

Vehicle Detection and Classification for Traffic Management and Autonomous Systems Using YOLOv8

Ms. R Sudha

Associate Professor
Vasavi College of Engineering
Hyderabad, India

r.sudha@staff.vce.ac.in

M Abhinash Rao

Computer Science and Engineering
Vasavi College of Engineering
Hyderabad, India

abhinashrao28@gmail.com

K Naga Sai Dhanush

Computer Science and Engineering
Vasavi College of Engineering
Hyderabad, India

kotadhanush1807@gmail.com

Abstract—Urban traffic has been growing rapidly, creating a pressing need for intelligent systems that can manage traffic flow efficiently and in real time. This project presents the design of an AI-based Intelligent Traffic Management System to optimize signal control and improve road utilization through the use of computer vision and deep learning techniques. It provides a single platform upon which traffic conditions from multiple lanes will be continually monitored using video input. To identify and classify the types of vehicles present (cars, buses, trucks, motorcycles, and emergency vehicles such as ambulances), a YOLOv8-based detection model is created. Once detected, the density of traffic (number of vehicles) is calculated for each lane, and the calculated density is used to dynamically adjust traffic signal timing to ensure smoother traffic flow and reduced traffic congestion. The system contains an ambulance prioritization mechanism, which will always provide the emerald green signal regardless of the current signal operating mode, allowing for fast response times and greatly improved response times for ambulances. Signal transitions are managed using a rule-based decision model that takes both density and timing into account to effectively manage signal transitions. Real-time monitoring of the current traffic conditions and performance will be available via an online dashboard created with the use of Flask. The implementation of this solution (AI) will reduce manual intervention, thereby increasing efficiency.

I. INTRODUCTION

Many modern cities are now experiencing unprecedented pressure on traffic management systems due to the rapid growth of urban populations and their rapidly increasing use of vehicles. To meet the demand for managing traffic flows, they traditionally rely on fixed time, independent intersection signal systems that are not fully aware of real-time traffic conditions. Therefore, they cause unnecessary delays, increased congestion, inefficient use of road capacity in most instances. However, advances in Artificial Intelligence (AI) and Computer Vision technology have begun to provide a new opportunity for the development of intelligent transportation systems that can dynamically respond to changing traffic patterns. This project aims to develop an AI-based Intelligent Traffic Management System (ITMS), using Deep Learning Methods (DLM) to analyze real-time traffic conditions manage the operations of traffic signals. An ITMS can use multiple video input

streams from multiple lanes at an intersection. A YoloV8 object detection model will then be employed by the ITMS to identify all types of vehicles (e.g., cars, buses, trucks, motorcycles, and emergency vehicles like ambulances) that travel through all lanes. The ITMS will then calculate the density of vehicles in each lane to modify the timing of the traffic signals in real-time to optimize traffic flow and reduce wait times. Also, the ITMS includes an Emergency Vehicle Priority (EVP) mechanism that overrides routine traffic signal cycles and grants immediate passage to ambulances traversing through intersections. Lastly, a web-based dashboard will be built to visualize, monitor, and analyze traffic conditions and the traffic management system on an ongoing basis in real-time. Through Intelligent detection, Adaptive control and Real-time monitoring, the proposed system provides an effective, scalable solution to traffic management in smart cities. The system focuses on developing a new approach to traffic efficiency that places emphasis on scalability, automation and real-time decision making, without the need for expensive physical sensors. This Camera Based System allows for greater flexibility, as it does not have to rely on embedded road infrastructure like conventional systems. Deep learning models are used in this system to provide accurate vehicle identification and classification in various conditions. The systems Adaptive Signal Control Mechanism ensures fair and equitable use of green time across all lanes. The system Dashboard provides useful analytical data that allows authorities to track trends in traffic patterns, and provide an efficient way of measuring System Performance. By making Traffic Management Data Driven, this proposed solution will help develop smarter, safer and more sustainable Transportation systems that can meet the increasingly complex demands of Modern Urban Mobility.

