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AI-Based Ambulance Priority Traffic Management System

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Abstract: Traffic jams at road intersections can cause delays for Ambulance. These delays make it hard to get emergency help to people fast. Most traffic signal systems use fixed timing. They do not react quickly when an Ambulance is coming. This paper presents an Ambulance Priority Traffic Management System. It uses computer vision, deep learning and automatic decision-making to help Ambulance move faster and to monitor traffic better at intersections. The system works at a four-way intersection with four traffic zones: North-West, North-East South-West and South-East. It uses the You Only Look Once (YOLO) object detection algorithm to analyze traffic images and video frames. A special YOLO model is trained to detect Ambulance. A general YOLO model identifies vehicles like cars, buses, trucks and motorcycles. The system draws bounding boxes and class labels around each vehicle. It also finds where each vehicle is located in the traffic scene. When Ambulance is detected the system finds the center point of Ambulance's bounding box. It then identifies which traffic zone Ambulance is in. After that the traffic light for that zone turns green. The lights for the three zones turn red in the prototype interface. This direction-based control gives priority to Ambulance. It stops traffic from moving at the same time. Once Ambulance has passed the system could later be designed to return the signals to normal using a control strategy. In addition to giving priority to Ambulance the system counts cars, buses, trucks and motorcycles. This helps create a picture of traffic. The counts are used to label traffic density as low, medium or high. This data can help monitor traffic conditions. It also lays the groundwork for adaptive signal-control strategies. The prototype was tested using traffic images and video clips. It showed its ability to detect vehicles choose the direction count vehicles and display signal changes. Detailed testing is needed to check how accurately the system detects vehicles, how fast it responds and how well it works in real traffic. The system shows how object detection and direction-specific signal control can be combined in an emergency traffic-management prototype. Future improvements might include live CCTV feeds, vehicle tracking, Ambulance siren detection, GPS location, predictive traffic analysis and multi junction coordination, across intersections. These upgrades could help build an efficient smart traffic management system.

Keywords: *Ambulance Detection, Artificial Intelligence, Computer Vision, Emergency Vehicle Priority, Traffic Density Classification, Traffic Signal Control, Vehicle Counting.*

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I. INTRODUCTION

Traffic congestion is an issue in city transportation. Cars moving in directions often compete for the same road space. At traffic lights long lines of cars and fixed signal times can slow things down even when one direction needs to go away. These delays are especially important for ambulances. Getting to an emergency quickly can mean the difference between life and death.

Standard traffic lights usually follow set time plans. These plans do not change based on what's happening on the road. Even though they help manage traffic they do not respond quickly when an ambulance is nearby. That is why researchers are looking at ways to watch traffic and change signals in time. Cameras and smart decisions are being studied to make intersections work better [1] [2].

Object-detection methods can show where different kinds of vehicles are in a picture or video. This project uses a YOLO-based detection system to spot ambulances and keep an eye on vehicles. Other studies have also looked at using AI to manage traffic and give priority to emergency vehicles [3] [9] [10]. These approaches help build a system that watches for emergency vehicles and reacts to what's happening on the road.

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The system divides the area around an intersection into four parts: North-West, North-East South-West and South-East. A special ambulance detector spots the emergency vehicle. The region where the ambulance is found decides which signal turns green. The other three directions get signals in the test version. This way of handling each direction is a part of the project.

Along with finding ambulances the test version also spots cars, buses, trucks and bikes. It counts how many of each are present. These numbers help decide if traffic's light, busy or heavy. This information helps the system understand the road situation and support the ambulance better. The current version is a computer vision test using pictures and videos of traffic. It is not meant to be used as a traffic controller on actual roads. More testing is needed before this idea could be used at traffic lights.

➢ *Problem Statement*

An ambulance approaching an intersection may face delays because traffic signals run on fixed schedules. Manual changes may not happen enough. Traffic monitoring systems that do not know which direction the emergency vehicle is coming from may not choose the right signal response. A computer-vision prototype is developed to detect an ambulance figure out where it is in a four-region intersection and show the signal priority.

➢ *Objectives*

The objectives of the proposed system are:

- To detect ambulances in traffic images and videos using a trained YOLO model.
- To detect cars, buses, trucks and motorcycles using a vehicle-detection model.
- To find the ambulance's location within the four predefined intersection regions.
- To assign a green signal to the direction where the ambulance is and red signals to the other three directions in the prototype.
- To display the types of vehicles detected and how many of each are present.
- To classify traffic density as low, medium or high based on vehicle counts.
- To lay the foundation for improvements, including live video, vehicle tracking, siren detection and coordination, across multiple intersections.

