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AUTOMATED HELMET DETECTION AND NUMBER PLATE RECOGNITION USING AI

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Abstract-**Ensuring road safety by enforcing the law on two-wheel riders is a significant adverse effect due to the proliferation of vehicles and the restrictions of manual monitoring methods. Conventional surveillance methods rely on human observation, which is very time-consuming, not always reliable, and is prone to misidentification. This article puts forward a deep learning-based system for automated helmet detection and vehicle number plate recognition to facilitate the traffic rule enforcement. The proposed method utilizes YOLOv8n to quickly locate the riders, helmets, and vehicle number plates in the traffic images. To make the classification more stable and to decrease the number of false detections, LSTM networks are further utilized to enhance feature representation. OCR is employed to retrieve alphanumeric data from detected number plates, thereby facilitating automatic vehicle identification. Their system achieves remarkable precision in the detection of the changes in the environment and the lighting conditions, thus it lessens the requirement for the manual intervention and is of great assistance to the traffic surveillance department, as per the experimental results.**

Keywords-**Helmet Detection, Number Plate Recognition, YOLOv8n, LSTM, Traffic Surveillance**

I. INTRODUCTION

"Road enforcement for motorcycle users is a significant problem." Basically, this is a result of more vehicles on the roads and the less efficient manual road monitoring systems at the same time. Many accidents involving motorcycles result in situations where people get seriously injured because the users of motorized two-wheelers do not wear helmets. Traditional enforcement systems depend on human monitoring and offline video processing. Those are quite time-consuming and may lead to wrong results both in offline and online scenarios, especially in regions with dense road traffic conditions [1], [2].

Now, computer vision implemented with deep learning is a very powerful tool for rider detection, helmet checks, and number plate reading under tough real-world situations like varied lighting, obstacles, and camera angles [3], [5]. Along with it, computer vision Algorithms utilizing deep neural networks have been established as very reliable in detecting two-wheeler riders, checking of helmets, and reading of the number plate in difficult real-world conditions like varied lighting, obstacles, and camera angles [3].

Presently, YOLO-based object detection frameworks are being widely adopted in such fields as Automated helmet and license plate identification for they deliver accurate and real-time outputs. It is found that lightweight versions of YOLO are equally competent in detecting cyclists, helmets, and also in number plates without a high computation demand. Thus, they play a crucial role in real-time, extensive traffic surveillance analysis [4], [8], [10]. Conversely, In the majority of scenarios, some limitations as to inaccuracies in object detection due to image confusion, presence of clutter, and image quality problems in most of the images, which means the demand for better refinement techniques is quite pressing [6], [9].

In connection with the dissertation, a fully automated automated helmet detection and number plate recognition identification system by means of a hybrid deep neural network model will be put forward. To get traffic images, motorbike riders, helmets, and number plates are effectively located by the means of YOLOv8n [3]. To significantly increase the classification accuracy and remove misclassification, LSTM frameworks have been employed to fine-tune the extracted features thus ensuring that the developed system can work in different environmental settings efficiently. Optical character recognition (OCR) strategies are applied for the easy-to-understand alphanumeric data extraction from the given number plates aimed at the automated identification and tracking of motorbikes [7], [11], [14].

The system under discussion will enhance law enforcement efficiency by reducing the manual work involved and will be of great help in smart traffic monitoring. By adopting the most advanced object detection and recognition methods, the envisaged the proposed system will further contribute to the safety aspect but also facilitate the creation of smart cities with the help of safe and efficient transport systems [12], [15].

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II. LITERATURE REVIEW

In [1], a YOLO-Darknet based model detected helmeted and non-helmeted riders with 81% mAP. An automated system using YOLOv3 and SSD reached 80% accuracy on validation data [2]. YOLOv8 was used for helmet and vehicle number plate detection, showing improved performance [3]. A YOLOv3 based approach using CCTV footage achieved 83.23% accuracy [4]. A survey pointed out the benefits of deep learning algorithms as opposed to traditional methods for helmet detection and number plate recognition [5].

