



MOTORBIKE IMAGE RECOGNITION USING YOLO

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**A PROJECT REPORT SUBMITTED IN PARTIAL
FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE
BACHELOR OF ENGINEERING IN COMPUTER ENGINEERING**

**FACULTY OF ENGINEERING & INTERNATIONAL COLLEGE
MAHIDOL UNIVERSITY**

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Computer Engineering Project
entitled
MOTORBIKE IMAGE RECOGNITION USING YOLO

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Thesis
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on
July 25, 2025

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25 หน้า

MOTORBIKE IMAGE RECOGNITION USING YOLO

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ABSTRACT

The paper describes an implemation of system to help in detection of motorbike, person using YOLO in combination with a custom model to detect head and helmet. In order to count these classes and document the class entering University gates through surveillance camera. The data is to be recorded throgh google sheet API, taking snapshot of a specific scenario where a civilians using motorbike are not wearing helmet. YOLOv8 is uses as the main framework for it performances and continuous supports from developers as well as its accessibility. The custom model for helmet and head detection are trained, annotated through ROBOFLOW program, and the datasets are from the university's cctv camera. Five model has been trained and, one of the five has been choosesn for their perfromace to be implemented for the detections. The product is a system that detects motorbike, person, helmet and head. Using BotSort tracker in conjunction to aid in the counting algorithm.

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CHAPTER 1

INTRODUCTION

1.1 Background

Urban traffic congestion and road safety, particularly for motorbikes, remain major issues. Motorcycles, due to their mobility, contribute greatly to traffic flow. However, they are also prone to violations, such as not wearing helmets or using the wrong lane, which increase the chance of an accident. Traditional traffic management systems lack the ability to detect and address such specific breaches in real time.

AI technologies, like as YOLO, a deep learning model for object detection, have showed potential in traffic surveillance but have not yet been routinely used to identify helmet use or lane breaches. Previous research has shown that YOLO is good for vehicle detection, but there is a gap in its use for targeted motorbike detection and safety compliance.

This research seeks to close this gap by utilising YOLO to detect motorcycles, check for helmet use, and identify lane violations. By focussing on these critical aspects, the system will improve road safety and aid in more effective traffic enforcement.

1.2 Objective

1. To detect motorbike, person, helmet and non-helmet user.
2. Count all the essentials object efficiently
3. upload system up to university's server.

1.3 Scope

1. Develop system to detect motorbike, person, helmet and non-helmet user.
2. Display annotated video.
3. Count all the essentials and display real time.
4. University server running on system efficiently.

1.4 Expected Results

1. To reduce illegal activities of riders.
 2. To ensure both safety of rider and pedestrian.
 3. To spread safety awareness.
 4. Has more than 80 percent accuracy .

1.5 Timeline

Table 1.1 Project Timeline

CHAPTER 2

LITERATURE REVIEW

The papers in the literature review are used as a foundation to guide the thesis, this included inspiration, the methodology, and expected results.

2.1 Video Image Recognition of Car Track Characteristics at Intersections [6]

The system relies on machine learning algorithms to interpret video data in real-time, helping to optimize traffic signal control, reduce congestion, and enhance safety. The study emphasizes its application in intelligent transportation systems and urban traffic flow optimization.

The use of YOLOv8, a popular deep learning model for object detection, because it offers a balance of speed and accuracy. YOLOv8 is efficient in processing real-time video streams, which is crucial for tracking vehicles at intersections. It excels in recognizing objects (like cars) in complex environments, and its architecture allows it to detect vehicles quickly while maintaining high precision.

2.2 A Lightweight Remote Sensing Small Target Image Detection Algorithm Based on Improved YOLOv8 [3]

The authors optimize the YOLOv8 architecture by refining the feature process and introducing techniques like multi-scale detection, anchor box adjustments, and a better feature fusion method. This helps the algorithm perform better with small targets, ensuring more accurate detection without significantly increasing computational cost.

they conclude that, this makes it suitable for real-time applications in remote sensing, where detecting small objects like vehicles, ships, or buildings in satellite imagery is critical. The enhancements lead to better precision and recall.

2.3 Traffic Detection and Enhancing Traffic Safety: YOLO V8 Framework and OCR for Violation Detection Using Deep Learning Techniques [5]

The YOLOv8 algorithm is a deep learning model that uses a convolutional neural network (CNN) to detect and classify objects in input images. It uses bounding box regression and class prediction to identify objects and assign class probabilities.

