

AI Based Smart Motorcycle Safety Monitoring System for Campus Environments

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Abstract:

Road safety violations such as riding without helmets and triple riding are prevalent concerns in college campuses, posing significant risks to student safety. Traditional monitoring methods rely heavily on manual supervision by security personnel, which is inefficient, inconsistent, and unable to provide real-time detection. This paper presents an AI-Based Smart Motorcycle Safety Monitoring System designed specifically for campus environments. The system utilizes CCTV cameras to continuously capture real-time video of moving vehicles. The captured video is processed using OpenCV for frame extraction and image preprocessing. A deep learning-based object detection model, YOLO (You Only Look Once), is applied to detect motorcycles, identify helmet usage, and count the number of riders on each motorcycle. Upon detecting a violation such as no helmet or triple riding, the system automatically captures the violation frame and generates an alert with visual evidence. The system is implemented using Python with OpenCV, Ultralytics YOLO, and NumPy libraries. The proposed system eliminates continuous human monitoring, improves detection accuracy, and ensures efficient enforcement of campus traffic safety regulations.

Keywords — Smart Motorcycle Monitoring, Helmet Detection, Triple Riding Detection, YOLO, Computer Vision, OpenCV, Deep Learning, Campus Safety, Object Detection, AI Surveillance.

I. INTRODUCTION

The rapid increase in motorcycle usage within college campuses has raised significant road safety concerns. Students frequently violate critical traffic regulations such as riding without helmets or engaging in triple riding, dramatically increasing the risk of accidents and injuries. In many institutions, monitoring of such violations relies on security personnel stationed at entry and exit points — a method that is resource-intensive and

inherently limited by human capabilities [1]. Conventional manual monitoring systems suffer from several drawbacks: inability to cover all campus areas simultaneously, susceptibility to human error, absence of real-time alert mechanisms, and lack of systematic violation records. These limitations make manual enforcement both ineffective and unsustainable as campus populations continue to grow. With the advancement of artificial intelligence and computer vision, it is now possible to automate surveillance

tasks that previously required significant human effort. Deep learning techniques, particularly Convolutional Neural Networks (CNNs) and

YOLO-based object detection, have demonstrated exceptional real-time detection capability with high accuracy and low latency [9][10]. This project proposes a Smart Motorcycle Safety Monitoring System that leverages CCTV cameras, OpenCV image processing, and YOLO-based deep learning to automatically detect violations within college campus environments.

II. LITERATURE REVIEW

A. Helmet Detection and Number Plate Recognition

Vijendar Reddy et al. (2024) conducted a comprehensive survey of helmet detection and number plate recognition techniques. The review covers traditional image processing, machine learning, and deep learning models including CNNs and YOLO variants, comparing their accuracy, speed, and computational complexity. The study identifies key challenges such as illumination variation, occlusion, and dataset limitations [4].

B. Safety Helmet Detection Using Adjusted YOLOv8

Yang et al. (2024) proposed an enhanced YOLOv8 model for helmet detection with modified network architecture and optimized training strategies to achieve superior feature extraction and faster detection speed. The system demonstrates high precision and recall rates suitable for real-time surveillance applications [5].

C. Robust Automatic Motorcycle Helmet Violation Detection

Tran et al. (2023) designed a robust deep learning framework capable of detecting helmet violations under challenging conditions including occlusion, motion blur, and poor lighting. The proposed system incorporates advanced optimization techniques and demonstrates high reliability for intelligent transportation deployment [3].

D. Real-Time Multi-Class Helmet Violation Detection

Aboah et al. (2023) developed a real-time multi-class detection system using YOLOv8 capable of simultaneously identifying helmet absence,

improper usage, and rider classification. The system shows improved efficiency over single-class detection approaches and is highly suitable for intelligent traffic enforcement [7].

E. Deep Learning for Human Action Recognition Using CNN

This study published in the International Journal of Scientific Research in Computer Science, Engineering and Technology (IJSRCSEIT, ISSN: 2456-3307, Volume 6, Issue 4, August 2020) explores the application of Convolutional Neural Networks (CNNs) for recognizing human actions from video sequences. The proposed approach leverages spatial feature extraction capabilities of CNNs to classify human activities with high accuracy. The methodology and feature extraction techniques from this work provide foundational insights applicable to rider detection and posture-based safety violation analysis in motorcycle monitoring systems [9].

F. Survey on Deep Learning Techniques for Human Action Recognition

This survey presented at IEEE ICCCI 2020 at Shree Shakthi Institute of Engineering and Technology, Coimbatore (January 2020) provides a comprehensive review of deep learning methods applied to human action recognition. The paper analyzes various architectures including CNNs, RNNs, and hybrid models in terms of accuracy and computational efficiency. The deep learning survey frameworks reviewed in this work directly inform the design of the rider detection and classification modules in the proposed campus safety monitoring system [10].

G. Deep Learning for Helmet Usage Detection

Siebert and Lin (2019) utilized Convolutional Neural Networks (CNNs) to detect motorcycle helmet usage, demonstrating robustness across diverse traffic conditions and viewpoints. Their research emphasizes deep learning superiority over traditional feature extraction methods for traffic monitoring applications [2].

