# Real-Time Motorbike Helmet Detection System Using Hybrid Deep Learning Model

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**Abstract.** In Bangladesh, motorcycle accidents are a major cause of mortality; most deaths are ascribed to riders not wearing helmets. This study intends to use a hybrid deep learning model to construct an effective, real-time helmet detection system in response to this rising issue. The system is intended to recognize helmets, riders, and license plates in intricate road scenarios by integrating YOLOv8 for object identification, ResNet50 for rider classification, and Paddle OCR for text recognition. The study used a large dataset from the Kaggle Helmet Detection Dataset and Bangladeshi real-life video footage, preprocessed using Roboflow for cleaning, annotation, and data augmentation. The model was trained using multiple checkpoints and selected best.pt due to superior performance. Data exploration and visualization techniques were used to ensure the dataset's quality and balance. Feature extraction techniques like edge detection and color histograms improved the model's accuracy in distinguishing helmets and riders. With a precision of 0.929, recall of 0.932, and mean average accuracy (mAP) of 0.949 at 50 percent IoU, the model's preliminary evaluations yield encouraging findings. These outcomes show how well the technology detects helmets in real-time, even in intricate traffic situations. In addition to providing insights that may be used to guide policy choices targeted at lowering motorcycle deaths, the project's results highlight the significance of incorporating deep learning technology for traffic safety.

**Keywords:** Motorcycle safety, Helmet detection, Deep learning, YOLOv8, ResNet50


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# 1 Introduction

The small motorbike has become a near fatal danger for millions and that is especially true in some very populous countries starting with Bangladesh where motorcycles are kings of public transit. Continually driving the use of bikes to increase, so is everything that goes with it. Today, helmet checking and law enforcement is probably hardest due to the presence of many on-road vehicles moving one after another in traffic signals, which makes it almost impossible for people sitting inside to take round check-ups. Intelligent helmet detection based on deep learning is implemented to detect whether helmets are worn during the real-world riding, and license plate recognition technology utilizes data augmentation as pre-processing steps for rider identification purposes. This system brings together several recent models (namely YOLOv8 for object detection, ResNet50 model for rider classification) to provide a robust road safety enhancement that has some degree of automation.

An important element of the problem is that it has to work in real-time and be very good at differentiating helmet use under complex traffic scenarios, like these ones found on streets such as Bangladeshi roads. In the meantime, the system will make it easier for authorities to enforce safety regulations more efficiently leading to a significant reduction of motorcycle deaths. Through this system, violators will also be identified using their license plates and it can serve as an all-encompassing device to ensure better compliance with traffic laws. The introduction speaks to the growing demand for traffic safety automation and lays a foundation for deeper technical discussion as had been provided in this project. We are developing a system that will provide important insights to policy makers and proper action based on these insights will ensure a reduction on the fatality rate by detecting motorbike helmets. Deep learning technology works marvellously when it comes to detecting any object. Detecting the helmet of the riders using a hybrid deep learning model, can reduce fatal injuries approximately 50% [1]. That is why we are developing a system that can provide reliable results in a complex road scenario like Bangladesh using the combination of YOLOv8 and ResNet50 methods of deep learning technology.

## 1.1 Problem Statement

In Bangladesh, most family and friends have a traditional conviction that conceptual illness concerns do not need any treatment. Students are the foundation upon which a nation In Bangladesh, one of the most significant causes of death in motorbike accidents is not wearing a proper helmet. 9951 people died in 2024 by road accident and among them, 3,091 people died by motorbike accidents. In addition, 88% of those 3091 people died due to not wearing a helmet. According to the Road Safety Foundation, wearing a proper helmet can reduce the risk of fatal injuries by an estimated 42 percent and non-fatal injuries by 69% [2].

### 1.2 Motivation

The trend of using motorcycles in our country is rising. And, it can continuously increase per year motorcycle users. This also, motorcycle accidents are increasing. Motorcycle accidents claim more lives than most other types of road mishaps. According to Road Safety Foundation, 11,669 motorcycle accidents occurred in 5 and a half years, 11,593 people were killed. And also, the number of motorcycle accidents during four years increasing with time in 2019, 2020 ,2021 and 2022 are 1189, 1381, 2078 and 2973. With 945, 1463, 2214 and 3091 deaths respectively. Compared with statistics from 2024, motorcycle deaths rose by over 43. 88% of people failed simply because they did not wear a helmet [3]. We were inspired as a team to do this project from the sheer number of deaths that could be saved if people simply wore good helmets.

