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## Machine Learning - Based Intelligent Traffic Management System

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**Abstract:** In today's fast-evolving world, technological growth and urban expansion have led to increased vehicular traffic, particularly in highly populated regions. This surge presents major challenges in traffic regulation, especially during peak periods and emergencies. To address these issues, we propose a machine learning-based traffic management solution aimed at improving vehicle navigation particularly for ambulances, and optimizing traffic flow. Our study leverages Python-enabled algorithms for real-time image and video analysis using object detection frameworks. By giving emergency and high-occupancy vehicles priority and altering signal phases in response to real-time data, the proposed solution aims to lessen congestion and increase the efficiency of traffic flow.

**Key words-** Machine Learning, YOLO, AlexNet, Smart Traffic System, Real-Time Analysis.

### I. INTRODUCTION

Effective traffic regulation is a vital component of urban infrastructure planning, as it directly impacts economic efficiency, environmental well-being, and the overall safety of the public. With rapid urbanization and population growth, cities are experiencing a surge in the number of vehicles, leading to persistent traffic congestion—especially in densely populated metropolitan areas. This growing challenge necessitates innovative approaches for city planners and traffic management authorities. Traditional traffic control systems, often based on static signal timing, are increasingly inadequate to handle fluctuating traffic volumes, particularly during peak hours or in emergencies. This inflexibility not only exacerbates delays but also hampers emergency response times, posing risks to public safety.

This study highlights the usage of Machine Learning (ML) approaches to manage the pressures of densely populated traffic environments. ML-based models offer the advantage of learning from historical and realtime traffic data, continuously improving their accuracy and decision-making capabilities to support intelligent and adaptive traffic control. Our approach automates traffic regulation and facilitates

emergency response, particularly the movement of ambulances, using a combination of datasets, algorithms, and image processing methods. We implemented these using Python, a versatile programming language well-suited for tasks involving object detection and real-time video analysis.

By incorporating these tools, our proposed system offers dynamic solutions for controlling traffic, thereby improving both routine management and emergency services. ML can support law enforcement by automating routine traffic tasks, allowing human officers to focus on high-priority situations such as emergencies and accident prevention.

In conclusion, this paper highlights the value of integrating ML into traffic management systems to enhance service delivery in urban environments. Such innovation promises significant economic, environmental, and societal benefits.

## II. RELATED WORK

In the past a few years, rising urbanization and a surge in vehicle usage have significantly intensified traffic congestion, particularly during rush hours and in emergencies. To tackle these traffic-related problems, many studies have introduced intelligent traffic management systems that integrate advanced technologies such as ML (Machine Learning) for improved efficiency.

Utkarsh Baviskar [1] proposed a smart traffic management model designed to ease traffic congestion and ensure uninterrupted transit for emergency vehicles like ambulances. The system leverages Python-based frameworks such as YOLO (You Only Look Once) for object detection, enabling real-time analysis of video footage and images. According to the detection system modifies traffic signals to prioritize emergency vehicle movement.

Unlike conventional traffic systems, this method introduces adaptive and intelligent decision-making capabilities. A dataset consisting of over 2,800 images of both emergency and non-emergency vehicles was created to train the CNN model. While the model effectively distinguishes between emergency and non-emergency vehicles, its reliance on manually curated data may hinder scalability in densely populated or large metropolitan regions.

While the model effectively distinguishes between emergency and non-emergency vehicles, its reliance on manually curated data may hinder scalability in densely populated or large metropolitan regions.. These models enable dynamic signal adjustments based on traffic flow and sensor data. While such approaches enhance system responsiveness, Baviskar's emphasis on real-time ambulance recognition and adaptive signal control offers a highly relevant contribution to smart city traffic systems.

### III. METHODOLOGY

The STMS (Smart Traffic Management System) uses live video streams in conjunction with machine learning techniques to automatically manage traffic flow across several lanes. Implemented in Python, the system employs a Decision Tree model to anticipate and manage traffic congestion. The detailed procedure is described in the subsequent subsections.

