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Smart Gate: Automatic Number Plate Recognition and Helmet Detection for Two Wheelers

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ABSTRACT: The increasing need for effective monitoring of vehicle entry and rider safety highlights the limitations of existing manual systems, which are prone to errors and inefficiencies. To address this, the “Smart Gate: Automatic Number Plate Recognition and Helmet Detection for Two-Wheelers” project leverages advanced technologies for real-time detection and data processing. Utilizing YOLOv5 for vehicle detection and an ALPR (Automatic License Plate Recognition) API for precise number plate recognition, the system captures key information, including helmet status, license plate details, and passenger count. This data is seamlessly stored in an Excel file for analysis and reporting. The use of YOLOv5 ensures high accuracy and reliability in detecting vehicles and rider behaviors, while the ALPR API enhances the precision of license plate identification. This system provides a robust solution for monitoring and enforcing traffic regulations, particularly at gates and entry points, promoting safety and compliance through automated data handling.

KEYWORDS: Number Plate Recognition, Helmet Detection, YOLOv5, Machine Learning, ALPR (Automatic License Plate Recognition) API, OCR (Optical Character Recognition), Email Notification, Real Time Monitoring

I. INTRODUCTION

Motorcycles are a primary mode of transport in developing countries, particularly in India, due to their affordability and convenience. However, the increasing number of motorcycles has also led to a rise in road accidents.

Road accidents continue to be a significant public health concern in India, with a notable increase in fatalities in recent years. In 2023, the country recorded over 4.80 lakh road accidents, resulting in approximately 1.72 lakh deaths—a 2.6% [1] rise from the previous year. Notably, two-wheeler riders, particularly those without helmets, accounted for a substantial portion of these fatalities. For instance, in Uttar Pradesh, 10,000 fatalities involved pedestrians and two-wheeler users, with 8,726 deaths attributed to over-speeding [1].

According to the India Status Report on Road Safety 2024, two-wheeler riders account for a significant share of road accident fatalities. A substantial portion of these fatalities is attributed to the absence of helmets. In approximately 50,000 out of 75,000 deaths involving two-wheelers, the victims were not wearing helmets [2]. The rising number of such accidents emphasizes the need for stricter enforcement of helmet laws and the adoption of AI-based surveillance to ensure compliance [3].

The state of Odisha also witnessed a concerning trend, with road accident deaths increasing by 7% in 2024 compared to 2023 [4]. The total number of fatalities rose from 5,739 in 2023 to 6,142 in 2024, underscoring the persistent challenges in road safety [4].

These statistics highlight the urgent need for enhanced road safety measures, stricter enforcement of traffic laws, and increased public awareness to mitigate the rising number of road accident fatalities in India.

Manual enforcement alone is insufficient given the growing number of vehicles, traffic congestion, and poor signal management in India. Many violations go unnoticed, increasing the risk of severe accidents. To address this issue, major cities have implemented CCTV-based surveillance, but these systems still require human intervention. Therefore, there is a need for AI-based automated systems to efficiently detect helmet violations and enhance road safety enforcement [5].

To address the limitations of manual monitoring and traditional CCTV-based surveillance, this research proposes an AI-powered system for automatic helmet detection and number plate recognition, enhancing road safety and law enforcement. The proposed system, Smart Gate, leverages YOLOv5 for real-time vehicle and helmet detection, while an ALPR API ensures accurate license plate recognition. This system efficiently captures and records key details such as helmet status, vehicle information, and passenger count, which are then systematically stored in an Excel file for further analysis and reporting. By automating the monitoring process, the system minimizes human intervention, reduces errors, and ensures effective enforcement of helmet laws. This contributes to improved traffic regulation compliance and promotes rider safety, particularly at entry points where manual inspection is challenging.

The proposed system aims to develop an automated solution for vehicle number plate recognition and helmet detection for two-wheelers, adhering to Indian standards. The system is designed to detect helmet usage and the number of passengers while ensuring compliance with traffic regulations. If a violation, such as the absence of a helmet, is detected, a warning is logged in a secure data record. This system is particularly beneficial for smart gate applications in college campuses and secured facilities, enhancing security and regulatory enforcement. The integration of YOLOv5 for object detection and Optical Character Recognition (OCR) for number plate extraction ensures high accuracy in identifying riders and their compliance with safety regulations.

