



Emergency Vehicle Detection And Traffic Control Using Opencv And Camera

¹Dr. Anitha Devi M D, ²Varun A Lohar, ³Tharun C Gowda, ⁴Raghavendra G, ⁵Umashankara

¹Associate Professor, ²UG Student, ³UG Student, ⁴UG Student, ⁵UG Student

¹Department of Electronics and Communication Engineering,

¹Sri Siddhartha Institute of Technology, Tumkur, India

Abstract: The growing urbanization and city population expansion have resulted in an immense rise in vehicle congestion, necessitating the need for advanced and responsive traffic control systems. The current research offers an advanced, real-time traffic management system implemented using Raspberry Pi and the YOLOv5 object detection engine. The system takes a real-time video feed as input and detects and classifies various vehicle classes, dynamically adjusting traffic signal timings based on vehicle density in particular lanes. One notable feature of the system is the detection of emergency vehicles—ambulances and fire trucks—and overriding regular signal functioning to give them constant right-of-way. The implementation is highly accurate, with a mean Average Precision (mAP@0.5) of 0.865, detection accuracy of 97% for ambulances, and a detection accuracy of 94% for fire trucks. Additionally, an easy-to-use web interface implemented using Flask allows real-time monitoring and control. This smart system significantly improves urban traffic flow and allows earlier emergency response, and it is a promising scalable part of smart city infrastructure.

Index Terms - Artificial Intelligence, Computer Vision, Emergency Vehicle Detection, Intelligent Traffic System, Traffic Management, YOLOv5

I. INTRODUCTION

Traffic congestion is a critical problem in contemporary urban areas, especially in relation to the timely passage of emergency vehicles like ambulances, fire engines, and police patrols. Traffic congestion delays can prove to be deadly, especially in medical emergencies, natural catastrophes, or criminal acts. Traditional traffic control systems are not sophisticated enough to distinguish between regular and emergency vehicles, leading to ineffective traffic flow and extended response times. The need for improved technology that can manage traffic adaptively based on conditions is driving the increased need for intelligent transportation systems (ITS). Combining adaptive traffic control systems with emergency vehicle detection is one proposed answer to this issue. The increasing need for advanced methods capable of efficiently managing traffic in real-time settings is being driven by the growing need for intelligent transportation systems (ITS). Combining adaptive traffic control systems with emergency vehicle detection is one potential answer to this issue. By utilizing technology such as image processing, machine learning, and Internet of Things (IoT) gadgets like cameras and Raspberry Pi, it can identify emergency vehicles and modify traffic signals appropriately, resulting in a seamless transit experience and significantly reduced reaction times.

II. LITERATURE SURVEY

In [1] this literature survey the paper discusses smart intelligent traffic control system for emergency vehicles, integrating sound sensor technology with traffic signals. The system proposes the activation of green lights for ambulances in congested areas, prioritizing high-density roads in case of ambulance

detection. The system aims to optimize traffic flow, improve emergency response times, and enhance road safety.

In [2] this study provides an overview of existing research on traffic congestion in Metro Manila, Philippines, is a significant issue with societal, economic, and environmental impacts. Researchers propose a CNN-based traffic light control system prototype that can detect, classify, and estimate traffic density. This system can adjust go and stop time durations based on congestion levels, such as emergency vehicles or high traffic density.

In [3] this literature review examines approach for emergency vehicle detection using vision-based systems. The approach detects the siren on top of the vehicle, ensuring it is identified as an emergency vehicle regardless of its shape. The researchers created a dataset and trained the classification layer of the YOLO architecture, achieving a training accuracy of

77.1% for siren detection. This approach provides a reliable methodology for emergency vehicle detection, crucial for traffic management systems in smart cities.

In [4] literature review delves into the core studies and theories that have shaped our understanding of this field. The traffic congestion in metropolitan areas is a major issue, with static traffic lights not adapting to real-time conditions. This paper proposes an adaptive traffic signal control system for less-lane disciplined heterogeneous traffic, using a sound sensor-based emergency vehicle detection system. The system accurately detects and classifies emergency vehicles by identifying their unique siren sound, and uses real-time traffic camera data to compute PCU counts. The system also includes a queuing theory-based cost function to improve vehicle flow and minimize delay for emergency vehicles.

