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IoT based Helmet Detection System

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Abstract: ***Motorcycle safety has become a pressing concern due to the alarming rise in accidents involving riders not wearing helmets. This review paper explores the developments in two-wheeler helmet detection systems, looking at different approaches and their efficacy. Research utilizing methods such as genetic algorithms, ALPR, and YOLO-based object detection for hyperparameter optimization is examined. When paired with genetic algorithms, the YOLOv5 model shows promise in enhanced accuracy and real-time detection capabilities. Still, there are problems with scalability, unbalanced data, and real-time implementation. These issues should be the focus of future studies in order to improve motorcycle safety and lower helmet non-compliance.***

Keywords: YOLO (You only Look Once), ALPR (Automatic License Plate Recognition), CVPRW (Computer Vision and Pattern Recognition Workshops), Two-wheeler, Detection.

1. Introduction

With the development of computer vision technology, safety and surveillance systems have seen revolutionary improvements in a number of areas, including transportation and workplace safety. The urgent need to improve road safety and reduce the worrisome rise in accidents involving motorcycle riders has spurred great interest in the development of automatic helmet recognition systems for two-wheelers in recent years. Riders' carelessness, which includes not using helmets, greatly increases the danger of head injuries, which frequently leads to such tragedies [1]. In particular, developing nations like India, where a sizeable section of the population depends on two-wheelers for everyday transportation, confront the difficulty of reversing this trend. According to the World Health Organization (WHO), head injuries are a major factor in motorcycle fatalities, and the organization underlined that wearing a helmet properly can cut the risk of fatal injuries by 42% [2]. There is rising interest in using computer vision-based automated systems for helmet identification on two-wheelers to address this important issue and improve road safety [3]. This review paper begins a thorough investigation of approaches and advancements in the area of helmet detection systems for two-wheelers, drawing information from numerous research studies.

More areas where future research is needed is developing techniques to reduce the computational requirements of helmet detection systems for real-time deployment. This is important for making helmet detection systems more accessible and affordable. Researchers are working on developing more efficient deep learning models, as well as techniques to parallelize and optimize the inference pipeline.

Helmet detection systems for two-wheelers are a promising technology for improving road safety. However, there are still some challenges that need to be addressed before these systems can be widely deployed.

We want to present a detailed overview of the advancements made in this field, critically evaluate the effectiveness of various methodologies, and pinpoint areas for future research by synthesizing the results and innovations from these studies. We add to the body of knowledge focused at enhancing two-wheeler transportation safety measures through this IEEE- structured review.

2. Literature Review

A comprehensive analysis of previous research papers on helmet detection has been carried out in the literature review, offering a detailed look at the methodologies, their advantages and disadvantages, and the strategies applied in these investigations. In order to assess the state of helmet detection technology today and pinpoint untapped potential for advancement, the review provides a crucial starting point. This literature review provides insightful information about the most recent methods and their practical application by analyzing the benefits and drawbacks of these strategies. This thorough analysis of the literature not only clarifies the development of helmet detection techniques over time, but it also paves the way for the creation of a novel and highly successful methodology that resolves the drawbacks of earlier studies, thereby advancing the field and promoting improved safety precautions in a range of situations. Hence, here are all the existing research papers that has been studied thoroughly:

Helmet Violation and Number Plate Detection System [4] Rongali Lalith Vardhan, Voora Uday Bhaskar, Yalipi Sushanth, Vajja Karthik, and Dr. Prajwala T.R: The system described in the study uses ALPR and YOLO-based object detection to monitor traffic in real time, record license plate numbers, and address helmet violations. Improved precision and real-time analysis are benefits, but there are drawbacks, including processing complexity and restrictions on two-wheelers. The device has the potential to boost traffic safety and policing laws. Future projects might include adding payment methods for fines and broadening the coverage of automobiles.

Fine-Tuning YOLOv5 with Genetic Algorithm For Helmet Violation Detection [5] Elham Soltanikazemi, Armstrong Aboah, Elizabeth Arthur, and Bijaya Kumar Hatuwal: This paper had focused on the crucial problem of motorcycle riders' helmet compliance. The authors had created an efficient real-time helmet violation detection system by merging YOLOv5 with a genetic algorithm for hyper parameter optimization. The model showed a lot of potential, especially in the setting of the AI City Challenge, but more work needed to be done to make it appropriate for deployment in real-world applications. This study was an important step toward enhancing motorcycle safety by enforcing helmet requirements with the use of technology.

