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A Novel Approach for Improved Traffic Management for Emergency Service Vehicles

Dhruvil Patel[1], Jiya Raval[2], Manav Bachani[3], Ritika Lohiya[4]
Department of Computer Science and Engineering, Adani University, Ahmedabad, 382421, Gujarat, India

Abstract: The rise in traffic congestion is one of the challenges in emergency response services. The surge in traffic congestion has led to unprecedented obstacles for emergency response services. Public safety is under threat due to the substantial number of causalities caused by the delay of emergency response vehicles. This paper proposes an Intelligent Traffic Light System for emergency service vehi- cles. This paper proposes an advanced traffic management system to prioritize emergency vehicles. The proposed system can modify traffic signals to ensure a seamless passage for emergency vehicles. The experimental analysis reveals that the proposed approach uses a mathematical time-sequencing algorithm to reduce emergency response time, optimize traffic flow, and elevate road safety standards. The proposed algorithm is validated via simulations. The real-time deployment can be achieved using YOLOv8 and CNN. The proposed approach intends to encourage the efficient implementation of an intelligent traffic manage- ment system. The results consist of a comprehensive study of the performance of the proposed system in different scenarios and a comparative time analysis against the conventional system. The presented algorithm successfully reduced the response time of the emergency services in various simulated circumstances. This paper includes mitigation strategies to overcome the possible challenges of the proposed system. The proposed approach aims to enhance the urban traffic management system by enabling emergency services to respond promptly with- out human input. The presented design intends to ensure reliability in urgent situations by providing innovative solutions to conventional traffic systems.

Keywords: intelligent traffic management system emergency vehicle emergency response time pygame vehicle detection

I. INTRODUCTION

Development and urbanization have increased the frequency of vehicles. Emergency vehicles are significant in providing timely medical aid but often get wedged in traffic, resulting in obstruction to receiving timely medical facilities Milanes et al. (2012). In this paper, we aim to present a novel approach that dynamically modifies traf- fic light signals to facilitate the smooth passage of emergency vehicles. The proposed system design can be integrated with the existing traffic system design, eliminat- ing the need for costly installation and upgrades. The presented approach intends to improve urban traffic management, ensuring rapid emergency response and seamless traffic flow without human intervention. The proposed research addresses this issue by integrating an algorithm for emergency vehicles that prioritizes their seamless pas- sage. Moreover, the presented system is responsible for the detection of emergency vehicles and the management of traffic light signals accordingly. Our objective is to ensure a safer and smoother passage for emergency response services. The current traffic management system blends both modern technology and conventional systems. Metropolitan cities frequently face substantial congestion due to high traffic density and insufficient infrastructure. Even with technological advancements, challenges such as lack of discipline and unsatisfactory public transport systems continue to hinder traffic management. While enhancing public transport to ensure sustainability, updating urban infrastructure to increase the efficiency of traffic management systems is necessary. Furthermore, integrating an intelligent traffic management system into the current conventional system is highly beneficial for society. The proposed system is an intelligent traffic management system that can efficiently handle emergencies. The results obtained are based on various performance metrics and ensure high accuracy. The presented approach intends to decrease death rates due to delays in emergencies and eliminate the shortcomings of the conventional system.

II. LITERATURE REVIEW

In urban and metro cities, emergency vehicles such as ambulances and firetrucks are affected by traffic congestion. Consequently, people could lose their lives because of an ambulance delay. Impediment in emergency services impacts patient health every minute, increasing the risk of ailment. The concern of emergency vehicles getting teth- ered in traffic is not limited to one region but is a global issue Biswas et al. (2016).

Many countries face similar challenges, with traffic congestion leading to an increase in response time for emergency services. Furthermore, it has been observed that traffic delays significantly hinder the efficiency of emergency medical services Khekare and Sakhare (2012). High traffic density and frequent delays faced by emergency ser- vices have highlighted the critical need for an advanced traffic management system Manikonda et al. (2011). Although emergency vehicles in many countries have the right to pass red lights and exceed the speed limit on roads to reach the patient, this adds another problem and might cause further accidents Nono et al. (2020). There exists a high co-dependency between traffic congestion and emergency response time. Furthermore, the high correlation between increased incident response time and adverse patient outcomes, emphasizes the importance of time in case of emergencies Black- well and Kaufman (2002). Similar findings indicate that traffic congestion significantly elevates the response time of emergency services. For instance, traffic congestion fre- quently delays ambulances, resulting in critical health risks Brent and Beland (2020).

