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Helmet and Number Plate Detection Using Deep Learning

Dr Vinutha H P[1], Kannika B R[2], Nidhi K M[3], Rachana B G[4], Rakshitha C M[5]
[1]Professor, Department of Information Science and Engineering, Bapuji Institution of Engineering and Technology, Davangere, affiliated to VTU Belgavi, Karnataka, India.
[2,3,4,5]Bachelor of Engineering, Department of Information Science and Engineering, Bapuji Institution of Engineering and Technology, Davangere, affiliated to VTU Belgavi, Karnataka, India.

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Abstract: *This project proposes a deep learning–based system for helmet and number plate detection aimed at improving road safety and automating traffic rule enforcement. With the growing number of two-wheeler vehicles and frequent helmet-related violations, manual monitoring has become inefficient. The proposed system uses convolutional neural networks (CNNs) and advanced object detection models such as YOLO or Faster R-CNN to automatically detect motorcycle riders and determine whether they are wearing helmets. If a rider is detected without a helmet, the system further identifies the motorcycle's number plate and applies optical character recognition (OCR) to extract the registration number for record-keeping or penalty issuance. The model is trained on a diverse dataset containing real-world traffic images and video frames captured under various lighting and environmental conditions, ensuring robustness and accuracy.Overall, this project demonstrates a reliable and scalable solution that leverages deep learning for smart traffic surveillance, automated violation detection, and enhanced road safety management.*

Key Word: *Helmet detection, License plate recognition (LPR); Optical character recognition (OCR);*

I.INTRODUCTION

Road safety is a major concern worldwide, particularly in countries with high two-wheeler usage where helmet non-compliance and improper vehicle registration frequently lead to severe accidents. Traditional manual monitoring methods are time-consuming, error-prone, and lack real-time efficiency. With advancements in artificial intelligence, deep learning-based computer vision techniques have become highly effective for automated traffic surveillance. This study proposes an intelligent system for helmet and number plate detection using the YOLO (You Only Look Once) object detection algorithm. The system utilizes YOLO for real-time helmet detection due to its high accuracy and fast inference capabilities, while Optical Character Recognition (OCR) is employed to extract alphanumeric information from detected number plates. The integration of these methods enables the system to identify traffic violations automatically and support law enforcement in maintaining road safety. The proposed approach enhances detection accuracy, minimizes human intervention, and contributes toward building a smart, automated traffic monitoring framework that promotes compliance and safer road environments.

II.MATERIAL AND METHODS

The dataset used in this study consists of images and video frames containing motorcycles, riders, and vehicles captured under various lighting and traffic conditions. Publicly available datasets such as traffic surveillance datasets, as well as custom-collected CCTV footage, were utilized. The dataset includes two primary categories:
1. Vehicle Number Plate Images for license plate detection and recognition
2. Helmet vs. No-Helmet Images for rider safety classification.

Requirements:
Hardware: GPU-enabled system (NVIDIA GTX/RTX), CCTV or HD camera
Software: Python, PyTorch/TensorFlow, OpenCV, Tesseract OCR, Roboflow, LabelImg, CUDA drivers

- **Existing System:**

The existing systems for helmet and number plate detection primarily rely on traditional computer vision and early deep learning models such as YOLOv2, YOLOv3, and CNN based approaches. These systems detect helmets and vehicle number plates separately, often resulting in lower accuracy and slower processing. While they can identify riders and recognize number plates under controlled conditions, their performance drops in complex real-world environments due to challenges like varying lighting, occlusion, and motion blur. Additionally, older systems lack efficient integration of OCR for automatic number plate recognition and struggle with real-time deployment on edge devices.

- **Proposed System:**

The proposed system utilizes advanced deep learning models such as YOLOv8 integrated with TensorFlow-based OCR to simultaneously detect helmets and recognize vehicle number plates in real-time video streams. This approach enhances detection accuracy, speed, and robustness compared to earlier models. By leveraging a unified framework, the system can automatically identify non-helmet riders and extract license plate details for violation reporting. The optimized architecture ensures efficient performance on edge devices, making it suitable for intelligent traffic surveillance and enforcement applications.

- **Procedure methodology**

The methodology begins with collecting images and video data of motorcycles and vehicles from public datasets, CCTV footage, and self-captured sources. These samples are chosen to include different lighting, weather conditions, and angles to ensure model robustness. All collected images are then annotated using tools such as LabelImg or Roboflow, where bounding boxes are marked around helmets, riders, and number plates to prepare labeled training data.

