

AI-Powered Traffic Control For Emergency Response

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Abstract - Emergency medical services are critical in saving lives, where even small delays can significantly affect patient outcomes. In metropolitan and densely populated areas, ambulances often face delays due to heavy traffic congestion and uncoordinated traffic signals. Traditional traffic systems lack the intelligence required to prioritize emergency vehicles and ensure smooth passage. With the advancement of Artificial Intelligence and smart transportation technologies, it is possible to develop systems that assist emergency vehicles in navigating traffic efficiently. This project proposes an AI-enabled Ambulance Routing and Traffic Management Framework that ensures faster and safer ambulance movement. The system detects the ambulance's lane and location using intelligent sensing techniques and automatically communicates with emergency control centers. It also interacts with traffic signal controllers to dynamically change signal phases and create a green corridor for the ambulance. An AI-based Estimated Time of Arrival (ETA) model predicts the ambulance arrival time at intersections using parameters such as vehicle speed and traffic density. The framework also sends real-time ETA updates to hospitals so that medical teams can prepare emergency facilities before the patient arrives. In situations involving multiple ambulances, a coordination module prioritizes vehicles based on emergency severity, distance to hospitals, and hospital readiness. By integrating artificial intelligence with intelligent traffic systems, the proposed solution improves ambulance mobility, reduces response time, and enhances the efficiency of emergency healthcare services in smart cities.

Key Words: Ambulance Routing, Artificial Intelligence, Traffic Signal Control, ETA Prediction, Emergency Response, Smart Transportation Systems.

1. INTRODUCTION

Road traffic congestion has become a major challenge in modern urban areas due to rapid urbanization and the growing number of vehicles. These conditions often cause delays in transportation, especially for emergency vehicles such as ambulances, where every minute is critical for saving lives. Traditional traffic signal systems generally operate on fixed timing cycles and do not have the capability to detect or prioritize emergency vehicles. As a result, ambulances frequently encounter traffic congestion and red signals at multiple intersections, increasing response time and reducing the efficiency of emergency medical services. Therefore, there is a strong need for an intelligent traffic management system that can support faster and uninterrupted ambulance movement during emergencies.

To address this issue, the proposed project "AI-Powered Traffic Control for Emergency Response" introduces an advanced

framework that uses Artificial Intelligence and intelligent sensing technologies to manage ambulance routing efficiently. The system detects approaching ambulances and dynamically adjusts traffic signals to create a green corridor, allowing smooth movement through intersections. An AI-based Estimated Time of Arrival (ETA) model predicts the ambulance's arrival time using parameters such as speed, traffic density, and signal cycles, and shares this information with hospitals so that medical teams can prepare in advance. The system also includes a multi-ambulance coordination module that prioritizes routes based on factors like emergency severity and hospital proximity. By integrating AI, communication technologies, and intelligent transportation systems, the proposed solution aims to reduce response time, improve traffic management, and enhance emergency healthcare services in smart cities.

2. LITERATURE REVIEW

Several researchers have worked on intelligent traffic management systems to reduce delays for emergency vehicles such as ambulances. With the growth of Artificial Intelligence, Internet of Things, and Intelligent Transportation Systems, many solutions have been proposed to improve traffic control and emergency response time.

Early traffic management systems mainly relied on fixed-time traffic signals. These systems could not adapt to real-time traffic conditions and often caused delays for emergency vehicles. Researchers later introduced sensor-based traffic monitoring, where cameras and sensors were used to detect vehicle density and adjust signal timing dynamically. However, these systems were still limited because they did not prioritize emergency vehicles effectively.

Several studies proposed the use of RFID and GPS technologies to detect ambulances approaching an intersection. In these systems, RFID tags or GPS modules installed in ambulances communicate with traffic signal controllers to provide a green signal for the emergency vehicle. While these approaches improved ambulance movement, they required dedicated hardware infrastructure and had limitations in large-scale urban environments.

With the advancement of Machine Learning, researchers began developing intelligent models to predict traffic patterns and optimize signal timings. Machine learning algorithms analyze historical and real-time traffic data to estimate congestion levels and adjust traffic lights accordingly. These predictive models significantly improved traffic flow efficiency and reduced waiting times at intersections.