In [5] literature survey the paper discusses an automated traffic control system with an emergency priority mechanism using PLC technology. Conventional traffic signals struggle to control overcrowding and congestion on specific paths due to increasing population. The system uses IR sensors to calculate vehicle density and allocate green light, benefiting emergency vehicles like ambulances and fire-brigades. The python code results show it can be executed in real-world scenarios without affecting conventional traffic control systems.

In [6] this study provides an overview of existing research on Real-Time Traffic Control System (RTTCS) based on Machine Learning (ML) to monitor traffic, detect objects, and detect license plates in India. The system uses You Only Look Once version-4 (YOLOv4) for object detection and pre-trained convolutional weights for optimization. This approach helps address road traffic congestion, rule violations, and accidents in India.

In [7] this literature review proposes traffic congestion is a major concern due to the increase in automobiles and delays between traffic signals. To address this, a prototype model is designed to control traffic based on vehicle density, with automatic signal timing changes. Infrared sensors capture density information, and a microcontroller aids decision-making. A power harvesting concept is proposed, generating electrical energy from piezo-electric methods to power street lights in traffic junctions.

In [8] this literature survey the paper discusses presents a nighttime vehicle detection system that uses a bioinspired image enhancement approach and weighted feature fusion technique. Inspired by retinal mechanisms, the system extracts features from convolutional neural networks, histograms, and local binary patterns. The method outperforms state-of-the-art techniques and can detect vehicles in various scenes, including different types, sizes, occlusions, and blurred zones.

III. METHODOLOGY

Deep Learning consists of a very enormous number of neural networks that use the multiple cores of a process of a computer and video processing cards to manage the network's neuron which is categorized as a single node. Deep learning is used in numerous applications because of its popularity especially in the field of medicine and agriculture. YOLO is a convolutional neural network (CNN) for doing object detection in real-time. The algorithm applies a single neural net5 work to the full image, and then divides the image into regions and predicts bounding boxes and probabilities for each region. These bounding boxes are weighted by the predicted probabilities. Our model uses YOLOv5 and it provides good results regarding object classification and detection.

- **Configuration Module**

we created a method to connect with user's local network of cameras through internet or use the internet accessible IP cameras. For our solution we have made use IP cameras but we can make use of other types cameras as well with slight changes to the code. Each camera has its own instance and it

will leverage all the features discussed. To connect cameras to the application, users have to provide their camera IPs/or anything equivalent to it like RTSP URL, etc. These IPs will be saved in database for reuse.

- **Data Annotation**

To train YOLO we need to annotate images for object detection models. Our dataset should be well annotated. There are different types of annotations available. Here a bounding boxes method is used. It creates a rectangle area over images that are present in our dataset. Since Annotation needs more time we are using a tool called LabelIMG to annotate our data.

- **Yolo V5 Training**

We use the IPs stored in the database as input for object detection module and we use OpenCV for any image processing related tasks. For object detection we are using pretrained YOLOv5 model trained on COCO dataset because of its high accuracy. YOLO recognizes objects more precisely and faster than other recognition systems. It can predict up to 80 classes. It can be easily trained and deployed in a production system. YOLO is based on a single Convolutional Neural Network (CNN). The CNN divides an image into regions and then it predicts the boundary boxes and probabilities for each region. It simultaneously predicts multiple bounding boxes and probabilities for those classes. YOLO sees the entire image during training and test time so it implicitly encodes contextual information about classes as well as their appearance. The real-time recognition system will recognize multiple objects from an image as illustrated in Figure 1.

