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Smart AI-Based Traffic Light Control System Using YOLO and Simulation

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ABSTRACT

Rapid urbanization and the increasing number of vehicles on roads have led to severe traffic congestion in cities worldwide. Traditional traffic light systems operate on fixed timing mechanisms, which are inefficient in handling dynamic traffic conditions. This project presents a smart traffic control system that leverages Artificial Intelligence (AI) and computer vision techniques to optimize traffic signal management. The system integrates traffic simulation with real-time vehicle detection using the YOLO (You Only Look Once) object detection algorithm.The proposed system consists of two primary modules: a traffic simulation module and a YOLO-based vehicle detection and counting module. The simulation module models traffic flow at intersections, allowing users to observe how intelligent signal control can reduce congestion. The YOLO module processes video input to detect and count vehicles in real time. Based on the number of vehicles detected in each lane, the system dynamically adjusts traffic signal timings.

A graphical user interface (GUI) is developed using Python's Tkinter library to provide user interaction. The GUI allows users to load traffic videos, run detection algorithms, and initiate simulations. This makes the system user-friendly and suitable for demonstration and experimentation purposes.The YOLO algorithm is chosen due to its high speed and accuracy in object detection tasks. It processes entire images in a single pass, making it ideal for real-time applications like traffic monitoring. The detected vehicles are classified and counted, providing essential data for intelligent decision-making.The system aims to reduce waiting times at intersections, improve traffic flow efficiency, and minimize fuel consumption and emissions. By adapting signal timings based on real-time conditions rather than fixed intervals, the proposed approach significantly enhances traffic management.This project demonstrates how AI can be effectively applied to real-world problems in transportation. It serves as a foundation for future developments such as integration with IoT devices, smart city infrastructure, and autonomous traffic systems.

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I.

II. INTRODUCTION

Traffic congestion is one of the most pressing challenges faced by modern cities. With the rapid increase in population and vehicle ownership, traditional traffic management systems are becoming inadequate. Conventional traffic lights operate on pre-defined time intervals, which do not adapt to real-time traffic conditions. As a result, vehicles often experience unnecessary delays, leading to increased fuel consumption, environmental pollution, and driver frustration.Advancements in Artificial Intelligence and computer vision have opened new possibilities for intelligent traffic management systems. These technologies enable real-time analysis of traffic conditions and support dynamic decision-making. One of the most promising approaches in this domain is the use of deep learning-based object detection algorithms such as YOLO (You Only Look Once).YOLO is a state-of-the-art object detection algorithm known for its speed and accuracy. Unlike traditional methods that process images in multiple stages, YOLO performs detection in a single pass, making it suitable for real-time applications. In the context of traffic management, YOLO can be used to detect and count vehicles from video feeds, providing valuable data for optimizing signal control.

This project focuses on developing a smart traffic light control system that combines simulation and real-time detection. The system includes a traffic simulation module that models intersection behavior and a YOLO-based detection module that analyzes video input. A user-friendly GUI is implemented using Tkinter, allowing users to interact with the system easily.The integration of simulation and detection provides a comprehensive platform for studying and improving traffic flow. The system dynamically adjusts traffic signal timings based on vehicle density, ensuring efficient utilization of road infrastructure. This approach not only reduces congestion but also enhances road safety and environmental sustainability.The proposed system is particularly relevant in the context of smart cities, where intelligent infrastructure plays a crucial role in improving urban living standards. By leveraging AI technologies, the system demonstrates a scalable and cost-effective solution for modern traffic challenges.

III. LITERATURE SURVEY (WITH EXISTING METHODS)

Several research efforts have been made to improve traffic management systems using advanced technologies. Traditional traffic systems rely on fixed-time control methods, which are simple but inefficient in handling varying traffic conditions. Researchers have explored adaptive traffic control systems that adjust signal timings based on traffic density.One of the earlier approaches involved the use of sensors such as inductive loop detectors and infrared sensors to measure vehicle presence. While these methods provide basic traffic data, they are expensive to install and maintain. Moreover, they lack flexibility and scalability.With the advancement of image processing techniques, camera-based traffic monitoring systems gained popularity. These systems use video feeds to analyze traffic conditions. Early methods relied on background subtraction and edge detection to identify vehicles. However, these techniques are sensitive to lighting conditions and environmental changes.

