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Intelligent Traffic Light Control Using Computer Vision

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***Abstract* - Traditional traffic signal systems operate using fixed-time intervals that are unable to adapt to varying traffic conditions, leading to traffic congestion, increased travel time, excessive fuel consumption, and higher carbon emissions. With the rapid growth of urban traffic, there is an increasing need for intelligent traffic management systems capable of making real-time decisions.**

This paper presents an Intelligent Traffic Light Control System Using Computer Vision, which integrates Artificial Intelligence, Deep Learning, and real-time traffic analytics to optimize signal control and improve road efficiency. The proposed system utilizes the YOLOv8 object detection model to detect, classify, and count vehicles from live CCTV surveillance feeds with high accuracy. Based on the detected traffic density, a Dynamic Timer Algorithm dynamically allocates green signal durations to each lane, thereby reducing unnecessary waiting times and improving overall traffic flow. The system further incorporates automated red-light violation detection, capturing images of vehicles crossing the stop line during a red signal to support traffic law enforcement.

To enhance adaptability under varying environmental conditions, weather-based signal optimization is achieved using real-time weather data obtained through an online API. A user-friendly Tkinter-based graphical interface provides live traffic visualization, vehicle counts, signal status, weather information, violation records, and automated daily traffic reports. Experimental evaluation demonstrates that the proposed system significantly improves traffic flow, reduces congestion and vehicle waiting time, enhances road safety, and provides a scalable, cost-effective solution for deployment in modern Smart City and Intelligent Transportation System (ITS) environments.

Keywords: Computer Vision, YOLOv8, Intelligent Traffic Management, Dynamic Traffic Signal Control, Vehicle Detection, Deep Learning, OpenCV, Red-Light Violation Detection, Smart Cities, Artificial Intelligence.

I. INTRODUCTION

Traffic congestion has become one of the most significant challenges in modern urban transportation systems due to the rapid growth in the number of vehicles [14], [20], [29]. Conventional traffic light systems operate using fixed-time signal intervals regardless of the actual traffic density on each road [2], [3], [14]. Consequently, roads with fewer vehicles often receive unnecessary green signal duration, while heavily congested lanes experience prolonged waiting times. This inefficient traffic management approach leads to increased fuel consumption, longer travel times, environmental pollution, and driver inconvenience [4], [16], [20].

Recent advancements in Artificial Intelligence (AI), Deep Learning, and Computer Vision have enabled the development of intelligent traffic management systems capable of making real-time decisions [21], [22], [30]. By integrating surveillance cameras with AI-based object detection algorithms, traffic conditions can be continuously monitored and analyzed to optimize signal timings dynamically [5], [6], [29], [30]. This approach significantly improves traffic flow while reducing congestion and unnecessary delays [3], [7].

The proposed Intelligent Traffic Light Control Using Computer Vision system utilizes the YOLOv8 deep learning model for accurate real-time vehicle detection and counting [6], [11], [24]. Based on the detected traffic density, a Dynamic Timer Algorithm automatically adjusts the duration of green signals for each lane [3], [15], [31], [32]. The system further incorporates weather-aware signal optimization using real-time weather information obtained through an API, allowing traffic signal durations to adapt to environmental conditions such as rain or fog[9], [26]. Additionally, an automated red-light violation detection module captures images of vehicles that violate traffic rules, supporting law enforcement and enhancing road safety [1], [2], [18]. An interactive Tkinter-based graphical user interface provides real-time visualization of traffic conditions, signal status, vehicle counts, weather information, and violation records, making the system suitable for deployment in intelligent transportation systems and smart city infrastructures [12], [13], [23], [25].

1.1 Project Aims and Objectives

To develop an AI-powered Intelligent Traffic Light Control System using Computer Vision, Deep Learning, and real-time traffic analytics to optimize traffic signal management, reduce congestion, improve road safety, and

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support the development of intelligent transportation systems for smart cities.