II. RELATED WORK

With the advancement of AI and computer vision technologies in intelligent traffic management systems, traffic management systems have become increasingly sophisticated. Older traffic management systems were based on fixed time signals and some basic sensor systems, with the latter not providing

any real-time information about traffic volumes or flows. So, as you might expect, these types of systems could not achieve a good flow of traffic, did not reduce congestion and resulted in long waiting times at intersections. To address these limitations, researchers developed camera and infrared sensor-based monitoring systems that could provide traffic data, including counts of vehicles and flow rates on roads. However, these types of monitoring systems were very expensive to install and had limited accuracy due to changes in weather conditions. As machine learning techniques have become more common, there has been a shift in how we analyze traffic patterns and optimize traffic signal timings. While previous systems used predefined features and statistical models to estimate traffic densities, the newer systems are primarily based on machine learning techniques. These machine learning-based systems allow for more automation; however, because they are based primarily on historical data, they frequently have difficulty adapting to changing traffic conditions in real time, especially in complicated traffic scenarios. Nevertheless, recent advances in object detection using deep learning models (e.g., YOLO) have improved our ability to analyze traffic more accurately than ever before. In addition, using YOLO models has greatly improved our ability to monitor vehicle activity in real time by allowing us to detect and classify vehicles from video streams. These advantages provide significantly greater performance than traditional methods because these models can combine both spatial and contextual information from visual data.

III. PROPOSED METHODOLOGY AND SYSTEM DESIGN

The system is designed as a multi-layered architecture that integrates deep learning models with a web-based monitoring platform. It is divided into two primary modules:

Traffic Monitoring Module:

This module captures and analyzes multiple lanes of traffic data. It uses a YOLOv8-based model to analyze video frames by determining the count of each vehicle type (e.g., car, bus, truck, motorcycle, emergency vehicle). It also counts the overall number of vehicles detected and computes the overall traffic density by lane based on these counts. It has an additional detector model for determining whether an ambulance is present, allowing for real-time awareness of emergency situations.

Traffic Control and Management Module:

This module uses processed data to control the system and make decisions about how to control the system. The module uses a dynamic signal control mechanism to change the duration of green lights based on traffic density. It is responsible for managing transitions between red, orange, and green signals while allowing smooth traffic flow along all lanes. There is a web-based dashboard integrated with this module that provides real-time visualization of traffic conditions, signal status, and analytical data for effective monitoring and management of the system.

A. Emergency Vehicle Priority Logic

The EVPM (Emergency Vehicle Priority Mechanism) is an innovative feature of the proposed system designed to allow

for fast and uninterrupted passage for ambulances during intersectional travel. With traditional traffic systems, ambulances often experience delays from fixed signal timing and lack of real-time counting capabilities. **Detection and Identification:** The system continuously analyzes video frames to detect ambulances using a trained deep learning model with a defined confidence threshold. Once an ambulance is identified in a particular lane, the system marks it as a high-priority event.

Priority-Based Signal Control:

When an ambulance is detected by traffic signal systems, the usual signal cycle is overridden and the lane where the ambulance is traveling to will immediately be displayed with a green signal. All other lanes will be set to red until the ambulance passes so that there is a clear path to allow the emergency vehicle through. This priority treatment will minimize delays in emergency response and improve the efficiency of emergency response.

System Continuity:

Once the ambulance has gone through, normal operation of the Dynamic Signal System continues without impacting the total flow of traffic. This mode of operation balances the need for handling emergencies with general optimization of traffic and gives the intelligent system a way to be effectively deployed in the real-world environment.

IV. TECHNICAL WORKFLOW AND ALGORITHMIC ANALYSIS

The new plan replaces rigid rule-based management of traffic with a new, dynamic data-driven traffic management system that incorporates real-time analysis and adaptive decision-making. In replacing the traditional method of assigning equal signal time to each lane, the proposed system considers a variety of factors to determine the optimum signal duration. Factors considered include vehicle volume/density and whether there are emergency conditions that should be considered in evaluating whether there should be an alternative to the normal setup. The result of this adaptive method of management will be to manage traffic in a more efficient manner, and also adapt continuously to changes in traffic patterns, and other roadway conditions.

A. Dynamic Density-Based Signal Timing Model

Using a dynamic timing model based on real-time traffic density, this system does not use fixed time signal allocations. By calculating a variable duration of green signal times, rather than simply assigning an equal amount of green signal times for each signal, systems calculate the duration of green signal times using weights based on the degree of lane congestion.

$$T_{green} = T_{base} + \min(D, D_{max}) \quad (1)$$

Where:

T_{base} = Minimum green signal time

D = Current traffic density

D_{max} = Maximum allowable density threshold

This approach ensures that lanes with higher vehicle density receive proportionally more green time, while preventing excessive delays in other lanes.