The introduction of machine learning and deep learning significantly improved the accuracy and reliability of traffic detection systems. Convolutional Neural Networks (CNNs) became widely used for image classification and object detection tasks. Among various models, YOLO has emerged as one of the most efficient algorithms for real-time object detection.YOLO divides an image into a grid and predicts bounding boxes and class probabilities directly. Its ability to process images quickly makes it suitable for applications requiring real-time performance. Several studies have demonstrated the effectiveness of YOLO in traffic monitoring, including vehicle detection, classification, and counting.Researchers have also explored simulation-based traffic management systems using tools like SUMO (Simulation of Urban Mobility). These systems allow testing of traffic control strategies in a virtual environment before real-world deployment. Combining simulation with real-time data has shown promising results in improving traffic flow.Recent works focus on integrating AI with IoT and cloud computing to create smart traffic ecosystems. These systems enable data sharing between intersections, centralized control, and predictive analytics. However, challenges such as data privacy, infrastructure costs, and system complexity remain.The proposed project builds upon these advancements by combining YOLO-based detection with a simulation module and a GUI interface, providing a practical and accessible solution for intelligent traffic management.

IV. EXISTING SYSTEM

The existing traffic management systems primarily rely on fixed-time traffic signals. These systems operate based on predetermined timing cycles, regardless of the actual traffic conditions. While simple to implement, they are inefficient in handling dynamic traffic patterns, especially during peak hours or unexpected congestion.Some advanced systems use sensor-based approaches, such as inductive loop detectors, infrared sensors, or pressure sensors embedded in roads. These sensors detect vehicle presence and adjust signal timings accordingly. However, such systems involve high installation and maintenance costs. Additionally, they are limited in their ability to provide detailed traffic information, such as vehicle type and count.Camera-based systems using traditional image processing techniques have also been implemented. These systems attempt to detect vehicles using methods like background subtraction and motion detection. However, they are highly sensitive to environmental factors such as lighting changes, weather conditions, and shadows, which reduce their accuracy.Moreover, most existing systems lack integration between real-time data analysis and simulation. They do not provide a platform for testing and evaluating traffic control strategies before implementation. User interaction is also limited, as these systems are often not designed with intuitive interfaces.Overall, the existing systems are either too rigid, costly, or inaccurate, making them unsuitable for modern traffic management needs.

V. PROPOSED METHOD

The proposed system introduces an intelligent traffic management solution that combines AI-based vehicle detection with traffic simulation. It uses the YOLO object detection algorithm to analyze video input and accurately detect and count vehicles in real time. This data is then used to dynamically adjust traffic signal timings, ensuring efficient traffic flow.The system includes a user-friendly graphical interface developed using Tkinter. Users can load traffic videos, run the YOLO detection module, and initiate traffic simulations. This interactive design makes the system suitable for both demonstration and research purposes.

Unlike traditional systems, the proposed approach does not rely on physical sensors, reducing installation and maintenance costs. The use of deep learning ensures high accuracy and robustness under varying environmental conditions.The simulation module allows users to visualize traffic scenarios and evaluate the effectiveness of dynamic signal control strategies. By integrating detection and simulation, the system provides a comprehensive platform for intelligent traffic management.The proposed system is scalable and can be extended to include features such as multi-intersection coordination, IoT integration, and real-time deployment in smart city environments. It offers a cost-effective, efficient, and modern solution to the challenges of urban traffic congestion.

VI. IMPLEMENTATION

The implementation of the Smart AI-Based Traffic Light Control System is carried out using Python, integrating computer vision, simulation, and a graphical user interface. The system is divided into three major components: GUI module, YOLO-based detection module, and traffic simulation module.The GUI is developed using the Tkinter library, which provides an interactive interface for users. It includes buttons to run traffic

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simulation, load video files, and execute YOLO-based vehicle detection. The interface also displays the selected file path and outputs logs using a text area. This ensures ease of use and accessibility for users without requiring technical expertise.

