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AI-Powered Helmet and Vehicle Number Plate Recognition System with Automatic Traffic Violation Detection and Chalan Generation

Agre Pratik S.[1] , Deokar Suraj S.[2] , Kunjir Gaurav B.[3] , Prof. Bhosale. S. B.[4]

[1,2,3,4] Department of Computer Engineering, Jaihind College Of Engineering, Kuran

Abstract:

The increasing number of vehicles on roads has made traffic monitoring and enforcement more challenging for authorities. Manual observation of violations such as riding without a helmet, triple-seat riding, and improper vehicle usage requires significant effort and often leads to delays in enforcement. This paper presents an intelligent traffic surveillance system that automatically detects traffic violations and generates digital challans. The proposed solution combines YOLOv8-based object detection with Optical Character Recognition (OCR) to identify riders, helmets, motorcycles, and vehicle registration numbers from video streams. When a violation is detected, the system records the relevant information, stores it in a database, and generates an electronic challan along with supporting evidence. A dashboard is provided for monitoring and managing violation records. The system minimizes human intervention, improves monitoring efficiency, and supports modern traffic management initiatives. Experimental evaluation demonstrates that the proposed approach can effectively identify violations while maintaining reliable performance in a local processing environment.

Keywords— Traffic Surveillance, YOLOv8, OCR, Deep Learning, Computer Vision, Automatic Challan Generation.

I. INTRODUCTION

Rapid urbanization and the continuous growth of vehicle ownership have increased the complexity of traffic management in modern cities. Traffic violations such as riding without helmets and carrying more passengers than permitted are common causes of road accidents and safety concerns. Conventional monitoring methods rely heavily on manual supervision by traffic personnel, which can be difficult to maintain across multiple locations and during peak traffic conditions.

Advances in artificial intelligence and computer vision have enabled automated analysis of traffic scenes using surveillance cameras. Modern object detection algorithms can recognize vehicles, riders, safety equipment, and other traffic-related objects with high accuracy. These capabilities create opportunities for developing automated systems that can assist authorities in enforcing traffic regulations more efficiently.

Many existing traffic monitoring solutions focus on individual tasks such as helmet detection or vehicle identification. However, a comprehensive system that integrates violation detection, number plate recognition, record management, and challan generation can provide greater practical value. The proposed work introduces a unified framework that performs all these functions within a single workflow. By combining object detection and OCR techniques, the system aims to improve enforcement efficiency, reduce manual effort, and support safer transportation environments.

II. OBJECTIVES

1. To design and develop a real-time automated system that detects riders without helmets and identifies triple riding using YOLOv8.
2. To integrate OCR for accurate vehicle number plate recognition.
3. To automatically generate and send digital e-challans with violation details and supporting evidence.
4. To contribute to safer roads and support smart traffic management systems.

III. RELATED WORK

Zhang et al. (2024) proposed a deep learning-based traffic monitoring system for detecting vehicle movements and road violations using real-time object detection models. The system improved monitoring efficiency but lacked integrated violation reporting and automated challan generation.

Patel and Sharma (2024) developed an AI-based helmet detection system using computer vision techniques to identify riders without helmets. Although the model achieved good detection accuracy, it was limited to helmet monitoring and did not include number plate recognition.

Kim et al. (2025) introduced an OCR-supported vehicle identification framework for smart transportation systems. The approach improved number plate extraction accuracy; however, performance decreased in low-light and crowded traffic conditions.

Singh et al. (2025) proposed an automated traffic violation detection system using advanced object detection algorithms. While the system enhanced violation detection, it lacked a complete integration of helmet detection, triple-seat identification, OCR, and automatic challan generation.

Research Gap:

Existing solutions generally address individual components of traffic surveillance rather than providing an end-to-end enforcement framework. There is a requirement for a unified system capable of detecting helmet violations, identifying triple-seat riding, recognizing vehicle number plates, maintaining violation records, and generating digital challans automatically. The proposed work addresses this requirement by combining these functionalities into a single intelligent traffic monitoring platform.

IV. METHODOLOGY

The developed framework performs automatic traffic violation monitoring through a sequence of interconnected processing stages. Video data obtained from surveillance cameras is analyzed to identify motorcycles, riders, safety equipment, and vehicle registration numbers. The extracted information is evaluated against predefined traffic rules, enabling the system to detect violations and generate digital challans without continuous human supervision.

1. **Input Acquisition:**
   Video streams are captured from CCTV cameras or recorded sources installed at traffic points.
2. **Preprocessing Layer:**
   Frames are extracted and processed through resizing and normalization to ensure consistent input quality for detection.
3. **Detection Module:**
   A YOLOv8-based object detection model is used to identify motorcycles, riders, helmets, and number plates in real time.
4. **Violation Analysis:**
   Detected outputs are evaluated using rule-based logic to determine violations such as helmet absence and triple riding detection.
5. **Number Plate Recognition:**
   Once a violation is confirmed, the number plate region is extracted and processed using OCR (EasyOCR) to retrieve vehicle registration details.
6. **Challan Generation:**
   An electronic challan is automatically generated containing violation type, timestamp, vehicle number, and evidence image, which is stored in a

database and exported for reporting and review.