Neural network-based helmet identification and license plate detection systems were studied in [6]. Early detection of helmets and license plates violation processing was explored in [9]. ALPR systems for unconstrained scenarios using CNNs were proposed in [7]. Lightweight YOLOv5 models for real-time detection of helmets and vehicle license plates on electric bikes were developed in [8]. CNN based systems that combined identification of helmet use and number plates achieved moderate accuracy [10]. Other Machine Learning based approaches efficiently integrated both tasks [11]. YOLO based edge-deployable ALPR systems were presented in [12] and [13]. Unified pipelines for license plate detection and OCR improved end-to-end recognition [14]. Improved vehicle and plate recognition methods for intelligent transportation systems were studied in [15].

III. PROPOSED METHOD

The implemented system that has been proposed utilizes a Deep Learning–based method for automated helmet detection as well as number plate recognition from the images captured during the traffic. The system is designed to produce high accuracy in detection, to be strong even in different kinds of weather conditions, and to require very little human intervention. The method adopted changes the stages of input data treatment, object detection, feature refinement, and character recognition.

A. Data Collection and Preprocessing

Images showing people riding two-wheelers on the traffic are collected from open-access datasets and real-world sources. The data also consist of both riders with helmets and those without helmets with the number plates clearly visible. For the purpose of improving the quality of data and to improve the performance of the models, several preprocessing stages, such as image resizing, normalization, noise removal, and annotation have been carried out.

Image Normalization:

$$I_{norm}(x, y) = (I(x, y) - \mu) / \sigma$$

whereI (x, y) is the original pixel intensity, μ and σ denote the mean and standard deviation of the image dataset.

Image Resizing:

$$Ir = \mathrm{Resize}\ (I, H \times W)$$

where H×W denotes the target image dimensions.

B. Object Detection using YOLOv8n

YOLOv8n is used to detect riders, helmets, and vehicle number plates in a single forward pass. Its lightweight, anchor-free architecture enables fast and accurate detection of small and complex objects under varying lighting and conditions.

YOLO Detection Function:

$$\hat{Y} = f_{yolov8n}(I_{norm})$$

Where $\hat{Y}=\{(b_i,c_i,p_i)\}i^N= 1$, b_i is the bounding box, c_i is the detected class (rider, helmet, plate), and p_i is the confidence score.

YOLO Loss Function:

$$L_{yolo} = L_{\beta ox} + Lc_{ls} + L_{o\beta j}$$

C. Feature Refinement using LSTM

To improve classification stability, feature vectors extracted from YOLOv8n are passed through an LSTM network. This step reduces false detections and enhances the distinction between helmet and non-helmet regions.

LSTM Feature Update:

$$h_t = \mathrm{LSTM}(x_t\,, h_{t-1})$$

where x_t represents the feature vector extracted from YOLO at time t, and h_t is the refined hidden state.

D. Number Plate Identification through OCR techniques

Detected number plate regions are cropped and processed using OCR to extract alphanumeric text. Deep Learning–based OCR handles variations in font, spacing, and illumination, enabling reliable vehicle identification.

OCR Text Extraction:

$$T = focr(Rplate)$$

Where, R_{plate} is the cropped number plate region, and T is the extracted alphanumeric string.

E. Violation Identification and Output Generation

Non-helmeted riders are flagged as violations, and corresponding vehicle numbers are recorded. The system generates structured outputs suitable for automated traffic enforcement and reporting.

Helmet Classification Probability:

$$P_{\mathrm{helmet}} = \sigma(W\,h_t + b)$$

Violation Decision Rule:

$$V = 1\,if\,P_{\mathrm{helmet}} < \tau, else\ 0$$

Where V=1indicates a traffic violation and τ is the decision threshold.

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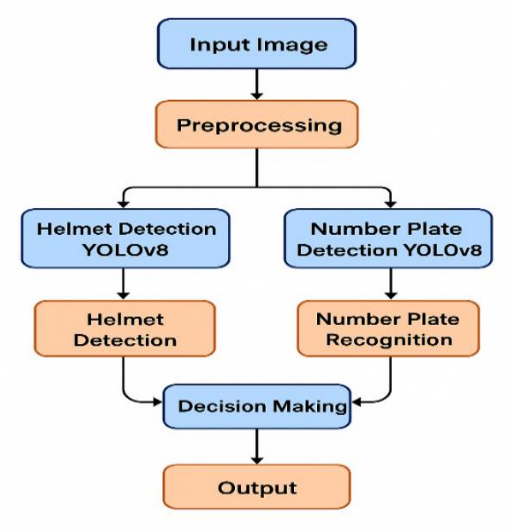

Figure 1: Data Flow Diagram

Figure 1 demonstrates the system workflow through which the automated the proposed system for helmet detection and number plate recognition, can be understood visually.

