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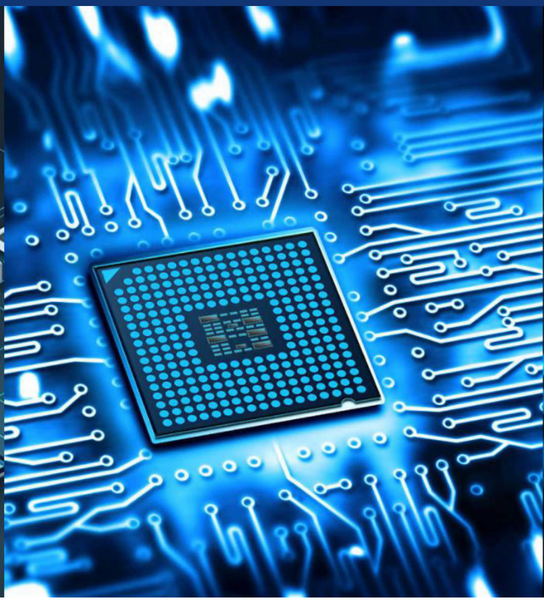


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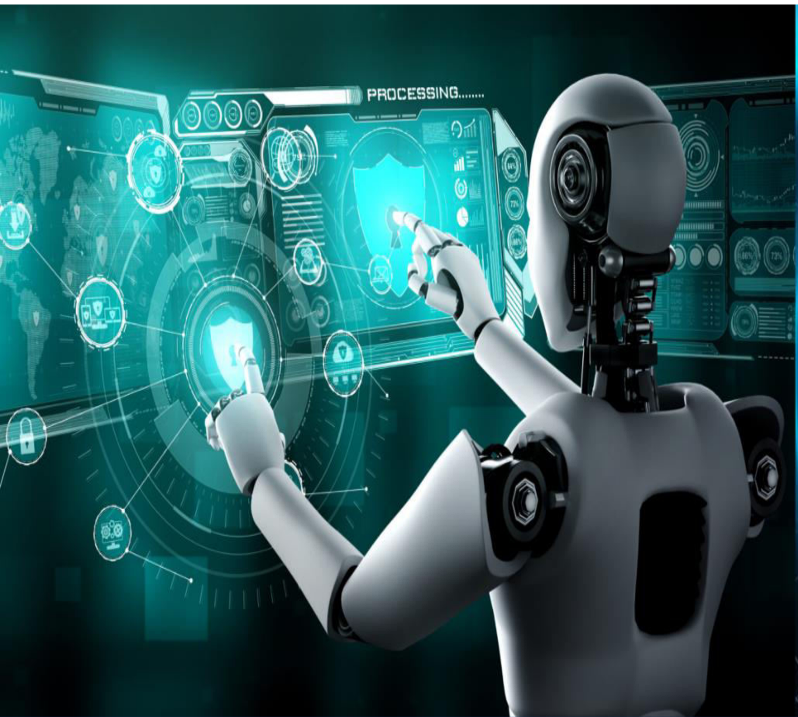

