles to reach their destinations more quickly and safely. Advantage of the above solution is Effective traffic management, improved response time, real time monitoring, and cost-effectiveness. Disadvantages are limited coverage, maintenance requirements, vulnerability to inference. Shyam Shankaran R et al. [6] proposed a model for a camera-based traffic monitoring and processing system that aims to improve traffic flow in urban areas. The system uses cameras to monitor traffic and adjust traffic signal timings in real-time, based on the volume of traffic in each direction. The system also has special provisions to prioritize emergency vehicles, such as ambulances and fire trucks, by detecting their presence and giving them a green signal to move through traffic. Advantages for the above proposed model include improved traffic flow, reduced travel time, priorities to emergency vehicles. Disadvantages are limited coverage; technical glitch may happen any time. Rushikesh Bhadage et al. [7] proposed approach aims to improve traffic flow by dynamically managing the density of vehicles present in each lane of the road using image processing and object detection. The advantages include Improved Traffic Flow, Emergency Vehicle Detection. Disadvantage includes cost and maintenance. Raji C. G et al. [4] proposes a system for detecting emergency vehicles during traffic congestion in three junctions. The system involves using RFID (Radio Frequency Identification) technology to collect signals from emergency vehicles and transmit the data to control traffic in the affected lanes. Advantages of this article includes improved response time for emergency vehicles, reduce the risk of accidents or delays that can occur when emergency vehicles are stuck in traffic. Disadvantages include initial cost and not easy to implement in complex traffic areas. Anam Firdous et al. [8] proposed their solution in the system of a smart traffic management system that uses digital IR sensors to detect vehicles and adjust the timing of traffic signals accordingly. The system is built using Arduino Uno ATMega 328 and is designed to be more efficient and effective than conventional traffic management systems. The digital IR sensors are placed adjacent to the road and detect the presence of vehicles based on the signal reflected from them. This information is then processed by the Arduino Uno to adjust the timing of the traffic signals based on the traffic density. The traffic signals are designed using LEDs and each signal consists of two LEDs for each lane. One advantage of this system is that it reduces the need for manual handling at traffic junctions, which can be stressful and time-consuming. Disadvantages include the system may not work as effectively in areas with heavy snowfall, as the IR sensors may be obstructed by snow. P Soundarya Lahari et al. [9] proposed a Density Based Traffic Control with Emergency Override system. This paper presents a system where traffic density in each lane is measured using IR sensors. Accordingly, the traffic signal lights give the green light based on vehicle density. Some of the advantages in this paper include implementing efficient traffic management, emergency override feature, and the use of IR sensors. However, there are also disadvantages like limited applicability, heavy dependency on sensors, and requirement of significant initial costs. Usha Mittal et al. [10] proposed Traffic Green Signal Optimization using Adaptive Neuro-Fuzzy Inference System on Coordinated Intersections. This paper presents an adaptive signal control system used for every junction in the coordination system, where the green light period is altered in real-time considering vehicle density on the road. There are some benefits we can gain such as adaptive signal control system and vehicle density consideration. There are also some crucial drawbacks like too much reliance on neuro-fuzzy inference system technology, and hence it breeds unfamiliarity, and there is also only limited scope due to the main focus on signal optimization.

III. MATERIALS AND METHODS

A. Algorithm for Emergency Vehicle detection

1. Initialization: Set up the frequency measurement library, configure input/output pins for the traffic lights, and initialize the traffic light states.2.Frequency Measurement: Continuously measure the frequency of the input signal (typically, a microphone input) and calculate the frequency value by averaging multiple readings together.3.Siren Detection: Check if the measured frequency falls within the predefined range for ambulance sirens (e.g., 2500 Hz to 4500 Hz). If the frequency falls within this range for a certain number of consecutive readings (e.g., 3), the system recognizes an ambulance siren.4.Traffic Light Management: When an ambulance siren is detected, the system interrupts the normal traffic light cycle and prioritizes the passage of the ambulance. It does this by turning the current green light to red (if it's not already red) and providing a green light in the ambulance's direction.5. Traffic Light System Continuation: After the ambulance has passed and the traffic light system has provided priority, the traffic light system resumes its normal operation.

6. Regular Traffic Light Cycle: If no ambulance siren is detected, the traffic light system continues to cycle through its regular traffic light sequence, changing the lights at predefined intervals.This algorithm effectively integrates siren detection with traffic light management to provide priority passage for ambulances during emergencies, potentially reducing response times and saving lives.