The model is pre-processed by converting the input video into frames, extracting features, and detecting objects. The YOLOv8 model then uses a grid to track objects, predicting bounding boxes and class probabilities. The model is fine-tuned on specific object classes and implemented for tracking, counting, and speed estimation.

This project consists of two main modules: one for vehicle count and speed detection, which uses a dataset of 800 images and video clips, and the other for number plate recognition. The first module uses computer vision techniques to accurately count vehicles and calculate speeds. The second module uses a Roboflow website dataset to extract license plate information, useful for applications like parking management and traffic monitoring.

This project aims to create two modules with distinct functions in traffic monitoring. The number plate recognition module enhances functionality for recognizing and tracking vehicles based on their number plates, while the vehicle count and speed detection module provides insights into traffic flow and speed trends.

The study on traffic detection using the YOLOv8 framework and Optical Character Recognition (OCR) has shown promising results. The system accurately detects traffic violations in real-time, while OCR enhances its ability to identify and classify violations like illegal parking or speeding.

YOLOv8 and OCR provides a robust solution for automating violation detection processes, demonstrating the effectiveness of deep learning methodologies in enhancing traffic safety and enforcing traffic regulations.

2.4 Smart Traffic Management System for Efficient Mobility and Emergency Response [1]

The proposed solution combines AI with real-time data analytics to improve traffic light management. It incorporates real-time congestion response, algorithmic optimization, data-driven decision making, and feedback loop integration.

The system uses a vast dataset of lane-specific traffic information to inform real-time adjustments. The Traffic Light Control System (TFS) is activated, and the dataset undergoes preprocessing to ensure compatibility with the algorithms. A predictive model is trained using machine learning techniques, and a feedback loop is implemented to continuously evaluate the effectiveness of the decisions.

The AI system also optimizes traffic flow during emergencies, adjusting timings to prioritize passage and ensure smooth traffic flow. This innovative approach aims to alleviate congestion and improve overall traffic flow, ultimately leading to sustainable and safer cities.

2.5 Utilizing Image Processing and the YOLOv3 Network for Real-Time Traffic Light Control [2]

The paper presents the creation of a traffic light control system which is aimed at relieving congestion in urban areas. The system is designed based on the YOLOv3 object detection algorithm and is capable of counting both vehicles and pedestrians at intersections in real time using a Jetson Nano board for data processing. The research further shows that traffic lights can be controlled by taking into consideration factors such as the number of vehicles that have stopped, the number of vehicles that are crossing over and the number of pedestrians thereby enhancing the efficiency of the system which in turn reduces negative impacts on the environment.

The authors note the cost entailed in relief from congestion in UK being in the region of £37.7 billion per year and admonish that such inefficient delay is caused by the inadequate control of traffic lights that energy loss is also the outcome of that inefficient management of the traffic signal is responsible. The developed system looks set to achieve average precision with average vehicle counting for 95 percent as supported by this research.

2.6 Research on Vehicle Lane Change Warning Method Based on Deep Learning Image Processing [4]

The paper presents the progress in work which is falling into the category of the development of the low-cost lane-changing warning system which works in the efforts to improve driving safety through monocular camera and deep learning algorithms. The main aim of the study is to detect when there is a potential vehicle-user behavior who would be changing the existing lane as this is paramount to mitigate risk of collision, consequently enhance safety of roads.

As a result, the authors enhanced the Mask Region-based Convolutional Neural Network (Mask R-CNN) aiming towards a vehicle target seeker. They used the K-means clustering technique to identify appropriate proportions of anchor frames for vehicle targets, which facilitated more precise candidate box generation without degrading the performance of the network. This led to introduction of a fresh anchor set and mAP increased by about 2.6 percent thanks to about 26 percent in the mean average precision improvement.

The system was trained in a vernacular fashion with a full with 66,389 vehicle targets which were adequately annotated for target annotation assuring their appropriate performance. The authors performed various evaluations and recorded an accuracy of 94.5 percent for detection of lane changing after identifying and validating marked images of lane changing sequences. This high accuracy demonstrates the effectiveness of the proposed system in real time applications.

