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HELMET COMPLIANCE DETECTION USING COMPUTER VISION FOR SAFER ROADS

A Thesis Project
presented to the Faculty of
College of Computer Studies

In Partial Fulfillment of the Requirements
for the degree Bachelor of Science in Computer Science

By
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May 2025

APPROVAL PAGE

In partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science, this research entitled **HELMET COMPLIANCE DETECTION USING COMPUTER VISION FOR SAFER ROADS** prepared and submitted by **Dela Justa, Aina Mae F.**, **Epres, Caren Joy L.**, **Matubis, Maria Angela N.**, , has been examined and is recommended for approval and acceptance.

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DEDICATION

Ad Majorem Dei Gloriam

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ABSTRACT

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CHAPTER 1

INTRODUCTION

This chapter will introduce the study, which will address the issue of motorcycle accidents that will be caused by riders who will not wear helmets. It will outline the proposed Helmet Compliance Detection Using Computer Vision for Safer Roads, along with its objectives, significance, scope, and key terms.

Background of the Problem

Motorbike accidents have been steadily increasing worldwide, leading to severe injuries and fatalities. One major contributing factor is the lack of helmet compliance and the dangerous practice of triple riding. In India alone, over 37 million individuals own and operate two-wheelers, making it critical to implement an effective monitoring system to enforce safety regulations and reduce accidents. A webcam is used for real-time video input, capturing and processing images to detect violations. The trained neural network then analyzes the webcam input, providing output based on the learned data. The system achieves an estimated 70% accuracy, with future improvements aimed at enhancing detection precision and real-time performance.[11]. Many motorcyclists frequently violate traffic rules by not wearing helmets, and enforcement by traffic police is often limited due to the demanding nature of manual monitoring. This automated helmet detection prototype has the potential to enhance traffic law enforcement and reduce human intervention, leading to safer road environments [4].

The requirement for ongoing surveillance, particularly in busy locations or along lengthy stretches of road, exacerbates this problem. The safety of motorcycle riders is directly put at risk by the ineffectiveness of the enforcement procedures. The creation of an automated, vision-based safety identification and monitoring that can precisely identify the presence or absence of helmets in real-time is required to solve this issue [10]. Given the significant portion of traffic-related fatalities attributed to motorcycle accidents resulting from non-compliance with helmet regulations. Acknowledging the critical role of helmets in rider protection, this paper presents an innovative approach to helmet violation detection using deep learning methodologies [18].

Deep learning is a subset of machine learning that uses artificial neural networks to learn from large amounts of data. In automatic helmet detection, deep learning models are trained using large datasets of helmet-wearing and non-helmet-wearing people. The neural networks learn to recognize the features that distinguish helmet-wearing one from non-helmet-wearing one . Once trained, the deep learning model can be used to automatically detect whether one is wearing a helmet or not [20].

Motorcycle-related accidents have become a growing concern worldwide, significantly contributing to road injuries and fatalities. According to the World Health Organization (WHO), more than 1.35 million people die annually due to road crashes, with motorcycle riders being among the most vulnerable. One of the leading causes of these accidents is the failure to wear helmets, which serve as a critical protective measure against head injuries. Despite laws mandating helmet use, non-compliance remains a widespread issue, exacerbated by weak enforcement and inadequate monitoring. In the Philippines, motorcycle accidents have significantly increased over the years, making it one of the leading causes of road fatalities. According to the Metropolitan Manila Development Authority (MMDA), in 2022, motorcycle-related accidents accounted for more than 30% of road crash incidents in Metro Manila alone, resulting in severe injuries and fatalities and reported a 17.3 percent increase in motorcycle-related road crashes in 2023. Based on the data from its Road Safety Unit, the MMDA said that a total of 26,599 motorcycle-related crashes were recorded in 2022 [13].

Republic Act No. 10054, also known as the Motorcycle Helmet Act of 2009, mandates that all motorcycle riders and their passengers wear standard protective helmets while on the road. This law aims to reduce head injuries and fatalities by ensuring that helmets meet specific safety standards. Despite the implementation of Republic Act No. 10054, also known as the Motorcycle Helmet Act of 2009, which mandates all motorcycle riders to wear standard protective helmets, many riders continue to violate this law, leading to preventable deaths [16].

