



Emergency-Aware Traffic Signal Control System using Machine Learning

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ABSTRACT: Urban traffic congestion significantly delays emergency vehicles such as ambulances and fire trucks, leading to critical loss of time and potential loss of life. Traditional traffic signal systems operate on fixed timing mechanisms and lack the ability to dynamically adapt to real-time traffic conditions. This paper presents an Emergency-Aware Traffic Signal Control System using Machine Learning, designed to prioritize emergency vehicles and optimize traffic flow.

The proposed system utilizes camera-based surveillance and a deep learning model (YOLO) for real-time detection of emergency vehicles and traffic density. Upon detecting an emergency vehicle, the system automatically switches the corresponding traffic signal to green, ensuring a clear path. In the absence of emergency vehicles, traffic signals are dynamically controlled based on vehicle density.

The system is implemented using Raspberry Pi 5 for real-time processing, along with OpenCV for image processing and Python-based machine learning frameworks. This approach reduces dependency on expensive GPS or RFID systems while improving scalability and efficiency. The proposed system aims to enhance emergency response time, reduce congestion, and contribute to smart city infrastructure.

KEYWORDS: Emergency Vehicle Detection, Traffic Signal Control, Machine Learning, YOLO Algorithm, Smart Traffic System, Computer Vision, Raspberry Pi

I. INTRODUCTION

Rapid urbanization has led to increased traffic congestion in cities, causing delays for emergency services. Conventional traffic systems rely on fixed timers, which do not account for real-time traffic conditions or emergency situations. This limitation can lead to severe consequences during critical emergencies.

Recent advancements in Artificial Intelligence and Computer Vision have enabled real-time vehicle detection and classification. By leveraging these technologies, traffic management systems can be made intelligent and adaptive.

This project proposes a machine learning-based traffic control system that detects emergency vehicles using camera input and dynamically adjusts traffic signals. The system aims to provide a cost-effective, scalable, and efficient solution for modern traffic management.

II. METHODOLOGY

A. Data Collection and Pre-processing

The system uses image datasets containing various types of vehicles, including emergency vehicles such as ambulances and fire trucks. The dataset is collected from online sources like Kaggle.

Pre-processing steps include:

- * Image resizing to standard dimensions (224×224)
- * Noise removal and normalization



* Annotation of emergency and non-emergency vehicles

B. Model Selection and Training

The YOLO (You Only Look Once) object detection model is used for real-time detection due to its high speed and accuracy. Transfer learning is applied to train the model on custom datasets.

C. Traffic Control Logic

The system follows a decision-based approach:

- * If an emergency vehicle is detected → Signal turns GREEN
- * If no emergency vehicle → Signal timing based on vehicle density

D. Hardware Integration

The trained model is deployed on Raspberry Pi 5, which processes real-time video input from a camera module. The output is used to control traffic signals using LEDs.

III. HARDWARE AND SOFTWARE REQUIREMENTS

Hardware:

- * Raspberry Pi 5
- * Camera Module
- * LED Lights (Red, Yellow, Green)
- * Buzzer
- * Breadboard and Connecting Wires
- * 5V Power Supply

Software:

- * Python 3.11
- * YOLO (Object Detection Model)
- * OpenCV
- * TensorFlow / PyTorch
- * Raspberry Pi OS

IV. RESULTS AND DISCUSSION

The system was tested using sample datasets and real-time camera input. The YOLO model successfully detected vehicles and classified emergency vehicles with high accuracy.

Key observations:

- * Real-time detection achieved with minimal delay
- * Accurate identification of emergency vehicles
- * Effective traffic signal switching based on conditions

Although the system is still under development, initial results demonstrate its potential to significantly reduce emergency response time and traffic congestion.

V. CONCLUSION

The Emergency-Aware Traffic Signal Control System provides an intelligent solution to modern traffic management problems. By integrating machine learning with real-time image processing, the system ensures priority for emergency vehicles and optimizes traffic flow.

Future work includes improving model accuracy, integrating multiple intersections, and implementing cloud-based monitoring systems. This system can play a vital role in smart city development and road safety enhancement.

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