2.7 Summary

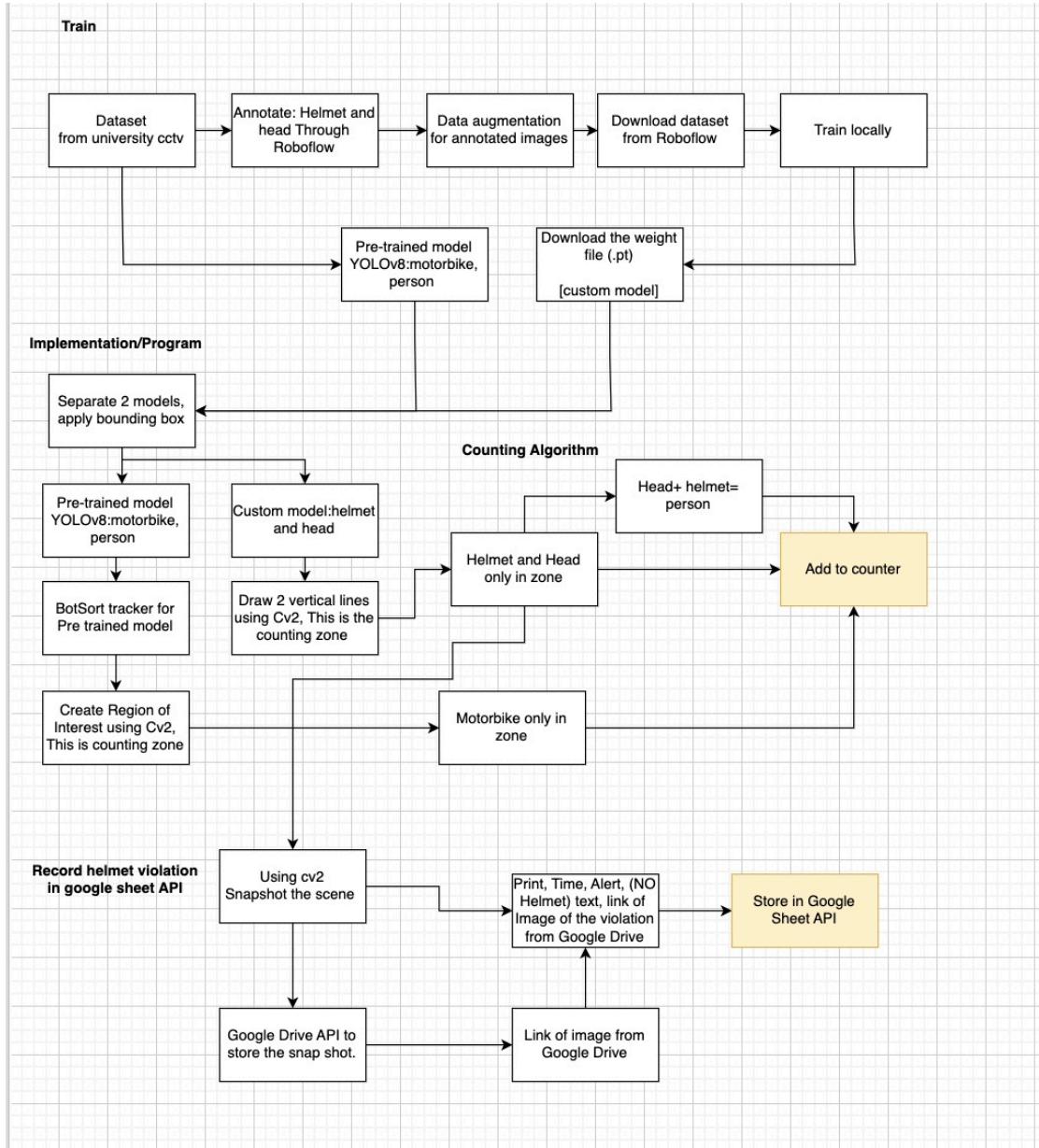
The reviewed studies highlight innovative uses of AI and deep learning for traffic management and safety. One study employs the YOLOv8 framework and Optical Character Recognition (OCR) to detect traffic violations in real-time, using modules for vehicle counting, speed estimation, and license plate recognition, achieving effective enforcement of traffic regulations. Another study integrates AI with real-time analytics to optimize traffic light control, dynamically responding to congestion and prioritizing emergency vehicles, thereby improving urban mobility and sustainability. Similarly, a traffic light control system based on YOLOv3 counts vehicles and pedestrians at intersections, achieving 95 percent accuracy in optimizing traffic flow and reducing urban congestion. Lastly, a lane-change warning system utilizing Mask R-CNN and K-means++ clustering achieves 94.5 percent accuracy in detecting lane changes, offering a cost-effective solution for collision risk mitigation and enhanced road safety. These approaches collectively demonstrate the transformative potential of AI in traffic management.