B. Algorithm for Density Regulation

1.Initialization: The code defines pin numbers for the traffic lights and ultrasonic sensors. It also initializes variables for lane counts, green light times, and an array to store lane states [3].2.Setup: In the setup() function, the necessary pins are configured as inputs or outputs, and the I2C interface for the PCF8574 is initialized.3.Main Loop: The loop() function cycles through the lanes, updating their traffic light states and reading ultrasonic sensor data. The green light duration for each lane is adjusted based on traffic density, as measured by the ultrasonic sensors.4.The count variable keeps track of the current lane.5.For each lane, the direction() function is called to update the traffic light states and read the ultrasonic sensor data.6.The grtime1, grtime2, and grtime3 variables store the green light durations for lanes 1, 2, and 3, respectively. These durations are adjusted based on the traffic density detected by the ultrasonic sensors.7.The num array stores the state of each lane, with 1 indicating high traffic density and 0 indicating low traffic density.8.Direction Function: The direction() function takes care of the traffic light state changes and reads the ultrasonic sensor data.The function takes in arguments for the pin numbers of the traffic lights, the num array, the green light duration (grtime), and a flag (no) to indicate whether to activate the emergency lane. The traffic lights are updated based on the input arguments, and the PCF8574 is used to control the traffic lights for the emergency lane.The ultrasonic sensors are triggered, and the distances to the nearest vehicles are measured. If a vehicle is detected within 50 cm for five consecutive readings, the corresponding lane's state in the num array is set to 1. The num array is used to adjust the green light durations for each lane based on traffic density. Overall, the code implements a traffic light control system that adjusts the green light durations based on traffic density, as measured by ultrasonic sensors. This adaptive system aims to improve traffic flow at the intersection.

C. Dataset

The ambulance siren can have a frequency between 550Hz-650Hz and 1450Hz-1550Hz.A sensor will detect the siren if its frequency exceeds the threshold of 1200Hz. project is designed for implementation at any 4-lane traffic junction. An RFID transmitter fixed to the ambulance will send an "EMERGENCY" message to a receiver fixed at the traffic junction. Two IR sensors will be positioned at the traffic signal, spaced 100m apart. The first sensor will detect the ambulance if it is close to the signal, while the second sensor will detect it if it is far away.

D. Architecture

*1.*Microcontroller: Arduino Uno is used as the main microcontroller to manage traffic signals and read sensor data.2.Traffic Signals: Four sets of traffic signals are implemented, each consisting of red, yellow, and green lights. The first three sets are connected directly to the Arduino's digital pins, while the fourth set is connected through a PCF8574 I/O expander.*3.*Ultrasonic Sensors: Three ultrasonic sensors are placed at three different lanes to measure the distance to the vehicles. These sensors are used to determine the density of the traffic in each lane. The fourth lane does not have an ultrasonic sensor, as it is reserved for emergency vehicles.4.Emergency Vehicle Detection: The system architecture integrates siren detection with traffic light management, allowing the system to provide priority passage for ambulances during emergencies, potentially reducing response times and saving lives. The code for this makes use of FreqMeasure and VirtualWire libraries for frequency measurement and communication respectively.5.PCF8574 I/O Expander: This component is used to control the traffic lights for the fourth lane (emergency lane). It is connected to the Arduino Uno via the I2C interface (SDA and SCL pins).