A. *Limitations of Conventional Traffic Management System*

The pre-set timer system has the following limitations Wang et al. (2018):

The existing traffic signal operates on pre-set timers, causing inadequacies for fluctuating traffic conditions. Due to predetermined schedules, the signals cannot adjust to real-time variations in traffic density and can cause congestion during peak hours.

Traffic police officials often manually handle signals during emergencies disrupt- ing normal traffic flow as fixed-timer systems do not prioritize emergency services resulting in delayed response times.

Lack of coordination at adjacent intersections can aggravate traffic congestion resulting in impediments to normal transport services.

Conventional systems struggle to adapt to upgrades in urban infrastructure and population growth.

Lack of discipline and reckless driving are major contributors to delayed response times.

B. *Critical Findings*

We aim to propose an innovative design to rise above the challenges set forth by urban traffic congestion. The system is adaptable and has been designed to prioritize emergency service vehicles. The proposed system has the potential to transform the urban traffic management system and improve public safety. The intelligent traffic system uses real-time data to upgrade the current traffic management by integrating the pro- posed algorithm. It makes navigation efficient for emergency services and eventually reduces response time.

III. METHODOLOGY

Object detection is of the essence in our suggested intelligent traffic light system (ITS) approach to detect Emergency vehicles Viola and Jones (2001). In our pro- posed approach, we have considered detection of emergency vehicles. The idea is to employ real-time object detection at traffic signals, wherein cameras are installed for surveillance.

A. *Emergency Vehicle Detection*

Emergency vehicle detection takes place using OpenCV Vaishnavi et al. (2023). You Only Look Once (YOLOv8), Convolutional Neural Network (CNN) and OpenCV are fundamental in the proposed system for emergency vehicle detection. The use of YOLOv8 and CNN in conjunction with surveillance cameras are significant as:

A WiFi module is connected to a microcontroller and the camera.

Cost decreases drastically as the same microcontroller can connect 45 cameras per connection.

Since the camera detects and transmits data remotely, the response speed is much higher than the actual response speed at the intersection.

Since this is the surveillance camera we use, the range is very high, which allows us to see a large amount of traffic in a single scan Agrawal et al. (2021).

Emergency vehicle detection can take place via GPS-based vehicle detection. GPS tracking operates by controlling the entire procedure between the GPS and GSM mod- ules with the help of an ArduinoMEGA. While the GSM module provides coordinates to the user via message, the GPS module can obtain the location of a vehicle. It first determines the vehicle’s coordinates to track its location.

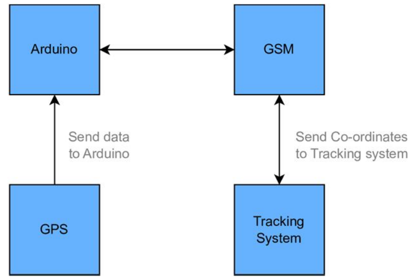

Fig. 1 Illustration of GPS-GSM model

The GPS module maintains a connection with the satellite to determine the coordi- nates. The ArduinoUNO will then receive the coordinates via GPS. Arduino MEGA extracts the data collected by the GPS. When the user sends a message to the GSM module via message, the GSM module works with the ArduinoMEGA to reply to the message and transmit it to the user. The message includes the coordinates of the vehicle Zohari and Nazri (2021). Another method for implementing emergency vehicle detection is sound detection. With the aid of a deep learning approach, the classifica- tion of vehicles is possible. The sounds of an ambulance and a firetruck are collected, MFCC values extracted, and 80% of the dataset is used in training the 1D CNN Algorithm. The remaining 20% of the dataset in testing helps optimise the model and lower model errors. Based on the frequency and decibel level of the emergency vehicle sirens, this deep learning model will assist in classifying emergency vehicles from other vehicles Sathruhan et al. (2022). Figure 1 depicts the working of the GPS-GSM model.

B. Lights Used in Intelligent Traffic System

1) Green: Allows all the vehicles to proceed through the intersection.
2) Red: Stop vehicles from moving forward.
3) Yellow: Provides a transition period between green and red phases.
4) Blue: Activated to create an emergency alert and prioritize the passage of emergency vehicles.

C. Proposed Method

1) Emergency Vehicle Detection: Motion image detection is used to locate the emergency vehicle from a distance. Since sound detection accuracy is lower and GPS infrastructure costs, such as GPS transmitters and receivers, are incurred, GPS and sound detection are not practical together. To present the simulation of traffic system , we have considered Pygame and Threading as our implementation platform to demonstrate the effectiveness of our approach. The time sequence will start as soon as the emergency vehicle is detected.
2) Emergency Situation Indicator (Blue colour): In order to notify other vehicles at intersection about an approaching emergency vehicle, our suggested method introduces an intutive solution: a blue signal in the traffic light system. This allows vehicles that are travelling in the opposite direction or far from the intersection to quickly recognize the situation and slow down. If the blue colour is not present, people might think that the traffic system is broken, which could result in mas- sive traffic jams that impede both emergency vehicles and the flow of traffic in that specific region or city.
3) Traffic Signal Time Adjustment: All traffic signals will have their timers changed to blue for a period of five seconds when an emergency vehicle is identified, alerting passing cars of the arrival of emergency vehicles.