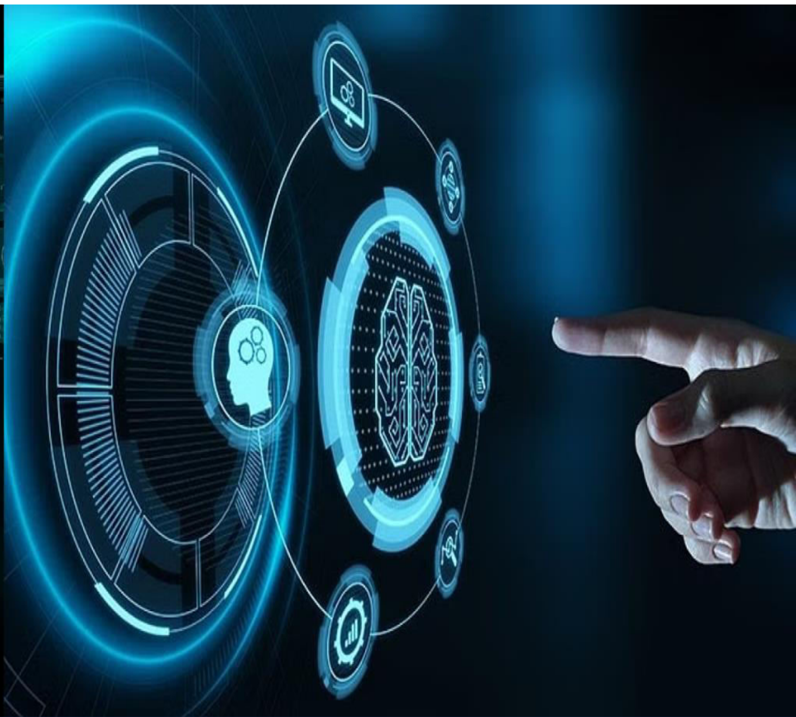

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To Design an AI-Powered Traffic Rule Violation Detection Framework Using Computer Vision

A.Elango[1], Sugandhi Mariyal D[1], Murugan B[2], Chandru Y[2], Krishnan S[2]

Assistant Professor, Department of Computer Science and Engineering, P.S.V College of Engineering and Technology, Mittapalli, Krishnagiri, India[1]

UG Scholar, Department of Computer Science and Engineering, P.S.V College of Engineering and Technology, Mittapalli, Krishnagiri, India[2]

ABSTRACT: Traffic rule violations such as helmetless riding, signal jumping, wrong-way driving, and lane violations significantly contribute to road accidents and congestion. This paper proposes an AI-powered traffic rule violation detection framework using computer vision for real-time monitoring and automated evidence generation.

The system captures video from roadside or CCTV cameras and performs frame-wise preprocessing followed by object detection to identify vehicles, riders, helmets, and traffic signals. Violations are detected using rule-based logic and tracked across frames to reduce false detections. Number plate extraction is optionally performed for documentation and reporting.

The framework is implemented using Python and OpenCV, with support from deep learning models such as YOLO for object detection. The proposed approach improves enforcement efficiency, reduces manual surveillance efforts, and enables scalable deployment in smart city environments. Experimental evaluation shows that the system can accurately detect common violations under varying traffic conditions, making it suitable for real-time traffic monitoring and automated rule enforcement.

KEYWORDS: AI-powered traffic monitoring, computer vision, deep learning, YOLO, OpenCV, traffic rule violation detection, real-time surveillance, automatic number plate recognition

I. INTRODUCTION

Traffic rule violations such as helmetless riding, signal jumping, wrong-way driving, and lane indiscipline are major causes of road accidents and congestion. Traditional traffic monitoring systems rely heavily on manual supervision by traffic police, which is time-consuming, labor-intensive, and prone to human errors, making continuous monitoring difficult. To overcome these limitations, this project proposes an AI-powered traffic rule violation detection system using computer vision. The system captures live video streams from CCTV cameras and processes them in real time using deep learning models like YOLO to detect vehicles, riders, helmets, and traffic signals. It identifies violations based on predefined rules, generates evidence with timestamps, and sends alerts to authorities. This approach reduces human effort, improves detection accuracy, and enhances road safety through efficient and automated traffic management.

II. LITERATURE REVIEW

1. **Chaudhary P. and Sharma V. (2019)** proposed a traffic signal violation detection system using video analytics. The system monitored stop-line crossing during red signals. Results indicated improved enforcement efficiency compared to manual monitoring. The research demonstrated real-time violation identification capability. It directly supports signal jumping detection modules.

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2. **Reddy K. et al. (2020)** developed a wrong-way vehicle detection system using motion analysis and deep learning. The model tracked vehicle direction across multiple frames. Experimental outcomes showed accurate detection of opposite-direction movement. The study emphasized accident prevention through early identification. It strengthens wrong-way driving detection mechanisms.

3. **Kumar A. and Singh D. (2021)** proposed a lane violation detection system using image segmentation and Hough Transform techniques. The system identified lane boundaries and monitored vehicle positioning. Results showed reliable detection under structured road conditions. The research demonstrated the effectiveness of computer vision in lane monitoring. It supports automated lane discipline enforcement.