The YOLO-based detection module is implemented using pre-trained deep learning models. When the user selects a video file, the system processes each frame and applies the YOLO algorithm to detect vehicles such as cars, buses, and trucks. YOLO processes the entire image in a single pass, making it highly efficient for real-time applications. Bounding boxes are drawn around detected vehicles, and the total count is calculated dynamically.Research shows that YOLO-based systems provide accurate and fast object detection, making them suitable for intelligent traffic systems . The detected vehicle count is used as input for decision-making in traffic signal control.The simulation module models traffic flow at intersections. It is implemented using a custom Simulation class that simulates vehicle movement, queue formation, and signal switching. Based on the number of vehicles detected in each lane, the system dynamically adjusts signal timings. For example, lanes with higher vehicle density receive longer green signals.The integration between detection and simulation ensures that the system mimics real-world traffic conditions. The simulation helps visualize how dynamic signal control reduces congestion compared to fixed-time systems.The implementation also ensures modularity, allowing easy extension of the system. Additional features such as real-time camera input, multi-lane analysis, and cloud integration can be incorporated in future versions.

Overall, the implementation demonstrates a practical application of AI in traffic management, combining deep learning and simulation for improved efficiency.

VII. ALGORITHMS

The proposed system primarily uses the YOLO (You Only Look Once) object detection algorithm along with a traffic signal control logic algorithm.

1. YOLO Object Detection Algorithm

YOLO is a deep learning-based object detection algorithm that processes images in a single forward pass through a convolutional neural network (CNN). The image is divided into a grid, and each grid cell predicts bounding boxes and class probabilities.

Steps:

1. Input video is divided into frames
2. Each frame is passed to the YOLO model

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3. The model detects objects and assigns class labels (vehicle types)
4. Bounding boxes are generated
5. Vehicle count is calculated

YOLO is preferred due to its real-time detection capability and high accuracy .

2. Traffic Signal Control Algorithm

This algorithm dynamically adjusts signal timing based on vehicle density.

Steps:

1. Count vehicles in each lane
2. Compare vehicle counts
3. Assign highest priority to lane with maximum vehicles
4. Allocate green signal time proportionally
5. Update signals cyclically

3. Simulation Algorithm

1. Initialize lanes and vehicles
2. Generate vehicles randomly
3. Move vehicles based on signal status
4. Update queue length
5. Repeat until simulation ends

These algorithms work together to provide an intelligent and adaptive traffic control system.

VIII. SYSTEM DESIGN

The system design follows a modular architecture consisting of three layers: input layer, processing layer, and output layer.

1. Input Layer

The input layer consists of video data and user interaction through the GUI. Users can upload traffic videos using the file dialog interface. This layer is responsible for capturing real-world traffic scenarios.

2. Processing Layer

This is the core of the system and includes two major components:

a) YOLO Detection Module

This module processes video frames and detects vehicles. It uses a convolutional neural network to identify objects and extract features. Advanced YOLO variants improve detection accuracy even in challenging conditions such as low visibility and dense traffic .

b) Decision-Making Module

This module analyzes vehicle counts and determines optimal signal timings. It uses rule-based logic to allocate green signal durations dynamically.

c) Simulation Module

The simulation module replicates traffic flow behavior. It models vehicle movement, waiting times, and signal transitions. This helps evaluate system performance before real-world implementation.

3. Output Layer

The output layer displays results through:

- GUI text logs
- Video frames with detected vehicles
- Simulation visualization

System Architecture Flow

1. User selects video
2. Frames extracted
3. YOLO detects vehicles

4. Vehicle count calculated
5. Signal timing adjusted
6. Simulation executed
7. Results displayed

Design Advantages

- Modular and scalable
- Real-time processing capability
- Cost-effective (no physical sensors required)
- Easy integration with smart city infrastructure

The system design ensures flexibility, efficiency, and extensibility for future enhancements.

SYSTEM DESIGN IMAGES

Now-a-days due to increasing number of vehicles it's becoming difficult to manage traffic efficiently which leads to longer duration journey and maximum petrol consumption and to avoid this problem standard techniques was introduce such as manual traffic control which require more number of traffic person, static time traffic control which is not effective as it will use same timer for all lanes with heavy and light traffic and sensor based traffic management but this require heavy budget of sensor deployment to sense and manage traffic based on density.