The system initiates with image input that is followed by image processing phases including image resizing, image normalization, and image denoising. The preprocessed image is fed concurrently to two YOLOv8-based object detection modules. The first module refers to helmet detection one, which ascertains the recognition of helmet presence on riders. The second component involves license plate detection one, which extracts the vehicle's registration number and proceeds with automated recognition. The decision-making component is the place where data from both modules are processed, thus confirming helmet compliance and, at the same time, associating the recognized vehicle registration number. Therefore, the system produces an output that displays helmet compliance and vehicle registration details.

IV. RESULTS

When comparing error precision and adaptability to other image processing methods and to the YOLO-based methods that were developed earlier, it is very clear that the proposed method with YOLOv8n yields better results. This is reflected by an F1-score of 0.90, mAP@0.5 of 0.941, and precision of 0.99 at high confidence thresholds. Consequently, all metrics exceeded those of other methods, which only resulted in mAP scores between 0.72 and 0.85.

Moreover, the consistency of the outcomes of training and validation, as well as the elevated quality of the confusion matrices also suggest correct classification and a low number of classification errors and the presence of specialized knowledge. The use of OCR technology with the help of number plate recognition makes the system more efficient in the automatic detection of traffic violations.

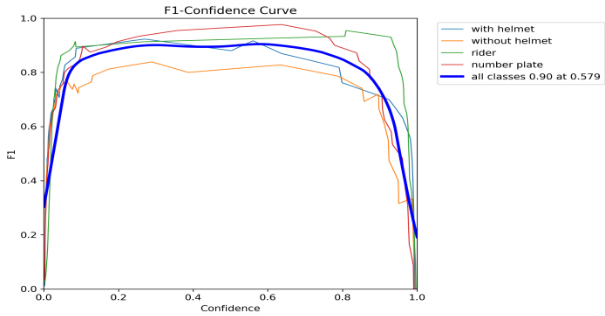

Figure 2: F1-Confidence Curve

From the F1-Confidence curve in FIG. 2, the variations of the F1-score for the helmet, without the helmet, rider, and number plate classes with the confidence threshold for the YOLOv8 model are noticeable. The confusion matrix further indicates that all the classes reach their best point between 0.4 and 0.7 confidence levels. When F1-score is plotted against confidence level, the merged model achieves maximum strength with an F1-score of 0.90 at a confidence level of 0.579. Evaluation via the confusion matrix reveals that all YOLOv8 model across all the object classes.

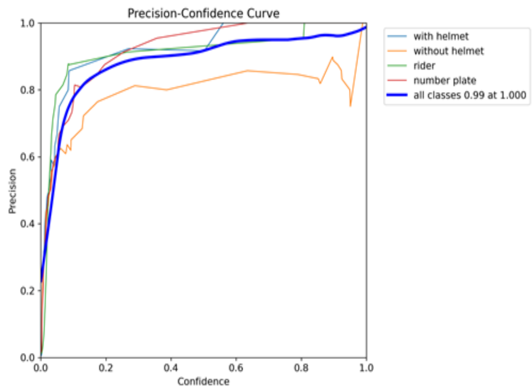

Figure 3: Precision-Confidence Curve

The Precision-Confidence graph shown in Figure 3 illustrates that precision goes up with the increment of the confidence threshold for all classes. This indicates the presence of less false positives with the confidence level getting higher. The precision values for the rider and number plate classes exceed those of the helmet classes because of the better visualization. The precision of the overall model is 0.99 at the confidence threshold of 1.0. It means that the YOLOv8 model is very accurate for the detection results with high confidence.