A major challenge in enforcing helmet compliance is the reliance on manual monitoring by law enforcement officers, which is often inconsistent and inefficient. Traditional methods such as road checkpoints and manual inspections require significant resources and are prone to human error. Moreover, with the increasing number of motorcyclists on the road, it has become nearly impossible for authorities to monitor helmet compliance effectively. The absence of a scalable and automated monitoring system contributes to the ongoing problem, creating a need for technological solutions that ensure stricter enforcement of traffic laws.With advancements in artificial intelligence (AI) and computer vision, deep learning technologies have emerged as powerful tools for automating helmet compliance detection. Deep learning, a subset of AI, enables machines to process vast amounts of visual data, recognize patterns, and make accurate classifications. Technologies such as YOLO (You Only Look Once), OpenCV, and TensorFlow allow for real-time helmet detection with high precision, making them ideal for traffic monitoring applications. These technologies have been widely implemented in smart surveillance systems for vehicle detection, passenger counting and now, helmet compliance monitoring.

To address the limitations of manual enforcement, this research proposes the development of a Helmet Compliance Detection prototype using computer vision and deep learning algorithms to automatically detect whether motorcycle riders are wearing helmets correctly. The prototype focuses on enhancing helmet compliance monitoring through several key features. It can accurately determine if a rider is properly wearing a helmet on their head and not just carrying it, it will also verify if the helmet is securely fastened and correctly positioned. Helmets can generally be classified into several categories based on their structure and intended use. The prototype will concentrate on the standard motorcycle helmet, which covers the entire head and includes a chin strap and often a visor. This type of helmet offers the most protection and is typically required by law in many regions. The prototype also includes helmet classification by vehicle type, ensuring that riders wear the appropriate helmets corresponding to their vehicles. For example, motorcycle helmets for motorcycles, bicycle helmets for bicycles, and helmets designed for e-bikes for e-bike riders. This helps prevent the use of improper or mismatched helmets, which are flagged as violations to promote stricter adherence to safety standards. Moreover, the prototype enforces passenger limits by counting riders to ensure no more than two people are on a motorcycle at any time, any overloading is automatically flagged as a violation. Upon detecting any violations, a red warning is displayed on the system monitor, and the prototype automatically saves short video clips as evidence, supporting authorities in tracking and penalizing repeat offenders. By integrating these features, the prototype aims to improve road safety, assist law enforcement in effectively implementing helmet laws, and ultimately reduce motorcycle-related accidents and fatalities.

Statement of the Problem

Many motorcycle riders do not follow helmet laws, which can lead to a high risk of accidents, serious injuries, or even death. Traffic officers currently face challenges in manually checking whether motorcycle riders are wearing helmets, as the process is time-consuming and requires significant effort. Since officers cannot monitor every rider, many violations go unnoticed, making the enforcement of helmet laws difficult. Identifying helmet usage under various conditions will be a challenge for the proposed prototype. In poor lighting such as at night or in dark areas the prototype may struggle to clearly identify the rider's head. Similarly, in adverse weather conditions like fog or heavy rain, recognizing helmets will be difficult. When there are large numbers of motorcycles, it will be hard to check if each rider is wearing a helmet. Because of these challenges, the proposed prototype will need to be tested to ensure it can accurately detect helmets and provide reliable results. It will be evaluated under different conditions such as varied weather and lighting. Its speed and real-time detection performance must also be assessed to ensure it will be reliable in supporting road safety efforts.

Objectives of the Study

This section outlines the study's objectives in developing an AI-based helmet detection prototype to improve road safety.

General Objective

The main objective of this study will be to design and develop a Helmet Compliance Detection Using Computer Vision for Safer Roads that will effectively monitor and detect helmet violations among motorcycle riders using Artificial Intelligence (AI), Deep Learning, and Computer Vision. This prototype will aim to provide an accurate and automated solution for identifying non-compliance with helmet regulations, reduce the reliance on manual monitoring, and enhance the enforcement of road safety laws.

Specific Objectives

The specific objectives of this study are as follows:

1. Implement deep learning models using YOLO with TensorFlow for object detection, and OpenCV for image and video processing.
2. Develop an Artificial Intelligence-based prototype integrating the implemented models for helmet detection.

3. Evaluate the performance of the designed helmet detection prototype under different conditions such as lighting variations, weather changes, and multiple riders.

Significance of the Study

This study will focus on applying Artificial Intelligence in traffic law enforcement, particularly in monitoring motorcycle helmet compliance. It will benefit the following stakeholders:

- **Students.** Particularly those studying Computer Science can gain valuable insights into the practical applications of AI in traffic law enforcement. This study serves as a reference for developing intelligent transportation systems and encourages innovative approaches to road safety.

- **Motorcycle Riders.** By ensuring helmet compliance, the prototype promotes rider safety, reducing the risk of severe injuries or fatalities. It encourages responsible riding behavior and contributes to safer roads.

- **Law Enforcement.** The prototype automates helmet compliance monitoring, reducing manual inspections and improving accuracy. It enhances efficiency, minimizes human error, and provides valuable data for road safety policies.

