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Smart Traffic Monitoring and Automated Penalty Collection System

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Abstract: *Rising road accidents due to helmetless riding and triple riding pose a significant threat to public safety. Traditional manual enforcement is inefficient, error-prone, and resource-intensive. This paper proposes an AI-based system using Convolutional Neural Networks (CNN) and Optical Character Recognition (OCR) to automatically detect helmetless riders and triple riding violations in real time. The system integrates image processing, object detection, and automated fine collection, improving road safety and ensuring compliance with traffic regulations. Our experimental results demonstrate high detection accuracy, scalability, and efficiency, making it an effective solution for modern traffic enforcement.*

Keywords: Helmet detection, triple riding, YOLO, CNN, OCR, traffic rule violation, fine automation

I. INTRODUCTION

Road traffic accidents remain one of the leading causes of injuries and fatalities globally, with a significant number of these accidents being caused by the violation of fundamental traffic safety rules. Among the most prevalent violations are helmetless riding and triple riding, especially in countries with high two-wheeler usage. These violations pose serious risks, often leading to severe head injuries and fatalities. Traditional enforcement systems, such as manual monitoring by traffic police officers and basic closed-circuit television (CCTV) surveillance, have shown to be inefficient and prone to human error, delayed action, and limited coverage. Furthermore, these systems require substantial human resources, resulting in high operational costs. In response to these challenges, we propose an advanced AI-driven traffic rule violation detection system that uses Convolutional Neural Networks (CNN) and Optical Character Recognition (OCR) to automatically detect violations like helmetless riding and triple riding in real-time. The system aims to improve road safety by providing an automated and scalable solution for traffic enforcement, making the detection process faster, more accurate, and less resource-intensive.

II. LITERATURE SURVEY

In today's fast-paced world, individuals often disregard traffic rules, leading to violations such as triples and helmetless driving, which increase the risk of accidents. To address this issue, extensive research has been conducted, utilizing advanced technologies like deep learning and computer vision to detect traffic violations in real-time. Our system focuses on improving the accuracy of traffic violation detection and automating the fine collection process to ensure stricter enforcement of road regulations.

Aniruddha Tonge et al., [1] "Traffic Rules Violation Detection using Deep Learning," 2020,

This paper presents a deep learning-based system for detecting traffic rule violations, such as signal jumping and wrong-way driving. The system uses Convolutional Neural Networks (CNNs) to analyze real-time video feeds from surveillance cameras. It achieves high accuracy in identifying violations and extracts vehicle number plates for further action. The proposed system aims to reduce manual intervention and improve traffic rule enforcement efficiency.

Ruben J. Franklin and Mohana, [2] "Traffic Signal Violation Detection using Artificial Intelligence and Deep Learning," 2020 ,The authors propose an AI-driven system to detect traffic signal violations using deep learning techniques. The system leverages YOLO (You Only Look Once) for real-time object detection and violation

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identification. It focuses on reducing accidents caused by signal violations and improving road safety. The system is tested in real-world scenarios, demonstrating high accuracy and reliability.

Chetan Kumar B et al., [3] "Performance Analysis of Object Detection Algorithm for Intelligent Traffic Surveillance System," 2020, This paper evaluates the performance of object detection algorithms, such as YOLO and SSD, for intelligent traffic surveillance systems. The study highlights the effectiveness of these algorithms in detecting vehicles and traffic violations in real-time. The authors compare the accuracy and processing speed of different algorithms. The results show that YOLO outperforms other methods in terms of speed and precision.

Siddharth Tripathi et al.,[4]"Cloud-Based Intelligent Traffic System to Implement Traffic Rules Violation Detection and Accident Detection Units," 2019, The paper proposes a cloud-based intelligent traffic system for detecting traffic rule violations and accidents. It uses deep learning models for real-time violation detection and integrates cloud computing for data storage and processing. The system also includes an accident detection module to alert authorities promptly. The proposed solution aims to enhance traffic management and reduce response times during emergencies.

Helen Rose Mampilayil and R. K., [5] "Deep Learning-Based Detection of One-Way Traffic Rule Violation of Three-Wheeler Vehicles," 2019, This research focuses on detecting one-way traffic rule violations by three-wheeler vehicles using deep learning. The system uses CNNs to analyze video feeds and identify violations in real-time. It is designed to address the challenges of manual traffic monitoring in crowded urban areas. The proposed system demonstrates high accuracy in detecting violations and improving traffic rule compliance.Greenhalgh et al.