CHAPTER 3

METHODOLOGY

3.1 System Design

The purpose of the helmet detection system is to track helmet use from CCTV footage on a college campus. Data preparation, model training, and counting implementation are the three primary phases of the system. The first step involves converting campus CCTV video footage into image frames, which are subsequently labelled with helmet and unhelmeted head information using Roboflow. A customised YOLOv8 object detection model that is tuned for real-time performance is trained using the annotated dataset. After training, the model is incorporated into a real-time system that recognises and categorises heads and helmets by processing incoming video frames. In order to provide real-time statistics that facilitate safety compliance monitoring, a counting mechanism is integrated to monitor the quantity of helmets and heads seen within a designated area of interest.

**Figure 3.1**

The flowchart illustrates the overall workflow of the system. It begins first obtaining the dataset, we obtain them through the cctv footage of the university camera. Specifically splitting the video footages into 3 frames per second using Roboflow. Then annotate each frames split, the annotated items are helmet and head, then using data augmentations from Roboflow. Then we can download the datasets. Finally, using dataset downloaded we can train locally through data.yaml, the data augmentations

details are to be specified in Chapter 3. After the training we will receive the weighted .pt file, the file is the model that will be used in the system in conjunction with the pre-trained model from YOLOv8. The Implementation phase is to apply the models, work with the video stream input. The bounding box and region of interest made from cv2. Using these zone we separate the counting zone for helmet, head, and another zone to count person and helmet. As for the person we decided to count the head and the helmet to total to person as there are issues about the camera angle limiting the accuracy of the person detection.

After implementing the program with the model, we use cv2 to take snapshot of the frame as when helmet violation occur. The system links and uses Google API, to store the detection evidence of the scenario. The Google Sheet API will append new rows each time a head detection occur. The image are visible, and stored by Google Drive API, to check the instances where it happens.

3.2 Data

Dataset: videos of riders wearing and not wearing helmets, collected from local sources which is gate six Mahidol University CCTV camera. Videos will then be split in Roboflow which allow custom annotation and training.

Annotations: Create two classes. first class containing the bounding box of helmet user only and the second class containing head(which is non-helmet user.)

Preprocessing: Includes resizing images to 640x640 pixels, normalizing pixel values, and applying augmentations (e.g., rotation, scaling, and brightness adjustments).

3.3 Custom Model

YOLOv8 Architecture:

The YOLOv8 model was chosen due to its real-time detection capabilities and high accuracy for object detection tasks. Custom classes were defined for detection: motorcycles, helmets, crosswalks, pedestrians, and lanes.

Training Process:

- The model was trained on a dataset collected from University CCTV footage of two-hours at a span of seven days during 8:00-10:00 am to monitor the motor-bike riders's safey.
- The video footage are then extracted by frame, for our project, we extrated them inside Roboflow into 3 frames-per-second.
- After the clips has been extracted, we can use the bouding box to draw on the helmet and head, and lable them accordingly.
- When the annoation is finish for the clips we move the annotated image into dataset, sliting them into Train, Validate, Test and download the data set into the device.
- Using data.yaml file to adjust the training configuration., and put them inside VS code.
- Data augmentation techniques such as flipping, contrast adjustments, and brightness changes were applied during training to improve generalization.
- The configurations needed used inside data.yaml is located in the Hyperparameter section.
- Hyperparameters, such as learning rate and non-maximum suppression (NMS) thresholds, were tuned for optimal performance.
- After the training has been finish the wieghted model files will be created in runs/detect select the .pt files as a yolo model.

3.4 Counting System

3.4.1 Helmet and Head

After customizing our YOLOv8 model, we implemented a counting system to track the number of helmets, unhelmeted heads, persons, and motorcycles detected in the video.

For helmet and head counting, we applied a double-line counting method. This defines a "counting zone" using two vertical lines, and only counts detections whose bounding box centers fall within the zone. To prevent duplicate counting across frames, we used a rolling memory of the last ten frames. If a new detection is within a set distance (e.g., 30 pixels) of a previously counted object of the same type, it is ignored.

This method improves reliability by reducing overcounting and stabilizing results, especially for slow-moving or flickering detections. The final counts are updated in real time and displayed on the video, offering a clear summary of helmet usage and safety compliance.