Objectives and Aims:

1) To detect and classify vehicles in real time using the YOLOv8 deep learning model from live CCTV or surveillance camera feeds.
2) To continuously count vehicles in each lane and estimate traffic density for intelligent traffic signal management.
3) To dynamically adjust green signal duration based on real-time vehicle density using a Dynamic Timer Algorithm.
4) To integrate weather information through online APIs for optimizing traffic signal timing under different environmental conditions.
5) To detect red-light violations automatically by monitoring vehicles crossing the stop line during a red signal.
6) To capture and store images of violating vehicles as evidence for traffic rule enforcement.
7) To develop a user-friendly graphical interface using Tkinter for real-time traffic monitoring and system control.
8) To display live traffic information, including vehicle count, queue length, signal status, weather conditions, and day/night status.
9) To generate automated daily traffic summary reports containing vehicle statistics, violation records, weather information, and system performance.
10) To reduce traffic congestion, vehicle waiting time, fuel consumption, and carbon emissions through intelligent traffic signal optimization.
11) To support traffic authorities with real-time monitoring, data analysis, and automated traffic management.
12) To develop a scalable traffic management framework that can be extended to multiple intersections and integrated into future Smart City and Intelligent Transportation Systems (ITS).

1.2 Application

- Smart Traffic Signal Management
- Adaptive Traffic Signal Timing
- Real-Time Vehicle Detection and Counting
- Red-Light Violation Detection
- Smart City Traffic Monitoring
- Intelligent Transportation Systems (ITS)
- Automated Traffic Analytics and Reporting
- Emergency Vehicle Priority Management
- AI-Based Urban Traffic Planning
- Traffic Congestion Prediction and Control
- Road Safety Monitoring and Enforcement

II. SOFTWARE

The software architecture of the Intelligent Traffic Light Control Using Computer Vision system is a multi-layered intelligent traffic management framework designed to monitor, analyze, and control traffic flow using Artificial Intelligence, Computer Vision, and real-time data processing [21],[22],[29],[30]. The system integrates live video acquisition, deep learning-based vehicle detection, traffic density analysis, weather-based signal optimization, violation detection, and graphical visualization into a unified platform [2], [3], [5], [15], [19].

The project primarily uses Python for implementing computer vision algorithms, deep learning models, traffic signal control logic, and graphical user interface development. The YOLOv8 object detection model is employed to detect and classify vehicles in real time from CCTV camera feeds [6], [11], [24], while OpenCV is used for video processing, object tracking, and image manipulation [10], [22], [30]. Real-time weather information is retrieved using the OpenWeatherMap API to optimize traffic signal timing according to environmental conditions. A Tkinter-based GUI provides an interactive interface for monitoring traffic density, signal status, violation images, and automated summary reports. The integrated software architecture enables intelligent traffic management, reduces congestion, improves road safety, and supports future Smart City and Intelligent Transportation System (ITS) applications [8], [16], [25], [33], [34].

2.1 Language Used

1. Python

Python was the primary programming language used for developing the Intelligent Traffic Light Control System. Its extensive ecosystem of libraries for Artificial Intelligence, Computer Vision, Machine Learning, and Graphical User Interface development made it the most suitable choice for implementing the proposed system [21], [22], [30]. Python was used to develop the YOLOv8 vehicle detection model, traffic signal control algorithm, weather integration module, violation detection system, report generation, and the Tkinter-

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based graphical dashboard [6], [11], [24]. Its simplicity, flexibility, and cross-platform compatibility significantly accelerated the development process.

2. SQL (SQLite)

SQLite was used as the lightweight database system for storing vehicle violation records, captured images, timestamps, and traffic statistics. It provides efficient local storage without requiring a separate database server, making it suitable for real-time traffic monitoring applications [12], [13].

3. HTML, CSS & JavaScript (Future Enhancement)

HTML, CSS, and JavaScript can be used in future implementations to develop a web-based traffic monitoring dashboard. Frameworks such as React.js or Angular can provide an interactive interface for remotely monitoring traffic conditions, traffic violations, weather information, and analytical reports from multiple intersections through cloud connectivity[12], [25].