D. Algorithm

To maintain traffic flow at intersections and prevent collisions without the assistance of traffic police, the proposed algorithm of the Intelligent Traffic Light system at the Intersection prioritizes the emergency vehicle for its safe and efficient passage without lowering its operational speed. CNN and OpenCV (a superior alternative to GPS and sound detection) enable the connectivity of up to 45 cameras with a single microcontroller when an emergency vehicle is at a junction.

YOLOv8 is used to detect moving objects using images. A high range with a quick response time makes it possible to detect traffic simultaneously Agrawal et al. (2021). When an emergency vehicle is detected, all the traffic signals at the intersection will start a timer and turn blue for five seconds simultaneously, alerting all the vehicles to the approaching emergency vehicle. This condition will cause the cars to slow down and move aside to make room for the emergency vehicle, preventing collisions between them as they will all be travelling at a reduced speed. The system will reset after the five-second blue phase finishes, returning to the initial state. The timer will also reset, and the direction from which the emergency vehicle approaches will first receive a green signal, allowing it to pass without slowing down. All other signals will turn red, and the time sequence will follow appropriately. Until the next emergency vehicle in any direction in any lane at the intersection is detected, the system will remain in its stable state. Our suggested algorithm is better for all traffic situations and locations since the timer is adjustable based on the intersection's traffic congestion throughout the day. The flowchart representation of the proposed algorithm is illustrated in figure 2.