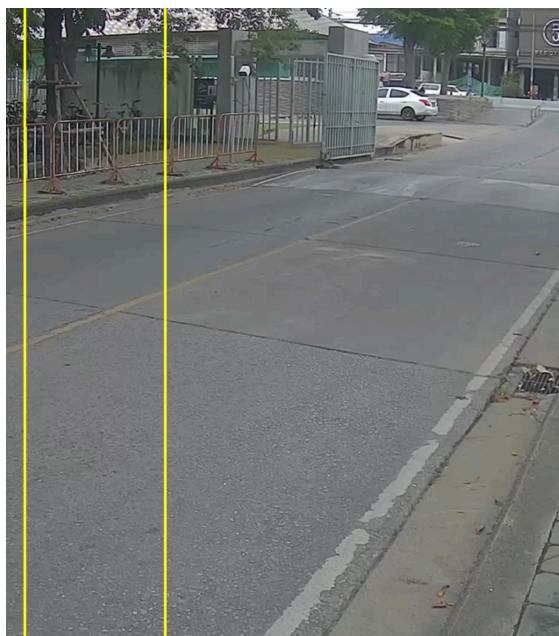


Figure 3.2

Figure 3.2 illustrates the designated counting zone used for helmet and head detection. The image shows two vertical yellow lines placed 150 pixels apart, which define the area for double-line counting. When an object passes through both lines in sequence, it is registered as a valid count. This method helps reduce duplicate or false counts caused by temporary detection overlaps or brief tracking loss.

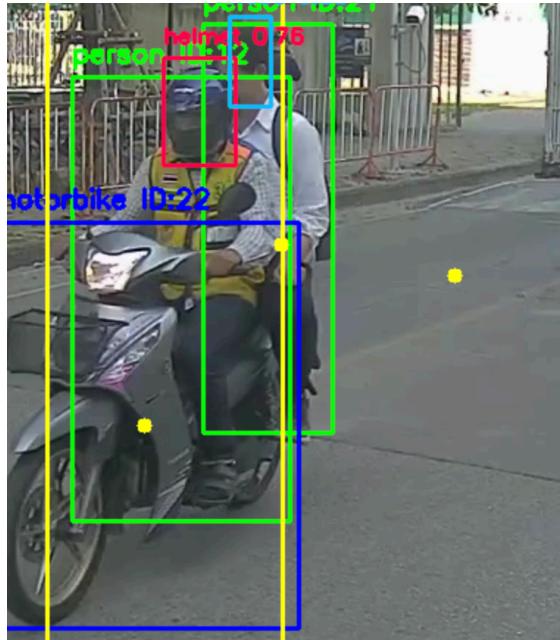


Figure 3.3

Figure 3.3 shows an example of the counting system in action when objects, such as a helmet and/or a head, enter the counting zone. As seen in the image, the objects are detected and labeled while passing through the two vertical lines, triggering the counting logic. This illustrates how the system identifies and differentiates helmeted and non-helmeted riders within the defined zone.



Figure 3.4

Figure 3.4 displays the result of the helmet and head counting process, shown at the top-right corner of the screen. These values are updated in real-time after the system detects and counts objects passing through the counting zone. This visual feedback confirms the detection and classification outcome for each rider, distinguishing between helmeted and non-helmeted individuals.

3.4.2 Person and Motorbike

However as for the Person, and Motorbike detection we can use the Yolov8s.pt model, class 0(person), and class 3(motorbike), as their model are well polished for tracking. For the tracking use Bot-sort tracker, obtain through Roboflow ultralytics/trackers/bot_sort.py. The tracker will be used to create specific id number for each class that has been detected. Using these id we will create center point of each classes which will be important in the counting method.

For the counting method, we can create a region of interest, through using open CV. From there we create a condition, to store the track id with track history. track_history = function will store the position cx, cy of the tracked object. We will use this value to identify its current and previous position to ensure that when object inside the Region of Interest, position compare is greater than the current position objected will not be used to count, while if the current position of the tracked id compared to stored id is less than it, it can be counted inside the ROI. This is to ensure that the person, and motorbike can be counted by what it can be tracked. The detection should look similar to figure1.