2.2 Libraries Used

1. Computer Vision & Artificial Intelligence Libraries

- **NumPy**
  NumPy provides high-performance numerical computations and array operations required for image processing, traffic density calculation, and timer computation.

- **Pandas**
  Pandas is used to organize, process, and analyze traffic statistics. It assists in generating daily traffic summary reports containing vehicle counts, violation records, weather conditions, and signal timing information.

- **PyTorch**
  PyTorch serves as the deep learning backend for the YOLOv8 model, enabling efficient training and inference for real-time vehicle detection.

- **Pillow**
  Pillow is used for image processing tasks such as displaying, resizing, and saving captured images of traffic violations within the graphical user interface.

- **OpenCV**
  OpenCV is used for video capture, frame processing, object tracking, image enhancement, stop-line monitoring, and red-light violation detection. It also assists in displaying processed video streams within the graphical interface.

- **Ultralytics(YOLOv8)**
  YOLOv8 is the core deep learning framework used for real-time vehicle detection and classification. It accurately detects vehicles such as cars, buses, trucks, and motorcycles from live CCTV footage while maintaining high processing speed and accuracy.

2. GUI & API Integration

- **Tkinter**
  Tkinter is used to develop the desktop-based graphical user interface that displays live traffic feeds, vehicle counts, signal status, weather conditions, captured violation images, and system reports.

- **OpenWeatherMap-API**
  The OpenWeatherMap API provides real-time weather information based on the selected city. Weather parameters are incorporated into the Dynamic Timer Algorithm to optimize traffic signal duration under different environmental conditions.

- **Requests**
  The Requests library enables communication with the weather API by retrieving current weather information over HTTP.

3. Data Storage & Reporting

- **SQLite**
  SQLite stores violation records, timestamps, vehicle counts, and traffic statistics for future analysis.

- **CSV Module**
  The CSV module is used to generate automated daily traffic summary reports that can be easily accessed and analyzed by traffic authorities.

- **Datetime**
  The Datetime module records timestamps for traffic violations, report generation, and system activity logs.

2.3 Future Perspective

The future scope of the Intelligent Traffic Light Control Using Computer Vision system includes several technological enhancements to improve traffic management efficiency and scalability [17], [23]. Future versions of the system can incorporate Automatic Number Plate Recognition (ANPR) for identifying violating vehicles and automatically generating electronic challans [1], [2], [18]. Integration with Edge AI devices such as NVIDIA Jetson Nano or Google Coral will enable faster processing with lower latency directly at traffic intersections [6], [11], [22].

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The system can also be expanded to support multi-intersection traffic coordination, where multiple traffic signals communicate intelligently to optimize traffic flow across an entire city [8], [25], [34]. Integration with Emergency Vehicle Priority Systems will allow ambulances, fire brigades, and police vehicles to receive dynamic green corridors during emergencies. Furthermore, cloud-based deployment, predictive traffic analytics using advanced machine learning algorithms, accident detection, and integration with Smart City Infrastructure will transform the proposed system into a comprehensive Intelligent Transportation System capable of supporting future urban mobility and sustainable traffic management [5], [7], [12], [16], [21], [25], [33].