II. LITERATURE REVIEW

Research on traffic management has looked at vehicle detection, traffic-density estimation, adaptive signal timing and emergency vehicle prioritization. These areas are the background for the proposed prototype.

Shirulkar et al. studied traffic signal management using real-time vehicle detection and tracking [1]. This work is relevant to systems that use observed vehicle detection to support signal timing. Benoygopal et al. showed a traffic monitoring and management system [2] reflecting the broader use of automated monitoring in traffic-control applications.

Pandiarajan et al. looked into an AI- and YOLO-enabled framework for traffic management with emergency vehicle priority [3]. This work is closely related to the study because both use object detection for emergency vehicle prioritization. Research on road traffic signal management has also looked at challenges in traffic control [4] while other studies have explored AI-supported traffic optimization and congestion management [5].

YOLO-based traffic signal optimization has been investigated to improve traffic-flow management [6]. Separately predictive approaches have been explored for traffic congestion management in smart-city settings [7]. These studies show ways in which vehicle detection and computational models can help traffic monitoring and signal-control decisions.

SubbaRao et al. presented an image-processing based traffic signal optimization approach that combines edge detection for traffic-density estimation with YOLO based detection to support emergency vehicle priority. This study is relevant to proposed work because both methods use computer vision for traffic monitoring and incorporate ambulance prioritization into traffic control.

Geetha et al. Examined an AI-enabled emergency vehicle recognition and adaptive traffic signal system [9]. This line of research supports the relevance of combining emergency vehicle recognition with decisions.

The reviewed work addresses aspects of intelligent traffic control, including vehicle detection, congestion estimation, adaptive signal management and emergency vehicle prioritization [1]–[10]. The present prototype brings together ambulance recognition, four-region direction selection, general vehicle counting, traffic-density classification and a simulated signal display in one workflow for traffic management. Its contribution is the integration and demonstration of these functions, than a claim that the underlying algorithms are new.

III. METHODOLOGY

➢ *Step 1: Input Acquisition*

The system receives an image or video that shows a traffic intersection. The input may come from a recorded traffic video. In later versions from live CCTV cameras.

➢ *Step 2: Frame Processing*

For a video the system pulls out each frame one after the another with OpenCV. It notes the frame size. Splits the intersection into four zones: North-West, North-East, South-West South-East. When a vehicle is found its location in a zone tells the system which way the vehicle is heading.

➢ *Step 3: Vehicle Detection and Classification*

A YOLO-based detector looks at each frame. Spots road vehicles. It can find cars, buses, trucks and motorcycles. The

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system draws boxes around each vehicle. Counts them. The total count gives an idea of how busy the intersection is.

➢ *Step 4: Ambulance Detection*

A special YOLO model is trained to find ambulances. When it spots an ambulance the system records the box coordinates. How sure it is. It calculates the ambulance's center point:

$X = (X1 + X2) /2$

$Y = (Y1 + Y2) /2$

The center point is checked against the four zones to see which direction the ambulance is coming from.

➢ *Step 5: Emergency Traffic Signal Control*

At first all four directions show RED. When an ambulance appears the ambulance's direction turns GREEN and the other three stay RED. For example if the ambulance is in the North-West zone the North-West light turns GREEN while North-East, South-West and South-East stay RED. This way the ambulance has priority and other traffic is kept out of the way.

➢ *Step 6: Vehicle Counting*

The system keeps a count of each vehicle type. The display can show how many cars, buses, trucks and motorcycles are in the frame or, in the whole scene.

➢ *Step 7: Traffic Density Prediction*

The total vehicle count tells the system how dense the traffic is. It can label the situation as: count → Low density; Moderate count → Medium density; Large count → High density. This gives another view of how busy the intersection is.

➢ *Step 8: Output Display*

The final screen shows all detected vehicles, the ambulance box, the ambulance's direction the counts of each vehicle type, the traffic-density label and the status of each of the four traffic signals. In this way the system gives an ambulance priority. Keeps track of traffic at the same time.