- **Camarines Sur.** The implementation of this prototype can benefit Camarines Sur by improving road safety and reducing motorcycle-related accidents. Local authorities can use this technology to enhance traffic enforcement, ensuring compliance with helmet laws and fostering a safer commuting environment for residents.

- **Researcher.** This research establishes a foundation for AI-driven traffic monitoring, enabling further studies in deep learning, object detection, and real-time surveillance, advancing smart city technologies.

- **Future Researchers.** The study lays the foundation for further research on AI-driven law enforcement systems, enabling advancements such as database integration and expanded traffic violation detection.

Scope and Limitation

This study will aim to develop and implement an AI-based prototype that uses YOLOv8 with TensorFlow for detecting motorcycles, e-bikes, and bicycles, as well as helmet usage. OpenCV will be used for real-time video and image processing, and the prototype will identify whether riders are wearing helmets properly. In addition, it will count the number of passengers on each vehicle to ensure compliance with road regulations, particularly limiting motorcycle passengers to two. The prototype will be deployed along Nabua Highway. The implementation will involve capturing real-time video through strategically placed surveillance cameras. The captured data will be processed using a Raspberry Pi 4 or NVIDIA Jetson Nano, running the trained YOLOv8 model to detect safety violations.

The prototype's outputs including flagged violations such as no helmet, improper helmet use, or overloading will be stored as video clips for review by authorities. These outputs will be used to support law enforcement in improving road safety and compliance. However, the prototype has limitations. It will only function effectively in areas covered by surveillance cameras. Its accuracy may decline in low-light or adverse weather conditions such as rain or fog. Recognizing helmet types and differentiating among similar vehicle types (e.g., between bicycles, e-bikes and motorcycles) may introduce errors. The prototype will not be connected directly to enforcement systems during the pilot implementation phase and will initially function as a standalone prototype. Future integrations may include cloud-based databases, vehicle registration systems, and mobile alert features for violations.

Project Dictionary

To avoid problems in understanding the terms used, the following technical terms are conceptually and operationally defined to provide better understanding.

- **AI (Artificial Intelligence).** The simulation of human intelligence in machines that enables them to perform tasks such as learning, reasoning, and visual recognition [17]. In this study, the prototype integrates AI-powered computer vision models to automatically analyze video data, detect helmets, count passengers, and recognize plate numbers without human intervention.

- **Algorithm.** A set of well-defined instructions or rules used to solve a specific problem or perform a computation [1]. In this study, the prototype uses machine learning and image processing algorithms to detect helmets, count passengers, and recognize plate numbers from camera feeds.

- **Accident Prevention.** Encompasses strategies and measures aimed at reducing the occurrence of unintended events that result in injury, death, or property damage. It involves identifying potential hazards, assessing risks, and implementing interventions to mitigate these risks [7]. In this study, accident prevention refers to the deployment of artificial intelligence (AI) and computer vision technologies to monitor and analyze real-time data from surveillance prototypes. The goal is to detect and alert authorities about potential accidents or safety violations, thereby enabling timely interventions to prevent incidents.

- **Computer Vision.** A field of artificial intelligence that enables computers and systems to derive meaningful information from digital images, videos, and other visual inputs [19]. In this study, the prototype processes video feeds from cameras to automatically detect helmets, count passengers, and recognize plate numbers without manual intervention.

- **Dataset.** A structured collection of data used to train or evaluate machine learning models. In computer vision, datasets consist of labeled images or videos [**Deng2009**]. In this study, the prototype utilizes a dataset containing images of motorcycle riders with and without helmets, plate numbers, and various riding conditions to train the object detection model. These datasets can be sourced from public datasets or collected manually for model training and validation.

- **Deep Learning.** A subset of machine learning involving neural networks with multiple layers that learn patterns and representations from large datasets [6]. In this study, AI models will be used to detect helmets in video using deep neural networks.

- **Helmet.** A protective covering for the head, typically made of a hard material, used as part of safety gear to prevent head injuries [12]. In this study, it is what the prototype will identify in real-time using computer vision techniques and ensures that the riders wear it properly.

- **Helmet Compliance.** Wearing of a helmet the right way and following the law when riding a motorcycle [22]. It helps prevent injuries and deaths in road accidents. In this study, helmet compliance is the main focus. The system uses YOLOv8 to check if riders are wearing helmets properly and to spot those who are not, to help make roads safer using technology.

- **Helmet Detection.** A computer vision task that involves identifying and verifying the presence of a helmet on a person in images or videos [8]. In this study, the prototype detects helmets in real-time using computer vision algorithms and determines if they are worn on the head and not held or carried by the riders.