## 2 Literature Review

Several researchers have been studying motorcycle helmet detection in recent years; some of them have even looked into license plate identification. Jia et al. [4] Construction of a Leading-edge System for Motorcycle Detection and Helmet Recognition in Developing Countries. A dual-purpose YoLOv5 motorcycle detector that processes motorcycles first and then sees helmets in the frame. First, the system uses a triplet attention mechanism and integrates Soft-NMS for robust occlusions. This system surpasses current methods for real-time helmet detection and attains mAP of 97.7% as well as an F1-score value of 92.7%.

Tran et al. [5] Estimating motorcycle helmet usage from video: A novel two-stage approach to enhance road safety surveillance. The system comprises a motorcycle and rider detector, followed by a segment that detects whether the identified riders are wearing helmets. Model: the framework utilizes deep learning-based methods, particularly the YoLOv8 algorithm to achieve 0.7754 accuracy improvement at AI City 2023 Public Leader board. The system combines advanced algorithms for handling specific challenges, such as lighting conditions and occlusions, showing its potential to robustly support glasses-wearing compliance surveillance of helmet usage in real-world traffic environments. Another work by Nagoriya [6] aims to achieve the automatic detection of motorcycle helmets based on a new frame- work approach for video surveillance visualization. The framework is two-stage: a detector to localize motorcycles and their riders, then an IDer of the helmet status. This is done by using the competition-class rank YOLOv8 model, which shows a large improvement concerning detection methods in previous works. The authors recommend that BIRL-based pose should consider advanced algorithms to handle the more challenging environment where different lighting effects and large partial occlusion exist such as for this particular case, a specific deep neural network is recommended. It also provides better-integrated control algorithms of iTSs and safer roads.

Chairat et al. [7] describes a new method framework for detecting the wearing of helmets on motorcyclists using video surveillance. This system overcomes these problems like the exact localization of motorbikes and driver-rider difference helmet compliance. The two-step process: a detector asking for motorcycles, and an identifier deciding if the seen rider is wearing a helmet. It will achieve high accuracy because the proposed method is performed better than other methods. The system has also been validated as a dependable unit in the enhancement of compliance with helmet legislation deployment and enforcement for road safety development. In another paper Agorku et al. [8], they described a method of the YOLOv5 deep learning model for identifying non-helmet using motorcycle riders. High speed and accuracy in traffic monitoring system with low false positives. Hence the authors combine ensemble learning methods to boost detection performance in different conditions and occlusions. The system significantly advances the tech from typical and deep learning approaches to up disorder statistics, tries hard in the road safety ecosystem, and saves motorcycle deaths caused by accidents.

Agorku et al. [9] proposed an automatic system for the recognition and tracking of license plates for helmetless motorcyclists It uses YOLOv2 and MLPoseNet, the model which have trained v3 for person, motorcycle, helmet. it also does license plate detection using Yolov4. With video input, it monitors traffic conditions in real-time and fines instead of through traditional manual labor. In the study, methods developed in deep learning increased detection performance and precision. License plate extraction is done through an optical character recognition (OCR) system. The study by Wang et al. [10] Video Analytics for Motorcycle Helmet compliance employs Deep learning to recognize and quantify helmet status instantly. A necessary condition to effectively enforce traffic law in high non-compliance settings. This system works robustly across video feeds — even in challenging scenarios including low light conditions and with occlusions. Experimental results indicate good performance, and therefore our system is highly beneficial for traffic authorities to keep roads safe.