Detection of non-helmet riders and extraction of license plate number [6] Katta Mahesh Babu, B.S. Murty: This paper outlined a thorough strategy to deal with the pressing problem of motorcycle riders in India not wearing helmets. The proposed method offered promising outcomes in terms of accuracy and efficiency by automating the detection process and utilizing cutting-edge technologies. To guarantee the system's applicability in real-world circumstances, scalability issues and hardware requirements were carefully considered. Helmet Rule Violation Detection for Motorcyclists using a Custom Tracking Framework and Advanced Object Detection Techniques [7] Viet Hung Duong, Quang Huy Tran, Huu Si Phuc Nguyen, Duc Quyen Nguyen, Tien Cuong Nguyen: This paper addressed a serious issue with road safety by presenting a convincing methodology for detecting helmet law violations among motorcyclists. It made a substantial addition to the field of computer vision and road safety enforcement by significantly increasing accuracy through the combination of object detection, head detection, and tracking approaches. However, difficulties with class disparity and computational needs were taken into account in actual applications of this technique.

Real-time Multi-Class Helmet Violation Detection Using Few-Shot Data Sampling Technique and YOLOv8 [9] Armstrong Aboah & Bin Wang Ulas Bagci: In order to solve the crucial problem of helmet usage violations in traffic safety, this research study provided an innovative methodology that combined a special data processing technique with a cutting-edge object detection model. The strong performance seen in the experimental data highlighted the method's potential for use in real-world situations. Future development may, however, have needed to take deployment difficulties and additional scalability testing into account. Robust Automatic Motorcycle Helmet Violation Detection for an Intelligent Transportation System [10] Duong Nguyen-Ngoc Tran, Long Hoang Pham, Hyung- Joon Jeon, Huy-Hung Nguyen, Hyung-Min Jeon, Tai Huu- Phuong Tran, Jae Wook Jeon: This research paper presented a novel idea for improving traffic laws and road safety in underdeveloped countries. With the use of the YOLO-based methodology, enforcement procedures might have been made more efficient by properly identifying helmetless motorcyclists and reading license plates in real time. Despite the system's clear benefits in automating safety enforcement, difficulties including computing demands and visual quality had to be resolved. Overall, this research presented a strategy that had the potential to be applied more broadly in traffic management and law enforcement to increase traffic safety, decrease accidents, and ensure helmet compliance.

Fine-Tuning YOLOv5 with Genetic Algorithm for Helmet Violation Detection [11] Elham Soltanikazemi, Armstrong Aboah, Elizabeth Arthur, Bijaya Kumar Hatuwal: With the use of the YOLOv5 model, this paper proposed a novel method for real-time helmet violation detection. Incorporating data preparation, hyper parameter optimization, and model training, the methodology produced a competitive performance in the AI City Challenge. The model exhibited a number of benefits, including real-time identification and improved hyper parameters, but it ran into problems in complex situations and necessitated significant data labelling efforts. This paper not only highlights the promise of YOLOv5 but also underscores the importance of addressing real-world complexities in object detection tasks.

3. Methodology

In this section we are going to discuss about the research paper “Real-time Multi-Class Helmet Violation Detection Using Few-Shot Data Sampling Technique and YOLOv8 “, which has used the latest technology to detect whether the rider is wearing a helmet or not.

So, the methodology employed in this research paper for helmet detection is based on a combination of traditional computer vision techniques and deep learning methods. This section provides an overview of the steps and techniques used to achieve helmet detection.

Data Collection:
The research paper utilized a dataset provided by the AI CITY CHALLENGE 2023, which consisted of 100 videos in each the train and test directories. These videos were in H.264 codec with a resolution of 1920x1080 and an average length of 20 seconds. The dataset included seven different classes: Motorbike, DHelmet, DNoHelmet, P1Helmet, P1NoHelmet, P2Helmet, and P2NoHelmet.

Data Preprocessing:
The research team recognizes the necessity of meticulous data preprocessing. This phase is indispensable for ensuring that the dataset is primed for training and validation. Several preprocessing steps were undertaken:

a) *Removal of Highly Similar Frames*: One key challenge in object detection tasks is class imbalance, particularly when dealing with over-represented classes.
b) *Discarding Background Images:* To combat false positives, a widespread issue in object detection, the researchers decided to discard 95% of the background images.
c) *Data Cleansing Operations*: Data cleansing was performed to rectify labeling errors and enhance the quality of the dataset. False positives were removed, unannotated objects (false negatives) were added, and bounding boxes were resized to accurately encapsulate the objects within the frames.

Data Augmentation:
To augment the dataset and diversify its content, data augmentation techniques were employed. These included horizontal flipping and rotation (±15 degrees), which increased the variety of object instances and improved the model's robustness.