Until next Emergency vehicle is not detected

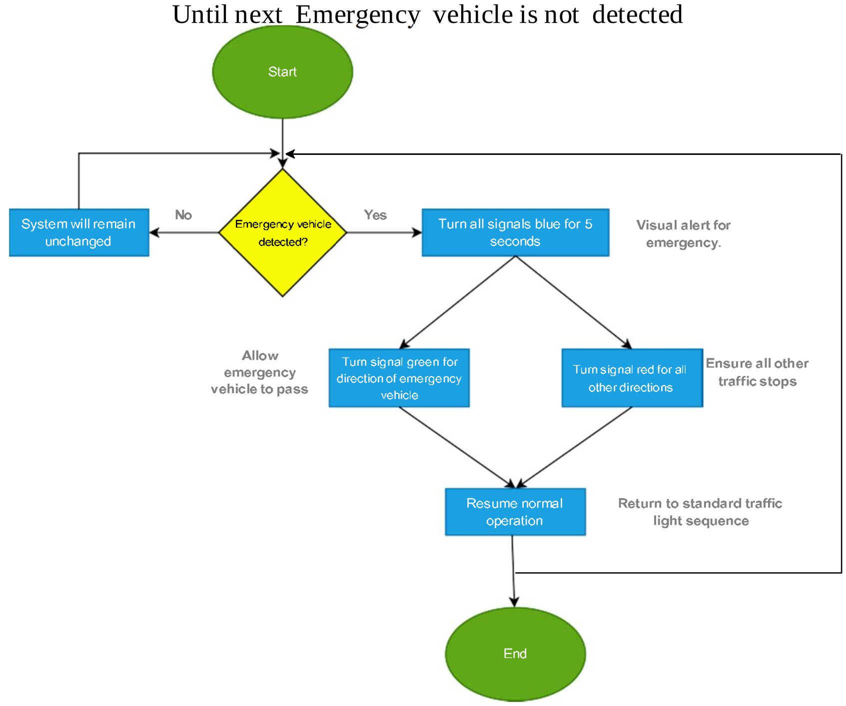

Fig. 2 Flowchart Representation of the Proposed Algorithm

A. Simulation Setup Overview

Our proposed algorithm was tested with the help of a simulation built with Python and Pygame to model the modern urban traffic intersection. Key components included defining vehicle classes (such as cars, buses, trucks, and emergency vehicles like ambu- lances and fire trucks). The random generation of these vehicles in random directions makes it as unpredictable as the real-life scenario of a real-world intersection. The traffic signals and timers are implemented logically with the aid of a library, such as Threading and time, allowing for the precise timing of each signal addition. Our simulation is 20% real-world scenario, and the timing of the results is 20% of the real-world scenario. The parameters we used for the for the simulation creation and testing of the algorithm are enlisted in table 1. Object-oriented programming, or OOP, allowed us to replicate every object from the actual world into the simulation. Even the vehicle's speed was replicated from actual real-world events. The algorithm's efficacy in increasing emergency vehicle passage while preserving overall traffic efficiency is demonstrated by the result, which was achieved after extensive testing under various congestion circumstances. The intersection's congestion can be manually changed in the simulation's Python code for better testing of the algorithm in all possible scenarios, from little fast vehicles to enormous slow-speed vehicles and from little congestion to extreme congestion at the intersection. In the simulation of the proposed algorithm, each of the four directions has a unique identifier ranging from 0 to 3. When an emergency vehicle approaches, a variable stores the identifier corresponding to the direction from which the emergency vehicle is arriving.

The saved value will subsequently serve as the input for the algorithm to decide its next steps.

Table 1 Parameters considered for the Simulation

Parameters	Values
Types of Vehicles	Normal vehicles, Emergency vehicles
Normal vehicles	Car, Bike, Bus, Truck
Emergency vehicles	Ambulance, Fire Truck
Speed of the vehicles (Pixels/Seconds) Ambulance: 1.8, Fire Truck: 1.8	Car: 2.25, Bike: 2.5, Truck: 1.8, Bus: 1.8,
Duration of the signals (Seconds) Time, Threading, Pygame, sys	Red: 60, Yellow: 5, Green: 15, Blue: 5 Libraries used Random,
Vehicle generation	Random

IV. RESULT ANALYSIS

Based on the achieved simulation results of our proposed approach, encouraging results were shown in terms of the emergency vehicle's effectiveness and safety when going through the intersection. Three levels of congestion have been simulated to assess the algorithm's performance under different traffic conditions: low, normal, and high.

1) Low Congestion: After the emergency vehicle was detected, the system calculated that it would take an average of 11 seconds to cross the intersection. Due to their rapid reaction times, emergency vehicles are given priority and rarely create delays to regular traffic. Table 2 consists of the observations for low congestion scenario and figure 3 depicts its traffic ensity.
2) Normal Congestion: Our proposed algorithm has maintained an average time interval of 14 seconds for emergency vehicles to clear the intersection from being detected to cross the intersection. This shows the effectiveness of our algorithm allowing emergency vehicles to navigate through the flow of traffic safely and promptly. Table 2 consists of the observations for normal congestion scenarioand figure 4 depicts its traffic density.
3) High Congestion: Our suggested algorithms maintain an average latency of 15 seconds from exposure to an intersection crossing for emergency traffic. This demon- strates how well our system works, even in congested intersections. Table 2 consists of the observations for high congestion scenario and figure 5 depicts its traffic density.
4) Comparison with Real-Life Scenarios: Simulation time intervals, without our algorithm, are faster or similar to manual processes currently used to guide emer- gency vehicles through intersections in a real-world setting in different categories. The design of the algorithm can reduce obstruction to normal traffic flow as well, as significantly increasing emergency response time. On average, our method took about 45 seconds to complete the simulation.

Table 2 Comparative Analysis of Proposed Algorithm and Existing System (in seconds) De Souza et al. (2017)

Attempts	Existing Approach	Proposed Approach		
		Low	Normal	High
1	15	8.66	10.57	12.11
2	66	11.85	12.59	15.23
3	52	12.98	14.08	15.12
4	20	13.74	11.05	14.34
5	50	6.54	13.20	16.02
6	60	7.46	9.71	21.10
7	29	8.72	15.41	13.03
8	58	14.45	20.41	15.24
9	53	18.87	20.19	14.35
10	47	17.89	18.95	15.14

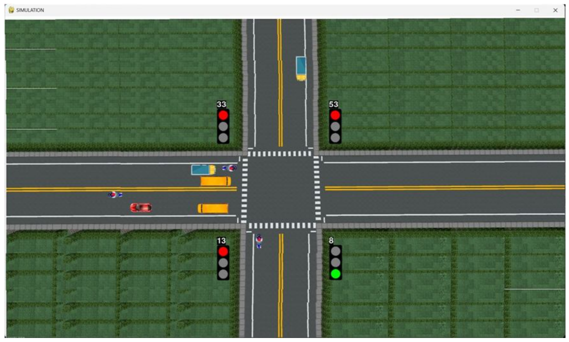
Fig. 3 Low Congestion

Overall, the results show that the proposed algorithm prioritizes the safe and efficient dispatch of emergency vehicles and controls traffic patterns. The graphical rep- resentation for a comparative analysis of different scenarios in figure 6. A goal-driven approach, that shortens emergency response times and increases future improvements in urban traffic infrastructure.