4. **Patel R. and Mehta S. (2022)** introduced an AI-based smart traffic monitoring framework integrating YOLO and deep learning models. The system detected multiple violations simultaneously from live video feeds. Performance evaluation showed high accuracy in dense traffic scenarios. The study highlighted scalability for smart city applications. It validates the feasibility of deploying AI-powered traffic rule violation detection systems.

III. METHODOLOGY

A. EXISTING SYSTEM

The existing traffic monitoring system mainly relies on manual supervision by traffic police and basic CCTV surveillance. Cameras are used only for recording traffic activities, and violations are identified through manual observation or later review of footage. Some systems use radar guns, speed cameras, or red-light detection systems, but they are limited to specific locations and single types of violations. These systems lack automation, real-time processing, and integration, making continuous monitoring difficult. Human involvement is required for verification and penalty processing, which increases workload and reduces overall efficiency.

B. DISADVANTAGES

- Existing systems rely on manual monitoring, which increases workload and leads to possible human errors.
- The process is time-consuming as violations are identified through manual observation or video review.
- Most systems detect only single types of violations and lack integrated monitoring capabilities.
- Lack of real-time detection delays enforcement actions and reduces overall system efficiency.

C. PROPOSED SYSTEM

The proposed system uses artificial intelligence and computer vision to automate traffic monitoring and violation detection. Live video is captured from CCTV cameras and processed frame by frame using image preprocessing techniques. A deep learning model such as YOLO is used to detect vehicles, riders, helmets, and traffic signals in real time. Object tracking ensures accurate identification across frames, and rule-based logic is applied to detect violations like helmetless riding, signal jumping, wrong-way driving, and lane violations. The system automatically generates evidence with timestamps, stores data in a centralized database, and sends real-time alerts to authorities, improving efficiency and accuracy.

D. ADVANTAGES

- Existing systems rely on manual monitoring, which increases workload and leads to possible human errors.
- The process is time-consuming as violations are identified through manual observation or video review.
- Most systems detect only single types of violations and lack integrated monitoring capabilities.
- Lack of real-time detection delays enforcement actions and reduces overall system efficiency.

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E. DESIGN OF THE SYSTEM

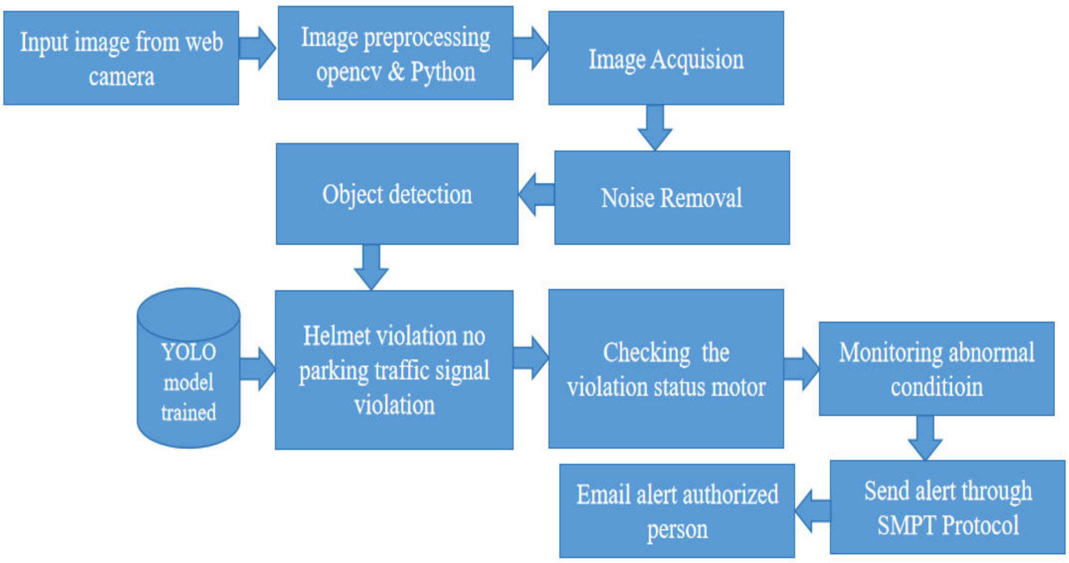

Fig. 1 diagram represents an AI-based traffic rule violation detection system. It shows how input images are captured from a web camera and processed using tools like Python and OpenCV. The system performs image preprocessing, noise removal, and object detection using a trained YOLO model. It identifies vehicles, riders, helmets, and traffic signals to detect violations such as helmetless riding, signal jumping, and no-parking violations. The system then checks the violation status and monitors abnormal conditions in traffic. Once a violation is confirmed, it generates alerts and sends notifications to authorized persons through the SMTP protocol. This automated process ensures real-time monitoring, improved accuracy, and efficient traffic management.