To overcome from above issues author of this paper is utilizing traffic cameras and YOLO object detection algorithms to estimate traffic density at all lanes and then adjust red and green signal time. Cameras will take snapshot of all lanes every five seconds and then estimate traffic at lanes and based on density green and red signal time will be adjusted.

In propose paper author has used PYGAME technique to simulate traffic environment and the used YOLO real environment to detect and count traffic from real traffic videos

To implement this project we have designed following modules

1) Run Traffic Simulation: using this module we can start PYGAME traffic simulation where you can see traffic control based on traffic density

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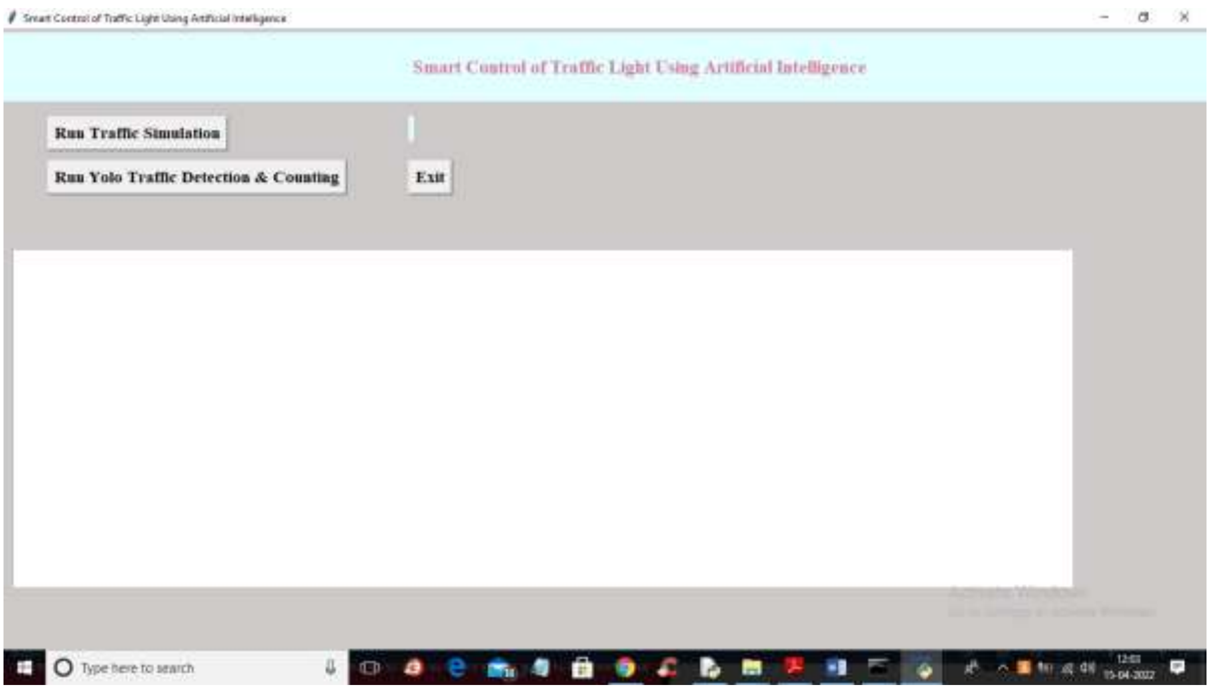
2) Run Yolo Traffic Detection & Counting: using this module we will upload traffic videos and then YOLO will detect traffic vehicles and estimate their density with speed

SCREEN SHOTS

To run project double click on ‘run.bat’ file to get below output



In above screen click on ‘Run Traffic Simulation’ button to start PYGAME simulation and get below output