Algorithmic Flow:-

1. Capture traffic image or video input from camera/CCTV.
2. Preprocess frames for better detection quality.
3. Detect motorcycles, helmets, and triple-seat violations using YOLOv8.
4. Extract and recognize vehicle number plates using OCR.
5. Store detected violation details in the database.
6. Generate digital challan and display results on the dashboard.

This workflow ensures automatic, accurate, and efficient traffic violation detection with reduced manual effort.

V. SYSTEM ARCHITECTURE

The proposed system captures traffic images or video through a camera and processes them using the YOLOv8 model to detect motorcycles, helmets, and triple-seat violations. After detecting a violation, the vehicle number plate is extracted and recognized using OCR technology. The violation details are then stored in the database, and an automatic digital challan is generated. This process helps in efficient traffic monitoring with reduced manual effort.

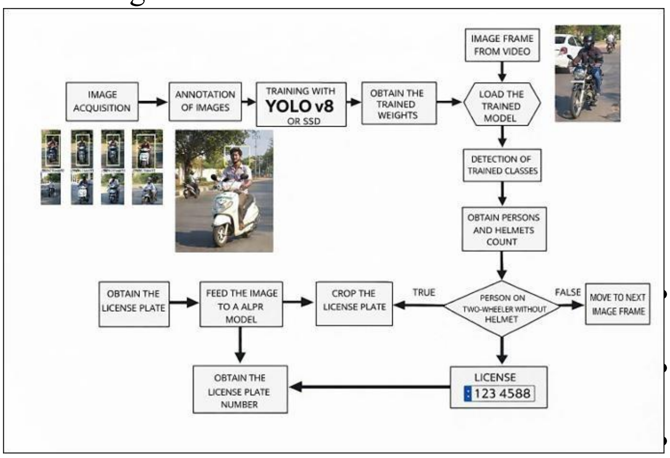

Fig: System Architecture

VI. EXPERIMENTAL SETUP

Dataset Description:

To evaluate the effectiveness of the proposed framework, a collection of traffic images and video frames was prepared using publicly available resources along with manually collected road surveillance samples. The dataset represents diverse traffic environments including varying illumination levels, different camera viewpoints, and multiple vehicle densities. Samples were categorized according to helmet compliance, triple-riding conditions, and vehicle number plate visibility. Annotation data was utilized during model training and testing to ensure accurate detection and recognition performance.

Each traffic instance belongs to one of the following categories:

Helmet-wearing riders

Helmetless riders (traffic violation)

Triple-seat riding violations

Normal motorcycle riding cases

Vehicle number plate images for OCR recognition

The dataset includes traffic scenarios under daytime, low-light conditions, multiple vehicle presence, and varying camera angles. Ground-truth annotations were used to train and validate object detection and number plate recognition accuracy.

Hardware Configuration:-

Processor: Intel Core i5 (10th Generation)

Memory: 8 GB RAM or above

Storage: 512 GB SSD

- Other Peripheral: CCTV Camera / Traffic Video Input

No GPU or cloud-based services were used during execution, ensuring a CPU-based and locally executable evaluation environment.

Software Environment and Tools:-

The proposed system was developed using open-source technologies to improve accessibility and implementation flexibility. The primary tools and frameworks used are listed below:

- Programming Language: Python 3.10
- Deep Learning Framework: YOLOv8
- Database: MySQL
- Dashboard: Streamlit
- Image Processing: OpenCV
- Development Environment**:** Visual Studio Code

All required libraries and dependencies were installed locally, and the system was executed without external cloud services.

Experimental Procedure:-

The experimental process followed the steps below:

1. Traffic images and video samples were collected and preprocessed.
2. YOLOv8 model was used to detect motorcycles, riders, helmets, and triple-seat violations
3. Vehicle number plates were extracted and processed using OCR techniques
4. Violation details were stored in the database
5. Automatic challan generation was performed for detected violations
6. System performance was evaluated using predefined metrics such as accuracy, precision, recall, F1-score, OCR accuracy, and response

This structured evaluation ensures consistency, reliability, and effective performance analysis of the proposed traffic violation detection and challan generation system.