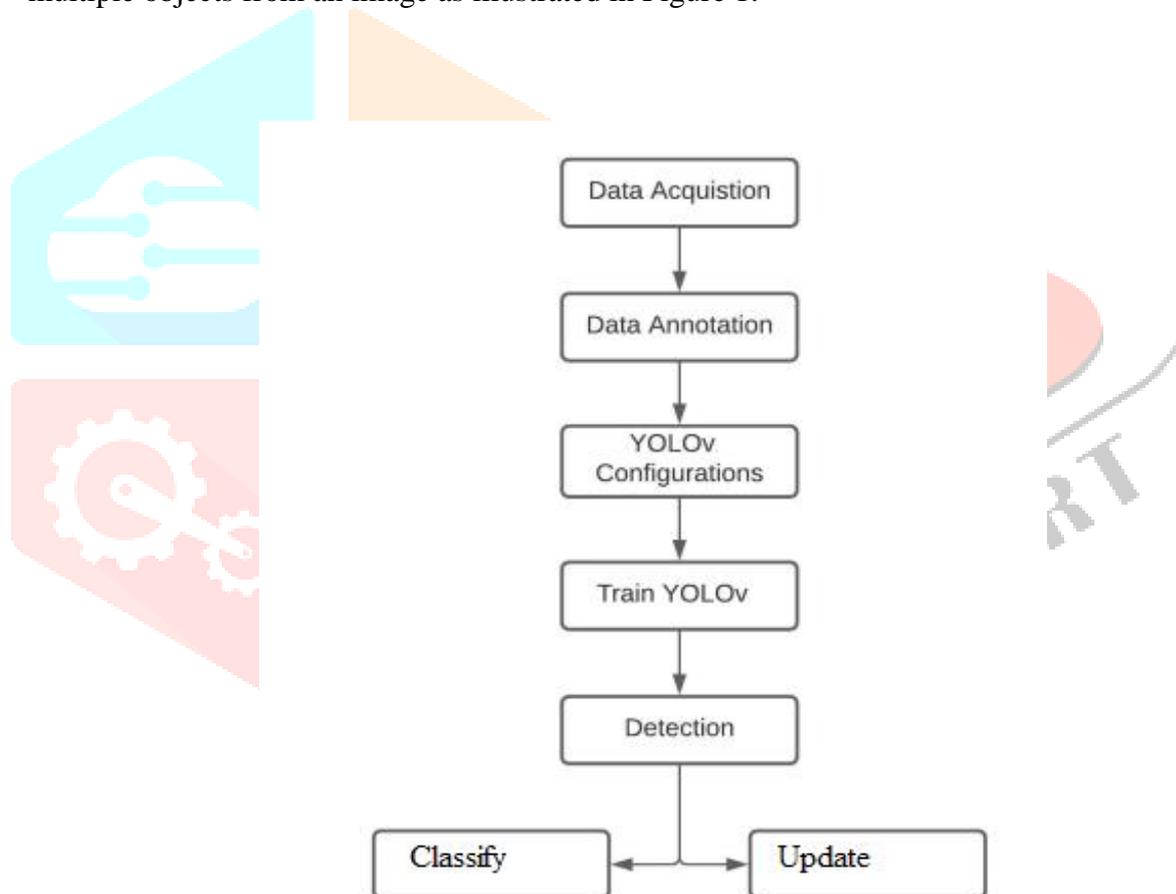


Figure 1: Methodology of the System

IV. BLOCK DIAGRAM AND IMPLEMENTATION

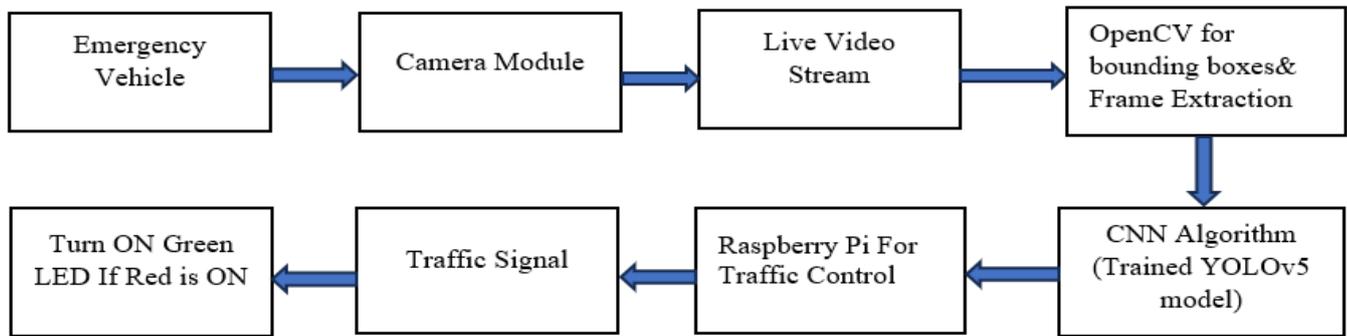


Figure 2: Block Diagram of the System

The system shown in Figure 2 is designed to automatically detect emergency vehicles and manage traffic efficiently using a combination of a laptop with a camera, a Flask web server, and a YOLOv5 deep learning model. The laptop acts as the primary processing unit, running a Flask-based Python application connected to a camera for live video streaming or pre-recorded footage analysis. YOLOv5, a state-of-the-art object detection algorithm, processes the video frames to identify and count vehicles, detect ambulances, and provide crucial information for traffic control. The Density Calculation Module calculates the number of vehicles in each lane based on YOLOv5 outputs, dynamically assigning longer green signals to lanes with higher traffic density for optimized flow. Simultaneously, the Ambulance Detection Module prioritizes emergency vehicles by immediately overriding normal traffic control and switching the corresponding signal to green.

The Flask web server is an integral part of the system, offering a user-friendly, web-based interface that displays real-time traffic conditions, lane densities, vehicle counts, and signal statuses. Users and traffic authorities can seamlessly monitor system operations through this live dashboard. Based on the data from the density and ambulance detection modules, the Traffic Signal Controller dynamically adjusts traffic lights, ensuring efficient management and emergency vehicle prioritization. This integrated setup significantly enhances traffic flow, reduces emergency response times, and provides a scalable, intelligent traffic management solution using accessible, open-source technologies.

V. RESULTS AND DISCUSSIONS

The implemented density-based intelligent traffic management system achieved successful real-time detection and counting of vehicles and ambulances using the YOLOv5 algorithm. By dynamically allocating green light durations based on lane-specific vehicle densities, the system demonstrated significant improvement in traffic flow compared to traditional fixed-timer systems. The ambulance detection module functioned reliably, ensuring immediate