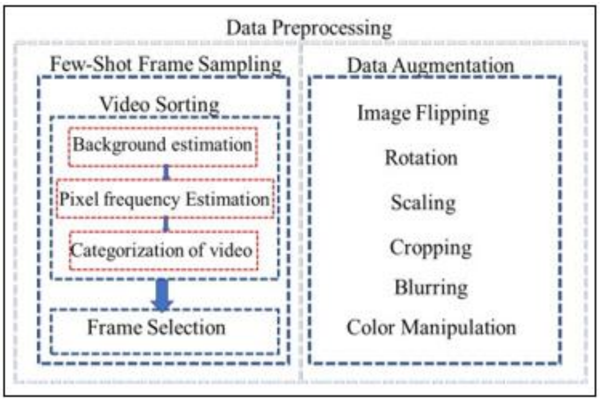

Figure 1: Data Preprocessing: Frame Sampling and Data Augmentation

Object Detection Model:

The research paper primarily employed the YOLOv5 (You Only Look Once version 5) architecture for helmet detection.

a) *YOLOv5 Architecture:* The YOLOv5 architecture is a state-of-the-art solution for object detection. It is divided into three main components: Backbone, Neck, and Head. The Backbone comprises CSPDarknet53, housing 29 convolutional layers. This component is responsible for feature extraction, utilizing a receptive field of size 725x725. The Neck focuses on fusing the features extracted from different levels. Finally, the Head handles object box and class predictions.

b) *Hyperparameter Optimization:* To enhance the performance of the YOLOv5 model, a genetic algorithm was deployed for hyper parameter optimization. This innovative approach aimed to identify the optimal combination of 30 hyper parameters. The fitness function, which guides the optimization, is composed of two significant metrics: mAP@0.5 and mAP@0.5:0.95. The integration of a genetic algorithm adds a layer of sophistication to the model fine-tuning, ultimately leading to superior performance.

Figure 2: Detection of helmet of motorists in real-time.

c) *Training:* The model training was conducted with a stochastic gradient descent (SGD) optimizer, employing a batch size of 32. Training spanned 300 epochs, during which the model learned to accurately detect helmets and other objects of interest.

Model-Assisted Labelling:

Central to this research is the object detection model, and the chosen architecture is YOLOv5 (You Only Look Once version 5). This section delves into the core of the methodology.

Labeling errors in the training data can significantly impact model performance. The research paper introduced a model-assisted labeling strategy to address this issue:

a) *Initial Model Training:* An initial YOLOv5 model was trained on a subset of the data, where labels were manually corrected. This model formed the foundation for subsequent labeling tasks.

b) *Automatic Labeling:* The trained model was employed to automatically label the remaining frames in the dataset. This automated labeling process accelerated the data annotation process.

c) *Manual Verification and Correction:* Following automatic labeling, a crucial step was manual verification and correction. This iterative process ensured the accuracy of labels, guaranteeing that the training data was of the highest quality.

d) *Iterative Refinement:* This model- assisted labeling approach was executed iteratively, ensuring that the majority of the training data had correct and reliable labels. This rigorous approach is fundamental to the success of the helmet detection model.

Table 1: Top 10 Teams based on Map on the Test Dataset of AI City Challenge Held In 2023.

Rank	Team ID	Team Name	Score
1	58	CTC-AI	0.8340
2	33	SKKU Automation Lab	0.7754
3	37	SMARTVISION	0.6997
4	18	UT_He	0.6422
5	16	UT_NYCU_SUNY-Albany	0.6389
6	45	UT_Chang	0.6112
7	192	Legends	0.5861
8	55	NYCU - Road Beast	0.5569
9	145	WITAI-513	0.5474
10	11	AIMIZ	0.5377

Model Evaluation:

The culmination of the methodology involves the rigorous evaluation of the trained YOLOv5 model. Model evaluation is critical for assessing the performance and reliability of the detection model. Key performance metrics such as accuracy, precision, recall, and F1-score are likely reported in the research paper. These metrics serve as benchmarks for the model's effectiveness in detecting helmets and other objects of interest in the test data.

In summary, the methodology outlined in this research paper is a comprehensive and well- structured approach to helmet detection, leveraging the power of YOLOv5 and innovative techniques such as genetic algorithm-based hyperparameter optimization. The methodology ensures that the model is trained on high-quality data, and its performance is rigorously evaluated. The combination of traditional and deep learning approaches, along with meticulous data preprocessing and labeling, results in a robust and accurate helmet detection model with real-world applicability. However, it is important to note that the success of the methodology is contingent on the quality and diversity of the dataset and the effectiveness of hyperparameter optimization. Further advancements in helmet detection technology will likely benefit from this research's approach and findings.