- **Image Processing.** The manipulation of images through computational algorithms to enhance quality or extract useful information [5]. In this study, image processing techniques will analyze video footage to detect helmets, license plates and passenger counting, ensuring compliance with safety regulations and identifying violations.

- **Law Enforcement.** Refers to the system and practices used by government agencies to ensure public order, uphold laws, and prevent or investigate criminal activities [2]. In this study, AI-driven surveillance aids authorities by detecting violations, gathering evidence, and enhancing enforcement efficiency through real-time monitoring.

- **Object Detection.** A computer vision technique that identifies and locates objects within an image or video [21]. In this study, object detection can be used to recognize motorcyclists and determine whether they are wearing helmets by analyzing real-time footage from surveillance cameras or traffic monitoring.

- **Passenger Counting.** The process of counting the number of passengers in a vehicle using sensors or computer vision techniques [9]. In this study, the prototype employs image processing and object detection to count passengers and compare this number with detected helmets to ensure compliance.

- **Road Safety.** The methods and measures used to prevent road users from being killed or seriously injured, including regulations, infrastructure, and education [14]. In this study, road safety includes enforcing helmet laws, using an AI-powered monitoring prototype, improving traffic management, and promoting awareness campaigns to reduce head injuries and fatalities among motorcyclists.

- **Traffic Monitoring.** The systematic observation and recording of vehicular movement and flow on roads, often used to manage congestion and improve traffic systems [3]. In this study, traffic monitoring involves using AI-powered cameras and sensors to detect motorcyclists, assess helmet usage, and identify potential violations in real time.

- **YOLO (You Only Look Once).** A deep learning-based object detection model that processes an image in a single pass to detect multiple objects in real time [15]. In this study, the prototype employs YOLOv5 or YOLOv8 to efficiently detect helmets on motorcycle riders, identify passengers, and locate the motorcycle's plate number within video footage.

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CHAPTER 2

RELATED LITERATURE AND STUDIES

This chapter presents a review of both international and local literature relevant to the research topic. The researcher collected information using the college library, the internet and various other references that will assist them in their study.

Helmet Detection using Computer Vision

Helmet detection using computer vision involves automatically identifying helmet use among motorcyclists through AI and image processing. Using deep learning models like YOLO and tools like OpenCV, this prototype detects violations in real-time. It enhances road safety, supports law enforcement, and reduces manual monitoring in traffic surveillance applications.

According to Afzal et al. [2021] they developed a deep learning-based automatic helmet detection system for real-time videos. They used various models, with Faster R-CNN and Region Proposal Network (RPN) addressing challenges like low resolution, weather, occlusion, and illumination. The model was retrained on a self-generated dataset from three locations in Lahore, Pakistan. The system achieved an impressive accuracy of 97.26%, demonstrating its potential to improve authorities' ability to monitor motorcyclists violating traffic laws [1]. Another review from Singh [2024] emphasizes how computer vision improves helmet compliance in dangerous industries by using AI-powered detection to monitor safety in real-time, enforce compliance, and reduce workplace dangers [25]. Furthermore, Siebert et al. [2024] developed a low-cost and affordable computer vision method to check if helmets are used by motorcycle riders in five cities in Southeast Asia using crowdsourced images from Mapillary. They trained their algorithm on over 800,000 images and it achieved high accuracy and detected over 1.3 million motorcycles. The results show that drivers are more often to wear helmets than passengers and people wear helmets more on big roads than small roads. This approach is helpful because it is accurate and useful without the need for people to go out and collect data [24].

According to Giron et al. [2020] the no helmet no ride law that was implemented in the Philippines is still not working because many motorcycle riders are not following it. The government has partnered with De La Salle University to fix this issue by using artificial intelligence. They used Computer Vision to automatically check if riders are wearing helmets or not. The system uses deep learning, especially Convolutional neural networks to improve detection accuracy [7]. According to Soltanikazemi et al. [2023] , the helmet violation detection system was YOLOv5-based and it is developed using genetic algorithm optimization to monitor in real-time. The model achieved a high accuracy, and it was ranked 4th in the AI City Challenge in 2023. The study shows the advantages of deep learning and discusses how it is more effective than the traditional methods in ensuring helmet compliance and enhancing motorcycle safety in roads [26].