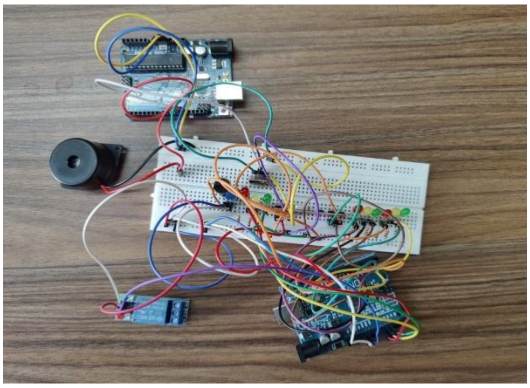

Fig. 1 – Circuit for Emergency Vehicle detection in three lanes

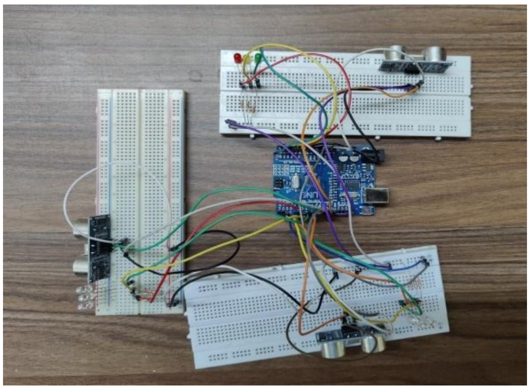

Fig. 2 – Circuit for Density Regulation in three lanes

IV. MATERIALS AND METHODS

A. For Ambulance Siren Detection System integrated with a traffic light system.

1. Ambulance Siren Detection: The system can detect the frequency range of an ambulance siren (between 2500 Hz and 4500 Hz) using the FreqMeasure library. By analyzing the input frequency, the system can recognize the presence of an ambulance nearby and act accordingly to prioritize its passage.
2. Traffic Light Management: The Arduino code integrates the ambulance siren detection feature with a traffic light system. This is implemented by controlling the red, yellow, and green lights of three different traffic light units. The system transitions between the different traffic light states by changing the output signal to the respective pins.
3. Priority for Ambulance: When an ambulance siren is detected, the traffic light system prioritizes the ambulance's passage by providing a green signal in its direction. This helps to clear the way for the ambulance, ensuring faster response times during emergencies.

4. Wireless Communication: The code also includes the VirtualWire library for wireless communication, which could be used to coordinate with other traffic light systems or receive messages from a central control system.Overall, this project combines ambulance siren detection with traffic light management to create a smart traffic control system that prioritizes emergency vehicles. This could significantly improve response times in urban areas, potentially saving lives in critical situations as shown in Figure 1.

B. For Traffic Light System with Vehicle density detection

1. Vehicle Detection: The system utilizes ultrasonic sensors to detect the presence of vehicles at each lane of a three-lane junction. This allows the system to adapt the timing of green lights depending on the traffic volume in each lane.
2. Adaptive Traffic Light Timing: The Arduino code provides an adaptive traffic light timing system that adjusts the duration of the green light for each lane based on the presence of vehicles. If a lane has a vehicle waiting, the green light duration is increased for that lane, ensuring a smoother flow of traffic and reducing waiting times.
3. Priority to Lanes with Detected Vehicles: The system prioritizes lanes with detected vehicles by providing longer green light duration (15 seconds) for those lanes compared to the standard green light duration (10 seconds). If a lane has no detected vehicles, the green light duration is reduced to 5 seconds, which helps optimize traffic flow.
4. Traffic Light Control: The code manages the red, yellow, and green lights for the three lanes of the junction. The system transitions between the different traffic light states by changing the output signal to the respective pins. Overall, this project combines vehicle detection with adaptive traffic light management to create a smart traffic control system that optimizes traffic flow based on the presence of vehicles in each lane. This could significantly improve traffic flow in urban areas, reducing waiting times and potentially decreasing congestion as shown in Figure 2.

V. RESULT AND DISCUSSION

The system successfully detects the frequency range of an ambulance siren and recognizes the presence of an ambulance nearby. The traffic light system effectively prioritizes the passage of the ambulance by providing a green signal in its direction. The traffic light system operates smoothly in a typical sequence (red-yellow-green) when there is no ambulance detected. This integrated system has the potential to significantly reduce the response time for ambulances during emergencies, which can ultimately save lives. Additional features could be integrated, such as a warning system for nearby drivers to yield to the approaching ambulance. The system's efficiency could be further improved by implementing real-time traffic monitoring and adjusting the traffic light system accordingly.

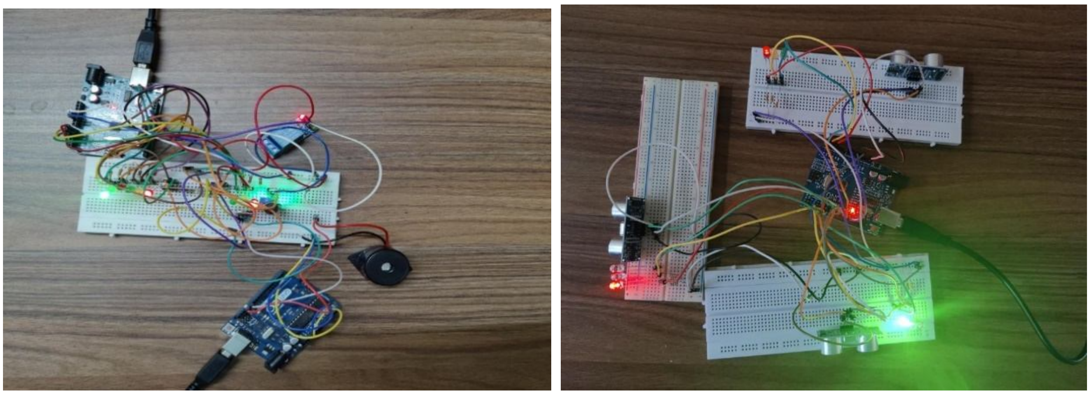

Fig. 3 – Implementation of emergency vehicle detection and traffic density regulation system for three lanes