The system operates through multiple key functionalities, including real-time monitoring of live video feeds, storing detected violations in an Excel database, and triggering automated email notifications to the relevant authorities for penalty enforcement. A login module is implemented to ensure restricted access, while an intuitive interface allows users to upload and analyze images or videos. The use of YOLOv5 enables the precise detection of helmets and passengers, while OCR facilitates the extraction of license plate numbers. By ensuring data security and accessibility, the system provides a reliable mechanism for monitoring and enforcing helmet compliance in restricted areas.

The paper is structured in the following manner: the initial section introduces the research, second section consist of literature the subsequent section outlines the methods utilized in the study and the dataset employed to derive the findings, the fourth section presents the proposed techniques, the fifth section represents system architecture ,sixth section is result and discusses their implications, seventh section is future scope and lastly, the conclusion is presented in the final section of the paper.

II. LITERATURE REVIEW

Ravi Kiran Varma Pa et al. [6] conducted a study on Automatic Number Plate Recognition (ANPR) for Indian number plates, addressing challenges like non-standard formats, varying illumination, and angular distortions. Existing ANPR systems primarily operate in controlled environments with standardized fonts and optimal lighting, making them unsuitable for Indian conditions. The study proposed an image processing-based approach incorporating morphological transformations, Gaussian smoothing, and Gaussian thresholding for preprocessing. Contour-based segmentation using border following and spatial filtering was applied to extract characters, followed by character recognition using the K-Nearest Neighbor (KNN) algorithm. The method demonstrated promising results in handling noisy, low-illuminated, and skewed number plates, making it a viable solution for real-world ANPR applications in India.

Sachin Prabhu B et al. [7] compared Open ALPR, KNN, and CNN for Indian license plate recognition in still images and live-stream videos. Their study found CNN to be the most accurate and adaptable, outperforming k-NN in character recognition. While k-NN required additional training for diverse fonts, CNN handled non-standardized plates effectively but was slower due to the sliding window approach. GPU acceleration improved its performance, making it suitable for Full HD CCTV footage and real-time applications.

Apoorva Saumya et al. [8] developed a machine learning based surveillance system for detecting bike riders without helmets and triple riding. The system processes traffic video footage using the YOLOv3 model for real-time rider detection. It identifies individuals riding without helmets and employs the vertical projection of a binary image to count the number of riders, flagging cases where more than two are present. The study highlights the effectiveness of YOLOv3 in traffic monitoring and enforcement.

Amirgaliyev Beibut et al. [9] reviewed various number plate recognition algorithms and proposed their own method. Their system effectively detects plates under varying distances and weather conditions, with improved performance in fixed-distance scenarios. The study highlights the need for enhanced segmentation and additional training data. Future improvements include integrating Artificial Neural Networks and Markov Chains for optical character recognition, along with a dedicated database and user interface for vehicle identification.

Yuan Jing et al. [10] developed an FPGA-based OCR system for license plate recognition using a feedforward neural network with an optimized hyperbolic tangent activation function. The system demonstrated 98.2% accuracy in recognizing characters from noisy and imperfect license plate images. Yogiraj Kulkarni et al. [11] proposed a system for detecting motorcyclists without helmets and recognizing their license plates from CCTV footage. The system employs background subtraction, object classification, and CNN-based helmet detection using transfer learning, achieving 98.72% accuracy. Identified number plates are stored for further action by authorities.

III. METHODS

A. Data Set

We created a diverse, well-annotated dataset featuring individuals with and without helmets, captured in varied lighting, angles, and environments. It includes real-world and controlled scenes, with labeled helmet types, number plates, and vehicles. This dataset supports accurate training for helmet detection, number plate recognition, and violation identification.