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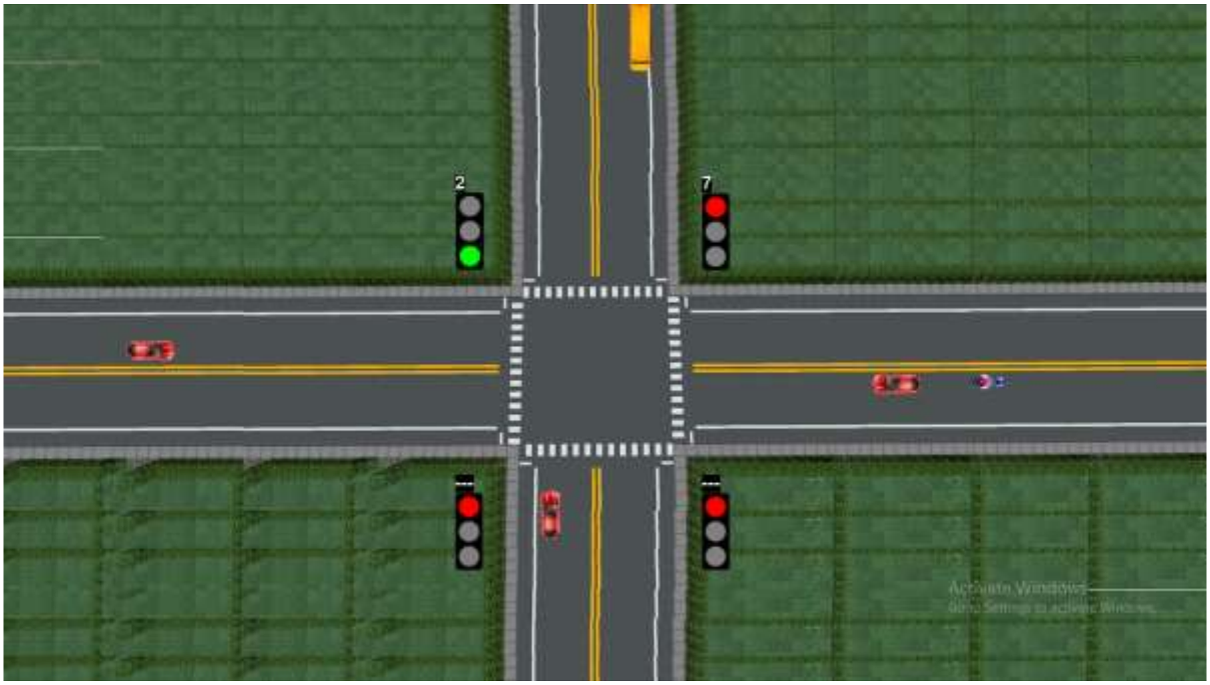