The system accurately detects the presence of vehicles in each lane using ultrasonic sensors. The adaptive traffic light timing system adjusts the green light duration based on vehicle detection, resulting in optimized traffic flow. The system prioritizes lanes with detected vehicles by providing longer green light durations, reducing waiting times for those lanes. The implementation of this adaptive traffic light system can lead to improved traffic flow, reduced congestion, and shorter waiting times for drivers.The system's performance could be enhanced by incorporating advanced vehicle detection methods, such as image processing or machine learning algorithms, to detect and classify different types of vehicles. For larger and more complex road networks, a centralized control system could be implemented to coordinate multiple traffic lights and manage traffic flow more efficiently as shown in Figure 3. Figure 4 shows the architecture diagram of traffic density regulation system for four lanes.

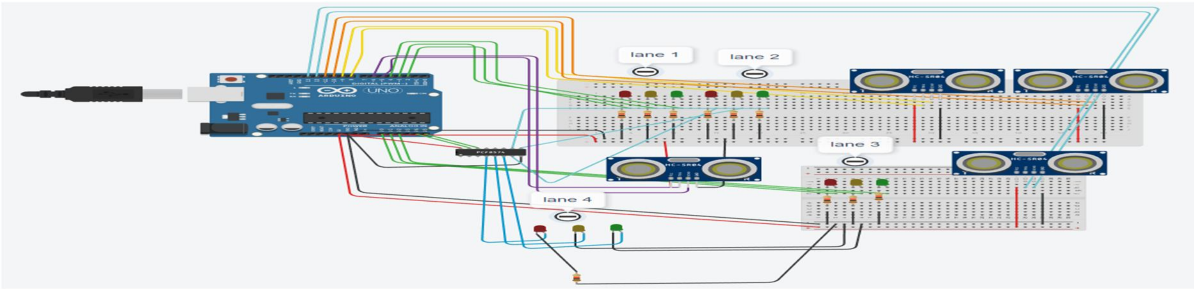

Fig. 4 - Implementation of traffic density regulation system for four lanes (in Tinker cad)

TABLE I : EMERGENCY VEHICLE DETECTION - STATE CHANGE DATA CHANGE DATA

Time	**States**			**Comments**
	Lane 1	**Lane 2**	**Lane 3**	
0	Green	Red	Red	INITIAL STATE
10	Yellow	Red	Red	
15	Red	Green	Red	
25	Red	Yellow	Red	
30	Red	Red	Green	
40	Red	Red	Yellow	
45	Green	Red	Red	Ambulance Siren ON
47	Green	Red	Red	Ambulance Siren OFF
48	Yellow	Red	Red	
49	Red	Red	Green	
59	Red	Red	Yellow	
64	Green	Red	Red	INITIAL STATE
74	Yellow	Red	Red	
79	Red	Green	Red	Ambulance Siren ON
81	Red	Green	Red	Ambulance Siren OFF
82	Red	Yellow	Red	
83	Red	Red	Green	
93	Red	Red	Yellow	
98	Green	Red	Red	INITIAL STATE

VI. CONCLUSION

Thus, the traffic light system with emergency vehicle detection and density regulation is an advanced and effective approach to managing traffic flow in urban areas. By using advanced sensors, the system can detect emergency vehicles and adjust traffic lights accordingly, allowing them to pass through intersections quickly and safely. Additionally, the density regulation feature helps to manage traffic flow during peak hours, reducing congestion and improving overall traffic efficiency.

TABLE II: DENSITY TRAFFIC REGULATION – STATE

States			Green Time	Traffic States		
Lane 1	**Lane 2**	**Lane 3**		**Lane 1**	**Lane 2**	**Lane 3**
Green	Red	Red	15	Moderate	Moderate	Moderate
Yellow	Red	Red				
Red	Green	Red	15	Moderate	Moderate	Moderate
Red	Yellow	Red				
Red	Red	Green	15	Moderate	Heavy	Moderate
Red	Red	Yellow				
Green	Red	Red	5	Moderate	Moderate	Moderate
Yellow	Red	Red				
Red	Green	Red	15	Moderate	Moderate	Moderate
Red	Yellow	Red				
Red	Red	Green	10	Moderate	Moderate	Moderate

The implementation of this system has the potential to significantly improve safety for both emergency responders and the general public while also reducing travel times, fuel consumption, and air pollution. While the initial costs of implementing such a system may be high, the long-term benefits and savings in terms of reduced congestion, improved safety, and increased efficiency would make it a worthwhile investment for cities and municipalities. Overall, the traffic light system with emergency vehicle detection and density regulation is an important technological advancement in the field of urban transportation management.

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