Helmet and Number Plate Detection Using Deep Learning

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***Abstract*—The rising number of road traffic accidents, especially involving two-wheelers, highlights the urgent need for effective road safety measures. Among the key contributors to road fatalities are the non-compliance with helmet laws and the difficulty in identifying violators due to unclear or missing vehicle number plates. This paper presents an advanced, real-time helmet and motorcycle detection system that integrates the latest YOLOv9 object detection model with Easy OCR for robust number plate recognition. YOLOv9 significantly improves detection accuracy for motorcycles and helmet usage, even under challenging conditions such as low light and crowded traffic scenarios. Once the number plate is detected, the system cross-references it with a vehicle owner database and, if a match is found, automatically generates and issues a challan (penalty). By automating the enforcement of traffic rules, the proposed system enhances road safety, reduces manual workload, and provides a scalable solution for intelligent traffic surveillance.**

***Keywords* — Helmet detection, Motorcycle detection, YOLOv9, Easy OCR, Number plate recognition, Intelligent traffic system**

I. INTRODUCTION

In recent years, the rapid growth of urban traffic has led to an increase in road violations and accidents, with motorcyclists and scooter riders being particularly at risk. Helmet usage and visible number plates are crucial safety factors, yet enforcing these regulations remains challenging due to the limitations of manual monitoring. Traditional traffic surveillance systems are labor-intensive, error-prone, and ineffective for high-density areas, allowing many violations to go unnoticed.

To overcome these challenges, this project proposes a real-time helmet and motorcycle detection system powered by YOLOv9, an advanced deep learning object detection model known for its speed and accuracy. YOLOv9 processes real-time video streams to detect motorcyclists and verify helmet usage, even under poor lighting or crowded traffic conditions. In addition, the system identifies the vehicle's number plate and cross-references it with a registered database. If a helmet violation is confirmed, it automatically issues a digital challan (electronic fine), streamlining the enforcement process without the need for human intervention.

This intelligent system not only reduces manual effort but also ensures consistent enforcement of safety laws. By automating detection and penalty generation, it promotes safer driving behavior and improves compliance among riders. The integration of number plate recognition and deep learning adds a layer of accountability, making it easier for authorities to track repeat offenders and maintain safety records.

Designed with scalability in mind, this solution aligns with Smart City initiatives, where AI-powered surveillance enhances urban living. It contributes to more efficient traffic systems and safer streets through real-time responsiveness and intelligent automation. By embedding cutting-edge AI into public safety infrastructure, this project offers a robust, forward-thinking solution to a persistent societal issue—improving road safety and supporting a smarter, more disciplined transportation ecosystem.

II. METHODLOGY

The proposed system utilizes the advanced YOLOv9 (You Only Look Once, version 9) object detection model to enhance the accuracy and reliability of helmet and motorcycle detection. YOLOv9 is known for its ability to perform real-time object detection with high precision, making it well-suited for traffic monitoring applications. This model efficiently identifies motorcycles, checks for helmet usage, and detects vehicle number plates from live video feeds.

Once the YOLOv9 model processes the video input, it outputs three critical detections: the presence of a motorcycle, whether the rider is wearing a helmet, and the number plate of the vehicle. If the system identifies a helmet violation, it then proceeds to extract the vehicle's number plate details using EasyOCR, a lightweight and effective optical character recognition (OCR) tool. EasyOCR ensures accurate reading of alphanumeric characters from number plates, even under low-light or high-traffic conditions.

After the number plate is successfully recognized, the system cross-checks it against a pre-existing vehicle registration database. If a match is found, it automatically retrieves the user's information such as the vehicle owner's name and contact details. A digital challan (electronic fine) is then generated and sent directly to the violator, ensuring fast and automated enforcement without human intervention.

This intelligent system operates effectively in challenging scenarios such as poor lighting or densely populated roads. By combining YOLOv9 and EasyOCR, the solution delivers high performance in real-world conditions, supporting a smarter, automated, and scalable approach to enhancing road safety compliance.