The paper ALWIN et al. [11] presents an approach to automatically detect helmetless riders using CCTV images with the annotated helmet and penalize them as per their license. The better YOLOv3 model was clearly able to distinguish real helmet use from stored ones, eliminating false positives. How license plate recognition enhances the accuracy of enforcement for fines and tickets However, the study also recognizes that pillion rider detection is still an open problem due to a lack of training data and hence comprehensive datasets are essential. The related authority believes the method can advance traffic law enforcement technology as well as render motorcycle safety checks almost completely autonomous. Soltanikazemi et al. [12] Real-Time Helmet Detection: introduced our helmet detection dataset and a real-time helmet system using the YOLOv5 model leveraging genetic algorithms for hyperparameter tuning. It is suitable to locate helmet non-adherence effectively, has an effective mean Average Precision score of 0.5377, and performs notably till the final standings in the AI City Challenge. Recently, YOLOv5 and other deep learning-based methods have been adopted in previous works to achieve better object detection results, especially for challenging situations. The research shows that there is a use of automatics in road safety measures and police helmet ability.

Using a single small dataset of 300 images, Susa et al. [13] employed YOLOv3 to recognize authorized helmets among motorbikers. Twenty-five models were made and tested, with Model 18 demonstrating the greatest performance, yielding an mAP of 0.97. These experiments showed that YOLOv3 could perform well in helmet detection, but that the method required optimized fine-tuning and comparing across models. Such studies could help minimize traffic crashes related to poor- focused safety and authorized helmet identification by assisting in the selection of appropriate models.

This paper Allamki et al. [14], instead is about a system developed to improve road security by controlling if motorcycle riders wear helmets. The authors in response to the increasing number of road accidents observed in India, automated detection and machine learning-based systems for disaster prevention. The essential ones are the importance of helmet-wearing for motorcyclists and discussing traffic analysis and object detection to emphasize the necessity of an effective system for detecting helmets. The approach uses the YOLOv3 model due to its fast speed and high-precision results within five classes: riders wearing helmets, "riders do not wear a helmet", motorcycles, passengers seated backside" persons, and license plate. The model, trained on a custom dataset of 11,000 images across over 50,000 iterations was able to achieve an average precision of roughly.75% and the OCR component had roughly 85% accuracy in identifying license plates.

This paper L. Wang et al. [15] employs the modified version of the YOLOv5 framework to detect safety helmets worn by construction workers. The study of the construction environment is faced with challenges such as complex backgrounds, crowded targets, and helmet irregular shapes. This procedure and methodology do so by incorporating CBAM with DCN to the core model of YOLOv5, which in turn achieves performance enhancement under complex cases due to the attention mechanism being utilized alongside adaptable feature extraction. To improve the precision of datasets with high-density objects, The study exchanges GIoU loss in Faster R-CNN to DIou loss. Trained using a custom dataset, which consisted of open-source data and self-captured images: it reached 91.6% accuracy with the speed at processing 29 frames per second solving for real-time use cases

This paper Yogameena et al. [16] focuses on the development of an automated surveillance system that improves road safety by monitoring motorcycle riders and checking whether they wear helmets. It looks to address the problem of motorcycle accidents in India which could be prevented by using helmets and some users have volunteered for it as an extra line of defense. The methodology uses a Gaussian Mixture Model (GMM) to segment the foreground objects in video clips and utilizes R-CNN approach for detecting motorcycles, as well helmets. This method is robust in the real world against problems such as low resolution, occlusion, different light conditions and illumination. Only a little bit more than the anarchic system but still, one of them deserves applause with an average precision mean at 82.925% and LP method reaches edge lines in up to 95%, which is quite good metric over other algorithms as well.

This paper Han & Zeng [17] outlined the problems of providing construction site workers with safety gear and significance helmet detection in many aspects. We then walk-through YOLO architecture and approach (treating object detection as a regression task) — finally, positing that since the model is broadly efficient + easily modified, it makes sense for us to base our work on this framework; we choose YOLOv5.

A fourth detection scale is added for small targets such as helmets, and an attention mechanism in the backbone network to improve feature representation. Results are presented with a mean average precision of 92.2%, a relative increase of 6.3% against the baseline YOLOv5, and an inference time of just 3.0 ms per image (640×640 pixels). Even more useful are the model's compact size and potential application in practical, real-world situations with workers wearing helmets for additional protection. The summary of literatures presented in Table 1.