Recent research focuses on integrating AI-based traffic prediction models with real-time communication networks. These systems use cameras, acoustic sensors, and IoT devices to detect emergency sirens and identify ambulances automatically. Once detected, the system creates a “green corridor” by coordinating multiple traffic signals along the ambulance route. This ensures uninterrupted movement and faster arrival at hospitals.

Another important research area is multi-ambulance coordination. In large cities, multiple ambulances may operate simultaneously in nearby locations. AI-based decision systems evaluate factors such as distance, emergency severity, and hospital capacity to determine priority routes. This helps reduce conflicts between emergency vehicles and improves resource allocation across the healthcare network.

Researchers have also explored integrating hospital communication systems with traffic management frameworks. By providing real-time Estimated Time of Arrival (ETA) updates to hospitals, medical teams can prepare equipment and resources before the patient arrives. This integration improves emergency care efficiency and reduces treatment delays.

Despite these advancements, existing systems still face challenges such as scalability, data accuracy, infrastructure cost, and coordination among multiple agencies. Therefore, modern research focuses on developing fully automated AI-driven traffic management frameworks that combine intelligent sensing, predictive analytics, and real-time communication.

The proposed system builds upon these previous studies by integrating AI-based prediction, automatic ambulance detection, traffic signal coordination, and hospital communication into a unified framework. This approach aims to reduce ambulance travel time, improve emergency response efficiency, and support the development of smarter urban transportation systems.

3. Technology used in AI-Powered Traffic Control For Emergency Response

Software used:

Visual Studio Code:

Visual Studio Code is a powerful code editor used to develop and manage the project source code. It supports multiple programming languages and extensions for efficient development.

Python:

Python is used to implement the system logic and process sensor data. It also supports AI and machine learning libraries used in traffic prediction.

HTML5:

HTML5 is used to design the structure of the web interface. It displays system information such as traffic status and ambulance location.

CSS:

CSS is used to style and format the web pages of the system dashboard. It improves the visual appearance and layout of the interface.

Hardware Tools Used:

SSD1306 OLED Display

A compact 128×64 pixel OLED module providing real-time visual feedback. Supports state-specific messages including Standby, Crash Location, ETA, Hospital, and Arrived. Ensures clear, high-contrast text and symbols for operational status updates in emergency and navigation systems..

Ultrasonic Sensor:

Ultrasonic sensors detect the distance between vehicles and the sensor. They help identify traffic density and vehicle movement on the road.

Camera Module:

The camera module captures real-time images of the road. It helps the system monitor traffic and detect emergency vehicles.

Traffic Light Module:

Traffic light modules simulate real traffic signals such as red, yellow, and green lights. They are automatically controlled to give priority to ambulances.

AI and Communication Technologies Used:

Artificial Intelligence:

Artificial Intelligence enables the system to make intelligent traffic control decisions. It helps prioritize emergency vehicles and reduce response time.

Machine Learning:

Machine learning analyzes historical and real-time traffic data. It predicts traffic congestion and optimizes signal timing.

Computer Vision:

Computer vision processes images from cameras to identify vehicles and ambulances. It helps monitor traffic conditions automatically.

Internet of Things:

IoT connects sensors, cameras, and traffic signals through the internet. This allows devices to share real-time traffic information.

Wireless Communication:

Wireless communication enables data exchange between ambulances, sensors, and traffic signals. It ensures quick communication during emergencies.

Global Positioning System (GPS):

GPS is used to track the real-time location of ambulances. It helps the system estimate arrival time and create a green corridor.

Cloud Computing:

Cloud computing stores traffic data and allows remote monitoring of the system. It enables traffic control centers and hospitals to access real-time information.

4. Proposed System

Improvements Over the Existing System:

- **AI-Based Ambulance Detection**

The system uses Artificial Intelligence along with sound sensors and camera-based lane detection to identify approaching ambulances. Siren detection and visual recognition help the system accurately determine the ambulance position and respond quickly.