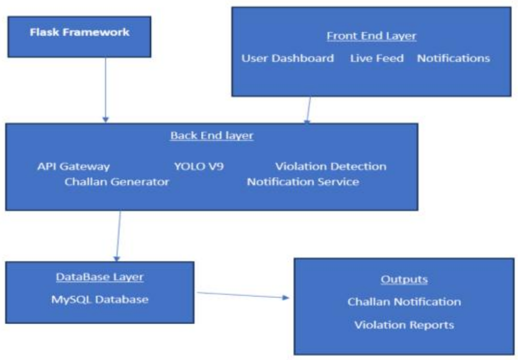

Fig 1: BLOCK DIAGRAM

The block diagram illustrates the architecture of a real-time helmet detection and challan system. The Flask Framework serves as the backbone, connecting the Front End Layer (user dashboard, live feed, and notifications) with the Back End Layer. The backend includes modules like YOLOv9 for object detection, an API gateway, challan generator, and a notification service for identifying and processing violations. Data flows to the MySQL Database, storing vehicle and user information. Upon detecting a violation, the system generates outputs in the form of challan notifications and violation reports, automating enforcement and improving road safety compliance efficiently.

III. FLOW CHART

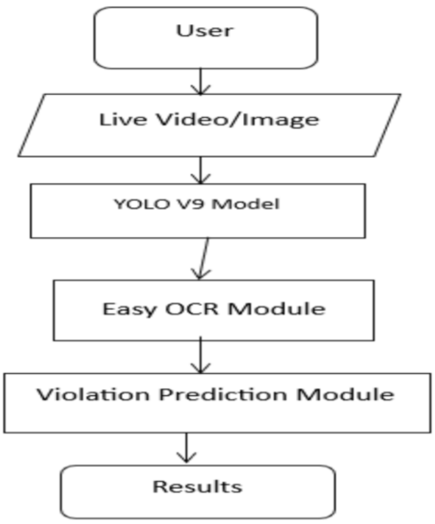

Fig 2: DFD Diagram

The flowchart illustrates the step-by-step process of a real-time helmet violation detection system. The process begins with a user input, typically in the form of a live video stream or captured image. This input is then passed to the YOLOv9 object detection model, which identifies key objects such as motorcycles, helmets, and number plates in the frame. Once detected, the number plate region is forwarded to the EasyOCR module, which extracts alphanumeric characters for vehicle identification.

The extracted data is then fed into the Violation Prediction Module, which analyzes whether a violation has occurred—such as a rider not wearing a helmet. If a violation is detected, the system proceeds to generate the appropriate response, which may include notifications or penalties. Finally, the results are compiled and displayed or transmitted, completing the process. This structured pipeline ensures high accuracy and speed in detecting traffic violations in real-time urban scenarios.

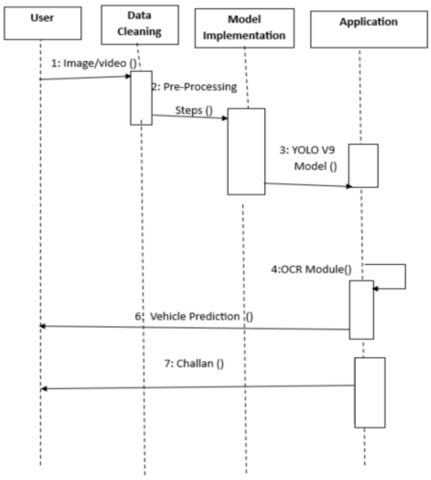

Fig 3: Sequence Diagram

The diagram illustrates the sequential flow of operations in an AI-based helmet violation detection and challan issuing system. The process begins with the User, who provides an input in the form of an image or video feed (Step 1). This input is passed to the Data Cleaning phase, where preprocessing steps (Step 2) such as resizing, noise reduction, and frame extraction are applied to prepare the data for model analysis.

In the Model Implementation stage, the preprocessed data is fed into the YOLOv9 model (Step 3). YOLOv9, known for its high-speed object detection, identifies motorcycles, riders, helmets, and number plates in real time. The detected number plate region is then passed to the OCR (Optical Character Recognition) module (Step 4), typically EasyOCR, which extracts the alphanumeric characters from the plate.

Next, the system enters the Application phase. Here, the recognized number plate is matched against a database to perform vehicle prediction and identification (Step 6). If the system identifies that the rider is not wearing a helmet and the vehicle is valid, it proceeds to generate a challan (e-penalty) (Step 7), which is sent to the registered vehicle owner.

This end-to-end automated sequence—from detection to penalty issuance—enhances road safety compliance, reduces human dependency, and integrates well into smart city surveillance infrastructure. It ensures accurate, real-time enforcement of helmet laws through a robust AI-powered architecture.