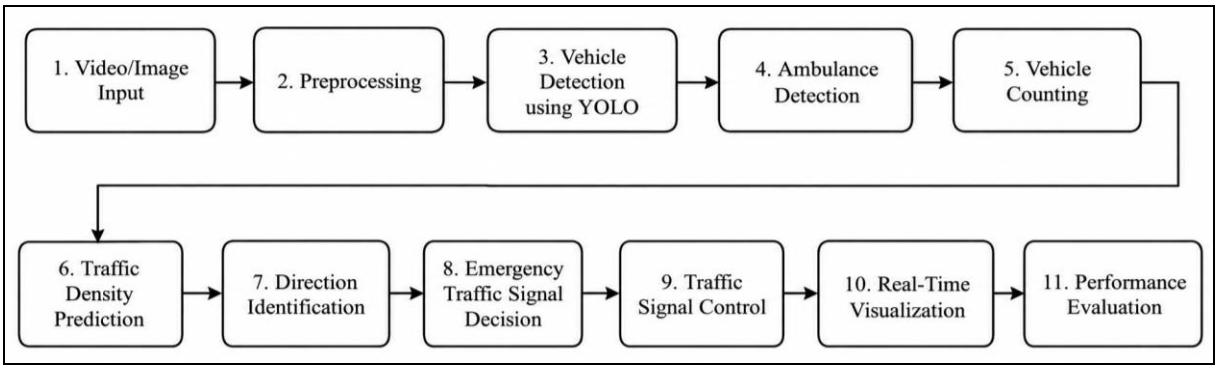


Fig 1 Workflow of the Proposed AI-Based Ambulance Traffic Management System

➢ *System Architecture Diagram*

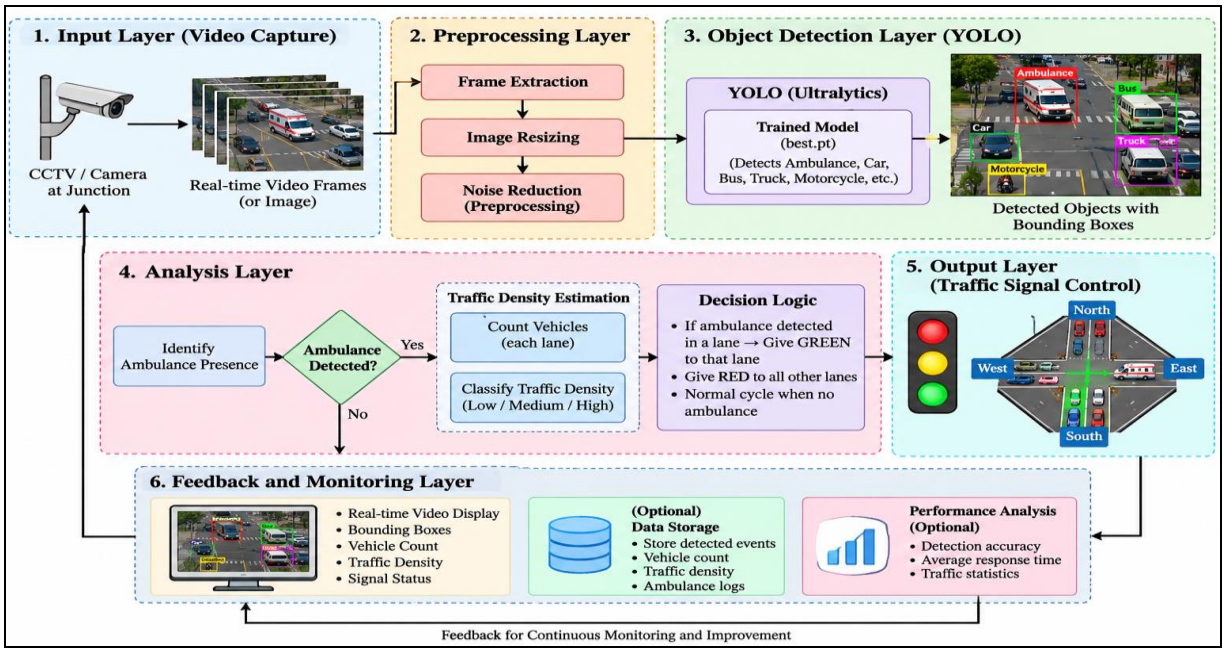


Fig 2 System Architecture Diagram

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IV. RESULTS AND DISCUSSION

The proposed AI-Based Ambulance Priority Traffic Management System is tested with traffic images and video clips to see how well it works for ambulance detection vehicle classification, direction identification, vehicle counting and traffic-density prediction. The system uses an object detection model to look at traffic scenes and decide which traffic signal should be green based on where the ambulance is. The results shown here talk about what the prototype did in practice not about numbers that measure its accuracy or how it would perform in the world.

➢ *Ambulance Detection and Direction Identification*

The custom-trained YOLO model used on the traffic images and video frames to spot ambulances. Whenever ambulance was found the model drew a bounding box around ambulance. Then used the coordinates of that box to find its centre and figure out which of the four pre-set regions ambulance belonged to.