V. COMPARING EXISTING AND PROPOSED METHODS

In contrast to various research studies, our proposed method includes a blue signal to warn other vehicles approaching the intersection from a distance. For instance, if an emergency vehicle is not visible, it may result in accidents and misinterpretations

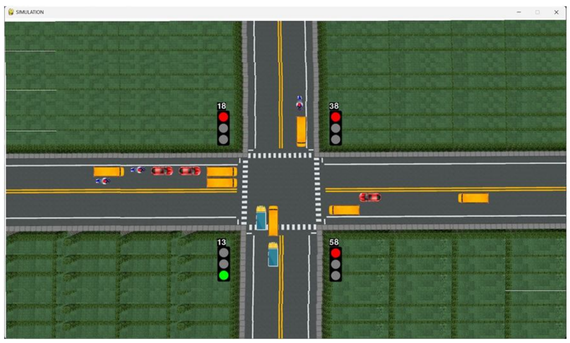
Fig. 4 Normal Congestion

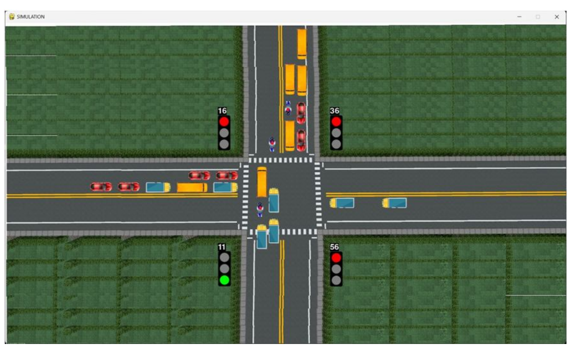
Fig. 5 High Congestion

of the signal, changes may give rise to rumours that the signals are malfunctioning and causing traffic jams because no one obeys the signal Thakare et al. (2024). There- fore, using the blue hue from our suggested way makes it more convenient because it alerts all other vehicles. Comparing our proposed method to the currently in use RFID (Radio Frequency Identification) method, which requires installing an RFID reader at an intersection and installing an RFID tag in the vehicle shows that it performs better because there is no need to modify emergency vehicles for the detecting pro- cess. Whenever a vehicle is detected, the system must record data such as the tag's RFID number in a database, which can confirm the type of vehicle.

All of them are expensive to implement, but the suggested approach is inexpensive since it utilizes the existing infrastructure and does not require a database containing entries for every vehicle bin Wan Hussin et al. (2019). Since most countries lack adequate infrastructure for emergency vehicles, our proposed method helps underdeveloped and undeveloped countries save lives by minimizing the time it takes for emergency response. Infrared sensors and an Arduino installed on emergency vehicles are used in certain studies to identify and remove all obstructions from emergency lanes to ensure that emer- gency vehicles can pass safely. Our approach does not necessitate the installation of an emergency lane or an IR sensor Rajee (2022). According to some research studies,

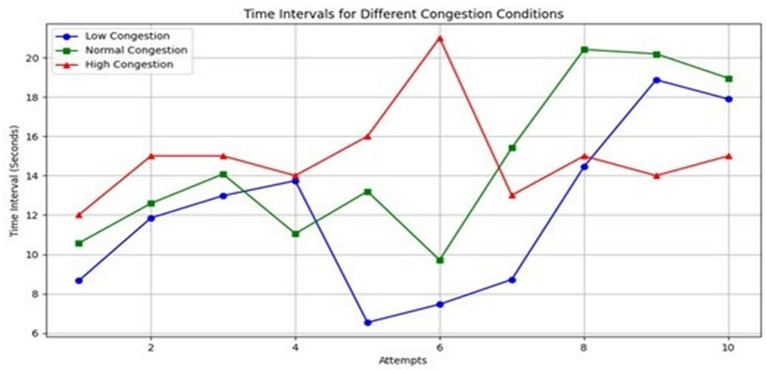

Fig. 6 Comparative Analysis of Three Scenarios

by installing intersection controllers, force resistive sensors and other sensors, emer- gency vehicle learning routes via the Internet of Things (IoT) can assist in resolving the problem of emergency vehicles becoming stuck at intersections. Table 2 consists of the observations of the conventional system. Our suggested approach is superior since it utilizes pre-installed security cameras at traffic intersections, saving on the expense of installing IoT devices Khan et al. (2018). Figure 7 is an analytical representation of the difference in the performance of the conventional system and the proposed system.