III. PROBLEM STATEMENT

Motorcycle safety violations are increasingly prevalent within college campus environments. Existing monitoring systems rely entirely on human

observation, which is inconsistent, unscalable, and unable to provide real-time enforcement. The core challenges identified include:

- Manual monitoring is time-consuming and demands significant manpower.
- Security personnel cannot monitor all campus zones simultaneously.
- No automated alert system exists for immediate violation detection and notification.
- Violation records are not maintained systematically for trend analysis.
- High rates of human error result in numerous undetected violations.

Therefore, an automated intelligent system is required that can continuously monitor campus roads, detect safety violations in real time, generate instant alerts with visual evidence, and maintain digital violation records to support effective rule enforcement and analysis.

IV. METHODOLOGY

A. Video Capture Module

CCTV or IP cameras installed at strategic campus locations continuously capture real-time video of motorcycles. This module serves as the primary input source for the entire system. Camera resolution, placement angle, and environmental lighting conditions are critical factors influencing detection accuracy and overall system performance.

B. Frame Extraction and Pre-processing Module

The captured video stream is divided into individual frames using OpenCV. Each frame undergoes pre-processing operations including resizing to 640x480 pixels, noise reduction, and normalization. These steps ensure that input data is clean and standardized for accurate YOLO-based object detection.

C. Object Detection Module (YOLO)

Each pre-processed frame is processed through the YOLO object detection model from the Ultralytics library. YOLO performs object localization and classification simultaneously in a single neural network forward pass, enabling real-time detection. The model identifies motorcycles and riders, generating bounding box annotations and confidence scores for each detected object.

D. Helmet Detection Module

This module analyzes detected rider head regions to determine whether helmets are worn. Each detected head is classified into either 'Helmet' or 'No Helmet' category. Color-coded bounding boxes green for compliant riders and red for violators are overlaid on video frames to provide clear visual feedback in real time.

E. Rider Count Detection Module

This module counts the total number of persons detected on a single motorcycle. If the count exceeds two riders, the system flags a triple riding violation. Bounding box coordinates from YOLO detections are used to associate multiple detected persons with their corresponding motorcycle in the frame.

F. Alert Generation Module

Upon violation detection, the system captures the violation frame and generates an alert message displayed prominently on screen in red ('ALERT: Helmet Not Detected'). The captured violation image along with violation type and timestamp details is saved locally and can be transmitted to campus security authorities for action.

G. Monitoring and Reporting Module

All detected violations are stored in a local database with corresponding evidence images and timestamps. This enables authorities to track repeat offenders, analyze violation frequency patterns, and generate reports to support ongoing improvements to campus safety enforcement policies.

V. RESULTS AND DISCUSSION

The Smart Motorcycle Safety Monitoring System was implemented and tested using Python 3.x with the Ultralytics YOLOv8n model and OpenCV library. The system was evaluated using real video footage recorded within a campus environment to assess detection accuracy and real-time processing capability. Helmet Detection Performance: The system successfully distinguished between helmet and no-helmet conditions with high confidence scores. When no helmet was detected, the alert message 'ALERT: Helmet Not Detected' was displayed prominently in red on the video frame. When a helmet was correctly worn, a green

bounding box confirmed compliance, providing intuitive visual feedback.



Fig.1. Helmet Detection and Alert System

Real-Time Processing: The system processed live video frames in real time, maintaining smooth detection performance consistent with requirements for live CCTV monitoring. The YOLOv8 single-pass detection architecture contributed to low processing latency without compromising detection accuracy.

Alert and Output Generation: Upon detecting a violation, the system correctly captured the corresponding frame and generated alerts with appropriate details. Output screenshots confirm bounding boxes accurately annotated detected persons, with confidence values displayed (e.g., person: 0.85). The project file structure comprising `project.py`, `video.mp4`, and `yolov8n.pt` confirms a clean and organized implementation.

Overall, the results demonstrate that deep learning-based automated monitoring significantly outperforms manual surveillance in speed, consistency, and accuracy for campus safety enforcement applications.

VI. CONCLUSION

This paper presented an AI-Based Smart Motorcycle Safety Monitoring System for college campus environments. The system integrates CCTV video capture, OpenCV image processing, and YOLOv8-based deep learning to automatically detect helmet violations and triple riding in real time. The proposed system successfully eliminates the limitations of manual surveillance by providing

continuous, automated monitoring with instant alert generation and digital violation record maintenance.

The implementation demonstrated accurate detection of both helmet and no-helmet conditions, real-time processing capability, and reliable alert generation. The system reduces human monitoring effort, minimizes detection errors, and significantly improves the enforcement efficiency of campus traffic safety regulations. With planned future enhancements including license plate recognition, cloud integration, and mobile-based notifications, the system can be further extended into a comprehensive smart campus safety platform.

VII. FUTURE SCOPE AND ENHANCEMENTS

Future development of the system includes the integration of automatic license plate recognition (ALPR) to uniquely identify violating vehicles and track repeat offenders. Deployment on cloud infrastructure will enable centralized monitoring of multiple campus camera feeds simultaneously. A mobile application and web-based dashboard will allow security authorities to receive instant push notifications and review violation reports remotely. Training the YOLO model on larger and more diverse campus datasets will improve detection robustness under varying lighting, weather, and crowd conditions. Integration with smart city traffic management systems could extend the solution beyond campus boundaries to public road enforcement.

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