B. Data Visualization

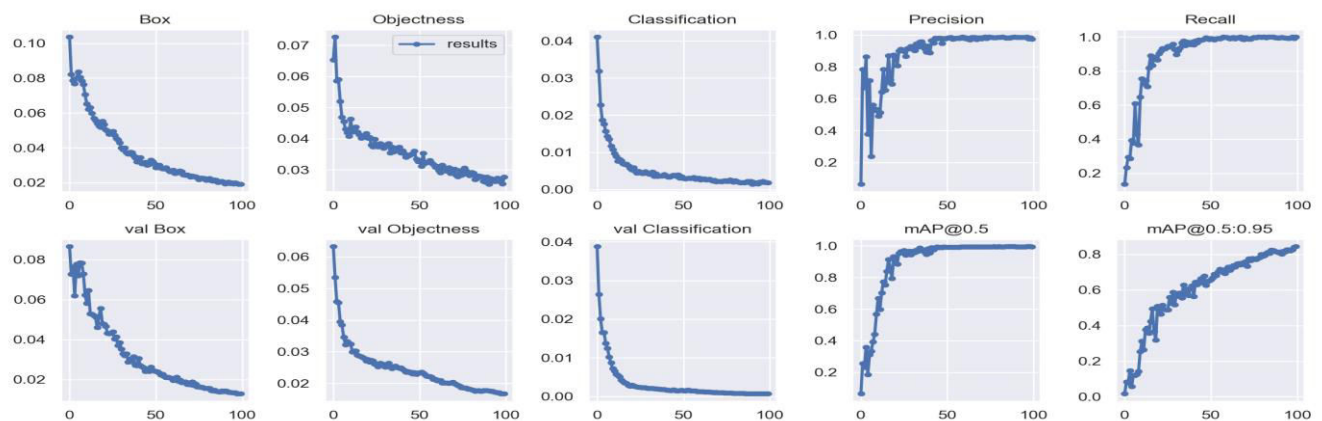


Fig. 1. Training and validation performance metrics of the YOLOv5 model over multiple epochs. The plots show the reduction in losses, improvements in precision and recall, and increasing mAP values, indicating model convergence.

Fig. 1 illustrates the training and validation performance of the YOLOv5 object detection model over multiple epochs. The ten subplots are organized as follows: the top row represents training metrics, while the bottom row represents validation metrics. Each plot provides insights into different aspects of the model's learning process. Overall, the declining losses and increasing precision, recall, and mAP values demonstrate that the YOLOv5 model is learning effectively, improving both detection accuracy and generalization.

IV. PROPOSED TECHNIQUE

• YOLOv5

YOLOv5, developed by Ultralytics, is a deep learning-based object detection model known for its efficiency and accuracy. Its architecture consists of three primary components: the backbone, neck, and head. The backbone, a modified CSPDarknet53, extracts essential features from input images while incorporating Cross Stage Partial (CSP) networks to enhance gradient flow and reduce computational complexity [12]. The neck, based on a Path Aggregation Network (PANet), facilitates multi-scale object detection by improving feature map fusion [13]. The detection head processes final predictions, ensuring precise bounding box localization and class probability estimation [14].

Several key enhancements contribute to YOLOv5's high performance. The model employs the Leaky ReLU activation function to mitigate the vanishing gradient problem and accelerate training [15]. A combination of optimized loss functions is used to balance bounding box regression, objectness scores, and classification accuracy [16]. Additionally, advanced data augmentation techniques, such as mosaic augmentation, enhance generalization by exposing the model to diverse image compositions during training [17].

YOLOv5 achieves superior accuracy and real-time inference, making it ideal for various applications, including autonomous driving, surveillance, and robotics. In self-driving cars, it facilitates pedestrian, vehicle, and obstacle detection [18]. Surveillance systems leverage YOLOv5 for real-time threat detection and security monitoring [19], while robotics applications benefit from its capabilities in object recognition and environmental perception [20]. These optimizations and applications demonstrate YOLOv5's adaptability and effectiveness in real-world scenarios.

• Optical Character Recognition

Optical Character Recognition (OCR) models extract text from images using deep learning techniques. They consist of three key stages: preprocessing, text detection, and text recognition. Preprocessing enhances image quality through noise reduction and binarization [21]. Text detection identifies text regions using object detection models like SSD or R-CNN [22].

• Automatic License Plate Recognition

An Automatic License Plate Recognition (ALPR) API processes images or videos to detect and extract vehicle license plate numbers using machine learning (ML) and optical character recognition (OCR) for high accuracy. These APIs offer key features such as real-time processing, enabling instant detection from live video feeds or images, and multi-regional support, allowing recognition of various plate formats across different regions. Deep learning models enhance accuracy under challenging conditions like poor lighting, adverse weather, and different viewing angles. Additionally, ALPR APIs provide easy integration through RESTful services and can extract vehicle metadata, including type, color, and model.