VI. DISCUSSION

Intelligent traffic light systems enable the response time of the emergency services to be faster and save more lives simultaneously. They automatically switch the lights so the emergency vehicles do not wait. Practically, this is the case, it allows for medical help to get where it is needed more rapidly, which can lead to lifesaving. The results achieved from the simulation of the proposed approach show the importance and imple- mentation of our algorithm. The proposed paper is a determined modus operandi and exhibits versatility by functioning in different types of congestion. The comparative analysis of the results depicts the prioritization of emergency service vehicles during traffic congestion in multiple scenarios and the performance of the proposed algorithm. Figures 8 to 11 illustrate the working of the proposed algorithm within the simulation.

Drivers have an easy ride because of the intelligent traffic system. The traffic flows seamlessly without the intervention of traffic police at the intersection to direct traffic. For instance, having a very intellectual person who supervises all the traffic

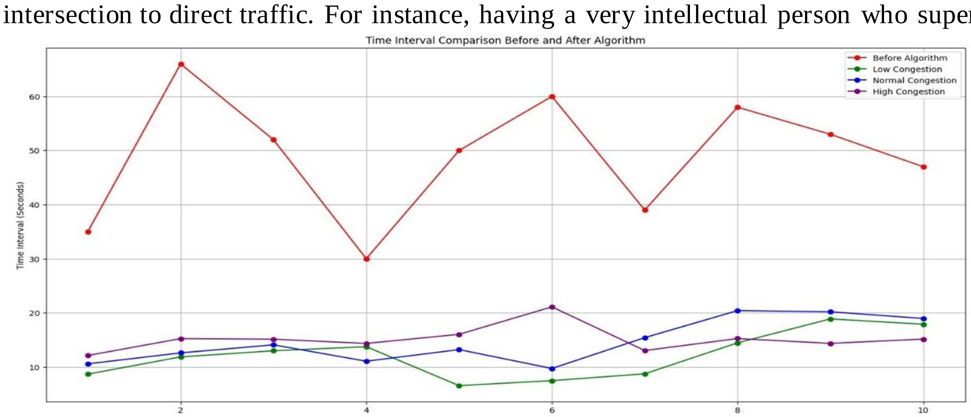

Fig. 7 Analysis of the difference between the systems

signal lights in the city, ensuring everybody's going in the right direction as quickly as possible without mistake.

This system is at its best when dealing with a calamity. It gives an efficiency boost to the assistants and the rest of the staff who work to save others. For the rest of the people, it makes driving around town a bit smoother and less frustrating.

Envision a city where traffic flows so effortlessly that people are not held up too long by red lights. The proposed traffic system incorporates every conceivable type of intelligent technology in managing all the vehicles on the road. The less time a car spends idling at lights, the more fuel saved, which later transcends to improving the air quality for breathing.

This city will function better, be more connected, and be kind to nature. It makes life easier for the residents, much the same as helping the environment. Many people would like to live in a modern and ecologically green place. The approach makes city life much better for everyone while at the same time protecting our planet.

An intelligent traffic system is always the smart and affordable choice for a city. It works with pre-existing traffic lights, so everything will not have to be replaced, making it less expensive than building new systems or hiring numerous traffic police. Computers are part of the system and control the traffic, reducing the number of people required to manage it daily.

It can also grow with the city—to work just as well in busy downtown areas as in quieter suburbs. One of the best things about this system is that it plays nicely with others. Cities can refine existing infrastructure smartly to make traffic flow smoother without breaking the bank.

An intelligent traffic system would improve public safety and create awareness in our cities. In such a way, one could inform the drivers if an ambulance or fire truck with a blue emergency light is already on the way. It will help the emergency vehicle pass through the traffic swiftly and potentially save lives.

This system can also avoid accidents through intelligent traffic lights. It will change the lights so that the vehicles slow down cars where there is road work or bad weather. It can keep a constant eye on the road conditions. It can facilitate a safer crossing of streets for people walking. It will be able to give more time to cross at busy intersections or places like schools or hospitals. It is beneficial for senior citizens or people not able to move fast.

It can also send text messages to individual phones in case of jams, accidents, or closed roads, thus allowing everybody to plan how to travel without hitting the accident spots. As people gradually become accustomed to these intelligent traffic lights, they will obey traffic rules more efficiently. They will realize that the lights change depending on the situation at the intersection and trust the system.

Such systems will, in times of extreme emergency like natural disasters, be able to help manage evacuations better. All the lights might turn green in the direction everybody needs to travel to shepherd them away from dangerous areas as quickly and safely as possible.

All these features work together to make the city a safe place for all road users: drivers, people walking, and cyclists. It's using new technology to keep everybody safer when they're out and about. The intelligent traffic light system can be integrated with other smart city systems such as public transportation and pedestrian management. This improves the coordination between different vehicles and supports the development of comprehensive urban planning strategies.