IV. IMPLEMENTATION

MODULE DESCRIPTION

a) Video Acquisition Module

The Video Acquisition Module serves as the primary interface between the physical environment and the digital system. It is responsible for fetching live video streams from roadside CCTV cameras or pre-recorded traffic footage. This module manages the frame rate and ensures that the stream is continuously fed into the processing pipeline. It supports various video formats and protocols to ensure compatibility with standard surveillance infrastructure, allowing for seamless data ingestion from multiple camera sources simultaneously.

b) Frame Preprocessing Module

Raw video data often contains noise, varying lighting conditions, or motion blur that can hinder detection accuracy. The Preprocessing Module applies several computer vision techniques to clean and standardize the visual data. Key operations include resizing frames to meet model input requirements, applying Gaussian filters for noise reduction, and adjusting contrast to improve visibility in low-light conditions. These steps ensure that the subsequent deep learning models receive high-quality, optimized data for analysis.

c) Object Detection Module

This is the core intelligence unit of the system, utilizing deep learning architectures to perform real-time identification of entities within each frame. The module is trained to recognize and locate vehicles, riders, and safety equipment such as helmets, as well as infrastructure elements like traffic signals. Each detected object is encapsulated within a bounding box and assigned a class label with a specific confidence score, providing the foundational data needed to evaluate traffic behavior.

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d) Violation Detection Module

The Violation Detection Module applies rule-based logic algorithms to the data provided by the detection stage. It evaluates whether the behavior of the detected objects contradicts established traffic laws. This includes logic for identifying helmetless riding by analyzing the head region of motorcycle users, detecting signal jumping by monitoring vehicle positions relative to stop lines during red light phases, and identifying wrong-way driving by calculating motion vectors against the permitted lane direction.

e) Tracking Module

To maintain consistency and reduce false positives, the Tracking Module assigns a unique identifier to every detected vehicle and follows it across consecutive frames. By utilizing temporal tracking algorithms, the system can distinguish between a single vehicle moving through a scene and multiple separate entities. This ensures that a single violation event is not counted multiple times for the same vehicle and allows the system to analyze continuous trajectories and speed patterns effectively.

f) Evidence Generation Module

Once a violation is confirmed, the Evidence Generation Module automates the documentation process for enforcement purposes. It captures high-resolution snapshots of the violation event and utilizes optical character recognition to extract vehicle identification details. The module compiles a comprehensive report that includes the violation type, a timestamp, the location ID, and visual proof, ensuring that the data is ready for storage in a central database or for transmission to traffic authorities.

V. RESULT

The proposed system is an AI-based Traffic Rule Violation Detection System that provides an efficient and intelligent solution for modern traffic management. The system captures live video streams from CCTV cameras and processes them using computer vision and deep learning techniques to detect traffic violations such as helmetless riding, signal jumping, wrong-way driving, and lane violations. Based on the detection results, the system automatically identifies violating vehicles and generates evidence including images, timestamps, and violation details. The system operates in real time with high accuracy, reducing human intervention and improving enforcement efficiency. It ensures reliable performance under different environmental conditions and supports continuous monitoring of traffic activities.

FigureNo:.1.Violution Decision

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Figure No: 2.Signal Violution

Fig. 2 shows the detection of a signal jumping violation using the proposed AI-based traffic rule violation detection system. In this image, the system monitors the traffic signal and identifies the red light condition. When a vehicle crosses the stop line during the red signal, it is detected as a violation. Using computer vision and the trained YOLO model, the system detects the vehicle and tracks its movement across frames. Once the violation is confirmed, the system highlights the vehicle with a bounding box and labels it as a "Signal Jumping Violation". This demonstrates the system's ability to automatically detect traffic rule violations in real time and assist authorities in maintaining road safety.