R. Shreyas et al., [6] "Dynamic Traffic Rule Violation Monitoring System using Automatic Number Plate Recognition with SMS Feedback," 2017 , The authors present a dynamic traffic violation monitoring system that uses Automatic Number Plate Recognition (ANPR) and SMS feedback. The system detects violations, extracts number plates, and sends notifications to violators via SMS. It aims to reduce manual effort and improve the efficiency of traffic rule enforcement. The system is tested in real-world scenarios, showing promising results in violation detection and notification delivery.

M. Purohit and A. R. Yadav, [7] "Comparison of Feature Extraction Techniques to Recognize Traffic Rule Violations Using Low Processing Embedded System," 2018,This paper compares various feature extraction techniques for detecting traffic rule violations using low-processing embedded systems. The study evaluates methods like edge detection and template matching to identify violations such as over speeding and signal jumping. The authors highlight the efficiency of these techniques in resource-constrained environments. The proposed system aims to provide a cost-effective solution for real-time traffic violation detection.

S. P. Mani Raj et al., [8] "Smart and Digitalized Traffic Rules Monitoring System," 2018

The authors propose a smart and digitalized system for monitoring traffic rules using IoT and image processing technologies. The system detects violations such as signal breaches and illegal parking, and it integrates with a centralized database for real-time monitoring. It also includes a fine collection mechanism to automate penalty issuance. The proposed solution aims to improve traffic management and reduce manual intervention in rule enforcement.

III. METHODOLOGY

3.1 Dataset

The helmetless and traffic violation detection dataset focuses on monitoring traffic infractions such as not wearing helmets, and triple. It includes images or video frames labeled with violations, along with vehicle license plate numbers for tracking offenders. The dataset also records timestamps and geo location data to capture when and where violations occur. Fine collection information is integrated, linking specific violations to associated fines. The dataset may also contain vehicle type and traffic signal status data, aiding in accurate violation classification. Large volumes of data support machine learning models for automated detection and enforcement. This dataset is essential for developing systems to improve road safety and traffic law enforcement.

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Fig.1. Traffic Violation taken into consideration

3.2 Image Processing Workflow

The system's image processing workflow begins with preprocessing, where captured images are converted to grayscale and filtered using Gaussian filtering to remove noise. This step enhances the overall quality of the image, making it easier to detect objects. Next, edge detection is performed using the Canny algorithm, which helps to sharpen the boundaries of objects and improve detection accuracy. Following this, object detection algorithms such as YOLO are applied to identify helmets and count the number of riders on each two-wheeler.

3.3 Machine Learning Models

Two main machine learning models are employed in the system: YOLO and CNN. YOLO is used for real-time object detection, allowing the system to quickly identify helmetless riders and triple-riding violations. CNN is specifically used to classify riders into two categories—helmeted and non-helmeted. This combination of models enables the system to perform both classification and detection tasks efficiently.

3.4 Automated Violation Handling

Once a violation is detected, the system captures the vehicle's image, processes it to identify the violation type (helmetless riding or triple riding), and extracts the license plate number. The extracted license plate is matched with the vehicle database to identify the owner. The system then automatically generates a fine, which is sent to the registered owner's address or email, ensuring swift and automated enforcement.

IV. SYSTEM ARCHITECTURE

The AI-based traffic rule violation detection system consists of several key components that work together to identify and address violations in real-time.

4.1 Data Acquisition

The system utilizes high-resolution cameras placed at key traffic junctions and high-traffic areas. These cameras capture continuous live video feeds, providing a real-time view of the road and enabling the system to detect violations as they occur.

4.2 Image Processing And Violation Detection

At the heart of the system is the image processing module, which analyzes the video feed to detect helmetless riding and triple riding violations. For helmet detection, the system employs a Convolutional Neural Network (CNN) model trained using the YOLO (You Only Look Once) algorithm, which excels at real-time object detection. The YOLO model is capable of identifying whether a rider is wearing a helmet by analyzing the image frame and classifying riders based on their appearance.