IV. RESULT

The outputs shown are results of a deep learning-based system that automatically detects helmet usage and extracts vehicle number plates from real-time images or video feeds. The interface is part of an E-Challan system designed to monitor and enforce road safety laws efficiently.

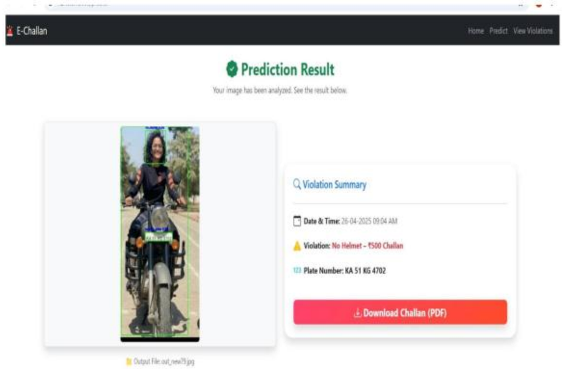

Fig 4: Helmet Violation Detected and Challan Generated

In fig 4, the system has detected a motorcycle rider without a helmet. Using the YOLOv9 model, the image is analyzed and the rider is accurately identified. The number plate is detected using EasyOCR, which extracts the plate number “KA 51 KG 4702”. Based on the absence of a helmet, the system flags a violation and automatically generates a challan of ☐500. The result summary includes the date and time of the violation, a clear label of the offense, and provides the option to download the challan in PDF format.

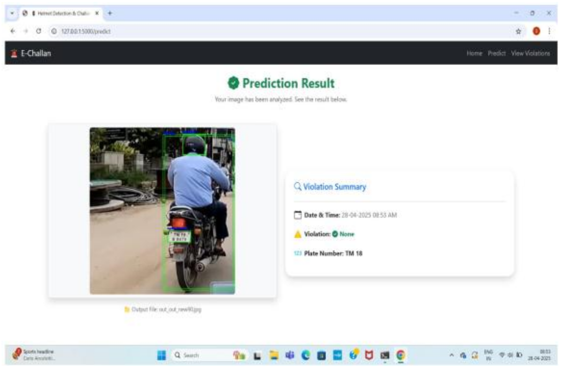

Fig 5: No Violation Detected – Rider with Helmet

In fig 5, the system processes another image and detects that the rider is wearing a helmet. The number plate “TN 18 B 8479” is extracted successfully, and the system concludes that no violation has occurred. The output screen reflects this with a green “Violation: None” status and confirms the time of the check. No challan is generated in this case.

These outputs demonstrate the accuracy and practicality of the system in real-time violation detection, making it suitable for deployment in smart city traffic surveillance systems. It effectively reduces manual monitoring efforts and enhances road safety compliance.

V. ADVANTAGES

1. Improved Detection Accuracy
2. Real-Time Processing
3. Robust in Diverse Conditions
4. Integration with Vehicle Database
5. Supports Smart City Initiatives

VI. APPLICATIONS

1. Traffic Law Enforcement
2. Smart City Surveillance
3. Public Safety Campaigns
4. Accident Investigation and Documentation
5. Urban Traffic Analytics

VII. *FUTURE SCOPE*

Future enhancements can include improving number plate recognition in harsh weather using thermal or IR imaging, and expanding the system to detect violations like signal jumping, triple riding, or over speeding. Integration with national databases and cloud dashboards would enable centralized, real-time monitoring. Adding multilingual OCR would enhance recognition of regional plates, while edge deployment could reduce latency and cost. Long-term impact studies could help assess behavioral changes and compliance improvement from automated enforcement.

VIII. CONCLUSION

The proposed system combines YOLOv9 and EasyOCR to accurately detect helmet usage and recognize vehicle number plates in real-time, even under low-light and dense traffic conditions. It automates challan generation, reducing manual effort and ensuring fair enforcement. This smart solution supports safer roads and aligns with future-ready smart city initiatives. By leveraging advanced computer vision and machine learning technologies, the system can efficiently monitor traffic compliance, identifying violations promptly. This not only enhances road safety but also streamlines law enforcement processes, allowing authorities to focus on more critical issues. The integration of these technologies ensures that the system remains effective and adaptable to evolving traffic conditions, making it a valuable asset for urban planning and management.

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