**Automating Helmet Enforcement with YOLOv9: A Deep Learning Approach**

Shivam Shivkumar Shukla  
Student  
Department of Computer Science and Engineering  
Govindrao Wanjari College of Engineering & Technology, Nagpur, Maharashtra

Harsh Sanjaysingh Kachhaway  
Student  
Department of Computer Science and Engineering  
Govindrao Wanjari College of Engineering & Technology, Nagpur, Maharashtra

Gaurav Dnyaneshwar Dupare  
Student  
Department of Computer Science and Engineering  
Govindrao Wanjari College of Engineering & Technology, Nagpur, Maharashtra

Tushar Marotrao Maske  
Student  
Department of Computer Science and Engineering  
Govindrao Wanjari College of Engineering & Technology, Nagpur, Maharashtra

Tushar Manesh Shinde  
Student  
Department of Computer Science and Engineering  
Govindrao Wanjari College of Engineering & Technology, Nagpur, Maharashtra

Prof. Nitin Thakre  
Professor  
Department of Computer Science and Engineering  
Govindrao Wanjari College of Engineering & Technology, Nagpur, Maharashtra

**Abstract—** This paper proposes a real-time automated helmet enforcement system using the YOLOv9 object detection model combined with OCR for license plate recognition. The system detects helmets, riders, and license plates in real-time from CCTV or mobile video streams. Upon detecting a rider without a helmet, it extracts and processes the license plate using OCR to identify the violator. The model demonstrates high accuracy and is deployable in urban traffic monitoring systems to automate helmet law enforcement. The system supports webcam and mobile IP camera integration, making it versatile, cost-effective, and scalable.

Index Terms—YOLOv9, Helmet Detection, Real-Time Surveillance, OCR, License Plate Recognition, Traffic Safety

**I. INTRODUCTION**

Motorcycles are among the most common forms of transportation in urban areas due to their affordability and convenience. However, they also contribute significantly to road accident statistics, especially when safety gear like helmets is not used properly. As per global traffic safety studies, the usage of helmets can reduce the risk of severe injury by 70% and fatalities by 40%. Despite strict helmet laws in many countries, real-world compliance remains poor due to limited enforcement capabilities.

Traditional traffic policing relies heavily on manual checks, which are time-consuming, resource-intensive, and prone to human error. To address these challenges, automation through advanced computer vision technologies becomes essential. Deep learning-based models such as YOLO (You Only Look Once) have gained popularity due to their high accuracy and real-time object detection capabilities. YOLOv9, the latest and most efficient version in this family, introduces transformer-based improvements and spatial awareness for even better detection.

This paper introduces a real-time automated helmet detection system using YOLOv9, coupled with an Optical Character Recognition (OCR) module for license plate extraction. The system is scalable, cost-effective, and easily integrable with existing CCTV or mobile surveillance systems, making it highly useful for smart city applications.

**II. METHODOLOGY**

The system is composed of the following major components:

#### A. Dataset Collection and Annotation

Custom dataset creation was a critical step, involving collecting thousands of images from traffic footage, both helmeted and helmetless riders. The dataset also included annotations for license plates and motorbikes using tools like LabelImg in YOLO format.

#### B. Model Selection – YOLOv9

YOLOv9 is chosen for its capability to perform multi-object detection in real-time. Unlike earlier models (YOLOv5 or v7), YOLOv9 uses dynamic head configurations and transformer-enhanced backbones, resulting in better feature extraction and robustness in various lighting conditions.

#### C. Object Classes

Five custom classes were defined:

1. Helmet
2. No Helmet
3. Person
4. Motorbike
5. License Plate

These classes allow the system to precisely detect violations and associate riders with vehicles and license plates.

#### D. OCR Module Integration

After detecting a violation, the system extracts the bounding box of the license plate and crops it. The cropped image is then processed using Tesseract OCR. Among multiple predictions, the one with the highest confidence is selected and stored.

**III. RESULTS**

The proposed helmet enforcement system was rigorously tested to validate its performance in real-world scenarios. The model was trained using a custom-annotated dataset containing diverse traffic images, including riders with and without helmets, license plates, and motorbikes. The training aimed to enable the YOLOv9 model to accurately detect five key object classes: Helmet, No Helmet, Motorbike, Person, and License Plate.

After training, the system demonstrated high detection accuracy, particularly in distinguishing helmeted and non-helmeted riders. The model efficiently processed real-time video feeds and showed consistent performance across various lighting conditions and camera angles. It was capable of handling both CCTV footage and live streams from mobile devices configured as IP webcams. This flexibility allowed for both fixed and portable deployment.

When a rider without a helmet was detected, the system successfully located and extracted the license plate region using bounding box coordinates. This cropped image was passed to an Optical Character Recognition (OCR) module, which returned a list of possible license plate numbers along with confidence scores. The result with the highest confidence was stored as the final output.

The integration of YOLOv9 and OCR enabled end-to-end automation of helmet violation detection, minimizing the need for manual monitoring. The model exhibited strong real-time performance, processing video at high frame rates without significant latency. Furthermore, the accuracy of the OCR module proved effective for most license plate formats, particularly in daylight or well-lit environments.

Overall, the system achieved its goal of providing an automated, accurate, and real-time solution for detecting helmet violations and extracting vehicle details. It presents a cost-effective and scalable option for traffic authorities to enhance road safety and streamline enforcement efforts.

**IV. CONCLUSION**

The paper successfully demonstrates a fully automated helmet detection system using YOLOv9 and OCR. The system is accurate, scalable, and deployable in various traffic monitoring scenarios. It reduces manual labor and enhances road safety by automatically identifying violators and logging their details.

This solution supports both static (CCTV) and dynamic (mobile) input systems and is capable of operating in diverse environmental conditions. It sets the foundation for smart traffic enforcement systems and can be further extended to detect other violations such as triple riding, speeding, or signal jumping.

### V. FUTURE WORK

In the future, this system can be enhanced by integrating:

* **Automatic e-challan generation**
* **Vehicle type recognition**
* **Face recognition for repeat offenders**
* **GPS mapping** for location tagging of violations

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**REFERENCES**

[1] Zhou F., Zhao H., Nie Z. Safety helmet detection based on YOLOv5. IEEE ICPECA, 2021.

[2] Waranusast R., et al. Motorcycle helmet detection using machine vision. IEEE IVCNZ, 2013.

[3] Tan S., et al. Improved YOLOv5 for helmet detection. IEEE ISR, 2021.

[4] Jia W., et al. Real-time helmet detection using YOLOv5. IET Image Processing, 2021.

[5] Li K., et al. Automatic helmet detection using deep learning. arXiv:1802.00264, 2018.

[6] Wu F., et al. Helmet detection with YOLOv3. IEEE ICNSC, 2019.

[7] Yung ND., et al. YOLOv5-v7 helmet detection comparison. IEEE GECOST, 2022.

[8] Li Y., et al. CNN-based helmet detection. Advances in Civil Engineering, 2020.

[9] Huang L., et al. Deep learning for helmet detection. Concurrency Computat.: Pract. Exper., 2021.

[10] Rubaiyat AH., et al. Construction safety helmet detection. IEEE WIW, 2016.