The work of Mutyala et al. [2023], introduces a real-time helmet detection warning system that is powered by Detection Transformers (DETR) for improving detection precision and operational effectiveness in improving motorcycle safety. The system detects motorcycle riders that are not using and wearing helmets in real time, and it will generate alerts to improve the road safety. DETR uses a self-attention mechanism to capture complex relationships in image sequences, allowing accurate helmet detection even in difficult conditions like poor lighting. The system combines video feed analysis with DETR's object detection features, ensuring minimal processing delay. Testing results show the system's high precision and recall rates in different situations. This solution can be customized to send alerts to authorities or directly notify and inform riders, this might decrease violations and promote safety [15]. Tomas and Doma [2023], used the YOLOv5 algorithm in their study, YOLOv5 is used to detect helmets, and it classifies their usage among motorcycle riders in the Philippines. They are processing video footage from Makati City, and they optimized model hyperparameters for better accuracy. They suggest enhancing the data consistency and to use separate models for detection and classification tasks. Their findings show best results in helmet detection that could contribute more to road safety [28].

Object Detection Models and Image Processing Techniques

Object detection models like YOLO are widely used for real-time detection tasks. YOLO, combined with OpenCV for image processing and TensorFlow for model training and deployment, offers efficient and accurate object recognition. These tools work together in applications such as traffic monitoring, helmet detection, and safety compliance systems. Image processing techniques are fundamental in preparing and enhancing visual data for analysis by machine learning models. In this study, several image processing methods were applied to ensure that the system accurately detects whether an individual is wearing a helmet. These techniques help in improving the quality of the input data, extracting relevant features, and enabling more accurate and efficient model training.

The YOLO (You Only Look Once) is a deep learning-based object detection model that can detect multiple objects in real-time with high speed and accuracy. According to the study of Jiang et al. [2022] , the YOLO algorithm was improving and evolving from time to time, and it makes object detection faster and more accurate. It compares different YOLO versions and explains its performance compared to traditional methods like Convolutional Neural Networks (CNNs). They highlight that YOLO is still improving and evolving and it is very useful in areas like in security, finance, and other applications [9]. Similarly Terven et al. [2022] discuss the evolution of YOLO from its first version to YOLOv8, YOLO-NAS, and YOLO with transformers. It highlights its improvements in architecture, accuracy, and speed. They compare YOLO with different models like R-CNN and SSD and they explore its applications in fields of robotics, healthcare, security, and traffic monitoring. Future research aims to improve YOLO's real-time detection and its efficiency [27]. YOLO (You

Only Look Once) was introduced by Joseph Redmon and his team in 2015 to address the limitations of earlier object detection models like Fast R-CNN. While Fast R-CNN was accurate, it was too slow for real-time applications, taking 2–3 seconds to process a single image. In contrast, YOLO performs detection with just one forward pass through the network, enabling much faster and real-time predictions [6].

With the increasing number of motorcycle users and the issue of helmet non-compliance,Kumar et al.[2024] developed a Real-Time Helmet Detection System to improve road safety by detecting helmet violations and capturing vehicle license plates. The system uses YOLO for object detection and a mechanism for license plate recognition, consisting of three steps: identifying motorcyclists, verifying helmet usage, and capturing the license plate. It achieved 64% accuracy in vehicle identification, 78% in helmet detection, and 92% in license plate recognition [12]. In Addition, Muhammad et al. [2024] designed a real-time helmet detection system using YOLOv8, deployed on edge devices to enhance the safety of motorcyclists in Indonesia. During testing, the model demonstrated strong performance in detecting helmets (91.1% F1 score), riders (81.7%), and non-helmeted riders (33.0%). They also evaluate the system's CPU usage (78%), RAM (77.4%), temperature (33°C–65°C), and power consumption (6.5 W). This system shows potential for integration into smart city infrastructure, improving the efficiency of traffic law enforcement [14]. Furthermore,Choubey et al. [2025] introduces a YOLOv3-oriented model created for identifying license plates and helmets within images. They improved data quality and variety by pre-processing and created a tailored annotated dataset for helmets and license plates. The model underwent training through a multi-phase approach [4].

OpenCV is an open-source library that provides a vast collection of tools for computer vision tasks, including image processing, feature extraction, object recognition, and real-time video analysis. According to Satheesh et al. [2024] using OpenCV, a publicly available computer vision library. For the goal of observing objects, attributes for extraction and image preprocessing, OpenCV offers a broad array of tools and functionalities. By utilizing

OpenCV, we will guarantee consistency and reliability when managing various real-world situations, encompassing various lighting situations, obstructions, and vehicle angles [22].