V. SYSTEM ARCHITECTURE

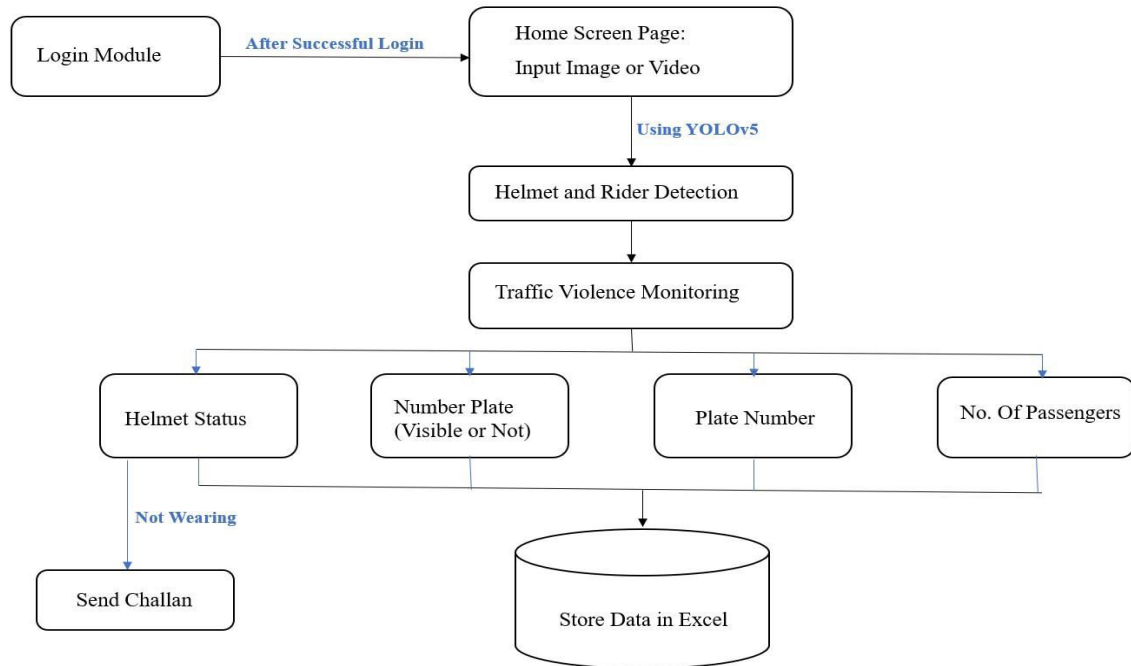


Fig. 3. Block Diagram of Model

The figure 3 represents the system architecture of the Smart Gate: Automatic Number Plate Recognition and Helmet Detection for Two-Wheelers, which automates helmet compliance and traffic violation monitoring using deep learning. The process begins with a Login Module, ensuring that only authorized users can access the system. After login, users can upload an image or video on the Home Screen Page for analysis.

The system employs YOLOv5, a deep learning-based object detection model, to identify riders and determine helmet usage. Simultaneously, Optical Character Recognition (OCR) and Automatic License Plate Recognition (ALPR) are used to detect and extract vehicle number plates.

Following detection, the system performs Traffic Violation Monitoring, analyzing key parameters such as Helmet Status, Number Plate Visibility, Plate Number, and Number of Passengers. If a violation, such as riding without a helmet, is detected, the system automatically generates a challan (fine notice). This challan is then sent via email to the violator for enforcement. Additionally, all extracted data is securely stored in an Excel database for future reference and monitoring.

VI. RESULT AND DISCUSSION

A. Graphical User Interface

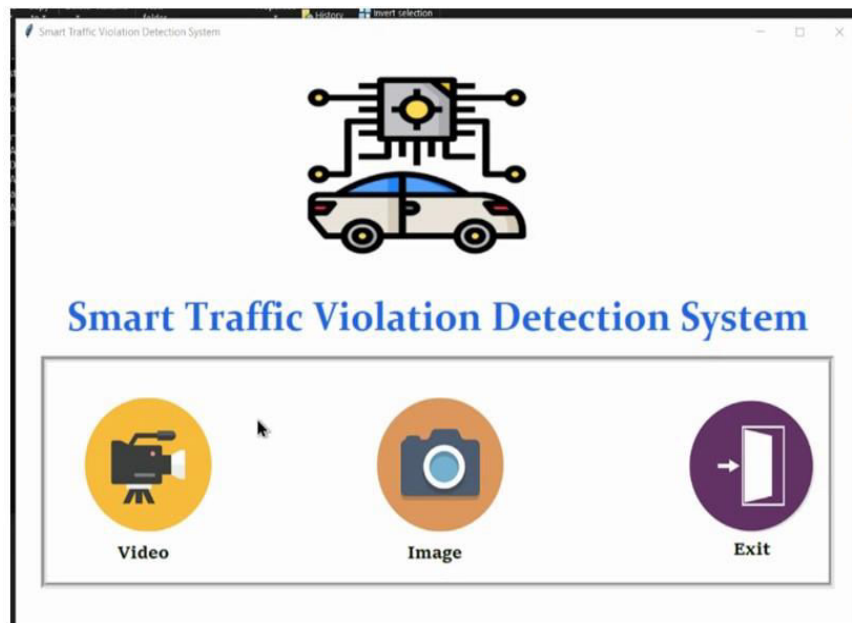


Fig. 4. Smart Traffic Violation Detection System Interactive Interface.