The intersection is split into four parts: North-West (NW) North-East (NE) South-West (SW) and South-East (SE). Once ambulance's spot was known the system chose that part as priority direction. This lets the prototype link ambulance detection to a traffic-control rule that depends on direction.

Ambulance detection can be better or worse if picture is blurry, light is bad, other cars hide ambulance, camera angle is wrong. If other cars look like ambulance. To know how accurate ambulance detection really is we need to run tests on a labelled dataset that gives true answers for precision, recall and overall accuracy.

➢ *Direction-Based Traffic Signal Control*

After ambulance was found in a region the system used a rule for traffic signals. Signal for that direction turned green. The other three directions stayed red. This way ambulance could move through intersection without stopping.

Table 1 Direction-Based Traffic Signal Allocation

Ambulance Region	North-West	North-East	South-West	South-East
North-West	Green	Red	Red	Red
North-East	Red	Green	Red	Red
South-West	Red	Red	Green	Red
South-East	Red	Red	Red	Green

- *Detected Ambulance Direction*

✓ NW signal NE signal SW signal SE signal

The table shows signal states that prototype uses. When ambulance is in a region that region's signal gets priority and turns green while other directions stay red in display.

This shows how ambulance detection works together with direction-based signal selection. Still the signals we see on screen do not prove that system would change traffic lights or that it would cut ambulance travel time. To use it in world we would need more safety checks rules, for turning signals and tests in actual traffic.

➢ *Vehicle Counting*

In addition to ambulance recognition the system used a YOLO-based model to detect other road vehicles, including cars, buses, trucks and motorcycles. Detected vehicles were shown with their corresponding labels and bounding boxes. The system also counted the number of detected vehicles in the supported categories. These counts gave information about the vehicles in the processed traffic scene. This information supported the ambulance-priority functionality.

Table 2 Vehicle Detection and Counting Output

Vehicle category	Information displayed by the system
Cars	Number of detected cars
Buses	Number of detected buses
Trucks	Number of detected trucks
Ambulances	Detection result and identified region

The vehicle-counting feature gives an overview of traffic composition. Counting accuracy can be affected by overlapping vehicles, missed detections, partial visibility and repeated detections across successive video frames. Since verified numerical test results are not available here specific detection counts and accuracy percentages are not reported.

➢ *Traffic-Density Prediction*

The system used the detected vehicle-count information to classify the traffic condition into three categories: low, medium and high density. The classification was based on the thresholds configured in the implementation.

The density-classification feature provides a simple representation of traffic conditions. It may help identify scenes containing more vehicles. It could also support the development of traffic-control strategies.

However the classification depends on the configured thresholds and the reliability of vehicle detection. A high vehicle count does not necessarily correspond to road occupancy in every scene. This is especially true when vehicles differ in size or spacing. Further evaluation using labelled traffic scenes is needed to determine how reliably the categories represent actual congestion levels.

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➢ *Overall System Performance*

The prototype integrates functions into a single workflow: ambulance detection, four-region identification, direction-specific signal selection, general vehicle detection, vehicle counting and traffic-density classification.

Table 3 Summary of Functional Evaluation

System component	Functionality	Further evaluation required
Ambulance detection	Uses a custom-trained YOLO model to identify ambulances	Precision, recall and detection accuracy
Direction identification	Assigns the ambulance to one of four predefined regions	Correct region-selection rate
Signal control	Selects green for the priority direction and red for the other three directions in the prototype	Signal-response time and safety validation
Vehicle detection	Identifies supported vehicle categories	Per-class detection accuracy
Vehicle counting	Displays counts for cars, buses, trucks and motorcycles	Counting error and duplicate suppression
Traffic-density prediction	Classifies traffic as low, medium or high	Agreement with labelled congestion levels

The functional results indicate how the individual components are combined to support the intended traffic-management workflow. The main feature of the proposed system is the integration of ambulance recognition and region-based signal selection with vehicle monitoring.

Nevertheless the evaluation remains qualitative. Numerical measures such as detection accuracy, F1-score, processing speed, signal-response time and reduction in ambulance waiting time should only be included after they have been measured through experiments.

V. LIMITATIONS

Limitations must be considered when interpreting the results. The quality of ambulance and vehicle detection depends on the training dataset and the visual conditions of the input.

Low-resolution frames, lighting variations and camera angle may cause missed or incorrect detections The region-based approach identifies the ambulances location in a frame. Does not independently establish its future trajectory. Vehicle counts may also include repeated detections, across video frames unless tracking is used to maintain vehicle identities. In addition the current signal-control behaviour is demonstrated through the prototype than a validated physical traffic-control installation.