signal switching to facilitate uninterrupted emergency vehicle movement. The integration of a Flask web server enabled real-time visualization of lane densities and signal statuses through a user-friendly interface, enhancing the system's transparency and operational control. Overall, the project validated the feasibility of AI-driven traffic control for smart city applications, showcasing both functional accuracy and operational robustness.

The system's object detection model was carefully tested as shown in Figure 5 with a confusion matrix as shown in Figure 3 and a precision-recall (PR) curve shown in Figure 4, giving a complete picture of how accurate and reliable the classifications were. The confusion matrix shows an excellent true positive rate, especially for the emergency vehicle class: the accuracy of ambulance detection reaches 97%, the accuracy of fire truck detection reaches 94%, and the accuracy of car classification remains at 91%. Misclassifications are rare and background elements are occasionally misidentified (less than 10%), but these have a negligible impact on emergency detection performance. This response confirms the model's ability to distinguish emergency vehicles from general traffic with high reliability, a critical requirement for automated traffic signal interventions.

Complementing this, the precision-recall curve (Figure 4) further validated the model's robustness. The ambulance class attained an outstanding precision-recall score of 0.994, indicating near-perfect identification without false positives or false negatives. Correspondingly, the fire-engine class recorded a strong score of 0.942, reinforcing the system's effectiveness in prioritizing emergency responses.

Although the car class lagged with a score of 0.657, it remains sufficient for general density estimation. The system achieved an impressive overall mean Average Precision (mAP@0.5) of 0.865, demonstrating a high-performance level across all object classes.

Together, these results underscore the effectiveness of the YOLOv5-based detection model in real-time traffic monitoring as illustrated in Table 1. High-precision and high-recall emergency vehicle dispatch ensures accurate and timely signal switching, greatly improving the operating objectives of the intelligent traffic management system.