- Initialization and Video Acquisition

The system begins by initializing a timer mechanism that controls the periodic monitoring of traffic conditions. Real-time video streams are captured simultaneously from four different lanes (Lane 1, Lane 2, Lane 3, and Lane 4) using strategically placed surveillance cameras.

These video inputs act as the unprocessed data for later phases of processing.

- Video Pre-Processing:

Captured video streams are subjected to pre-processing operations such as frame extraction, resizing, normalization, and noise reduction. These operations enhance the quality and consistency of the data fed into the object detection model, ensuring higher accuracy in vehicle detection and tracking.

- Object Detection Using YOLO:

For object detection, the YOLO algorithm is employed to recognize and categorize vehicles captured in each frame of the surveillance video. YOLO's real-time performance and high detection accuracy make it suitable for traffic monitoring applications. The model provides bounding box coordinates and class labels for all detected vehicles.

- Density Estimation and Threshold Evaluation:

Traffic density is computed by analyzing the count of vehicles identified in each individual lane. A predefined threshold value is used to compare the computed density. If the density in a particular lane is below the threshold, the system switches the camera view to monitor another lane with potentially higher congestion.

- Congestion Prediction Using Decision Tree:

In lanes where density exceeds the threshold, the system invokes a Decision Tree-based predictive model. This model is trained on historical traffic data and real-time features (e.g., vehicle count, time of day, lane usage) to determine the likelihood of congestion. The model outputs priority scores indicating the urgency of traffic clearance for each lane.

- Priority Assignment and Timer Adjustment:

Using the predicted priorities, the system dynamically adjusts the timer settings for each traffic signal. Lanes with higher congestion levels receive extended green light durations, thereby enabling faster vehicular movement and reducing overall traffic buildup.

- Iterative Monitoring and Control:

The system operates in a continuous loop, where the camera view is periodically updated, video is captured and processed, object detection is performed, and predictions are made to inform realtime traffic signal adjustments. This feedback loop ensures responsive and adaptive traffic control based on evolving road conditions.

### 3.1 ALGORITHM ARCHITECTURE

The system architecture integrates several Convolutional Neural Network (CNN) models to perform object detection, feature extraction, and classification tasks efficiently. The architecture is composed of layered components, each serving a specific role in processing and learning from traffic-related visual data.

#### 3.1.1 Convolutional Neural Network (CNN) Architecture

Convolutional Neural Networks (CNNs) are a robust deep learning architecture widely used in the processing of visual information like images and videos. CNNs are designed to learn and extract meaningful features from raw input through the use of multiple specialist layers. Convolutional layers use filters to detect different visual attributes, such as edges, forms, and textures. Then, pooling layers are utilized to decrease the dimension of the derived feature maps to lower computational complexity without sacrificing essential information required for subsequent analysis.

To improve the model's capacity for learning complicated patterns, activation functions like ReLU (Rectified Linear Unit) are used, enabling the network to learn non-linear relationships among the data. On the last stage, fully connected layers transform the learned features into precise predictions or classifications.

When correctly combined, the different layers in a Convolutional Neural Network (CNN) collaborate to convert raw visual information into meaningful and interpretable data. This feature makes CNNs specially suited for real-world applications like smart traffic management, such as vehicle detection, surveillance, and automatic identification of traffic conditions and vehicle types.