**Table 1.** Summary of Helmet Detection Papers

| Author(s), Year | Method/Algorithm | Key Results |
|---|---|---|
| Allamki et al. (2019) | YOLOv3 + OCR | mAP: 75%, OCR Acc: 85% |
| Wang et al. (2022) | YOLOv5 + CBAM + DCN + DIoU | Acc: 91.6%, Speed: 29 FPS |
| Yogameena et al. (2019) | GMM + R-CNN | mAP: 82.9%, LP method: 95% |
| Han & Zeng (2021) | YOLOv5 + Extra Scale + Attention | mAP: 92.2%, Time: 3 ms/image ($640^2$) |
| Liang & Seo (2022) | GhostNet + MSFFN + LRCA-NetV2 | mAP: 93.5%, Speed: 42 FPS |
| Geng et al. (2021) | YOLOv3 + Gaussian Fuzzy Augmentation | Confidence: 0.92 |
| Siebert & Lin (2020) | YOLO9000 + RetinaNet | Acc: 74.6% |
| Tomas & Doma (2024) | YOLOv5 + YOLOv7 + Deep SORT | Prec: 95.6%, Recall: 91.2%, mAP@0.5: 95.1% |
| Agorku et al. (2023) | YOLOv5 + Data Augmentation | mAP: 52.6% |
| Shan et al. (2023) | YOLOv5 + ECA + BiFPN | Acc: 95.9% |

## 3 Research Methodology

The methodology diagram is presented in Fig. 1. The idea generation phase focuses on developing an integrated system for real-time traffic monitoring based on image processing algorithms. The technology was designed to detect motorcycle riders while also determining whether or not they were wearing helmets and performing license plate recognition (LPN). These three jobs were created to function together effortlessly with low delay, even in high-traffic environments.

The annotation workflow is given in Fig. 2. The object detection of the concept's first module was YOLOv8 with an optimal balance of speed and accuracy. The You Only Look Once version 8 (YOLOv8) can successfully detect small objects in complex scenes so that it is appropriate for detecting riders, helmets, motorcycles, etc. in video frames. Its CSPDarknet backbone model enables precisely feature extraction, and PANet neck model makes better use of the features. (Anchor-free detection paradigm and CIoU loss) It enhances bounding box accuracy, which is important for real-time traffic surveillance.

If riders are detected, helmet classification is conducted by ResNet50. This deep model uses residual connections to address the vanishing gradient issue so that it can learn the higher-level features. Pre-trained on the ImageNet and fine-tuned on a customized dataset of helmeted vs. non-helmeted riders, ResNet50 efficiently learns to differentiate between two classes by considering shape, structure, and appearances (color).

The last system combines YOLOv8 for object detection, ResNet50 for helmet classification and LPN for vehicle identification. These models provide an all-in-one, online traffic surveillance, and law enforcement approach which can effectively accommodate the arbitrary streetscapes on the roads of Bangladesh. The architecture is optimized for fast, accurate, and robust processing for a reliable performance in various traffic conditions.