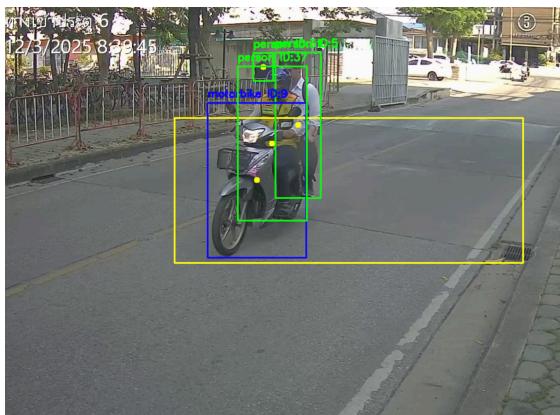


Figure 3.5

3.4.3 Output Generation

The output generation phase transforms the detection and counting results into a visual and interpretable format. For each processed video frame, the system overlays bounding boxes and labels indicating the object class (helmet, head, person, or motorcycle), along with live counts displayed on the top-left corner using OpenCV. These real-time visual indicators allow users to monitor helmet usage compliance at a glance.

Additionally, the system can produce an annotated video file as output, which includes all detections and updated counts across the entire duration. This output is valuable for both immediate observation and later review or reporting, providing a clear and documented summary of safety compliance in the monitored area.

3.4.4 Storing Output in Google Sheet API

After the output has been generated, we store the detection into a log using Google API from the video stream. The Google API integration is used for logging and evidence storage for helmet violation cases. Firstly as mention the two model, YOLOv8 pre-trained model, and custom model for head/helmet detection. How the system works is, when a head is detected within the zone. The frames will be stored, using cv2 to snap-shot the specific frame of head detection. We log the detections events to Google Sheet, it records, the timestamp, head detection, alert, and link to Google Drive file to the captured image.

The credentials.json file can be obtained through Google API, the system will connect to pre-defined Google Sheet as we name them(Data log) and appned the new rows with each detection events that occurs, the image are uploaded to Google Drive using the Drive API, and public access links are generated per log. This implementation allows users to store datas of the detection, this is to allow scalable and automated solution for monitoring helmet violations. The result is as seen in the figure below.

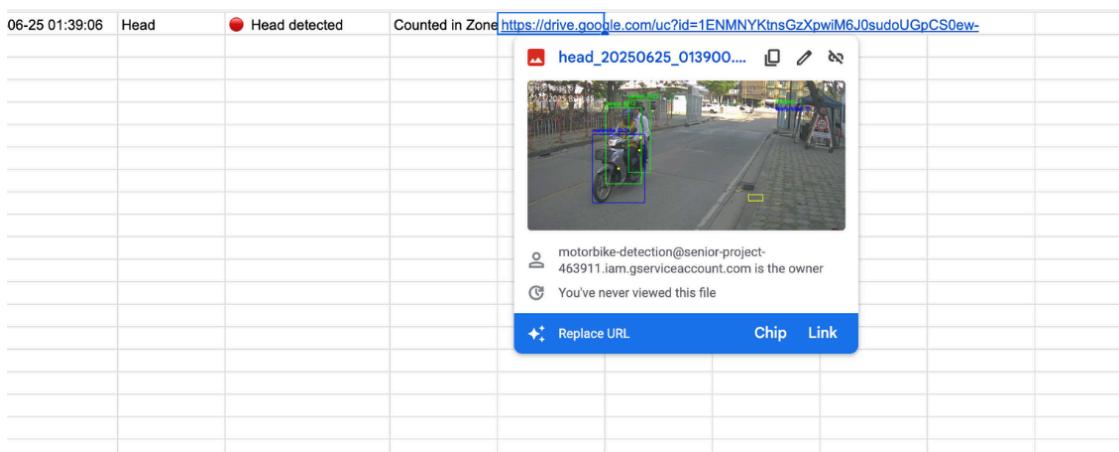


Figure 3.6

3.5 Tools and Frameworks

- **YOLOv8 Framework:** For object detection.
- **Libraries:** Python libraries such as ultralytics, opencv-python, numpy, collections.
- **Annotation Tools:** Roboflow.

3.6 Hyperparameter Configurations

Key hyperparameters used during training included:

Image size: 640 pixels Batch size: 32 Epochs: 500

depending on convergence and performance on the validation set.

the epochs can be changed depending on the accuracy of the detection. Data Augmentation : Flip , Change contrast, Rotate , Change brightness (Can be changed later)

3.7 Performance Evaluation

The trained YOLOv8 model was evaluated using: mAP: To quantify detection accuracy. Confusion matrix: To identify true positives, false positives, and negatives. The purpose of the performance evaluation is to help our team, look at the development of the different models. The benefits of finding the best model is to use them for the best accuracy for the counting systems.