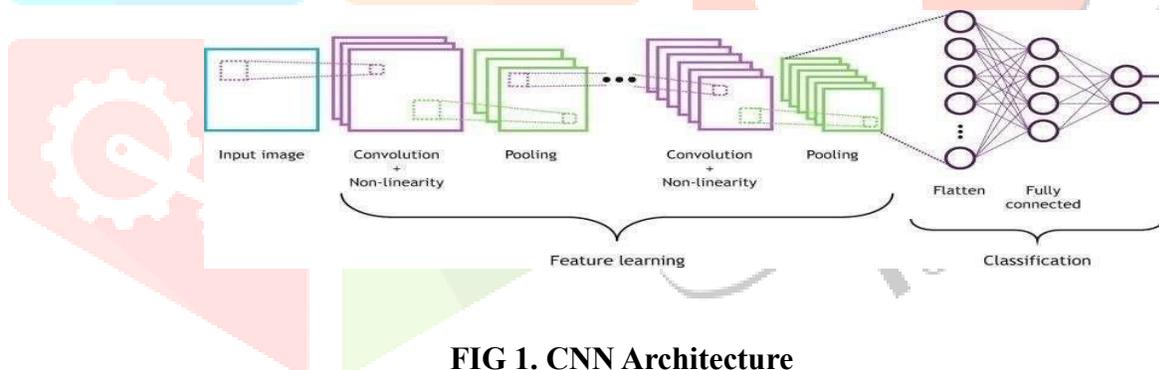


FIG 1. CNN Architecture

#### 3.1.2 YOLO (You Only Look Once) for Object Detection

YOLO is a single-shot object detection algorithm which uses a single-pass convolutional neural network to detect objects of various kinds in a single frame. The input image is subdivided into a grid, and every cell in the grid makes predictions of bounding boxes, class labels, and confidence scores all at once. The end-to-end system renders YOLO much more efficient and effective for real-time traffic monitoring applications. YOLO's ability to detect and mark objects in real-time with high precision plays a major role in the capability of the system to track car movement and identify traffic signs.

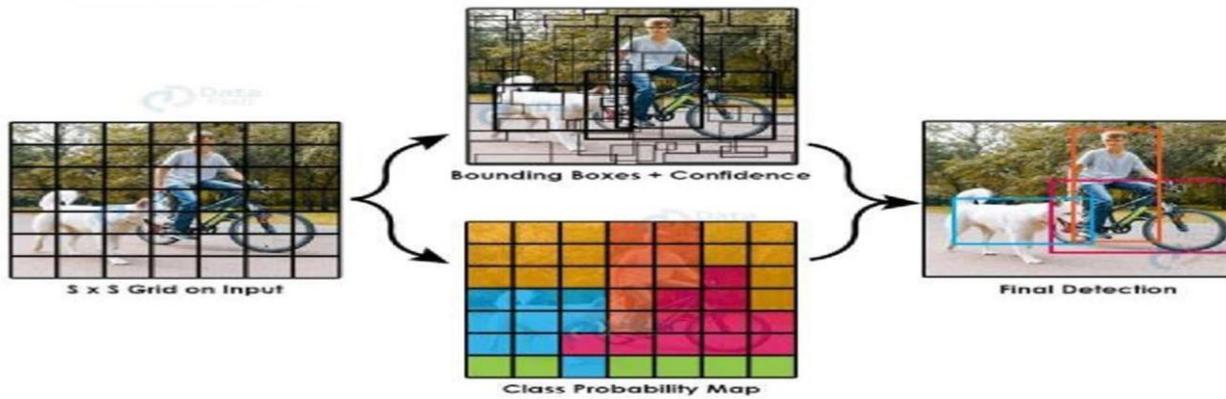


FIG 2. YOLO Architecture

### 3.1.3 AlexNet for Feature Extraction and Classification

AlexNet is a convolutional neural network (CNN) which was made famous after its stellar performance in the ImageNet Visual Recognition Challenge. It consists of many convolutional and fully connected layers which are used to extract intricate features from input images.