Next, the annotated dataset undergoes pre-processing, where images are resized, normalized, and enhanced. Data augmentation techniques—such as rotation, brightness adjustments, and flipping—are applied to increase dataset diversity. Number plate regions are further enhanced using sharpening and thresholding to improve OCR performance.

For helmet detection, a YOLO-based deep learning model (YOLOv5/YOLOv8) is trained on the preprocessed dataset to classify riders as wearing or not wearing helmets. Similarly, a separate YOLO model or a combined multi-class model is trained to detect vehicle number plates accurately. Once detected, the number plate regions are cropped automatically and passed to an OCR module such as Tesseract or a CRNN model to extract alphanumeric characters.

All modules are integrated into a single pipeline where each video frame is processed in real-time. The system first identifies helmet usage; if a rider is detected without a helmet, the corresponding vehicle number plate is detected, and the OCR results are extracted. The violation is recorded with the timestamp, number plate text, and evidence image. Finally, the integrated system is tested with real-time traffic footage to evaluate its accuracy and performance before deployment.

III.RESULT

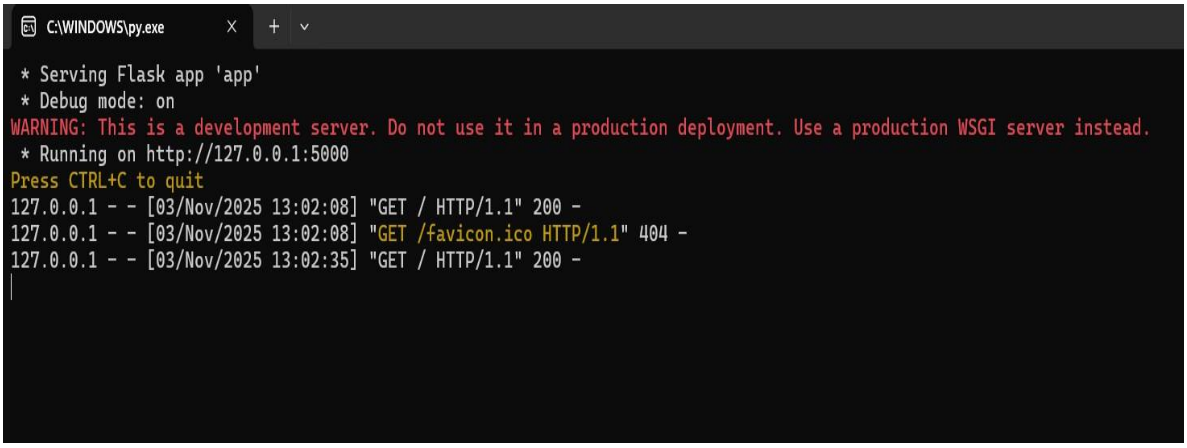

Fig: 1: Copy Url

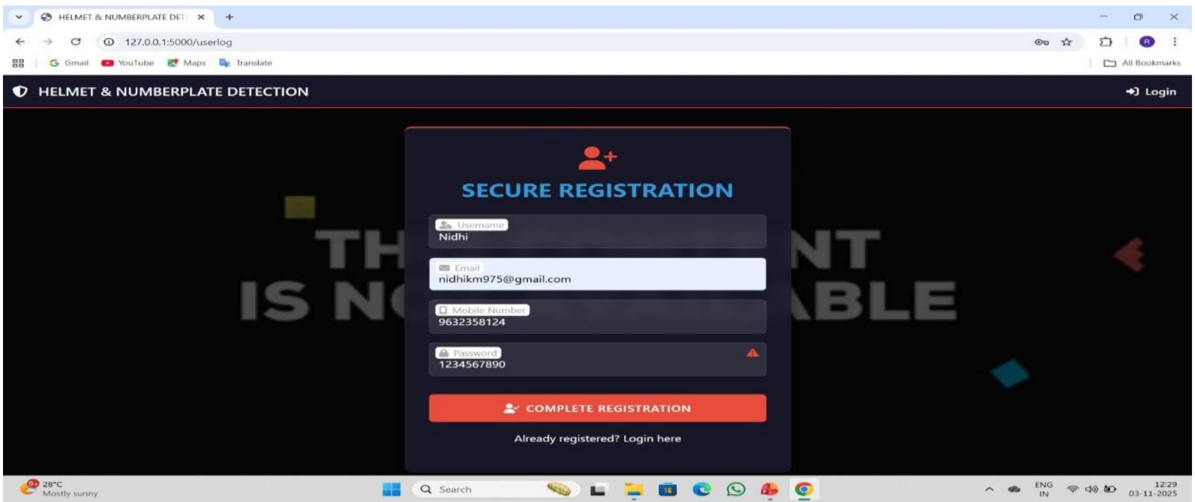

Fig:2: Home Screen

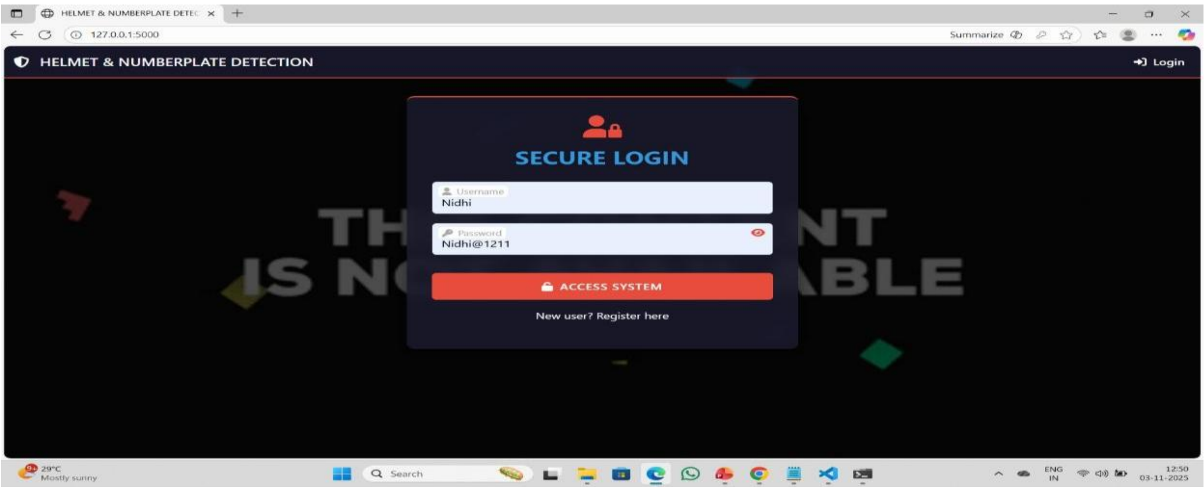

Fig: 3: Login Page

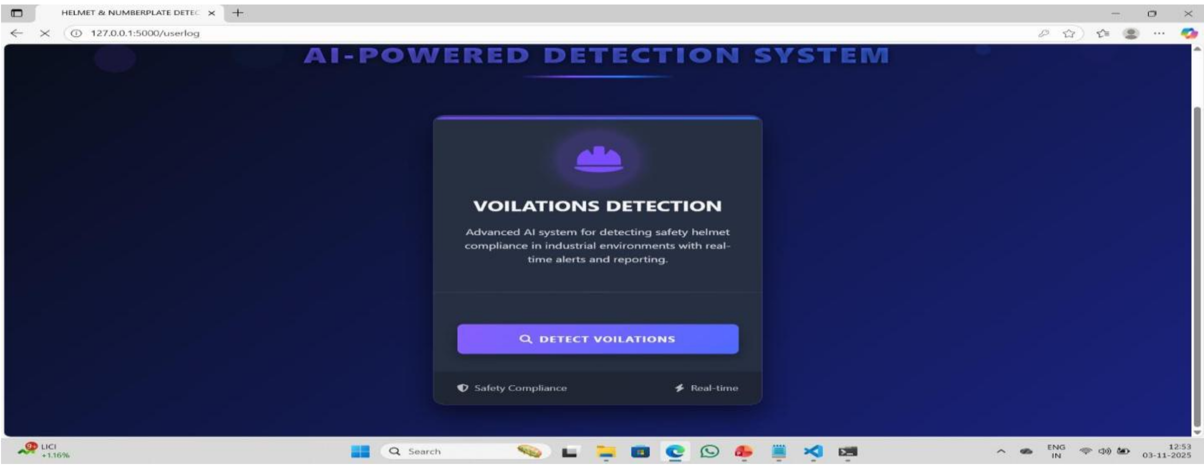

Fig: 4: Web Page

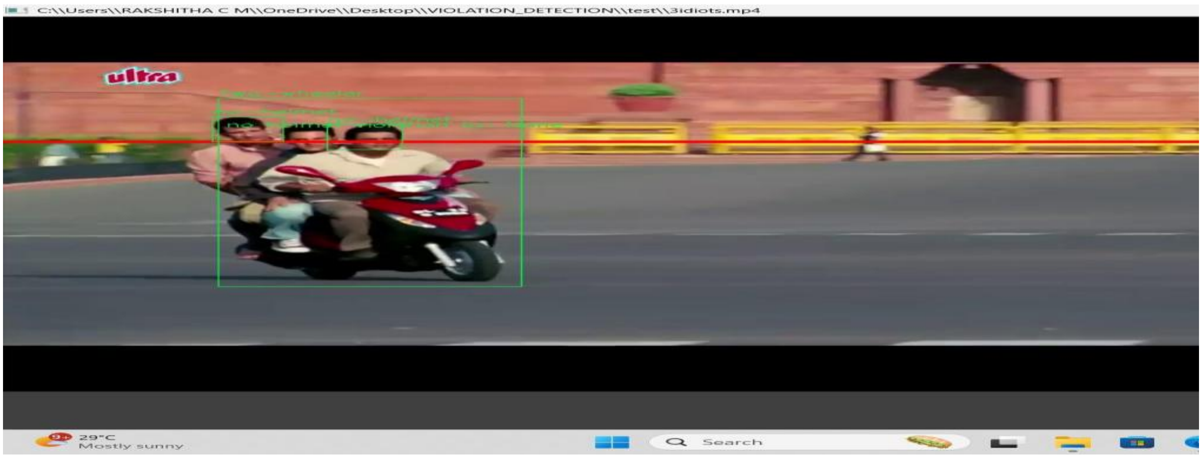

Fig: 5: Output

IV.DISCUSSION