CHAPTER 4

RESULT

We have used pre-recorded footage from CCTV cameras to analyze and compare the performance and accuracy of the detection and counting system.

To evaluate the accuracy of the model, we compared detection counts with manual counting over a ten-minute span of one video with every model we have. The aim of this is to see the accuracy and improvement of our model. The results in Table 4.1 shows the accuracy results of different models. Person and motorbike used YOLO pretrain model to detect these two classes, so the accuracy and considered constant throughout different models. Helmet detection rises from 42% to 96%, which is 54% improvement from the first model to latest model. The calculation method of finding helemt detection accuracy across different models is to find the total ground truth and detection of the train model, then divide it to find the accuracy. We find the best confident for each model by comparing confident of 0.15 and 0.3 to find the best accuracy. Best17 model have the ground truth helmet of 60, we have the confident set to 0.15 and detected the detection number to be 55, which is 90%. On the other hand, we change the confident to 0.3 and the results of the detection is 58, which is 95% resulting in a better accuracy.

After evaluating the model's detection accuracy, we proceeded to assess the performance of the counting system. This analysis was conducted using two pre-recorded CCTV footage videos. Tables 1.2 and 1.3 present the counting accuracy for helmeted and non-helmeted (head) riders, derived from Video 1 and Video 2 respectively. These tables utilize a double-line counting method.

For the helmet and head detection specifically, we experimented with adjusting the length of the double-counting lines to evaluate their impact on counting accuracy. For instance, we tested line lengths such as 300 pixels for Line X and 450 pixels for Line Y, along with several other variations. The results indicated that optimal performance oc-

curs when the length of the double lines is kept within approximately 150 pixels. Longer lines tended to increase the likelihood of multiple or false counts due to prolonged object overlap with the counting zone.

In contrast, Tables 1.4 and 1.5 focus on motorbike and person counting accuracy, also based on Video 1 and Video 2. However, these use the BotSort tracking and counting method instead of the double-line approach. This separation allows us to compare the performance of different counting techniques across different object categories and scenarios.

To evaluate counting accuracy, we use a relative error formula to calculate the percentage difference between the counted value and the ground truth. This approach provides a clear measure of overcounting or undercounting, allowing us to identify and analyze overflow or missed counts in the system.

4.1 Model Result

Table 4.1

Model Name	Person	Motorbike	Helmet
BestV8	87%	96%	42%
Best21			72%
Helmet_model			82%
Head_model			86%
Best17			95%

The figure presents the detection accuracy of various models across three object categories: person, motorbike, and helmet. The accuracy values for person and motorbike detection remain constant across models—87% and 96% respectively—because these classes were detected using the pretrained YOLO model without additional fine-tuning. In contrast, the helmet detection results vary significantly between models, as each represents a different version of a custom-trained helmet detection model.

4.2 Counting Result

Table 4.2

Video 1	Double Line Counting		Ground Truth	
	Head	Helmet	Head	Helmet
	25	26	25	25

Table 4.2 shows the counting results for Video 1 using the double-line method compared to the ground truth. The system accurately counted heads (25 vs. 25) but slightly overcounted helmets (26 vs. 25), likely due to duplicate detections or crossing artifacts.

Table 4.3

Video 2	Double Line Counting		Ground Truth	
	Head	Helmet	Head	Helmet
	29	24	32	29

Table 4.3 shows the double-line counting results for Video 2. The system counted 29 heads and 24 helmets, while the ground truth recorded 32 heads and 29 helmets. This indicates undercounting in both categories, which could be due to missed detections or rapid movements causing objects to skip the counting lines.

Table 4.4

Video 1	BotSort Counting		Ground Truth	
	Head	Helmet	Head	Helmet
	25	26	25	25

Table 4.4 presents BotSort counting results for Video 1. The system detected 52 persons and 32 motorbikes, compared to the ground truth values of 51 persons and 30 motorbikes. This reflects a small overcount in both categories, likely due to brief tracking ID switches or overlapping detections in crowded scenes.