Fig 3(a). Ambulance Detection and Priority Identification at a Traffic Intersection

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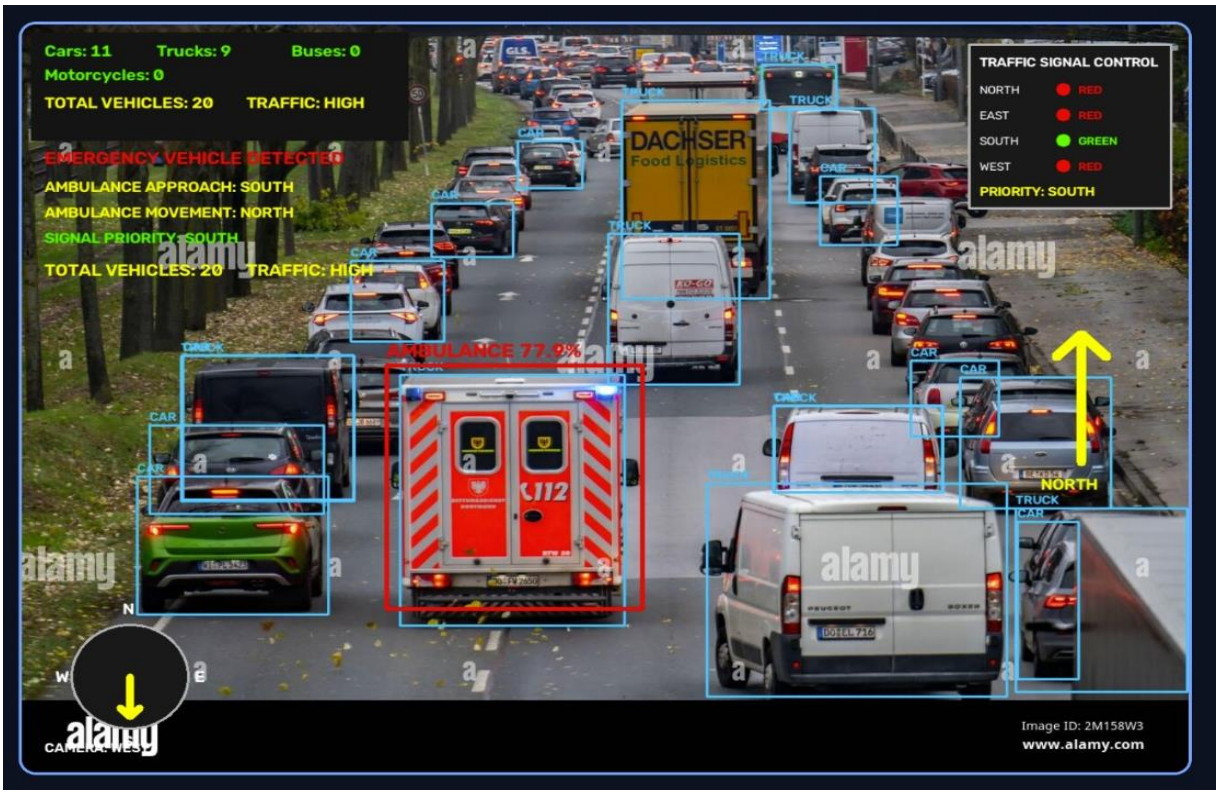


Fig 3(b) Real-Time Ambulance Detection and Direction Identification in Congested Traffic

VI. CONCLUSION AND FUTURE ENHANCEMENTS

This paper introduced an AI-based ambulance priority traffic management prototype. The system combines technologies: YOLO-based ambulance detection, general vehicle detection, four-region localization, signal-state selection, vehicle counting and traffic-density classification. It uses the location of the detected ambulance to send a green signal in the direction the ambulance is coming from while turning the other directions red. The prototype interface also shows the number of cars, buses, trucks and motorcycles on the road. It then classifies the traffic density as low, medium or high.

The system shows how computer vision can help create a direction emergency priority workflow and provide useful traffic data.. To know how well the system works in real life we still need quantitative detection results, measurements of how fast the signals respond and field validation beyond the prototype stage.

Looking ahead future improvements could include connecting the system to live CCTV streams tracking vehicles to avoid counting the vehicle more than once using siren detection to confirm ambulance presence and making direction estimation more accurate. The system could also be expanded to coordinate with intersections.

More development work should also focus on safety checks during changes testing under different lighting and traffic conditions and evaluating the system using labeled datasets. Before the system can be used in traffic it will need proper hardware integration a review by traffic engineers and thorough safety validation.

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