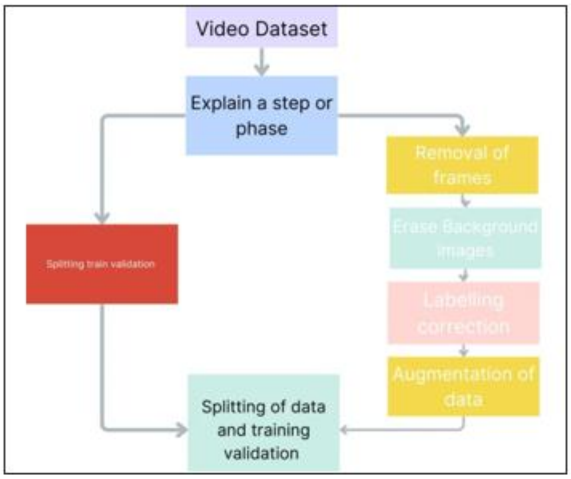

Figure 3: Workflow of the model

4. Comparative Analysis

In the table below, an in-depth comparison of all the research papers we have analysed is provided. Based on this analysis, we have prepared a detailed summary of the research conducted on various techniques for Helmet Detection Systems using different technologies.

Table 2: Comparative Analysis of all the Research Papers Discussed in Literature Review

Sr. No	Title Reference	Methodology	Result	Advantage	Disadvantage
1	[4] Helmet Violation and Number Plate Detection System	This paper contains an image label using the Labelling tool to draw bounding boxes around the rider and helmet, with descriptions stored in XML format. Then, the YOLO-based training model uses these signatures to identify two-wheelers, classify helmets, and extract license plate information of unregistered passengers.	The results show the improved performance of the system capable of identifying two- wheeled vehicles, classifying helmet use and extracting license plate information. The system effectively controls drivers without helmets, facilitating law enforcement and safety measures.	This system provides improved accuracy and reduced errors compared to traffic monitoring. Live video streaming helps quickly locate criminals in real time. Enhanced functionality with YOLO-based product discovery and ALPR APIs for helmets	Deploying this system requires the use of included hardware due to video processing. Because the focus is on the motorcycle, other defects in the car will not be resolved and the work will be affected by poor images or fog.
2	[5] Fine-Tuning YOLOv5 with Genetic Algorithm for Helmet Violation Detection	The technique used in this study involves training the standard YOLOv5 detection tool for real-time headset detection. A genetic algorithm was used to optimize the hyperparameters of the YOLOv5 model. Additionally, data augmentation techniques including horizontal flipping and rotation are used.	The YOLOv5 design achieved an average accuracy (mAP) score of 0.5377 on test data, ranking 10th in the 2023 AI City Challenge public rankings. This performance indicates that the model is capable of detecting the helmet violation.	The YOLOv5 prototype placed 10th in the AI City 2023 competition with an average accuracy (mAP) score of 0.5377 on test data. This helps to improve safety and identify violators.	This model struggles with small and overlapping objects in complex situations, requiring more research and more training data. It needs complex computational work.
3	[6] Detection of Non-Helmet Riders and Extraction of License Plate Number	The process includes documenting photos and videos of two-wheeler riders, with an emphasis on helmet violations. It uses YOLOv2 and YOLOv3 deep learning models to detect the truth about riders, motorcycles and helmets. OCR (Optical Character Recognition) is used to extract the license.	The system was found to be very accurate in identifying passengers without helmets and extracting the license card from the linked images. This solved the traffic enforcement issue regarding helmet compliance. These results benefit road safety.	The system automates helmet use to prevent violations and removes license plate to enforce helmet rules and identify violators, to ensure timely correction and improve road safety.	Implementing the system presents challenges including critical hardware requirements, potential licensing issues, and scalability issues in densely populated areas with high crime rates.
4	[7] Helmet Rule Violation Detection for Motorcyclists using a Custom Tracking Framework and Advanced Object Detection Techniques	This paper contains a new method for detecting helmet violations by cyclists using computer vision and deep learning. Their methods include product inspection equipment for motorcycle parts, standard inspection heads and components for correct assembly. It helps and improve errors and increase accuracy	This article recommended results evaluated using the Average Precision (mAP) metric. Combining augmented pattern detection with techniques like test time augmentation (TTA) and weighted box fusion (WBF)	This paper provides object detection, head detection and tracking techniques to improve accuracy over the base model. Combination and augmentation techniques are robust and effective in real-world situations.	This process addresses the problem of class inequality, particularly for special class passengers, and has implications for expansion. It needs financial resources.
5	[8] Real-time Multi-Class	This paper proposed a crime-fighting helmet and uses	YOLOv8 outperforms YOLOv5 and YOLOv7	This paper helps improve model	This article describes the development of