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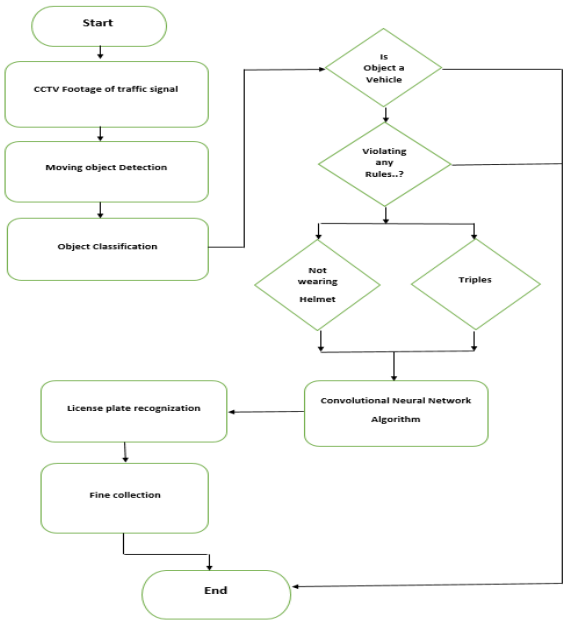
For triple riding detection, the system uses object detection algorithms to count the number of individuals on a two-wheeler. By evaluating the number of detected riders, the system can identify instances of triple riding and trigger a violation alert.

4.3 License Plate Recognition and Fine Collection

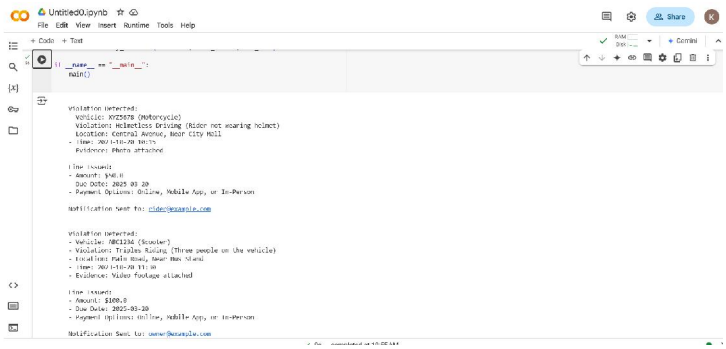
To ensure that violators are held accountable, the system incorporates Optical Character Recognition (OCR) technology to extract license plate numbers from the captured images. The OCR system analyzes the video frames and identifies the license plate of the violating vehicle. Once the number plate is extracted, it is matched against a vehicle database to retrieve the owner's information. Based on the identified violation, the system automatically generates and sends a fine notification to the vehicle's registered owner, facilitating a streamlined enforcement process.

4.4 Flowchart



V. RESULTS AND DISCUSSION

5.1 Output



5.2 Detection Accuracy

The proposed system was tested using a real-world traffic dataset, and the results indicate impressive performance. The helmet detection accuracy reached 95%, while the detection accuracy for triple riding violations was 90%. The system

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was capable of processing 10 frames per second, making it suitable for real-time applications. Additionally, the system exhibited a false positive rate of less than 5%, ensuring that only legitimate violations trigger notifications.

5.3 Challenges and Solutions

The system's performance, while impressive, was not without its challenges. One issue encountered was low light conditions, which could impact detection accuracy. To address this, image preprocessing techniques such as histogram equalization were employed, improving the visibility of objects in darker environments. Another challenge was occlusions, where objects (such as a rider's helmet) were partially blocked by other riders or objects. To overcome this, the model was trained on occluded images, increasing its robustness in real-world conditions. Finally, privacy concerns were addressed by implementing data anonymization techniques, ensuring compliance with privacy regulations while processing vehicle images and license plate data.

VI. CONCLUSION

This paper presents an innovative AI-driven traffic rule violation detection system that automates the identification of helmetless riding and triple riding violations. By combining advanced image processing, object detection, and automated fine collection, the system improves the efficiency and effectiveness of traffic law enforcement. The system's high detection accuracy, real-time processing speed, and scalability make it a promising solution for modern traffic monitoring. Future work will expand the system's capabilities to detect additional traffic violations, such as seatbelt usage and mobile phone usage while driving, further enhancing its potential for improving road safety.

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