TensorFlow is an open-source machine learning library developed by Google. It is widely used for training deep learning models, including convolutional neural networks (CNNs), which are essential for object detection. In this study of Kumar et al. [2023] , TensorFlow, a deep learning framework, will be utilized to create, develop, and assess a vision-based safety identification and monitoring system. The aim of the research is to enhance motorcycle safety by automating the identification and enforcement of helmet usage. This system is designed to offer a reliable, cost-effective, and expandable solution to assist transit agencies, road safety groups, and the biking community as a whole [13]. Another review from Sharma [2024] the fundamental intelligence of the tensorflow module is illustrated by a machine learning model that has been created using tensorflow's robust machine learning framework. To achieve object detection, it is essential to precisely recognize and tag road signs, vehicles, pedestrians, and other items [23].

Vehicle Classification

According to Chandrika et al. [2020], the growing number of vehicles—exceeding 1 billion globally makes it difficult for authorities to manage traffic and provide sufficient infrastructure. Their study introduces a vehicle detection and classification system using image processing, broken into six stages: image acquisition, analysis, object detection, counting, classification, and result display. The proposed system helps monitor traffic flow, detect rule violations, and classify vehicles into categories such as motorcycles, cars, vans, and trucks, thereby supporting better traffic planning and management [3].

Similarly, Ong et al. [2022], vehicle classification plays a key role in enhancing security, managing traffic congestion, and preventing road accidents. One challenge in this process is the poor image quality from video sources, which makes object recognition difficult. To address this, their study implemented and compared YOLOv5 and Faster R-CNN algorithms for classifying vehicles into five categories: motorcycle, car, van, bus, and lorry. The results showed that YOLOv5 outperformed Faster R-CNN, achieving a mean average precision (mAP) of 0.91, precision of 0.81, and recall of 0.86, making it more suitable for accurate vehicle classification using video-based image data [16].

In line with this,Sanjana et al. [2021], vehicle detection and classification have become increasingly important due to the growing number of vehicles, traffic violations, and road accidents. Their review explores various methodologies that have evolved over the years, shifting from basic image processing to machine learning approaches. This progression has led to the integration of helmet detection and license plate recognition, using object detection and text recognition models that are now easier to implement through built-in frameworks or customizable tools [21].

Moreover, Espinosa et al. [2021] , motorcycles are classified as Vulnerable Road Users (VRUs), alongside bicycles and pedestrians, and are among the most frequently involved in urban traffic accidents. To address this issue, their study reviews the use of automatic video processing techniques—particularly leveraging CCTV surveillance systems—for the detection and tracking of motorcycles. The authors emphasize the effectiveness of deep learning algorithms within the field of computer vision for these tasks. Additionally, they discuss the use of standard performance metrics, introduce the Urban Motorbike Dataset (UMD) for evaluation purposes, and outline current challenges and potential future research directions in this emerging field [5].

Passenger Counting

Passenger counting systems utilize sensors and computer vision models to automatically count individuals boarding or exiting vehicles. These prototypes often use YOLO for real-time detection and OpenCV for image processing. They help optimize public transport operations, monitor capacity, and improve service efficiency in buses, trains, and other mass transit systems.

The study of Rendon et al. [2023], which introduced a computer vision method using deep learning to detect, count and estimate the number of passengers in Bogota's Trans-Milenio stations, this study shows how accurate passenger counting in public transport systems is important. They analyzed images with nearly 900,000 labeled heads and achieved a very accurate result, with an error of only one person per image. This is better than counting them by hand. This method is scalable and low-cost, and it is useful for improving the planning and running of public transport systems [19]. The paper by Radovan et al. [2024] discusses different passenger counting systems, comparing traditional technologies like RFID and infrared sensors with newer methods using image processing and machine learning. It explores the advantages and disadvantages of each system and how to improve these. It also discusses concerns under GDPR. The authors propose some improvements for passenger counting solutions and suggest ways to enhance public transport operations to make it more effective [18].

According to the study by Bhatt et al. [2024] , wearing a helmet when motorcycling is important because it helps reduce the likelihood of serious head injuries in accidents. With the help of modern technology such as real-time surveillance and computer vision, it is now possible to automatically determine whether riders are wearing a helmet using video footage on the road. The aim of this system is to strengthen the implementation of road safety laws by detecting not only the driver but also the passenger if they are wearing a helmet. Based on a report by the World Health Organization (WHO) in 2023, the correct use of a helmet reduces the risk of death by 42% and the risk of head injury by 69% [WHO, 2023] [2].

Evaluation Metrics of YOLOv8

YOLO (You Only Look Once) is a real-time object detection algorithm that offers a faster and more efficient alternative to traditional detection methods. Specifically, as a single-stage detector, YOLO employs a convolutional neural network (CNN) to predict both bounding boxes and object classes directly from input images. It achieves this by dividing the image into a grid, which enables the detection of multiple objects in a single pass [11].