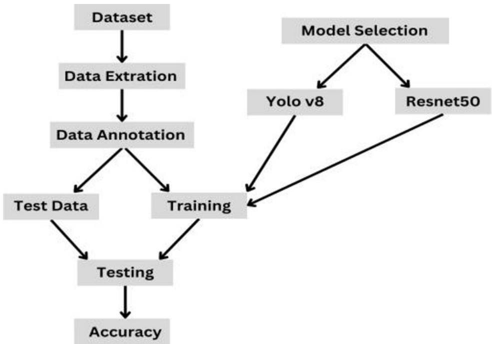


**Fig. 1.** Proposed System Methodology

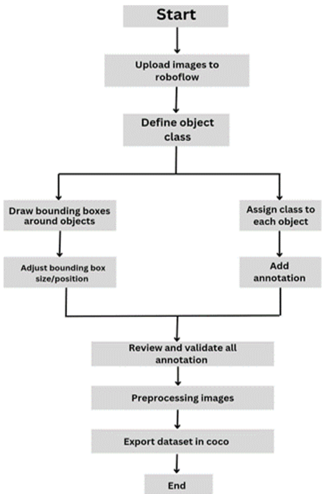


**Fig. 2.** Data Annotation Process

The models were trained on the combination of a public dataset and our own collection of real-world videos. The public collection, in particular, the Kaggle Helmet Detection Dataset, offered us pre-processed images of riders wearing helmets and riding without helmets, taken in different situations to simulate how humans take a photo on the road [18]. This solidified the base of the first model training. Helmets, riders and license plate were all annotated using Roboflow and were essential in teaching YOLOv8 the many aspects of helmet detection. Furthermore, custom real traffic on Dhaka Street video taken with 20 smartphones, was used to train the model with various weather, traffic conditions and angles. The data was resized, cleaned, augmented, and separated into training, validation, and test data. The same pre-processing steps including resizing, normalization, and augmentation etc., were also performed, followed by training the models such as YOLOv8 and ResNet50 (re-trained with pre-trained weights). This fitting method enabled integration into real world challenges and generalisation well. The sample bounding box is presented in Fig. 3.

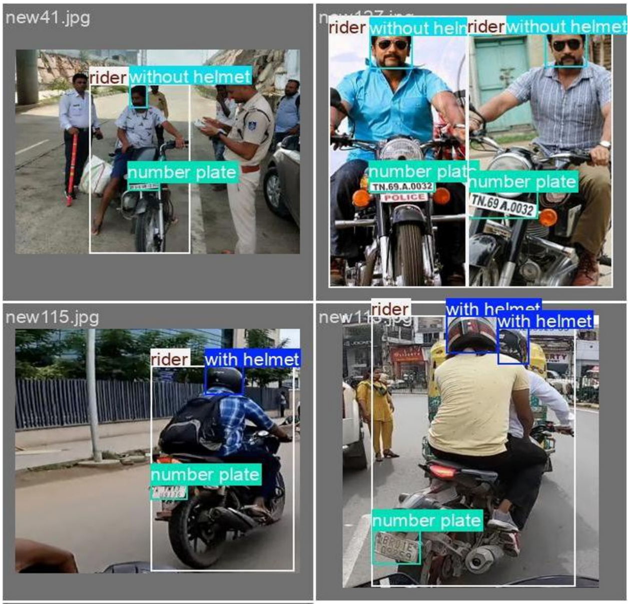


**Fig. 3**. Sample of Bounding Box

## 4 Experimental Results and Discussion

### 4.1 YOLOv8 for Object Detection

The detection of motorcycle, rider, helmet and license plate was performed in real-time by 20 epochs of training the YOLOv8 model with the combination of COCO128 and the custom recorded traffic videos. The model's performance continuously increased during its training phase, resulting in dramatic decreases in its training and validation losses: Box Loss from 1.107 to 0.672, Classification Loss from 2.138 to

0.478, and the DFL value decreased significantly throughout its training, which means our model has become increasingly better at locating objects. Meanwhile, performance metrics of the model was improved, mAP 50 increased from 0.592 to 0.949, mAP 50-95 increased from 0.422 to 0.764, which reflected better at object detection accuracy and more efficient at object classification to the stricter criteria being met.

### 4.2 ResNet50 for Helmet Classification

The normalized confusion matrix for applied model is given in Fig. 4. The ResNet50 model is integrated into the system to classify whether a detected rider is wearing a helmet or not. The ResNet50 model's deep architecture allows it to extract fine-grained features, which is 50crucial for distinguishing between helmeted and non-helmeted riders in real-world scenarios.