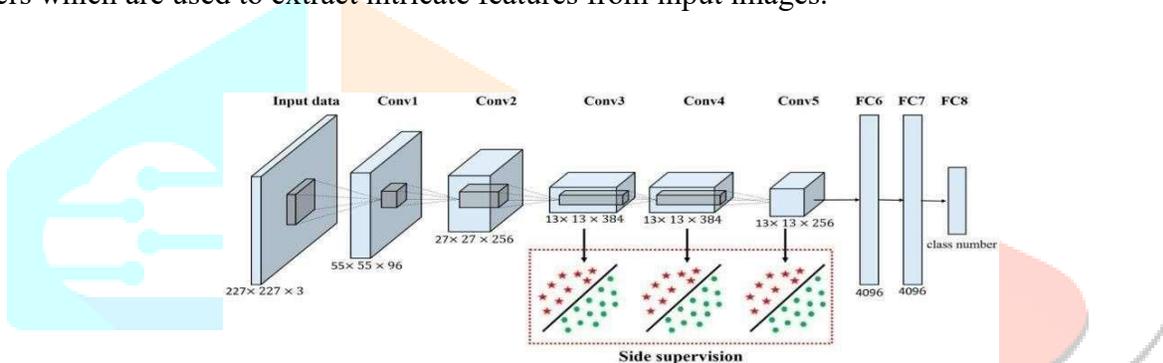


FIG 3. ALEXNET Architecture

### 3.1.4 Integration of YOLO and AlexNet in Traffic Systems

Both YOLO and AlexNet are CNN-based models, sharing foundational components like convolutional layers and activation functions. However, their applications differ. YOLO is best suited for detecting and pinpointing the location of objects in an image, whereas AlexNet excels at analysing and classifying the identified regions. Integrating both models in the proposed traffic system allows for precise vehicle detection and deep analysis, leading to more accurate traffic flow tracking and congestion assessment.

## 3.2 DATASET

For this research, a diverse dataset was assembled, emphasizing a wide variety of vehicle categories, including both emergency and non-emergency types. The images were gathered from open-access sources to ensure diversity in vehicle models, angles, and environmental conditions. The final dataset consisted of 2,876 images, comprising 1,380 emergency vehicles like fire trucks and ambulances, and 1,496 standard vehicles used in everyday traffic.

To train and evaluate the machine learning models effectively, the dataset was divided into training and testing sets. This separation ensures that the model is exposed to unseen examples during testing, enabling it to perform reliably under real-world traffic conditions by avoiding overfitting.

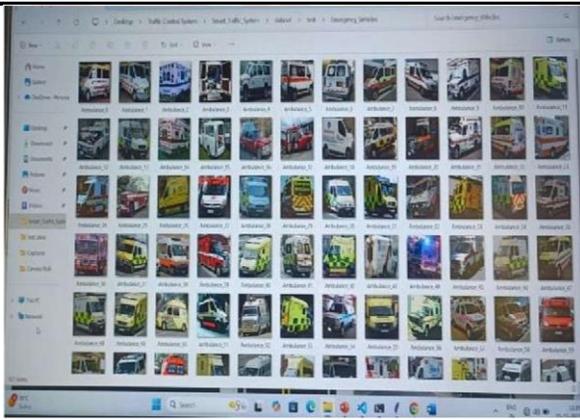


FIG 4. Emergency Vehicles

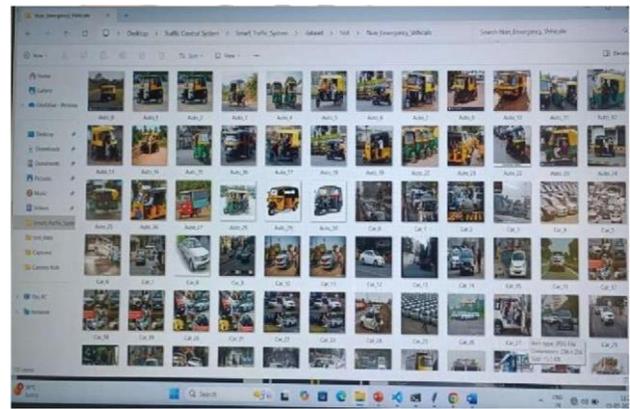


FIG 5. Non-Emergency Vehicles

#### IV. Results & Discussions

The intelligent traffic light management system, developed utilizing YOLO and AlexNet, exhibits considerable potential in real-time traffic surveillance. Through effective vehicle detection and traffic signal automation, the system effectively minimizes traffic congestion, especially in zones with heavy vehicle flow. The experimental results demonstrate that the proposed method improves traffic light synchronization and facilitates smoother vehicle flow by utilizing real-time data. YOLO enables accurate vehicle detection, while AlexNet enriches data interpretation by identifying vehicle characteristics.