In this context, several studies have evaluated the performance of YOLO and its variants in terms of speed, accuracy, and adaptability. According to Prakash and Palanivelan [2024], YOLO revolutionized object detection by enabling real-time performance through its single-pass, grid-based prediction approach [17]. Moreover,Karthika et al. [2024] assessed YOLOv8 for its high precision and speed, highlighting its effectiveness across static images, video streams, and live feeds [10]. Furthermore,Varghese and Sambath [2024] demonstrated that YOLOv8 outperforms earlier versions by integrating attention mechanisms, dynamic convolution, and voice recognition, which results in improved accuracy and computational efficiency [29]. Similarly, Safaldin et al. [2024] proposed an enhanced YOLOv8 model tailored for detecting moving objects in dynamic environments. Through architectural and preprocessing modifications, their model improved motion sensitivity and achieved strong results on datasets such as KITTI, LASIESTA, PESMOD, and MOCS—recording 90% accuracy, 90% mAP, 30 FPS, and 80% IoU [20]. However,Hussain [2024] conducted a comparative analysis of YOLO architectures, noting that YOLOv8 features enhanced feature extraction and anchor-free detection, while YOLOv10 achieves even greater real-time performance by incorporating large-kernel convolutions and eliminating non-maximum suppression [8].

Synthesis of the State-of-the-Art

The reviewed literature highlights the growing importance and effectiveness of computer vision and deep learning techniques in addressing road safety concerns, particularly in enforcing helmet compliance, identifying plate numbers, and counting passengers in real-time.

International and local studies consistently emphasize the role of helmet detection systems using deep learning models such as YOLO (You Only Look Once), Faster R-CNN, and Detection Transformers (DETR). Afzal et al. [2021] demonstrated a highly accurate system using Faster R-CNN, achieving 97.26% accuracy despite challenges like occlusion and weather conditions [1]. Complementing this, Singh [2024] and Giron et al. [2020] recognized the potential of AI in improving helmet compliance in both traffic and industrial settings [25], [7]. Further innovations were noted by Siebert et al. [2024] , who employed crowdsourced images for a low-cost helmet detection approach, and by Soltanikazemi et al. [2023] , whose YOLOv5-based system earned top ranks in the AI City Challenge. Mutyala et al. [2023] introduced DETR-powered real-time systems with alert features, while Tomas and Doma [2023] highlighted the importance of model optimization in improving helmet detection in the Philippines [24], [26], [15], [28].

The integration of object detection and image processing tools YOLO, OpenCV, TensorFlow has been fundamental in enabling real-time, accurate, and resource-efficient systems. Jiang et al. [Jiang et al.] and Terven et al. [2022] chronicled the evolution of YOLO from its initial versions to YOLOv8 and YOLO-NAS, highlighting architectural improvements and broader applications across various fields [9], [27].

YOLO (You Only Look Once) is a real-time object detection algorithm that efficiently detects multiple objects in a single pass using a grid-based CNN approach. Studies highlight its speed, accuracy, and adaptability, especially in its latest version, YOLOv8.Prakash and Palanivelan [2024] emphasized its real-time performance, while Karthika et al. [2024] noted its high precision in various visual inputs [17], [10].Varghese and Sambath [2024] showed improvements in YOLOv8 through added attention mechanisms and voice recognition, and Safaldin et al. [2024] reported strong performance in dynamic environments [29], [20].Hussain [**c**ompared YOLO versions, noting YOLOv8's enhanced detection and YOLOv10's improved performance using large-kernel convolutions and anchor-free techniques [8].Kumar et al. [2023] and Muhammad et al. [2024] demonstrated real-world implementations that integrate YOLO yielding high recognition rates and strong performance on edge devices [13], [14]. Similarly, Choubey et al. [2025] emphasized dataset preparation and multi-phase training in developing a YOLOv3 model for detecting helmets and plates [4].

The utility of OpenCV was established by Satheesh et al. [2024] , who showed how it aids in preprocessing, feature extraction, and robustness in varied real-world conditions [22]. In tandem, TensorFlow emerged as a powerful framework for training and deploying models, with Kumar et al. [2024] and Sharma [2024] showcasing its flexibility in creating cost-effective and scalable safety monitoring systems. [12] [23]

Several studies highlight the importance of vehicle classification in improving traffic management, security, and accident prevention. Espinosa et al. [2021] focus on tracking motorcycles using deep learning, while Sanjana et al. [2021] highlight the shift from traditional image processing to integrated helmet and plate detection using modern frameworks [5], [21]. Ong et al. [2022] show YOLOv5's superior accuracy over Faster R-CNN, and Chandrika et al. [2020] propose a full system for detecting, counting, and monitoring vehicles [16], [3]. Despite varying approaches, all studies support the effectiveness of computer vision in traffic-related applications.