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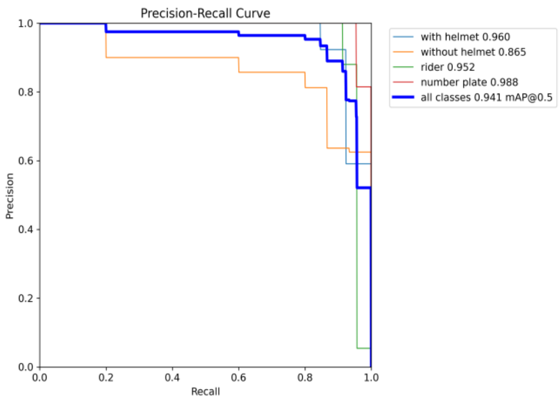

Figure 4: Precision-Recall Curve

The PR-curve in figure 4 visually demonstrates the YOLOv8 model's excellent accuracy for static images. The model reaches very high AP values for the classes of the helmet, rider, and number plate. However, the without helmet class achieves a marginal decrease in accuracy owing to the variations. The mAP@0.5 is 0.941, which is a strong confirmation of the model's high precision in traffic surveillance.

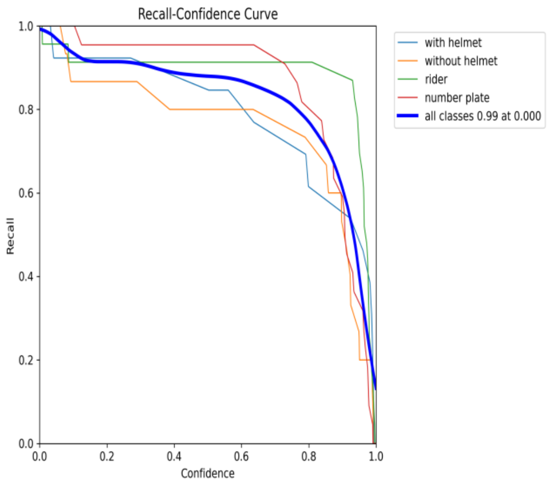

Figure 5: Recall-Confidence Curve

Figure 5 shows clearly that for Recall-Confidence, recall values are high at low confidence levels, and recall decreases as confidence increases. With respect to a rider, a number plate, and a helmet-related classes, recall is high at a moderate level of confidence. But, the ones with a helmet only have a slightly quicker drop-off in recall. In general, the joint classifier performance is great.

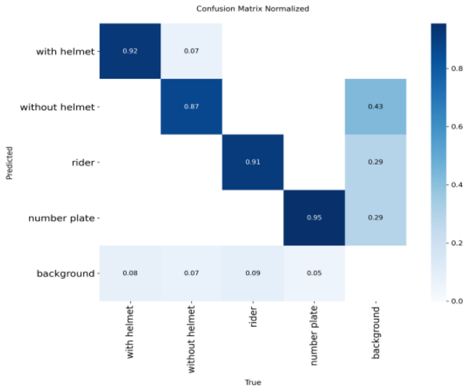

Figure 6: Normalized Confusion Matrix

Figure 6 shows the normalized confusion matrix, which is an indication of the superior classification performance for all classes. This means that the highest values are shown on the diagonal for the detection of helmets, riders, and number plates. Besides that, it also shows a few slight confusions to the background class, however, these confusions are to be expected in a complex scenario. The results therefore show the effectiveness of the algorithm in handling still images beyond any doubt.

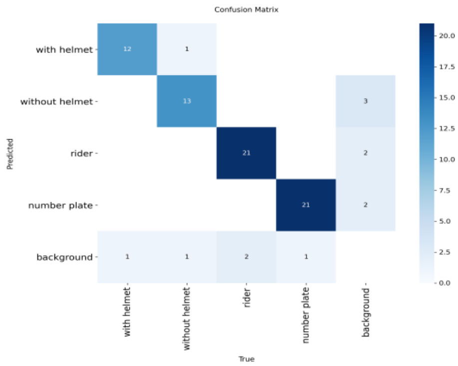

Figure 7: Confusion Matrix

From the confusion matrix in figure 7, the classification performance of the different classes can be considered as good. A large number of riders and registration numbers have been successfully detected. Also, the helmet and no helmet classes have been accurately identified without any misclassification. A limited number of errors are observed in the background class that are inevitable when referring to real images.