B. Automated Traffic Analysis and Decision Feedback

A real time mean feedback system has been created to monitor and adapt to changing traffic patterns. Vehicle detection will be performed using the YOLOv8 model and the total number of detected vehicles will be used to estimate lane-by-lane traffic density. This will allow the system to dynamically adjust signal timing and transition between signal states. In the event of an ambulance, the system overrides normal cycle and gives priority to that lane. Additionally, the system has a web-based dashboard that provides updates in real-time to facilitate continuous monitoring and assessment of system performance.

V. PROCESS FLOW DIAGRAMS

A. System Architecture Overview

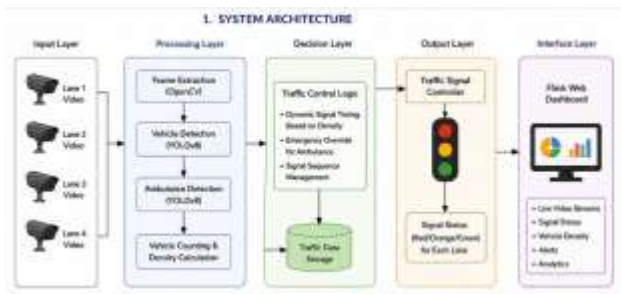


Fig. 1. Overall architecture of the proposed Intelligent Traffic Management System

In this design, the stages of the intelligent traffic control system form multiple layers of configuration, including input layer, processing layer, decision making layer, output layer, and interface layer. Within the input layer, four video feeds will be collected from each of the lanes in to the processing layer using the OpenCV library for extracting the video frames. In the processing layer, the YOLOv8 model will then be applied to detect the vehicles and ambulances in individual frames before counting each detected vehicle and estimating that lane's overall density. The decision making layer implements the traffic control logic (i.e., the dynamic timing of signals and an emergency override), which is used by the output layer to control the traffic signals to each lane. Finally, the interface layer provides a web-based dashboard for monitoring in real-time, analytic reports, and visualization of the above processes.

B. System Workflow

The Workflow Diagram provides a visual guide for the sequential procedures of the system. Initially, traffic video files are either uploaded to the system or streamed into it. Next, the frames of these video files are extracted from the file(s) and processed through the YOLOv8 model to identify which of the vehicles in the frames are ambulance(s). After identification of the different vehicles in the video, the system will calculate

2. SYSTEM WORKFLOW

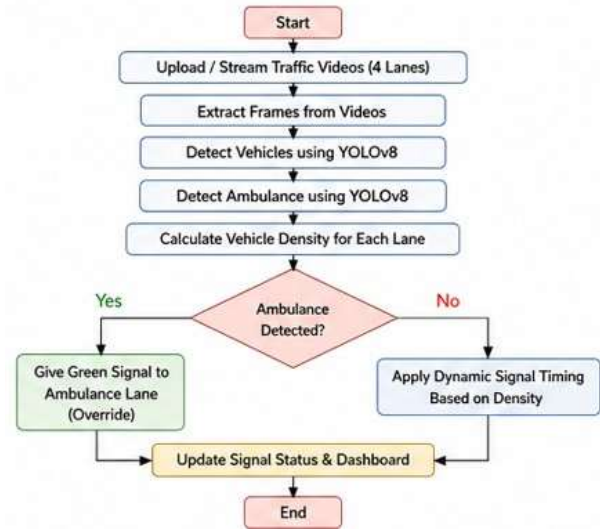


Fig. 2. Workflow of the proposed system

how many vehicles are in each of the lanes and then make a decision based on whether or not an ambulance has been detected within the video. If an ambulance has been detected, then that lane will be assigned a green signal. If there is no ambulance detected, then the system uses the density of the vehicles in order to apply dynamic signal timing. Finally, the system will update the signal status of each lane and show the outcome on the dashboard.