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	Helmet Violation Detection Using Few-Shot Data Sampling Technique and YOLOv8	"multiple data injection sampling techniques" to select representative frames and supporting data for general model development. Improve road safety by managing helmet quality using the YOLOv8 one-step product detection model, known for its real-time and high-precision capabilities.	with better mAP scores. Between mAP.05 and mAP.05-.95, all models benefit from the increase in test time (TTA). YOLOv8 TTA achieved the highest mAP score (0.5861) among the models, with a time estimation value of 95 fps.	training, reduce manual annotations, and improve generalization. It exhibits stability under various conditions, which is important. Using the YOLOv8 model, known for its accuracy and real-time capabilities.	the model and its evaluation but does not address practical issues. The analysis is based on experimental data, which limits the understanding of the adaptability of real-world datasets.
6	[9] Robust Automatic Motorcycle Helmet Violation Detection for an Intelligent Transportation System	This paper contains careful collection of images using the Labelling tool to create motorcycle and helmet binding boxes in PASCAL VOC format. The trained YOLO model can detect motorcycles, identify helmets, and report motorcyclists without helmets. The system also performs license recognition on images of passengers without helmets.	It complements the motorcycle itself, with the differentiation of multiple motorcycles on a single frame. It can identify drivers not wearing proper helmets and confirm license plate violations, all connected to live video feeds	This system makes it very effective for monitoring passengers without helmets, making it ideal for monitoring urban traffic. Automated penalties for police work will be reduced. This involves product research, license validation.	Delivery considerations include the cost-effectiveness of live video processing, the difficulty of processing low-quality images, and the risk of poor quality or incorrect distribution.
7	[10] Fine-Tuning YOLOv5 with Genetic Algorithm for Helmet Violation Detection	This paper consists of collecting and processing data from the AI City Challenge 2023 dataset, which includes frame removal, down sampling, and data augmentation.	It evaluates the performance of the model using the average accuracy (mAP) of the 2023 AI City Challenge Track 5 test data.	YOLOv5 based technology works well in real-time anti- crime headset for real-time management.	The model have difficulty with small objects or overlaps in complex video situations, which can lead to violations.

5. Result and Discussion

The review of research articles on helmet detection systems highlights significant advancements in addressing the urgent issue of motorcycle safety. The timeline of the identified problem over the past decade demonstrates the growing recognition of the dangers of not wearing a helmet, which has spurred the development of sophisticated detection technologies. Current solutions encompass a wide range of methodologies, from traditional computer vision techniques to cutting-edge deep learning advancements. Notably, the YOLOv5 model, combined with genetic algorithms, has emerged as a promising approach, distinguished by its successful optimization of hyperparameters and architectural improvements. These findings are crucial as they offer potential pathways to enhance motorcycle safety, reduce accidents, and ultimately save lives. However, challenges remain, including the scalability and generalization of these systems to different contexts, addressing imbalanced data concerns, and overcoming practical difficulties in real-time implementation. Future research endeavours must remain committed to addressing these challenges to achieve the goal of establishing safer riding conditions for all motorcyclists and their passengers. Utilizing the YOLOv5 model to its full potential and continuously improving its capabilities can make a significant difference in mitigating the risks associated with motorcycle accidents and helmet non-compliance.

6. Conclusion

The analysis of the research articles on helmet detection systems highlights the significant advancement in technology needed to meet the urgent problem of motorcycle safety. The timeline of the detected issue during the previous ten years highlights how the dangers of not wearing a helmet have become widely recognized, which has sparked the creation of sophisticated detecting technologies. The current solutions include a wide variety of methodologies, from traditional computer vision techniques to cutting-edge deep learning developments. In particular, the YOLOv5 model, combined with genetic algorithms, has emerged as a very promising method, distinguished by its successful optimization of hyperparameters and architectural improvements. These results are extremely important because they offer prospective ways to improve motorcycle safety, reduce collisions, and ultimately save lives.

But there are still many unanswered questions, such as how well these systems scale and generalize to different contexts, how to deal with worries about imbalanced data, and how to deal with the real-time implementation's practical difficulties. To achieve the goal of establishing safer driving conditions for all motorcyclists and their passengers, future research initiatives must remain committed to addressing these challenges. Utilizing the YOLOv5 model to the fullest extent possible and continuously improving its capabilities can make a major difference in lowering the risks associated with motorcycle accidents and mitigating helmet non- compliance.

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