- **Dynamic Traffic Signal Control**

Once an ambulance is detected, the system automatically communicates with traffic signal controllers and creates a dedicated green corridor by adjusting signal phases in real time.

- **Real-Time GPS Tracking**

The ambulance location is continuously monitored using GPS technology, allowing real-time tracking and

immediate transmission of location data to the traffic control center.

- **AI-Based ETA Prediction**

The framework calculates the Estimated Time of Arrival (ETA) using parameters such as ambulance speed, traffic density, and signal timing. This helps intersections and hospitals prepare in advance.

- **Multi-Ambulance Coordination**

The system manages situations where multiple ambulances operate in nearby areas by assigning priority based on emergency severity, distance to hospitals, and current traffic conditions.

- **Hospital Notification System**

Hospitals receive real-time updates about ambulance location, ETA, and emergency status, allowing medical teams to prepare equipment and staff before the patient arrives.

Unlike the existing systems, our system includes the following roles:

1. **Traffic Control Center:**
Monitors ambulance movement, manages traffic signals, and coordinates the overall emergency traffic management system.
2. **Hospital Panel:**
Receives real-time updates about ambulance location and ETA, allowing medical staff to prepare emergency facilities in advance.
3. **AI Traffic Management System:**
Analyzes real-time traffic data, predicts ambulance arrival time, controls traffic signals, and manages multi-ambulance coordination.
4. **Ambulance Unit:**
Equipped with GPS and detection sensors to transmit location, speed, and emergency information to the traffic management system.

5. Challenges Faced During Implementation

Hardware Integration Issues

Integrating devices like ESP32, Raspberry Pi, cameras, and Ultrasonic Sensor was challenging because each component required proper configuration and stable connections.

Wireless Communication Reliability

Maintaining stable Wireless Communication between vehicles and traffic control units was difficult due to signal interference and limited range.

Accurate Ambulance Detection

Ensuring reliable ambulance detection using ultrasonic signals sometimes caused false detection or delay in response.

Vehicle Detection Accuracy

Implementing Computer Vision for vehicle counting was challenging because lighting conditions, camera angles, and moving vehicles affected detection accuracy.

Real-Time Data Processing

Processing large amounts of sensor and camera data quickly on Raspberry Pi required optimization to avoid delays.

System Coordination

Synchronizing multiple vehicles, traffic lights, and sensors required careful system design to avoid conflicts in traffic signal control.

Web Application Integration

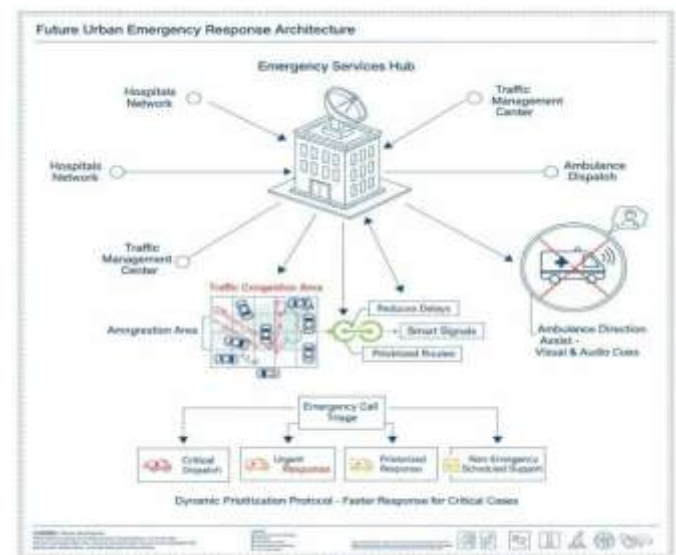
Integrating hardware data with the web monitoring system developed using Django required proper data communication and API handling.

Testing in Real-Time Conditions

Simulating real traffic conditions with multiple vehicles and emergency scenarios was difficult during testing.