VI. RESULTS AND FUNCTIONAL CAPABILITIES

A. Traffic Monitoring and Control Interface



Fig. 3. Live Traffic Monitoring Dashboard showing real-time vehicle detection, signal status, and lane-wise density across multiple lanes

The suggested system consists of an intelligent and interactive web-based dashboard that allows real-time monitoring and control over the condition of traffic across many lanes of travel. The dashboard will have live video feeds of the current situation each lane, as well as dynamically updated traffic signal status (red, orange, green), and will provide real-time information regarding the density of vehicles and whether ambulances are in detection mode. This will provide users with a clear view of the current traffic situation in order to make

quick and accurate decisions when needed; especially when experiencing high-volume traffic conditions.

The system has not only basic monitoring capabilities, but also an extensive range of automated controls for operational efficiency improvements. An override is automatically initiated upon detection of an ambulance. The lane associated with the detected ambulance receives a signal to proceed through a green light and other lanes will be restricted. The dashboard produces alerts and updates in real time so the user is aware of important occurrences without having to manually check for them. Analysis components provide the ability to monitor vehicle counts as well as system operation history on a time basis. Therefore, it serves as an all-in-one tool for real world management, along with performance testing against expectations.

B. Performance Evaluation Metrics

The performance of the proposed system is evaluated based on key parameters such as accuracy and efficiency. Accuracy refers to the system's ability to correctly detect and classify different types of vehicles using the YOLOv8 model. Efficiency measures the system's capability to optimize traffic flow and reduce delays.

VII. CONCLUSION

The AI-based Intelligent Traffic Management System provides an innovative way to more comprehensively solve the increasing problem of urban traffic congestion through the integration of computer vision with dynamically controlled signals. By employing a YOLOv8-based detection model, the proposed traffic management system will accurately detect both vehicles and emergency vehicles and provide real-time traffic density estimates and adaptive decision-making. In contrast to traditional, fixed-time traffic systems, the proposed traffic management system will adaptively change the amount of time signals are turned on or off based upon actual current traffic patterns to improve the efficiency of the use of the roadways, as well as reduce the wait time at signals. Additionally, the proposed implementation of an emergency vehicle clearance system in the Intelligent Traffic Management System allows immediate clearance of ambulances from traffic signals and locations; thus, it will improve emergency response time in critical life-threatening situations. Furthermore, the development of a web-based traffic monitoring, visualization, and analytic dashboard for the Intelligent Traffic Management System allows for continuous, real-time traffic data monitoring and analysis and for practical real-world implementation of the Intelligent Traffic Management System for current smart city development. Overall, through the combination of intelligent detection, automated control, and real-time feedback, the Intelligent Traffic Management System represents a scalable, efficient, and reliable method to improve the management and control of urban traffic.

REFERENCES

[1] Q. Wang, H. Feng, H. Feng, Y. Yu, J. Li, and E. Ning, "The impacts of road traffic on urban air quality in Jinan based

GWR and remote sensing," *Scientific Reports*, vol. 11, no. 1, 2021.

[2] J. K. Stolaroff, C. Samaras, E. R. O'Neill, A. Lubers, A. S. Mitchell, and D. Ceperley, "Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery," *Nature Communications*, vol. 9, no. 1, 2018.

[3] L. Wu, Y. Ci, Y. Wang, and P. Chen, "Fuel consumption at oversaturated signalized intersections considering queue effects," *Energy*, vol. 192, 2020.

[4] G. J. L. Micheli and F. Mantella, "Environmentally-extended inventory routing problem under carbon control policies," *International Journal of Production Economics*, vol. 204, 2018.

[5] H. Cheng et al., "Truck platooning reshapes greenhouse gas emissions," *Nature Communications*, vol. 14, 2023.

[6] C. Nangini et al., "A global dataset of CO emissions for 343 cities," *Scientific Data*, vol. 6, 2019.

[7] M. Geisslinger, F. Poszler, and M. Lienkamp, "Ethical trajectory planning algorithm for autonomous vehicles," *Nature Machine Intelligence*, vol. 5, 2023.

[8] M. Chen, X. Yu, and Y. Liu, "PCNN: Deep convolutional networks for traffic congestion prediction," *IEEE Transactions on Intelligent Transportation Systems*, vol. 19, no. 11, 2018.

[9] G. N. Kouziokas, "LSTM neural networks in traffic flow forecasting," in *Advances in Mobility-as-a-Service Systems*, Springer, 2021.

[10] W. Joe and H. C. Lau, "Deep reinforcement learning for dynamic vehicle routing," *ICAPS*, 2020.