III. ORGANIZATION OF WORK

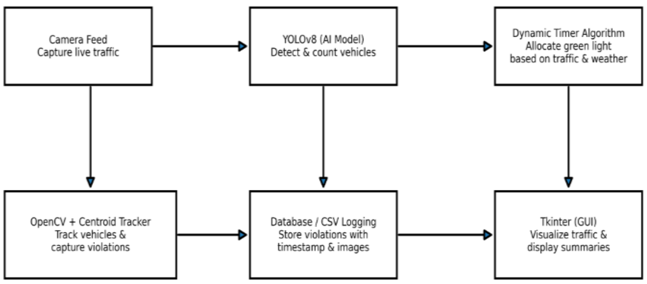

Figure 1: Organization of work

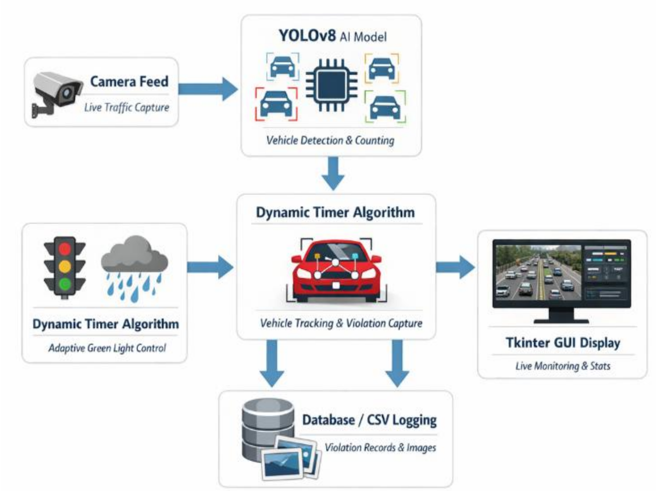

Figure 2: Overall Flow Diagram

IV. METHODOLOGY

This study followed a structured methodology to develop an Intelligent Traffic Light Control System Using Computer Vision for efficient and adaptive traffic management. The research began by identifying the limitations of conventional fixed-time traffic signal systems, including traffic congestion, increased vehicle waiting time, fuel wastage, and the absence of intelligent traffic monitoring. A comprehensive literature review was conducted to understand existing approaches in intelligent transportation systems, computer vision, and deep learning-based traffic control [5], [21], [25], [29].

The proposed system was designed to utilize YOLOv8, a state-of-the-art object detection model, for real-time vehicle detection and classification from live CCTV or surveillance camera feeds. The detected vehicles were continuously counted to estimate traffic density for each lane [4], [19], [30]. Based on the vehicle count, a Dynamic Timer Algorithm was developed to allocate green signal duration dynamically, ensuring that roads with higher traffic density receive longer green signals while reducing unnecessary waiting time for less congested lanes [5], [21], [25], [29]. Additionally, real-time weather information was obtained through the OpenWeatherMap API to optimize signal timing according to prevailing environmental conditions.

The methodology also incorporated an automated Red-Light ViolationDetection module that continuously monitored the stop line during the red signal phase. Whenever a vehicle crossed the stop line while the signal was red, the system automatically captured the vehicle image and stored the violation details for future reference [1], [2], [18]. A Tkinter-based Graphical User Interface (GUI) was developed to provide real-time visualization of traffic feeds, vehicle counts, signal status, weather conditions, captured violation images, and generated traffic summary reports [12], [13].

The performance of the proposed system was evaluated using recorded traffic videos under different traffic conditions. Vehicle detection accuracy, traffic density estimation, signal timing efficiency, and violation detection were analyzed to assess the effectiveness of the system [4], [5], [16], [19]. Finally, the obtained results were compared with conventional traffic signal systems to demonstrate improvements in traffic flow, congestion reduction, and road safety. The complete methodology, implementation, and experimental observations were documented to ensure reproducibility and provide a foundation for future enhancements in Intelligent Transportation Systems (ITS) [23], [25], [27], [28].

V. RESULTS

- **Output in Python Notebook:**

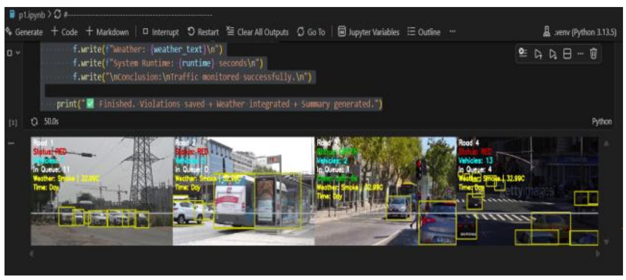

Figure 3: Output in Python Notebook

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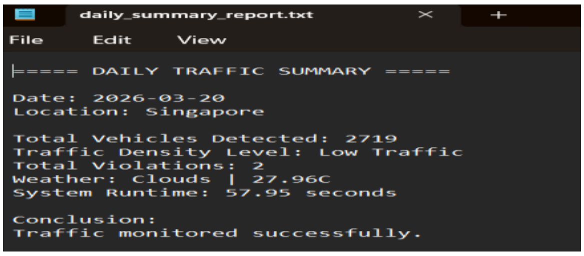
- **Summary Report:**



daily_summary_report.txt

File Edit View

===== DAILY TRAFFIC SUMMARY =====

Date: 2026-03-20
Location: Singapore

Total Vehicles Detected: 2719
Traffic Density Level: Low Traffic
Total Violations: 2
Weather: Clouds | 27.96C
System Runtime: 57.95 seconds