6. System Design

6.1. Architecture of the System



6.2 Module Include

1. Smart Vehicle and Traffic Control Module

- Vehicles are built using ESP32 microcontrollers that communicate wirelessly and share movement data.
- Traffic signals are automatically controlled based on vehicle flow to maintain smooth traffic.

2. Ambulance Detection and Priority Clearance Module

- The ambulance is connected to a Raspberry Pi and sends signals using an Ultrasonic Sensor.
- Other vehicles detect the signal and the system gives priority by clearing traffic and changing signals.

3. Vision-Based Vehicle Counting Module

- A camera connected to the Raspberry Pi captures road images.
- Using Computer Vision, the system detects and counts vehicles to analyze traffic density.

4. Web Monitoring and Data Management Module

- A web application built with Django monitors the system in real time.

- It collects data from ESP32 and Raspberry Pi devices and displays traffic and ambulance information.

7. Implementation and Results

7.1 System Development

The system was designed to control traffic and give priority to emergency vehicles. It integrates vehicles, sensors, cameras, and traffic signals to create an intelligent traffic management system.

Hardware Setup

Vehicles were developed using ESP32 microcontrollers, while the ambulance unit was integrated with Raspberry Pi, a camera module, and an Ultrasonic Sensor for detection and communication.

Communication Implementation

The vehicles and traffic units communicate using Wireless Communication to exchange real-time data such as vehicle position and emergency alerts.

Vision-Based Vehicle Detection

A camera connected to the Raspberry Pi uses Computer Vision techniques to detect and count vehicles in front of the ambulance. This helps analyze traffic density.

Traffic Control Mechanism

Based on vehicle data and ambulance detection, traffic signals are dynamically controlled. When an ambulance is detected, the system automatically clears traffic and provides a priority path.

Web Application Development

A web monitoring system was developed using Django to display real-time traffic information, ambulance movement, and system status.

System Testing and Deployment

The complete system was tested by simulating traffic conditions with multiple vehicles. The results showed improved traffic management and faster emergency vehicle movement.

7.2 System Testing

To ensure the reliability and efficiency of the proposed system, the following testing strategies were implemented:

Unit Testing:

Individual components such as ambulance detection, lane identification, ETA prediction module, and traffic signal control were tested independently to verify their correct functioning.

Integration Testing:

All modules including sensing units, AI prediction models, communication with traffic signals, and hospital notification systems were integrated and tested to ensure smooth coordination and data flow between components.

User Acceptance Testing:

The system was evaluated using simulated emergency scenarios to verify accuracy, response time, and usability for traffic authorities, emergency control centers, and hospital staff.

Results:

The system performed effectively during simulated emergency scenarios. The ambulance detection and lane identification modules accurately identified the approaching ambulance and transmitted the information to the emergency control center successfully. The AI-based ETA model generated reliable arrival time predictions and enabled timely signal adjustments to create a green corridor. Real-time communication with hospitals functioned properly, allowing medical teams to receive early updates and prepare emergency facilities. The multi-ambulance coordination module also operated as expected by prioritizing ambulances based on emergency severity and distance, ensuring smooth and efficient movement across the traffic network.

7.3 Results :



Fig 7.1: Home



Fig 7.2: Ambulance Dashboard



Fig 7.2: Hospital Dashboard

8. DISCUSSION AND ANALYSIS

8.1 Advantages of AI-Enabled Ambulance Routing and Traffic Management System

Faster Emergency Response

The system enables quicker ambulance movement by automatically adjusting traffic signals and creating a green corridor, reducing delays during emergencies.

Smart Traffic Signal Control

Traffic signals are dynamically controlled based on ambulance location and predicted arrival time, ensuring smooth passage through intersections.

Real-Time Ambulance Detection and Communication

Lane detection and sensing technologies accurately identify approaching ambulances and instantly notify emergency control centers and traffic management systems.

AI-Based ETA Prediction

The integrated AI model calculates the estimated arrival time at each junction using real-time traffic data, ambulance speed, and signal timing.

Improved Hospital Preparedness

Hospitals receive real-time ETA updates, allowing medical staff to prepare emergency facilities and resources before the patient arrives.