Table 4.5

Video 2	BotSort Counting		Ground Truth	
	Head	Helmet	Head	Helmet
	29	24	32	29

Table 4.5 summarizes the BotSort results for Video 2. The model counted 56 persons and 44 motorbikes, while the ground truth showed 60 persons and 34 motorbikes. This indicates slight undercounting of persons and significant overcounting of motorbikes, which may result from false positives or tracking drift over longer video durations.

4.3 Discussions

4.3.1 Model Improvement

The comparison table highlights the performance improvement of various helmet detection models, while person and motorbike detection accuracies remain constant across all models at 87% and 96%, respectively. This consistency is expected, as all models use the original YOLOv8 architecture for detecting persons and motorbikes. The main focus of model optimization lies in helmet detection, which has undergone several iterations of training using custom datasets. The earliest version, BestV8, achieved only 42% accuracy in helmet detection, likely due to limited training data or suboptimal labeling. This was significantly improved in Best21, which reached 72% accuracy. Subsequent models, such as Helmet_model and Head_model, showed further improvements to 82% and 86%, respectively, indicating better dataset quality and fine-tuning strategies. The most refined version, Best17, achieved a 95% helmet detection rate, demonstrating the effectiveness of progressive model training, class balancing, and more consistent annotation.

4.3.2 Helmet and Head Double Line Counting

In the first video which is table 4.2, the accuracy of our helmet and head detection are very precise, since the video displays a clear bounding box of head and helmet detection and no overlapping with other head and helmet. Table 4.2 showing the accuracy of

non-helmet to be at 100%, but there are minor flaws in helmet accuracy as it exceed the ground truth. The reason there are 26 helmets being displayed from the counting system is because the person who is in the front often blocks out the person who is in the back and this can cause false detection, classifying people who are not wearing a helmet as wearing it.

In the second video which is table 4.3, the accuracy went down compared to the first video. The reason is that there are many occasions where multiple motorbikes come through at the same time, causing confusion of our model and causing many overlapping bounding boxes of head and helmet. This makes the accuracy of helmet detection to 82% and non-helmet to 90%.

4.3.3 Person and Motorbike BotSort Counting

Table 4.4 shows the accuracy of person detection to be 98% and motorbike accuracy to be 93%. this result is being tested on video 1, which is the video where overlapping hardly appear, making the result satisfying.

Table 4.5 which is being tested on the second video where this video overlapping appears often more than the first video resulting in lower accuracy comparing to the first video. As person accuracy drop down to 93% and motorbike drop to 77%. Occasionally motorbike with two person on it can cause confusion in bounding boxes and it can appear to detect one person instead of two person, since the people who is driving and riding is really close to each other. Our BotSort method works well with less overlapping of bounding boxes, and as the more overlapping occur, it causes a confusion of unique ID tracking system when it is in the counting zone. Causing a new unique ID to be create even though it is consider the same person or motorbike proceeding throughout the frame.

CHAPTER 5

CONCLUSION AND DISCUSSION

This project presents a helmet and head detection system trained on a custom dataset using the YOLOv8 architecture, combined with a counting mechanism applied to university CCTV footage. The final model achieved significant accuracy improvements in helmet detection, reaching up to 95% in our latest version. The double-line counting method effectively reduced duplicate counts and stabilized results, especially for slow-moving or occluded objects. For person and motorbike tracking, the system performed well in low-overlap conditions, providing strong results that demonstrate the system's potential for practical monitoring and analysis of helmet usage compliance. As for the counting for motorbike and person class, we can implement Bot_sort tracker as their Yolo model are much for refine allowing us to count regularly through trackers.

5.1 Obstacles

During system development and testing, the main challenge involved dealing with overlapping bounding boxes, particularly when multiple motorcycles and riders appeared close together. This sometimes led to incorrect object counts or detection errors, such as merging two people into one or misidentifying a detection. The tracking system also struggled when many objects entered the counting zone at once, occasionally creating new IDs for the same object. These issues were more pronounced in crowded scenes and highlight the limitations of relying on bounding box-based tracking in complex real-world environments.

5.2 Future Work

In future iterations, the focus will be on improving both the detection model and the tracking accuracy. Training with more diverse and balanced data will help the model generalize better across various environments and video conditions. Further enhancement

of the counting and tracking logic is also planned to address issues with ID switching and occlusion. Additionally, while deployment to the university server is not yet complete, it remains a key objective for real-time monitoring in a practical setting. These improvements will support the goal of developing a more accurate, stable, and scalable helmet compliance monitoring system.

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