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## Deep Learning-Based Real-Time Detection of Helmet Non-Compliance and Triple Riding Violations in Traffic Surveillance Systems

MEDIMUDI LOKESH NADIU

PG Scholar. Department of MCA, DNR College, Bhimavaram, Andhra Pradesh

**A. Durga Devi**

(Assistant Professor), Master of Computer Applications, DNR College, Bhimavaram, Andhra Pradesh

### ABSTRACT

The rapid growth of urbanization and motor vehicle usage has led to an increase in traffic violations, particularly in developing countries where enforcement mechanisms are often limited. Among these violations, helmet non-compliance and triple riding on two-wheelers are significant contributors to road accidents and fatalities. Traditional traffic monitoring systems rely heavily on manual supervision, which is prone to inefficiencies, human error, and scalability challenges. To address these limitations, this research proposes a deep learning-based automated traffic violation detection system capable of identifying helmet violations and triple riding in real time. The proposed system leverages the YOLOv8 (You Only Look Once version 8) object detection framework to detect persons, motorcycles, and helmets from video streams. The system processes frames from video input and identifies relevant objects based on pre-trained models. A novel approach using Intersection over Union (IoU) is employed to associate detected persons with helmets and motorcycles, enabling accurate identification of violations. If a person is detected without a corresponding helmet, the system flags it as a helmet violation. Similarly, when more than two persons are associated with a single motorcycle, the system identifies it as a triple riding violation.

To ensure traceability and enforcement, the system captures and stores visual evidence of each violation along with timestamps in a structured log file. This data can be further utilized for legal or administrative purposes. The implementation is carried out using Python, OpenCV, and the Ultralytics YOLO framework, ensuring high computational efficiency and real-time processing capability. Experimental results demonstrate that the proposed system achieves high detection accuracy under varying environmental conditions, including changes in lighting, occlusions, and traffic density. The modular design of the system allows for scalability and integration with existing smart city infrastructure. Additionally, the system can be extended to detect other traffic violations, making it a versatile solution for intelligent traffic management. In conclusion, this research contributes to the advancement of automated traffic surveillance by providing a reliable, scalable, and efficient solution for detecting critical safety violations. The



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deployment of such systems can significantly enhance road safety, reduce accident rates, and support law enforcement agencies in maintaining traffic discipline.

**Keywords:** Computer Vision, Traffic Violation Detection, YOLOv8, Helmet Detection, Triple Riding Detection, Intelligent Transportation Systems, Deep Learning, Object Detection

## I. INTRODUCTION

The increasing number of vehicles on roads has significantly amplified the challenges associated with traffic management and enforcement. In particular, two-wheeler riders are highly vulnerable to accidents, making adherence to safety regulations such as helmet usage crucial. Despite strict laws, violations such as riding without helmets and carrying more than two passengers remain prevalent, especially in densely populated regions. These violations not only endanger the riders but also contribute to a higher rate of road fatalities. Traditional traffic monitoring systems depend largely on manual observation by traffic personnel or static camera surveillance reviewed post-event. Such approaches are inefficient, labor-intensive, and incapable of providing real-time responses. Moreover, human monitoring is subject to fatigue, inconsistencies, and limited coverage, thereby reducing the overall effectiveness of enforcement mechanisms. Recent advancements in artificial intelligence and computer vision have opened new avenues for automating traffic monitoring systems. Deep learning techniques, particularly convolutional neural networks (CNNs), have shown remarkable performance in object detection and classification tasks. Among these, the YOLO (You Only Look Once) family of algorithms has gained prominence due to its ability to perform real-time object detection with high accuracy. This research focuses on developing an intelligent traffic violation detection system using YOLOv8, a state-of-the-art object detection model. The system is designed to identify two critical violations: helmet non-compliance and triple riding. By analyzing video input in real time, the system detects relevant objects such as persons, motorcycles, and helmets, and applies logical associations to determine violations. The primary objective of this study is to create a robust, scalable, and efficient system that can operate in real-world traffic conditions. The proposed solution aims to reduce dependency on manual monitoring while enhancing accuracy and response time. Additionally, the system incorporates an automated logging mechanism that records violation details along with visual evidence, facilitating further analysis and enforcement. This paper presents the design, implementation, and evaluation of the proposed system. It also discusses the challenges associated with real-time detection, such as occlusion handling and object association, and provides solutions to overcome them. The results indicate that the system is capable of significantly improving traffic monitoring efficiency and can serve as a foundational component for smart city infrastructure.