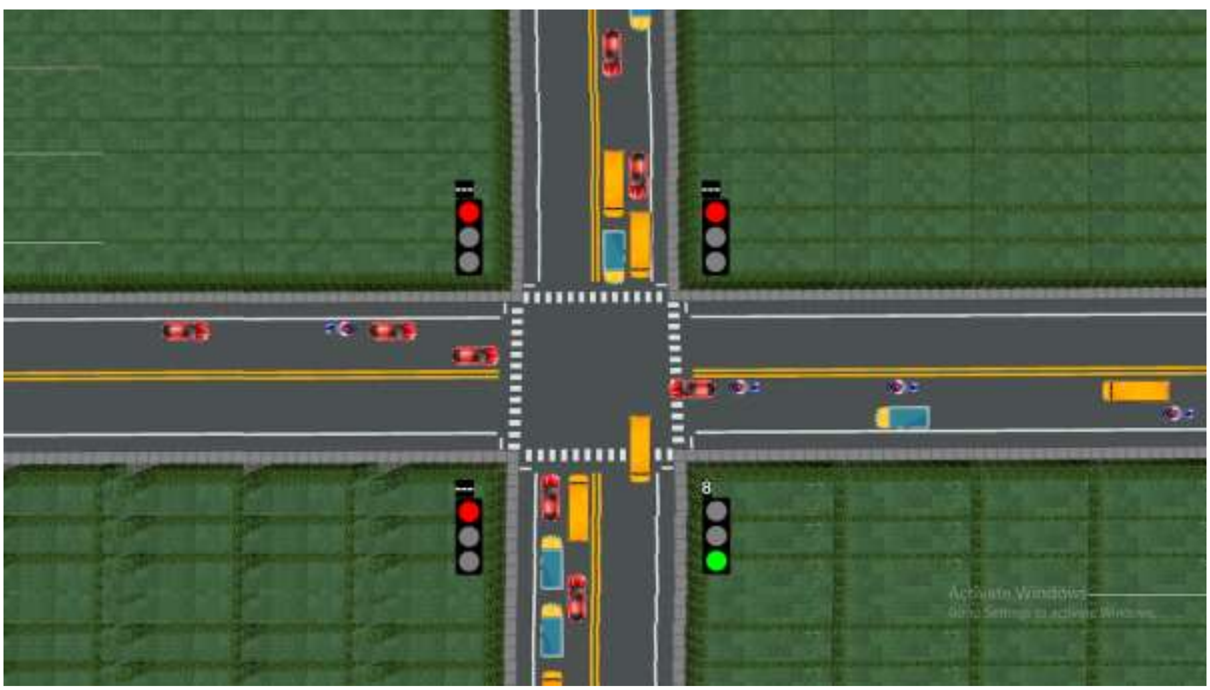

In above screen you can see PYGAME simulation output and at each lane traffic density is calculated and then adjust green and red line. This simulation run in INFINITE loop so you press 'windows' key from keyboard and then close application and then restart and run second YOLO module

Now in above screen click on 'Run Yolo Traffic Detection & Counting' button to upload traffic video and then estimate traffic density

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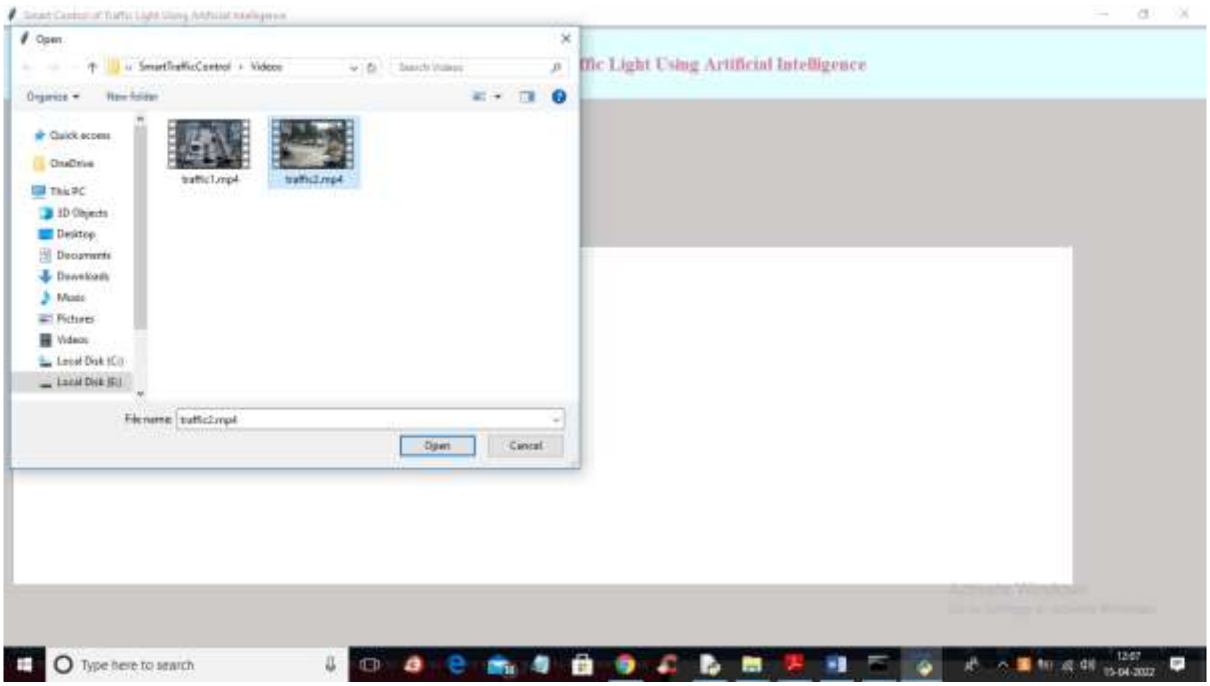
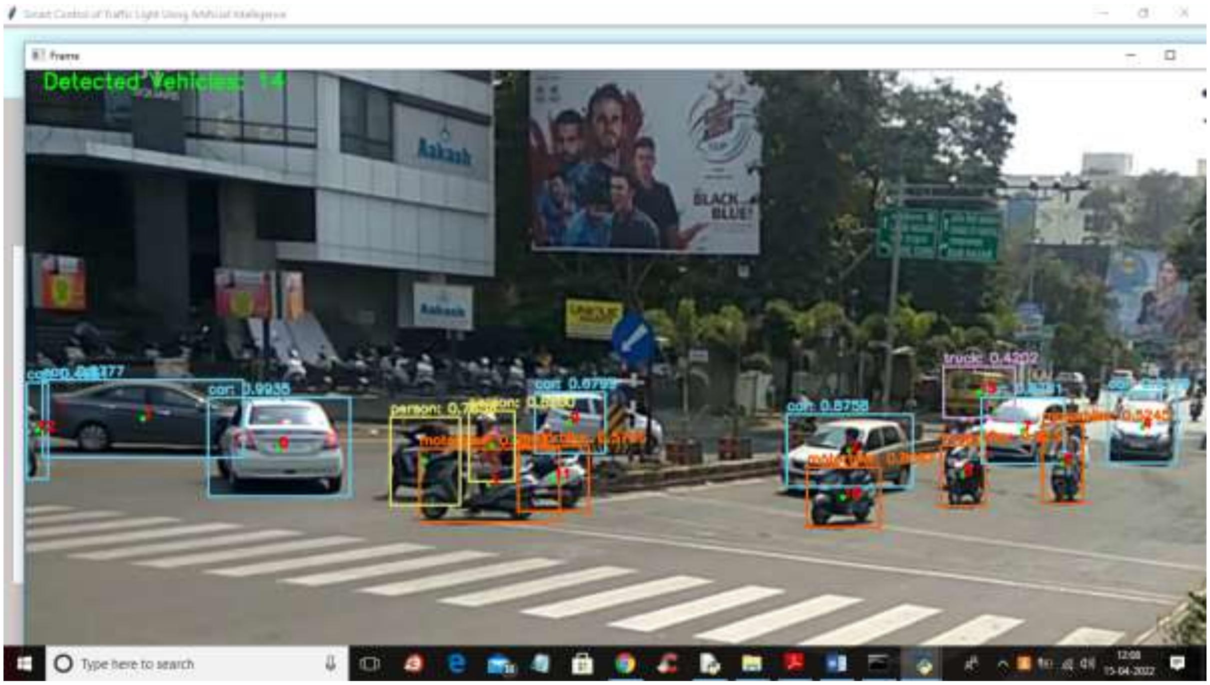