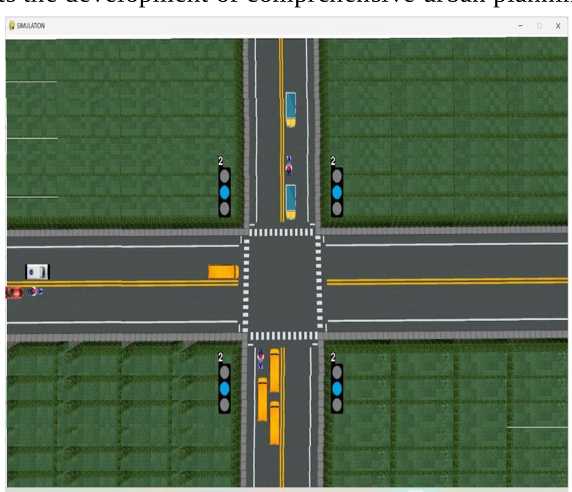

Fig. 8 Blue light when emergency vehicle approaches

VII. CHALLENGES

There are several real-world challenges to be reckoned with when implementing intelligent traffic signals with blue lights.

A. Hardware Implementation

Implementation of hardware as per the requirements of the proposed system may face some challenges:

Fig. 9 Emergency vehicle successfully departs

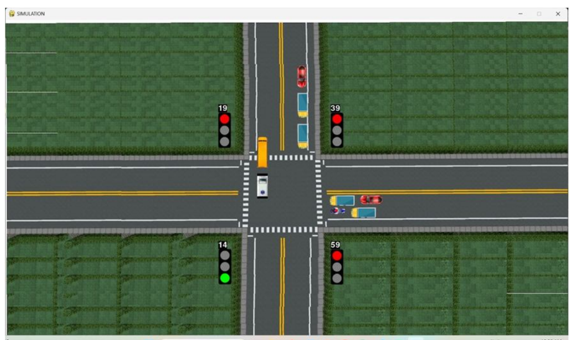

Fig. 10 Green light for emergency vehicle to pass

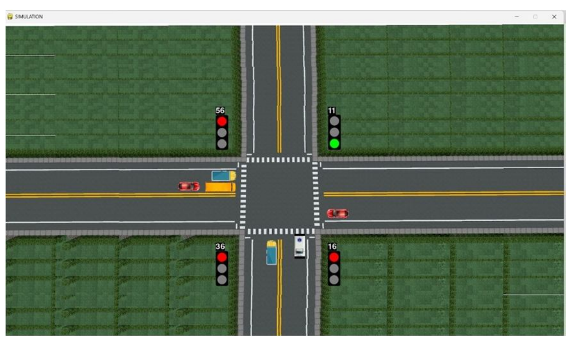

Fig. 11 Testing and Validation

1) Infrastructure Retrofitting and Structural Assessments: The majority of the existing infrastructure of the traffic signal structures will need retrofitting to accommodate the new blue lights. The current equipment may not have the structural capacity required to implement the proposed system.
2) Colour selection: The light should be visible under wide-ranging environmental conditions. A light with an optimal wavelength will be visible during bright daylight, overcast conditions, and nighttime.
3) Power supply: Introduction of a new light needs a stable supply of electricity as its incorporation into the existing systems while ensuring that the standard red, yellow, and green lights remain unaffected, is a complex task.
4) Cost and maintenance: The expenses of buying equipment, installing and main- taining should be budgeted. It may require a phased implementation. Maintaining the whole system and conducting regular performance tests is necessary for effective results.

B. Vehicle Detection

There will be many challenges in vehicle detection as the current technology on vehicle detection is not sufficient enough to detect accurately.

1) Speed and motion: When vehicles move at high speeds, they commonly generate motion blur, which diminishes the clarity of each captured frame. Processing the real-time video frames to identify the objects within the stipulated period can be computationally demanding.
2) Lights and Sirens: If the model is not trained with sufficient data, flashing lights might occasionally confuse. Detection issues may arise from flickering lights since the direct flash on the cameras prevents from capturing emergency vehicles.
3) High Computational Demand: YOLOv8 and CNNs require significant compu- tational power for real-time inference, especially for high-resolution video streams. When fine-tuned or trained on large datasets, Deep CNN requires GPUs or TPUs, increasing costs.
4) Energy Consumption: Real-time inference for object detection requires GPUs or edge AI hardware that consumes significant energy, especially when processing multiple video streams simultaneously.

VIII. MITIGATION STRATEGIES

Public awareness and education will be crucial for the new light signal system used in traffic systems. This system depends on the assumption that people are aware of their role in ascertaining the free movement of emergency vehicles.