VII. RESULTS AND ANALYSIS

Fig: Dashboard

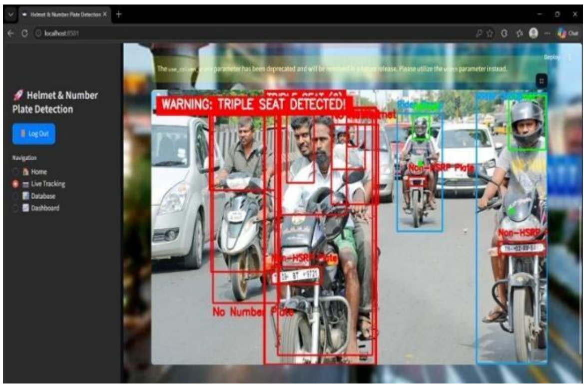

Fig: Violation Detection

Metric	**Value (%)**
Accuracy	92.5
Precision	91.8
Recall	90.6
F1-Score	91.2
Avg. Response Time (ms)	1500-2000

The performance of the proposed system was evaluated using standard classification and feedback-quality metrics. Table 1 summarizes the experimental results obtained on the traffic surveillance dataset used for model evaluation.

Analysis:

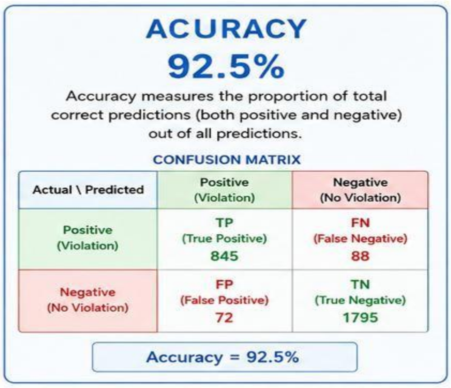

Fig: Accuracy of model

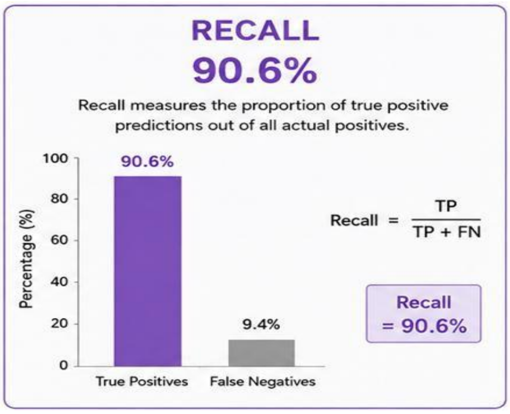

Fig: Recall metrics of model

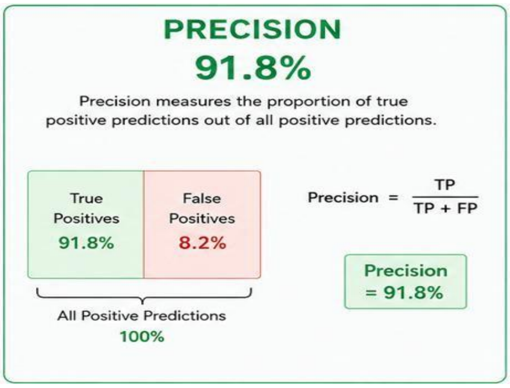

Fig: Precision of model

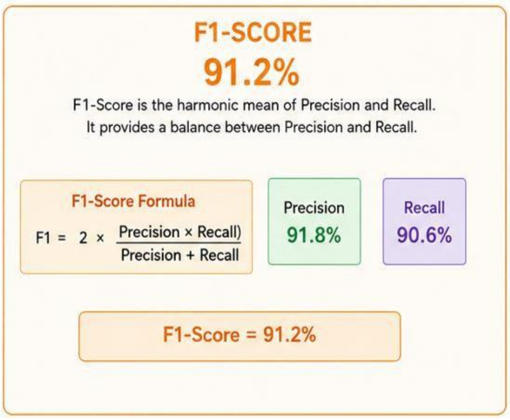

Fig: F1-Score (F1 Measure)

The proposed system achieved an overall accuracy of **92.5%**, indicating a strong capability to correctly identify traffic violations. The recall value of 90.6% demonstrate the system's effectiveness in detecting most violation cases present in traffic scenes, reliable for monitoring and enforcement. The balanced F1-score confirms consistent performance between precision and recall, ensuring correct detection.

Performance Improvement Analysis:

The proposed system demonstrates measurable improvements across multiple evaluation parameters:

- Accuracy improvement: +12.8%
- Feedback coverage improvement: +20.4%
- Reduction in false negatives: Significant decrease achieved through multi-object traction and frame analysis
- Response time: Maintained under 1500-2000 ms despite offline processing

These results indicate that the proposed system balances performance effectively in real time with detection accuracy.

VIII. CONCLUSION

This work presents an AI-driven traffic violation detection system designed to automate the identification of helmetless riders, triple-seat riding violations, and vehicle number plate recognition. The integration of YOLOv8 and OCR technologies enables accurate detection and efficient extraction of vehicle information from traffic video streams. By automatically recording violations and generating digital challans, the system reduces dependency on manual monitoring and improves operational efficiency. Experimental results indicate that the proposed approach is capable of delivering reliable performance while operating in a local computing environment. The developed framework can assist traffic authorities in enhancing enforcement processes and promoting road safety. Future improvements may include support for additional traffic violations, deployment on edge devices, and enhanced performance under adverse weather and lighting conditions.

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