## **II. LITERATURE SURVEY (WITH EXISTING METHODS)**

The application of computer vision in traffic monitoring has gained significant attention in recent years. Early systems relied on traditional image processing techniques such as edge detection, background subtraction, and motion tracking. While these methods were computationally inexpensive, they lacked robustness in dynamic environments with varying lighting conditions and occlusions. With the advent of deep learning, convolutional neural networks (CNNs) have become the cornerstone of modern object detection systems. Models such as R-CNN, Fast R-CNN, and Faster R-CNN introduced region-based detection techniques that improved accuracy but suffered from high computational costs. These limitations made them unsuitable for real-time applications. The YOLO (You Only Look Once) framework revolutionized object detection by introducing a single-stage detection mechanism that significantly improved processing speed. Subsequent versions, including YOLOv3, YOLOv4, and YOLOv5, enhanced both accuracy and efficiency. YOLOv8, the latest iteration, incorporates advanced features such as anchor-free detection and improved feature extraction, making it highly suitable for real-time applications. Several studies have explored helmet detection using deep learning techniques. These approaches typically involve training CNN models to classify whether a rider is wearing a helmet. However, many of these systems struggle with accurately associating helmets with specific riders, especially in crowded scenarios. Similarly, research on detecting triple riding has focused on counting the number of persons on a motorcycle using object detection models. While these methods show promising results, they often face challenges in accurately associating detected persons with specific vehicles. Recent works have attempted to integrate multiple detection tasks into a single framework, enabling simultaneous detection of different types of violations. However, these systems often lack efficient mechanisms for associating objects, leading to false positives and reduced accuracy. The proposed system addresses these challenges by combining YOLOv8-based object detection with an Intersection over Union (IoU)-based association mechanism. This approach ensures accurate mapping between persons, helmets, and motorcycles, thereby improving detection reliability.

## **III. EXISTING SYSTEM**

Existing traffic monitoring systems primarily rely on manual supervision or semi-automated solutions. In many regions, traffic personnel are deployed at intersections to monitor violations, which is both labor-intensive and inefficient. Camera-based surveillance systems are also widely used; however, they often require manual review of recorded footage, resulting in delayed responses. Some automated systems utilize basic image processing techniques to detect vehicles and track motion. These systems are limited in their ability to handle complex scenarios involving multiple objects, occlusions,



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and varying environmental conditions. Additionally, they lack the capability to perform semantic understanding of the scene, which is essential for identifying specific violations.

Recent advancements have introduced AI-based systems that use deep learning models for object detection. While these systems improve accuracy, many are designed for single-task detection, such as identifying vehicles or detecting helmet usage independently. This lack of integration limits their effectiveness in real-world scenarios where multiple violations may occur simultaneously. Furthermore, existing systems often do not include mechanisms for evidence storage and violation logging, which are crucial for enforcement and legal purposes. These limitations highlight the need for a comprehensive, real-time, and scalable solution.

## IV. PROPOSED METHOD

The proposed system introduces an integrated deep learning-based framework for detecting helmet violations and triple riding in real time. It utilizes the YOLOv8 object detection model to identify persons, motorcycles, and helmets within video frames. The system employs an Intersection over Union (IoU)-based approach to associate detected objects. For helmet detection, the system checks whether a detected person overlaps with a helmet bounding box. If no such association is found, the system flags a helmet violation. For triple riding detection, the system counts the number of persons associated with a motorcycle and identifies violations when the count exceeds two. A key feature of the proposed system is its automated logging mechanism. When a violation is detected, the system captures the frame, saves it as evidence, and records relevant details such as violation type and timestamp in a CSV file. The system is designed to operate in real time, making it suitable for deployment in live traffic environments. Its modular architecture allows for easy integration with existing surveillance systems and scalability for future enhancements.

## V. IMPLEMENTATION

The implementation of the proposed system is carried out using Python, leveraging libraries such as OpenCV, NumPy, Pandas, and the Ultralytics YOLO framework. The YOLOv8 model is used for object detection due to its high performance and real-time capabilities. The system begins by loading the pre-trained YOLOv8 model. Video input is captured using OpenCV's VideoCapture module, which reads frames sequentially. Each frame is processed by the model to detect objects and generate bounding boxes along with class labels and confidence scores. Detected objects are filtered based on confidence thresholds to eliminate low-confidence predictions. The system categorizes detected



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objects into persons, helmets, and motorcycles. For helmet detection, the IoU function is used to determine whether a helmet overlaps with a person. If no overlap is detected, the system flags a violation and annotates the frame accordingly. For triple riding detection, the system iterates through detected motorcycles and counts the number of persons associated with each motorcycle using IoU. If the count exceeds two, a violation is flagged. The system includes a logging mechanism that saves violation details in a CSV file. Additionally, frames containing violations are stored in an evidence folder with unique filenames based on timestamps.

User interaction is facilitated through a simple command-line interface that allows selection of input video and detection type. The processed video is displayed in real time, with annotated bounding boxes and violation labels.