The emergency vehicle prioritization function, which dynamically modifies signals to permit ambulances and other priority vehicles to pass quickly, is a significant innovation. Emergency response times are greatly reduced by this improvement. Scalability and integration with more general smart city technologies, like The architecture also facilitates scalability and integration with other smart city technologies, like cloud infrastructure and the Internet of Things. Thus, the system provides a solid basis for sophisticated urban traffic ecosystems.

In essence, this ML-based smart traffic solution is both effective and adaptable, offering valuable insights and control mechanisms to city planners and traffic authorities. Future improvements could further optimize its performance and applicability across diverse environments.

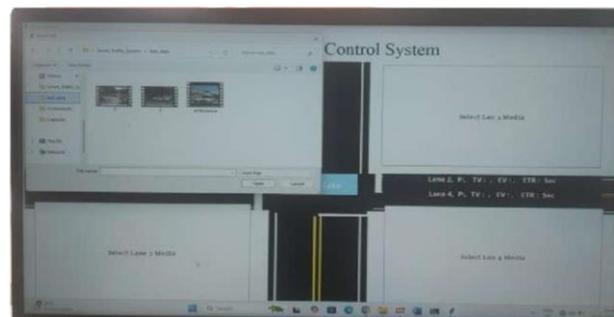
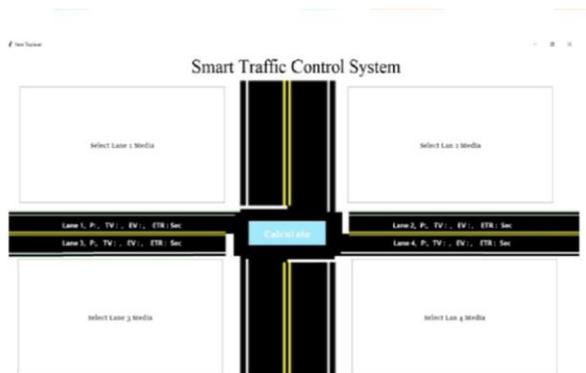


FIG 6. Dashboard Screen

FIG 7. Structure of Input File



FIG 8. FINAL RESULT

## V. CONCLUSION

This study introduces a Machine Learning-Based Intelligent Traffic Management System, utilizing YOLO for object detection and AlexNet for feature extraction. The integration of these models facilitates real-time vehicle tracking, traffic sign recognition, and predictive analysis of traffic conditions. The system delivers timely alerts to drivers and enhances traffic flow efficiency, contributing to road safety and reduced congestion.

Both YOLO and AlexNet demonstrated high accuracy in detecting vehicles and analyzing their attributes, proving essential in generating actionable traffic insights. Despite the positive outcomes, the study acknowledges limitations related to the scale of training data and real-world hardware deployment.

## VI. FUTURE SCOPE

The developed framework opens multiple directions for future advancements, such as:

- **Autonomous Vehicle Integration:** The system can be incorporated into self-driving cars to enhance situational awareness, traffic sign recognition, and collision avoidance.
- **Live Traffic Adaptation:** Enhancing the system for real-time traffic signal control based on active traffic conditions can further optimize urban mobility.
- **Multi-modal Coverage:** The model can be extended to monitor other modes of transport, including bicycles and pedestrians, for improved road safety.
- **Environmental Assessment:** The system holds the potential to analyze traffic behavior and propose eco-friendly traffic solutions to minimize emissions and pollution.

## VII. ACKNOWLEDGEMENT

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