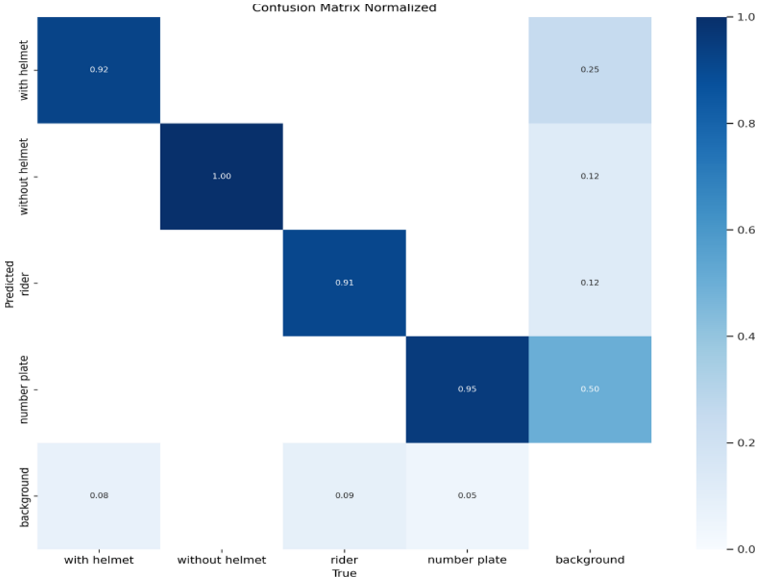


**Fig. 4**. Normalized Confusion Matrix

The precision-recall curve for the applied model is depicted in Fig, 5. To further evaluate the system, we examined precision, recall, and F1 score at various confidence levels. The Precision-Recall curve demonstrated the model's high accuracy, with mAP50 at 0.94903 and mAP50-95 at 0.76361, suggesting strong performance across all item categories. The F1 score peaked at 0.91 with a confidence level of 0.522, indicating a balanced performance between precision and recall. The Precision-Confidence curve showed near-perfect precision of 1.00 at a confidence threshold of 0.931, especially when detecting riders and license plates. Meanwhile, the Recall-Confidence curve demonstrated high recall at lower thresholds, guaranteeing that most objects were accurately spotted.

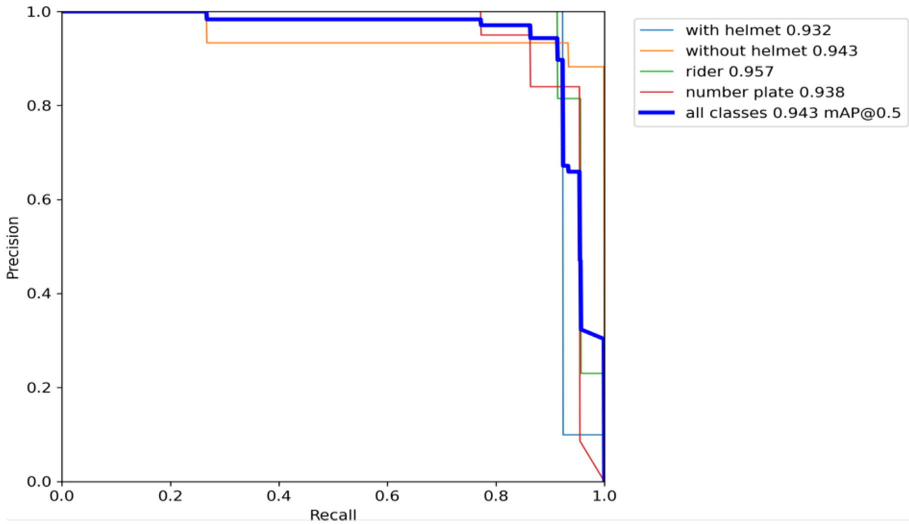


**Fig. 5.** Precision-Recall Curve

## 5 Conclusion

This research succeeded in developing an automated system of motorcycle helmet detection and license plate from Real-time Service. This is important for Bangladesh as here people are not interested in wearing a helmet law. It achieves high accuracy in real-world traffic through deep learning models, which includes YOLOv8 for object detection, ResNet50 helmet classification. The primary goal of the project was to develop a practical tool for law enforcement to help enforce helmet use and ultimately save lives in motorcycle-related traffic collisions.

As we can observe in the paper, the system performs well across metrics for accuracy (resolving whether there are any abnormal speeds detected or not), precision and recall rates of accurately determining those abnormal licenses), mean Aver- age Precision(mAP). With respect to the current solutions, this system provides a tradeoff between high performance and real-time efficiency making it feasible for deployment in busy traffic scenarios. Its operation is also in compliance with data privacy requirements, and it was realized as well within the departments of information ethics, legal restrictions but most importantly environmental impacts.

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