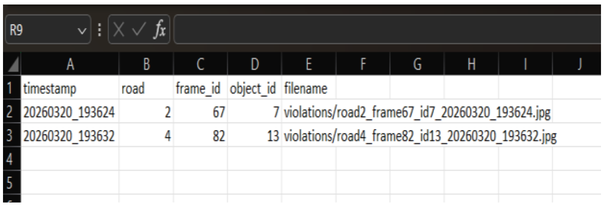
Conclusion:
Traffic monitored successfully.

Figure 4: Summary Report

- **Violation Image:**

Figure 5: Violation Image

- **CSV File:**



timestamp	road	frame_id	object_id	filename
20260320_193624	2	67	7	violations/road2_frame67_id7_20260320_193624.jpg
20260320_193632	4	82	13	violations/road4_frame82_id13_20260320_193632.jpg

Figure 6: CSV File

- **User Interface:**

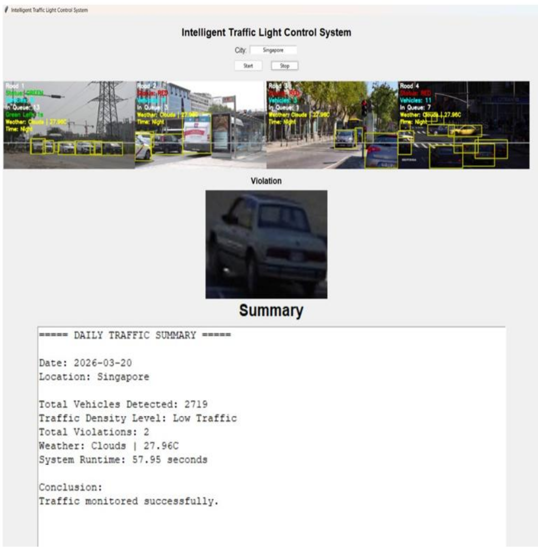


Figure 7: User Interface

VI. CONCLUSION

The Intelligent Traffic Light Control Using Computer Vision project presents an innovative approach to modern traffic management by integrating Artificial Intelligence, Computer Vision, and real-time traffic analytics [21], [22], [29], [30]. The proposed system successfully utilizes the YOLOv8 deep learning model to detect and classify vehicles from live surveillance camera feeds, enabling dynamic adjustment of traffic signal timings based on actual traffic density [6], [11], [24]. This adaptive approach significantly improves traffic flow, reduces vehicle waiting time, minimizes fuel consumption, and lowers carbon emissions compared to conventional fixed-time traffic signal systems [2], [3], [14].

In addition to intelligent signal control, the system enhances road safety through automated red-light violation detection, capturing images of violating vehicles for future enforcement. The integration of weather-based signal optimization and a Tkinter-based graphical user interface further improves the practicality and usability of the proposed solution by providing real-time monitoring, traffic analytics, and automated reporting [9], [12], [13], [18], [26].

Overall, the proposed system demonstrates the potential of Artificial Intelligence and Computer Vision in developing scalable and intelligent transportation solutions for smart cities [5], [16], [25], [33], [34]. Future enhancements such as Automatic Number Plate Recognition (ANPR), emergency vehicle prioritization, cloud-based deployment, multi-intersection coordination, and predictive traffic analytics can further improve system efficiency and support the development of next-generation Intelligent Transportation Systems (ITS) [7], [8], [17], [23], [27], [28], [31], [32].

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constructive suggestions greatly enhanced the quality of our work.

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