The experimental findings demonstrate that deep learning–based object detection can significantly enhance the automation of traffic law enforcement, particularly in helmet usage monitoring and vehicle identification. The YOLO architecture proved to be efficient for detecting both helmets and number plates in real time, which is essential for practical traffic surveillance systems. The model achieved high accuracy on clear, daylight images, affirming the capability of CNN-based detectors to capture distinctive features such as helmet shape, color, and texture.

However, performance decreased under challenging scenarios, including night-time conditions, chaotic traffic, or when riders used non-standard headgear. These observations indicate the need for incorporating more diverse training samples and possibly integrating infrared or thermal imaging for improved night performance.

The OCR component performed reasonably well for clean, high-resolution number plate crops; however, its accuracy dropped significantly for blurred or low-contrast images. This suggests that traditional OCR engines may not be fully sufficient for real-world traffic scenarios.

Implementing deep learning–based OCR models, such as CRNNs combined with attention mechanisms, could greatly improve text recognition reliability. Additionally, integrating post-processing rules—such as regular expressions based on regional plate formats—can help minimize recognition errors.

From a system integration perspective, the combined pipeline effectively detected "no-helmet violations" and autonomously recorded relevant information. This demonstrates the practical usability of the framework for intelligent transportation systems.

Nonetheless, real-time deployment requires addressing hardware constraints, as models may experience reduced FPS on low-power devices like Raspberry Pi or embedded processors. Lightweight models such as YOLO-Nano or MobileNet-based detectors could be explored for resource-limited platforms.