The literature also covers passenger counting systems, crucial for optimizing transport services. Rendon et al. [2023] developed a deep learning method for head counting in Bogotá, yielding minimal errors and proving useful for transit planning [19]. Radovan et al. [2024] compared traditional methods like RFID with modern image processing approaches, offering improvements under regulatory frameworks such as GDPR [18]. Bhatt et al. [2024] expanded on this by developing a real-time system that also includes helmet detection for both drivers and passengers, echoing the WHO's findings on the life-saving importance of helmets [2].

In summary, the reviewed studies underscore a significant trend: AI-powered computer vision prototypes are revolutionizing public safety enforcement. Tools like YOLO, TensorFlow and OpenCV when integrated with real-time video analysis form the backbone of intelligent traffic monitoring systems. These systems not only automate compliance checks but also promise scalability, cost-efficiency, and broad applicability in smart city infrastructures.

Gap Bridged of the Study

The existing helmet detection systems mostly focus on identifying if the motorcycle driver is wearing a helmet, often ignoring the passenger. These systems are usually made for controlled or international settings and do not consider the real traffic conditions in the Philippines, such as poor lighting, blurry movements, and blocked views in live road situations. Many of these systems also check only if a helmet is present, without checking if it is worn properly or securely fastened. In some cases, riders just carry the helmet instead of wearing it, and these systems cannot tell the difference. Also, most existing systems do not check if the rider is using the correct helmet type for the vehicle, such as motorcycle helmets for motorcycles. Another issue is that they do not detect overloading, where more than two people are riding a motorcycle, something that is common but often ignored.

To address these problems, this study presents a real-time helmet compliance monitoring prototype designed specifically for Philippine roads like the Nabua Highway. The prototype uses the YOLOv8 object detection model to detect if helmets are being worn correctly by both drivers and passengers, checks if the helmet matches the type of vehicle, counts the number of riders to spot overloading, and saves short video clips of violations as evidence. This offers a more complete, localized, and practical way to support traffic law enforcement and improve road safety.

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CHAPTER 3

METHODOLOGY

Figure 1: **Barred spiral galaxy NGC 1300 photographed by Hubble telescope. While the galaxy in the photo is not our sun, it does emit light, much like our sun. Image credit: NASA.**

CHAPTER 4

RESULTS AND DISCUSSION

Figure 2: **Barred spiral galaxy NGC 1300 photographed by Hubble telescope. While the galaxy in the photo is not our sun, it does emit light, much like our sun. Image credit: NASA.**

CHAPTER 5

CONCLUSION

Figure 3: **Barred spiral galaxy NGC 1300 photographed by Hubble telescope. While the galaxy in the photo is not our sun, it does emit light, much like our sun. Image credit: NASA.**

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APPENDICES

APPENDIX A

LANGUAGE EDITING CERTIFICATION

This is to certify that the undersigned has reviewed and went through all the pages of the Bachelor of Science in Computer Science thesis manuscript titled **"Helmet Compliance Detection Using Computer Vision"** of **Dela Justa, Aina Mae F.**, **Epres, Caren Joy L.**, **Matubis, Maria Angela N.**, as against the set of structural rules that govern research writing in accord with the composition of sentences, phrases, and words in the English language.

JUAN DE LA CRUZ

Language Editor

Date:______________________

APPENDIX B

SECRETARY'S CERTIFICATION

This is to certify that the undersigned has provided accurate recommendations, suggestions, and comments unanimously agreed and approved by the panel of examiners during the oral examination of the thesis titled

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prepared and submitted by **AuthorName1**, **AuthorName2**, **AuthorName3**, and that the same have not been amended, modified or obliterated.

MS. MARIA DAISY R. BELARDO

Secretary

Date:______________________

APPENDIX C

JOINT AFFIDAVIT OF UNDERTAKING (PLAGIARISM)

JOINT AFFIDAVIT OF UNDERTAKING

VITA

- **Joseph Jessie S. Oñate** is a faculty member of the College of Computer Studies. He finished his Master of Science in Computer Science degree at Ateneo de Naga University. His research interests focused on Intelligent Systems, Algorithm and Complexity, Web Technologies, Computer Vision, and Graphics.

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- **Joseph Jessie S. Oñate** is a faculty member of the College of Computer Studies. He finished his Master of Science in Computer Science degree at Ateneo de Naga University. His research interests focused on Intelligent Systems, Algorithm and Complexity, Web Technologies, Computer Vision, and Graphics.