1) Public Awareness Campaigns: Demonstrations conducted in public places can inform people of the blue light signal. Live demonstrations conducted at intersections can display how the system works.
2) Social Media Campaigns and Promotions: Promotion of educational resources through social media platforms using videos, infographics, or FAQs about the signal. Using hashtag campaigns can make it easier for people to share information and their experiences with the system. The availability of all materials, like brochures, guides, and video tutorials, should be announced at the transport hubs.
3) School Awareness Program: Introducing the Blue Light system in the gen- eral road traffic safety awareness for school children is required. Engaging students interactively through role-playing and mock traffic intersections to explain the sys- tem is necessary. Cooperate with schools to conduct an annual traffic safety week emphasizing the blue light initiative.
4) Inclusion in Driving Tests and Training: The questions and scenarios regarding the blue light system in the driving license tests are necessary. Periodic refresher courses for licensed drivers, both online and in person, must be made available to train licensed drivers about the system. Simulations that depict real scenarios of the blue light signal make it easier to understand.
5) Public Feedback Mechanisms: Feedback channels with online surveys, mobile applications, suggestion boxes and toll-free numbers enable people to share their experiences and difficulties in the system. Refine information in educational material based on feedback, dispel myths, and change the system as needed.

IX. FUTURE SCOPE

Based on the acquired result of the proposed algorithm and analysing the challenges to the motive, the future research directions derived are :

1) Inbuilt advanced AI-driven prioritization: Developing algorithms to handle multiple emergency vehicles converging on a scene from different directions. Han- dling of emergency vehicles could be evaluated against the traffic density, along with possible route options, for prioritizing real-time traffic management for emergency vehicles.
2) Smart city infrastructure integration: The designed traffic management system should be adaptable to perform inter-city communication, such as ways of trans- port within the city space, pedestrian crossings, and databases of city planning. Therefore, it can become more comprehensive in dealing with and coordinating the challenges offered by the traffic management system.
3) Detection enhancements: Investigate state-of-the-art sensor fusion techniques, integrating visual, infrared, and acoustic sensors for more accurate and robust vehi- cle detection. It shall enhance performance under all weather conditions and lower false positives or negatives.
4) Vehicles for Infrastructure communication: Allow direct communication between the emergency vehicle and traffic signals for precise location awareness with priority. It would also support the transmission of specific emergency information to the traffic management system.

5) Emergency predictive routing: Develop a system that, through historical data and accurate information, gives the emergency vehicle the best possible routes that might have the metal to clear the traffic in its front.
6) Adaptive blue light: Develop an adaptive light that changes intensity and wave- length of the ambient lighting conditions so that there is always visibility throughout the day. In the case of different weather conditions, water does not make the light less visible.
7) Public awareness and response system: Designing a networked system that sends alerts to nearby drivers through their smartphone applications or in-car systems when an emergency vehicle is approaching will be beneficial.
8) Integration with autonomous vehicle systems: It provides integration with autonomous vehicle systems by devising protocols for how self-driving cars should respond to a blue light or any other signal indicating that an emergency vehicle has gained priority.
9) Environmental Impact Assessment: Long-term system impact research into emission reduction through reduced idling and improved traffic flow, in particular for emergency vehicles.
10) Scalability and Standardization: Research of a standardized system that is replicable in all different types of urban settings across all infrastructures that cover the scalability and adaptability of various infrastructures.
11) Cybersecurity measures: Developing secure protocols will ensure the system is safe from hacking or manipulation to assure the integrity of the emergency vehicle prioritization.
12) Machine Learning for pattern recognition: Implement machine learning algo- rithms that learn patterns in emergency vehicle movement and traffic flow, enabling the system to improve its work over time.

These future research directions are comprehensive in a way that spells out techno- logical advancement, system integration issues, and urban planning considerations as a holistic view towards further development and improvement of intelligent traffic system.

X. CONCLUSION

Implementation of this system will be beneficial for urban environments. An unob- structed route for emergency vehicles will significantly reduce response time. This system adjusts traffic signals, optimizes traffic flow and diminishes congestion, which benefits everyday commuters. Furthermore, it contributes to environmental sustain- ability by reducing halts, thus reducing fuel consumption and emissions. It also supports smart city initiatives by utilizing advanced technologies for urban infras- tructure and constant improvements. It is cost-efficient, scalable and adaptable for various scenarios. Additionally, public safety is ensured by spreading awareness regarding emergencies and promoting obedience to traffic rules. Conclusively, its ability to integrate with existing systems and smart city initiatives make it more reliable and supports widespread urban development strategies.

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