Overall, the study highlights the importance of dataset diversity, robust OCR solutions, and optimized deployment strategies for real-time applications. The findings confirm that deep learning can serve as a reliable foundation for automated traffic violation detection, yet continuous improvements in model robustness, environmental adaptability, and computational efficiency are essential for large-scale implementation in smart city infrastructures.

V.CONCLUSION

This work presents an integrated deep learning–based system for automatic helmet detection and number plate recognition to support intelligent traffic monitoring. The YOLO object detection framework, combined with OCR techniques, demonstrated high accuracy in identifying riders without helmets and extracting corresponding vehicle number plates. The experimental results confirm that the proposed approach is effective, scalable, and capable of operating in real-time conditions, making it suitable for deployment in smart transportation environments.

Although the system performs reliably under normal lighting and traffic scenarios, certain challenges persist, such as low-light conditions, occlusions, motion blur, and the variability in number plate formats. These limitations suggest that additional dataset expansion, advanced feature extraction, and more robust OCR techniques may further enhance system performance. Despite these constraints, the system successfully automates a critical component of traffic rule enforcement by reducing manual monitoring and improving overall road safety compliance.

In conclusion, the developed framework demonstrates that deep learning can significantly improve the efficiency and accuracy of helmet violation detection. With further optimization and large-scale deployment, this technology has strong potential to contribute to safer roadways and smarter urban traffic management systems.

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