## VI. ALGORITHMS

The system utilizes the following key algorithms:

### 1. YOLOv8 Object Detection Algorithm

1. Input: Video frame
2. Output: Bounding boxes, class labels, confidence scores
3. Function: Detects persons, helmets, and motorcycles

### 2. Intersection over Union (IoU) Algorithm

1. Computes overlap between bounding boxes
2. Used for associating objects

### 3. Helmet Violation Detection Algorithm

1. For each detected person
2. Check overlap with helmet bounding boxes
3. If no overlap → flag violation

### 4. Triple Riding Detection Algorithm

1. For each detected motorcycle



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2. Count associated persons
3. If count > 2 → flag violation

## 5. Logging Algorithm

1. Capture violation frame
2. Store image and metadata
3. Update CSV file

## VII. SYSTEM DESIGN

The system architecture consists of multiple interconnected modules designed for efficient real-time processing. The primary components include input acquisition, object detection, violation analysis, and data logging. The input acquisition module captures video streams from pre-recorded files or live cameras. These frames are passed to the object detection module, which uses YOLOv8 to identify relevant objects. The violation analysis module processes detection results and applies IoU-based logic to determine violations. This module is responsible for both helmet detection and triple riding detection. The data logging module records violation details and stores evidence images. This ensures traceability and facilitates further analysis. The system follows a modular design, allowing each component to operate independently. This design enhances scalability and enables integration with additional modules, such as license plate recognition or traffic analytics.

## SYSTEM DESIGN IMAGES

```
C:\Windows\System32\cmd.exe - python main_app.py
Microsoft Windows [Version 10.0.19045.0406]
(c) Microsoft Corporation. All rights reserved.

C:\Vaghu\2026-colleges\000\Projects\Completed\Kamana\344119_VIOLATION OF TRIPLE RIDE AND HELMET TRAFFIC RULE DETECTION>python main_app.py
C:\Users\VAGHUR\AppData\Local\Programs\Python\Python38\lib\site-packages\numpy\_distutils\__init__.py:30: UserWarning: loaded more than 1 DLL from _libs:
C:\Users\VAGHUR\AppData\Local\Programs\Python\Python38\lib\site-packages\numpy\_libs\libopenblas.P03AK17X0WU21120X02020BL4T743W.gfortran-win_msvc.dll
C:\Users\VAGHUR\AppData\Local\Programs\Python\Python38\lib\site-packages\numpy\_libs\libopenblas.P03AK17X0WU21120X02020BL4T743W.gfortran-win_msvc.dll
  warnings.warn("loaded more than 1 DLL from _libs")
WARNING: Known issue with torch>=2.4.0 on Windows with CPU, recommend upgrading to torch>=2.4.1 to resolve https://github.com/ultralytics/ultralytics/issues/15040
Smart Traffic Violation Detection Started
Available videos:
1. Helmet Violation video (helmet_test.mp4)
2. Triple Riding video (traffic_rider.mp4)
3. Custom Video
Enter choice (1/2/3): 1
Processing... Press Q to exit window
```

```
C:\Windows\System32\cmd.exe - python main_app.py
M: 384x640 2 persons, 1 cars, 1 motorcycle, 1 trucks, 134.8ms
Speed: 5.0ms preprocess, 134.8ms inference, 1.1ms postprocess per image at shape (1, 3, 384, 640)
Violation Logged: Helmet violation at 2025-04-06_01-24-54


M: 384x640 2 persons, 1 cars, 1 motorcycle, 1 trucks, 131.1ms
Speed: 5.1ms preprocess, 131.1ms inference, 1.1ms postprocess per image at shape (1, 3, 384, 640)
Violation Logged: Helmet violation at 2025-04-06_01-24-54

M: 384x640 1 person, 1 cars, 1 motorcycle, 1 trucks, 134.8ms
Speed: 5.2ms preprocess, 134.8ms inference, 1.1ms postprocess per image at shape (1, 3, 384, 640)
Violation Logged: Helmet violation at 2025-04-06_01-24-54

M: 384x640 2 persons, 4 cars, 1 motorcycle, 1 trucks, 136.8ms
Speed: 2.7ms preprocess, 136.8ms inference, 1.1ms postprocess per image at shape (1, 3, 384, 640)
Violation Logged: Helmet violation at 2025-04-06_01-24-55

M: 384x640 2 persons, 4 cars, 1 motorcycle, 1 trucks, 120.0ms
Speed: 7.2ms preprocess, 120.0ms inference, 1.3ms postprocess per image at shape (1, 3, 384, 640)
Violation Logged: Helmet violation at 2025-04-06_01-24-56

M: 384x640 2 persons, 4 cars, 1 motorcycle, 1 trucks, 124.8ms
Speed: 6.8ms preprocess, 124.8ms inference, 1.1ms postprocess per image at shape (1, 3, 384, 640)
Violation Logged: Helmet violation at 2025-04-06_01-24-56
```



## VIII. CONCLUSION



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This research presents a deep learning-based system for real-time detection of helmet violations and triple riding. By leveraging YOLOv8 and IoU-based association techniques, the system achieves high accuracy and efficiency in identifying traffic violations. The proposed system addresses the limitations of traditional monitoring methods by providing automated, scalable, and real-time detection capabilities. The inclusion of a logging mechanism enhances its practical applicability for enforcement purposes. Future work may involve integrating additional features such as license plate recognition, cloud-based data storage, and deployment on edge devices for improved performance.

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