In above screen selecting and uploading ‘traffic2.mp4’ video and then click on ‘Open’ button to get below output



In above screen detecting traffic and then estimating its count and based on that traffic time will be adjusted. YOLO runs very slowly in normal laptop so let it finish all frame processing then u will get output.mp4 file which you can play as normal video with traffic density.

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Detected Vehicles: 40
Type here to search

IX. CONCLUSION

The Smart AI-Based Traffic Light Control System demonstrates an effective approach to solving traffic congestion using Artificial Intelligence and computer vision. By integrating YOLO-based vehicle detection with a dynamic signal control mechanism, the system provides a significant improvement over traditional fixed-time traffic systems.The use of YOLO enables real-time detection and accurate counting of vehicles, which forms the basis for intelligent decision-making. Unlike conventional methods that rely on static timing or expensive sensors, the proposed system adapts to changing traffic conditions dynamically. This results in reduced waiting times, improved traffic flow, and lower fuel consumption.The inclusion of a simulation module further enhances the system by allowing users to visualize and evaluate traffic scenarios. This makes the system not only practical but also useful for research and educational purposes.

Recent advancements in YOLO models have further improved detection accuracy and efficiency, making such systems highly reliable for real-world deployment . The project highlights the potential of AI in building smart transportation systems and supports the vision of smart cities.In conclusion, the proposed system offers a scalable, cost-effective, and efficient solution for modern traffic management challenges. Future work may include integration with IoT devices, deployment on edge computing platforms, and expansion to multi-intersection coordination systems.

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