Multi-Ambulance Coordination

The system intelligently prioritizes multiple ambulances based on emergency severity, distance to hospitals, and hospital readiness to avoid conflicts in traffic routes.

8.2 Future Work

Integration with city-wide smart traffic infrastructure for better coordination. Incorporation of drone-based monitoring for real-time traffic analysis. Development of a mobile application for ambulance drivers and traffic authorities. Deployment on large-scale smart city platforms to support multiple emergency services.

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10. CONCLUSION

The AI-enabled Ambulance Routing and Traffic Management Framework represents a significant advancement in emergency medical services by combining artificial intelligence, IoT, and real-time communication to address the critical challenge of ambulance delays in congested urban areas. By integrating automated ambulance detection, intelligent traffic signal control, predictive ETA calculation, multi-ambulance coordination, and hospital notification systems, the framework ensures a seamless and efficient emergency response network. This system not only reduces travel time for ambulances but also enhances hospital preparedness, enabling timely medical intervention that can save lives. The AI-based ETA prediction and coordination modules improve decision-making, optimize resource allocation, and prevent route conflicts even in scenarios involving multiple ambulances. Furthermore, the framework demonstrates the potential of smart city technologies to create a connected and responsive urban healthcare ecosystem. With future enhancements such as autonomous vehicle integration, predictive traffic analysis, and patient monitoring, this system can be further developed to provide more accurate, adaptive, and scalable solutions for emergency services. Overall, the proposed framework contributes to reducing critical delays, improving patient survival rates, and establishing a safer and more intelligent urban environment, showcasing the transformative impact of AI-driven systems on public safety and healthcare management.

REFERENCES

1. Ahmad, I., & Kumar, A. (2020). IoT Enabled Emergency Vehicle Routing and Traffic Signal Control. *International Journal of Engineering Research & Technology (IJERT)*, 9(9), 732–737. [IJERT]
2. Bharadwaj, R., Deepak, J., Baranitharan, M., & Vaidehi, V. V. (2013). Efficient Dynamic Traffic Control System Using Wireless Sensor Networks. *Proceedings of the International Conference on Recent Trends in Information Technology (ICRTIT)*. DOI: 10.1109/ICRTIT.2013.6844280. [IEEE]
3. Chaitanya, D. R., & Anitha, T. (2019). Smart Ambulance System with Automatic Traffic Signal Control and Route Optimization. *International Research Journal of Engineering and Technology (IRJET)*, 6(5), 4580–4585. [IRJET]
4. Choudhury, K., & Nandi, D. (2021). Detection and Prioritization of Emergency Vehicles in Intelligent Traffic Management System. *IEEE Bombay Section Signature Conference (IBSSC)*. DOI:10.1109/IBSSC53889.2021.9673211. [IEEE]
5. Hancke, G. P., & Nellore, K. (2016). Traffic Management for Emergency Vehicle Priority Based on Visual Sensing. *Sensors (Basel)*, 16(11), 1892. DOI: 10.3390/s16111892. [NIH]
6. Memon, A. M., & Bhatti, N. (2020). AI-Based Smart Ambulance System for Dynamic Traffic

- Management. International Journal of Advanced Computer Science and Applications (IJACSA), 11(4),
7. Nellore, K., & Melini, S. B. (2012). Automatic Traffic Monitoring System Using Lane Centre Edges. IOSR Journal of Engineering, 2(1), 1–8. [IOSRJEN]
 8. Patel, R., & Sharma, D. (2021). IoT-Based Smart Traffic Signal System with Emergency Vehicle Clearance. International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE), 9(4), 876–882. [IJIRCCE]
 9. Rajeshwari, S., Santhosh, K., & Balaji, S. (2017). Intelligent Traffic Control System for Ambulance Using RFID and GPS. International Journal of Computer Applications, 145(2), 0975–8887. [IJCA]
 10. Reddy, P. S., & Kumar, R. (2020). Machine Learning Based Emergency Vehicle Detection and Priority Management. IEEE Access, 8, 155200–155210. DOI: 10.1109/ACCESS.2020.3018756. [IEEE]