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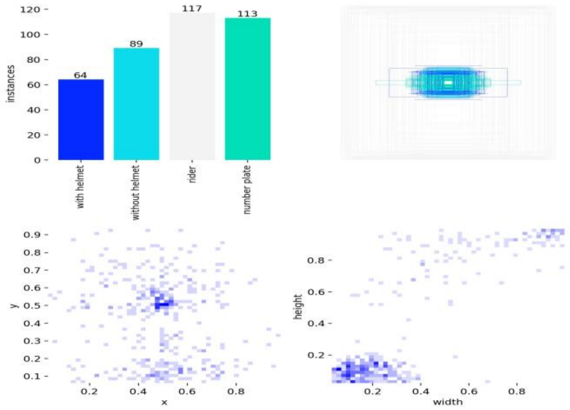

Figure 8: Dataset Class Distribution and Bounding-Box Spatial Analysis

In figure 8, the figure above emphasizes the dataset distribution and the bounding box properties used for training. The dataset's two primary classes are rider and number plate, by which the classes of without helmet and with helmet that simulate real practical scenes of road-going vehicles follow. The graphical representation of the used bounding boxes and heat maps indicates that most of the objects are around the image center. Number plates are in smaller boxes, and the other two are in medium boxes. This confirms that the dataset is organized well and can be used for accurate detection in static images.

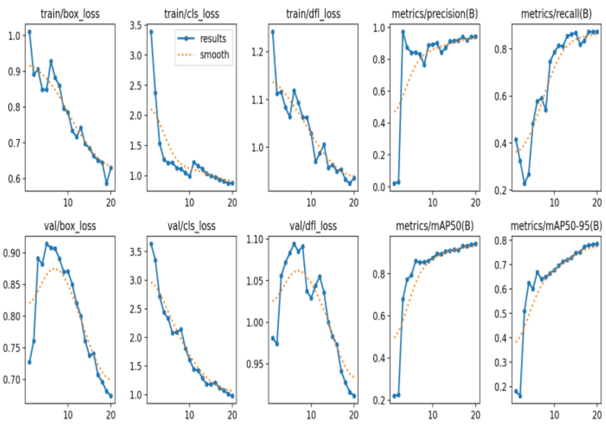

Figure 9: YOLOv8 Training vs Validation Loss and Performance Metrics Across Epochs

The graph in figure 9 shows how the YOLOv8 model performed on the training and validation sets for 20 epochs. Each epoch training and validation loss for the box, class, and DFL parts were reduced. This signifies that the model has learned successfully and that there is no chance of overfitting. Precision, recall, mAP50, and mAP50-95 parameters continue to achieve improved with the augmentation of epochs. At the last epoch, the precision and recall value are even greater than 0.90, and the mAP50 value is close to 0.96.

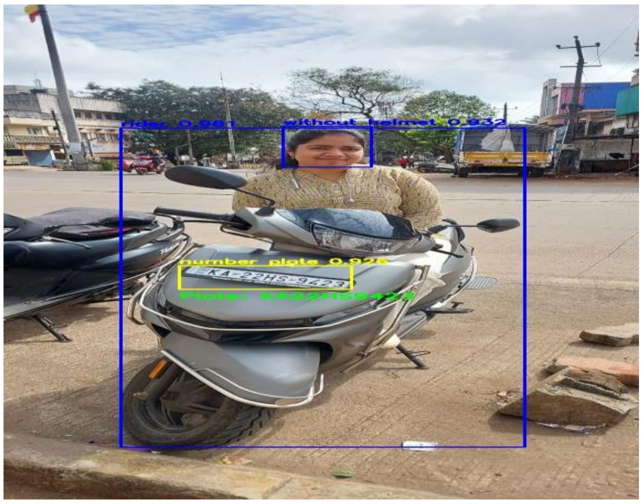

Figure 10: Final Output

The output associated with the proposed system is shown by the image in figure 10. The rider is detected by YOLOv8n, and it operates as noted that the individual is not wearing a helmet, thus, a helmet violation is indicated. Moreover, vehicle's number plate along with its text KA22HS9423 is also detected which can be seen. This indicates the system's capability of automated traffic monitoring for helmet violations as well as vehicle details through the proposed system.

V. CONCLUSION

The system aims to be equipped with the ability of detecting helmets and facilitating number plate recognition. Such system is planned to involve YOLOv8n implementation, enhancement by the LSTM method, and OCR. This technique ensures a high level of accuracy and reliable detections of images referring to traffic still images. By the means of a system that can very well verify helmet violations and also read out the car registration details, the human work in the traffic management process is almost totally done away with. This method may serve as a tool for raising road safety levels and for the advancement of intelligent transportation systems.

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