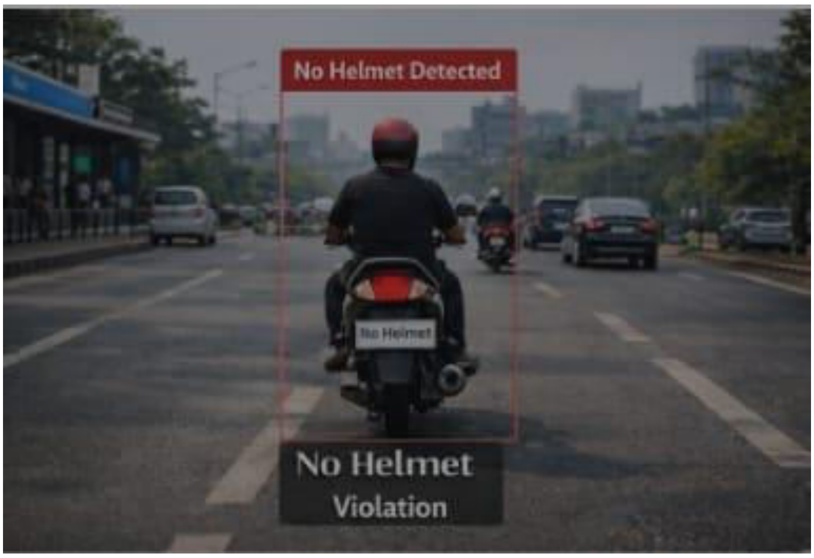

Figure No: 3. Helmet Violution

Fig. 3 shows the detection of a helmet compliance (no violation) using the proposed AI-based traffic rule violation detection system. In this image, the system captures a rider on a two-wheeler and analyzes the head region using computer vision techniques. The trained YOLO model detects that the rider is properly wearing a helmet. Since the safety rule is followed, the system does not mark it as a violation. The rider may still be highlighted with a bounding box for detection, but it is labeled as "Helmet Detected" or "No Violation". This demonstrates the system's ability to accurately distinguish between violations and non-violations, ensuring reliable and fair traffic monitoring.

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VI. CONCLUSION

The proposed AI-Powered Traffic Rule Violation Detection Framework using Computer Vision successfully demonstrates an automated and intelligent approach to traffic monitoring and rule enforcement. By integrating Python, OpenCV, and deep learning models such as YOLO/CNN, the system efficiently detects violations including helmetless riding, signal jumping, wrong-way driving, and lane violations in real time. The framework reduces dependency on manual surveillance and improves enforcement accuracy through automated evidence generation. Frame preprocessing and object tracking techniques help minimize false detections and enhance system reliability. The solution is scalable and can be deployed with existing CCTV infrastructure in smart city environments. Experimental evaluation confirms that the system performs effectively under varying traffic conditions with satisfactory detection accuracy. Although challenges such as poor lighting and occlusions may affect performance, they can be addressed with advanced model training and hardware optimization. Overall, the proposed system offers a cost-effective, reliable, and scalable solution for intelligent traffic management and automated rule enforcement.

VII. FUTURE ENHANCEMENT

The proposed system can be further enhanced by integrating automatic number plate recognition (ANPR) to identify vehicles and generate challans automatically, reducing manual effort. Cloud-based storage can be implemented for centralized data management and remote access, improving scalability and monitoring across multiple locations. A mobile application can be developed to send real-time alerts and notifications to traffic authorities for faster response. The system can also be improved to perform effectively in low-light and adverse weather conditions using advanced deep learning techniques. Additionally, incorporating analytics dashboards can help analyze traffic patterns and violation trends, supporting better decision-making and smart city development.

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3. **Reddy, K., et al. (2020).** Wrong-Way Vehicle Detection Using Deep Learning.The study developed a system for identifying vehicles moving in the wrong direction. It enhanced road safety measures. The research is relevant to intelligent traffic systems.
4. **Kumar, A., & Singh, D. (2021**). Lane Detection and Monitoring Using Computer Vision.This research introduced lane detection using image processing methods. It improved lane discipline monitoring. The findings support automated lane violation detection.

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