This graphical user interface (GUI) represents a Smart Traffic Violation Detection System designed for automated traffic monitoring. It provides three main options: Video, which processes traffic violations from recorded footage; Image, which detects violations from a single image; and Exit, which closes the application. The interface is designed to be simple and user-friendly, ensuring efficient detection and analysis of traffic violations.



Fig. 5. Detection of helmet violations and number plates using YOLO-based model.

Figure 5 illustrates the helmet detection and number plate recognition system in action. The system accurately detects riders and classifies helmet usage with confidence scores. It also identifies and extracts license plate information.

Subfigures (a) and (b) show compliant riders wearing helmets, while (c) and (d) highlight cases of non-compliance. The model efficiently differentiates between helmeted and non-helmeted riders while ensuring accurate number plate recognition.

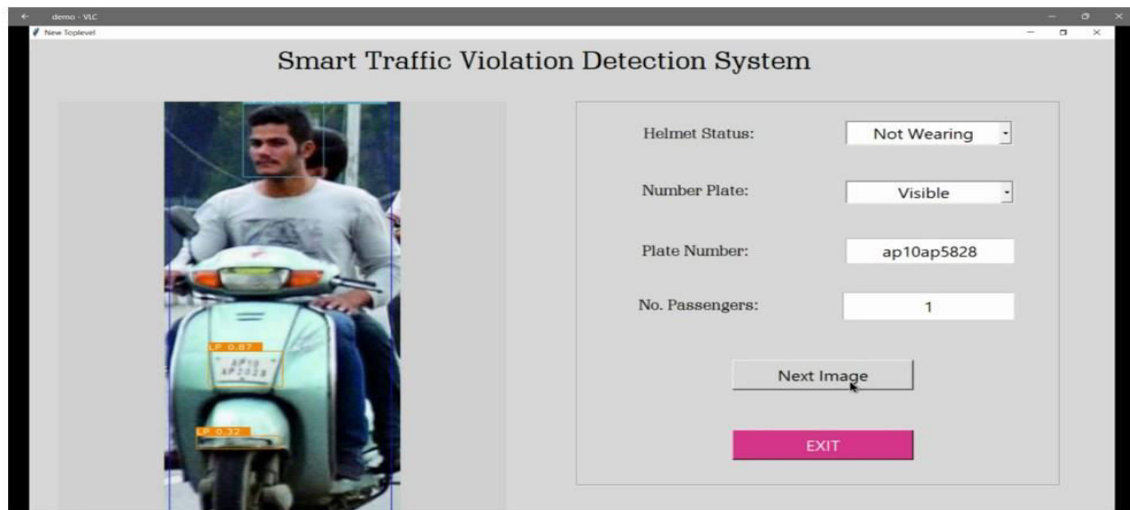


Fig. 6. Smart traffic violation detection system GUI. Source:

Figure 6 real-time detection and classification of traffic violations. The system automatically identifies whether a rider is wearing a helmet, extracts the vehicle's number plate, and determines the number of passengers. As shown in the interface, the detected rider is classified as "Not Wearing" a helmet, and the number plate is successfully recognized as "AP10AP5828." The system provides options for navigating through images, facilitating efficient monitoring and analysis of traffic violations.

VII. CONCLUSION

This study successfully integrates advanced technologies such as YOLOv5 and OCR to enhance traffic monitoring and safety enforcement. The system effectively detects helmet usage, identifies license plates, and monitors passenger counts, ensuring comprehensive data collection for traffic regulation and rider safety compliance. By storing detected data for further analysis, it facilitates actionable insights into vehicle entry patterns and safety practices. The high accuracy of YOLOv5 in vehicle detection, combined with precise OCR based license plate recognition, underscores the system's effectiveness and reliability. These advancements contribute significantly to automating traffic safety measures at entry points, promoting safer road practices, and aligning with the broader objectives of intelligent transportation systems and smart city initiatives.

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