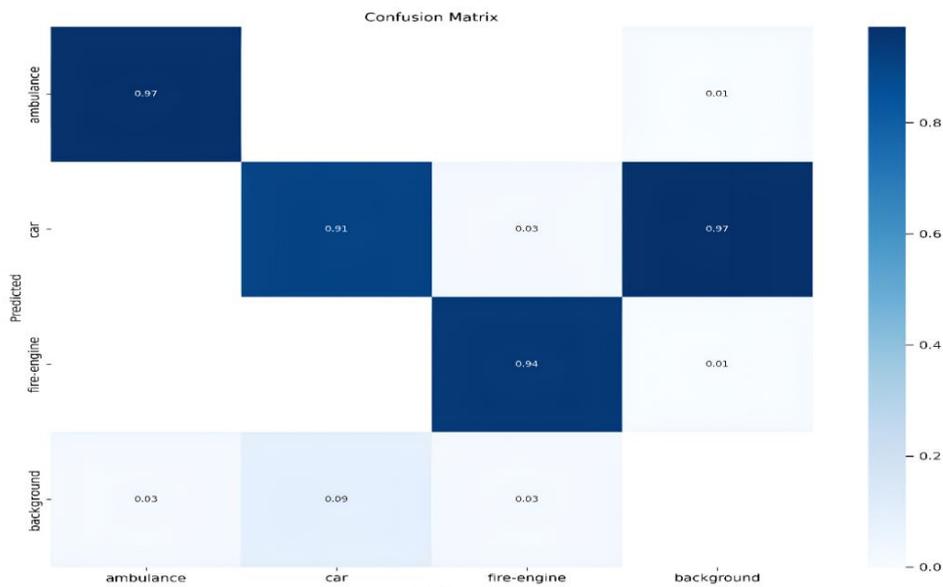


Figure 3: Confusion Matrix of the Trained Model

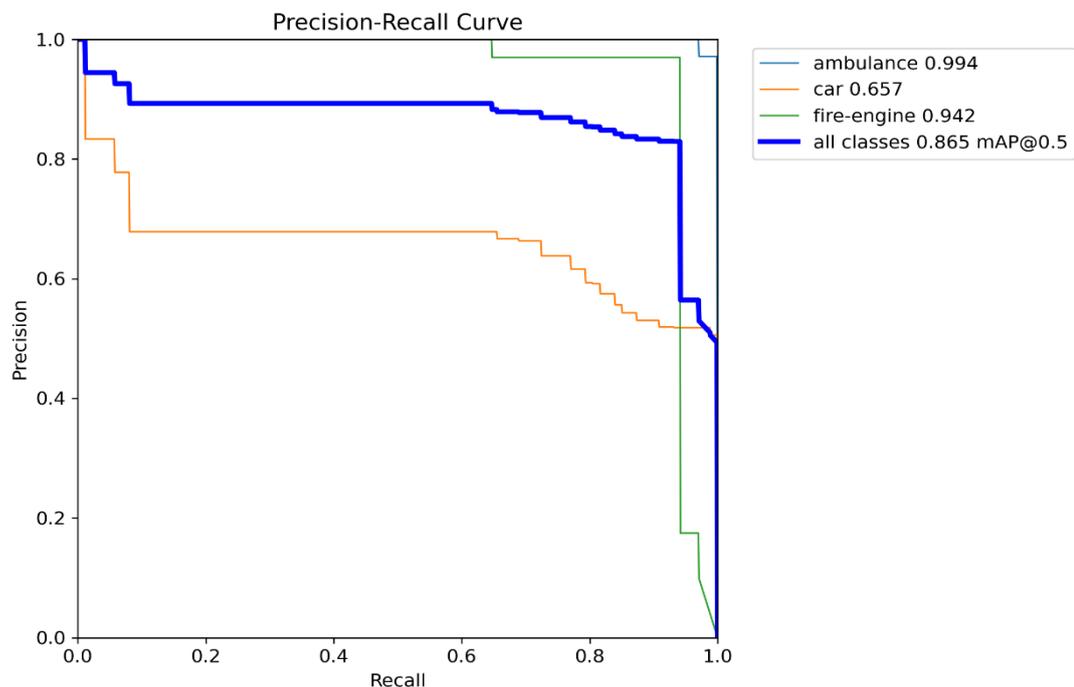


Figure 4: Precision-Recall Curve of the Trained Model

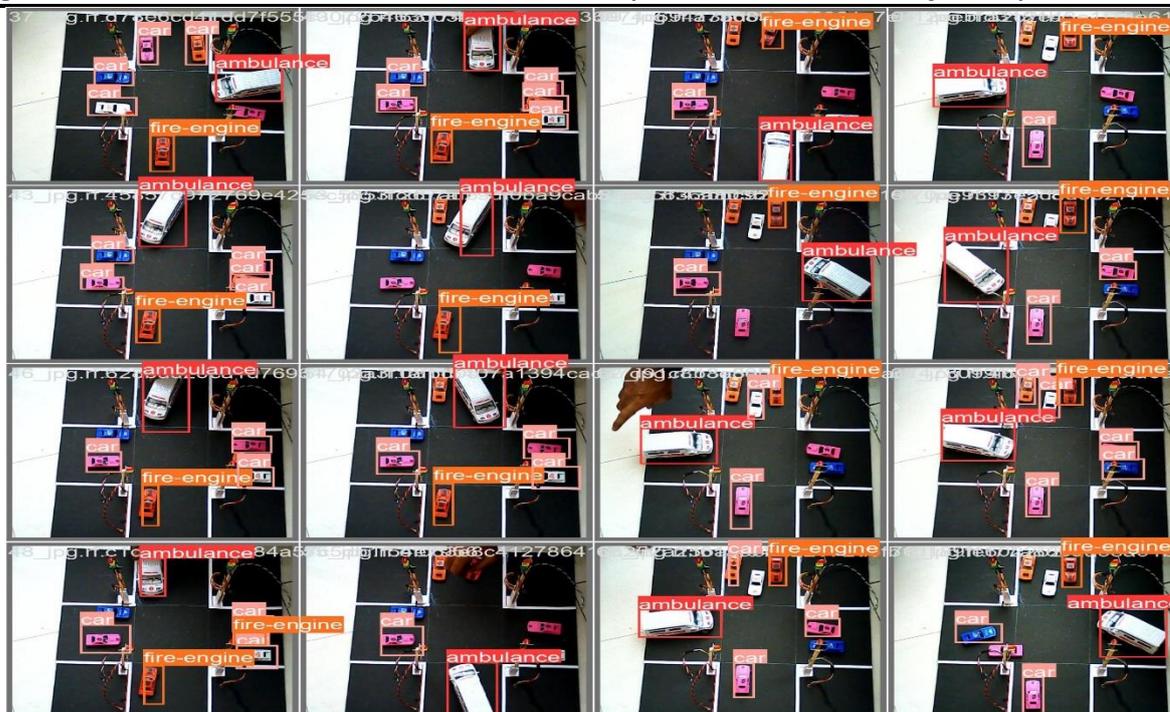


Figure 5: Working of the Trained Model

Table 1: Performance Metrics of the Trained Model

Class	Precision	Recall	F1-Score
Ambulance	0.994	0.98	0.96
Car	0.657	0.66	0.68
Fire engine	0.942	0.93	0.92

VI. CONCLUSION AND FUTURE SCOPE

This project successfully demonstrates how to develop and construct a density-based intelligent traffic control system with Raspberry Pi and YOLOv5. The system successfully identified emergency vehicles including fire engines and ambulances while dynamically optimising traffic signal timings depending on lane-specific vehicle density by using real-time object detection and classification. The use of a Flask-based web interface enabled real time monitoring, increasing system transparency and control. The system's resilience and dependability in urban traffic situations were validated by evaluation metrics, such as a mean Average Precision (mAP@0.5) of 0.865 and high class-wise accuracy scores (fire engine at 94%, ambulance at 97%) shown in Figure 4. All things considered, the study shows that AI-powered traffic control systems are feasible and have the potential to improve municipal infrastructure by making it safer, smarter, and more effective. The future scopes are as follows:

- Integration with IoT sensors for additional data like weather and road conditions.
- Deployment of edge computing devices for faster processing.
- Enhancement of object detection capabilities to identify more vehicle types.
- Expansion to include predictive traffic modelling using historical data and machine learning.

VII. REFERENCES

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