



Master Thesis Research

Real-Time Object Detection of Personal Protective Equipment in Video Streams Using Deep Learning Techniques

Thesis_AI900_T3_MSIAI_Second Trimestre 2024

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Agenda



Introduction

PPE importance, challenges, Technologies in Object detection



Objective

Create a model that caters to the requirements, for detecting PPE in AI systems and offer an explanation of performance indicators (KPIs) metrics.



Conclusion and Future Work

Effectiveness of the Model, & Future work.



Problem Definition

Address current problem, and motivation to solve those limitations using AI.



Methodology

Describe the dataset, and Model Implementation and Evaluation



Questions

Q&A Opened space



Previous Work

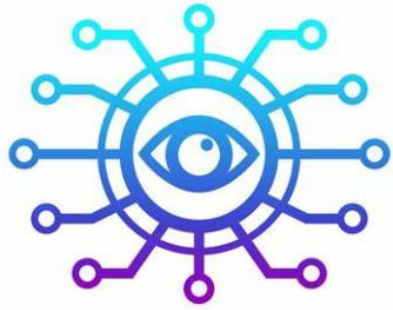
List previous techniques and advances ones, and provide high level comparison.



Results and Discussion

Present Performance KPIs, showing Visual examples & Model performance main KPIs

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Importance of Personal Protective Equipment

- Overview of Personal Protective Equipment (PPE) in ensuring workplace safety



Need for Automation

- Challenges in traditional PPE monitoring methods



Advances in Technology

- Introduction to deep learning and its role in enhancing PPE compliance

Introduction



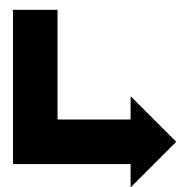
Importance of Personal Protective Equipment (PPE)

- Overview of Personal Protective Equipment (PPE) in ensuring workplace safety



Workers Safety

Worker adherence to safety rules within workplace is a challenges that addressed in last decades, as countries are expanding the projects and workers safety becomes critical requirements



- Using Personal Protective equipment, and there is multiple types of them, Helmet, googles, Earplug, Masks, Gloves, safety shoes, and more
- Safety Protocols training, and companies special Safety arrangements and certificates



Companies Needs

Companies looking to have high safe environment for the workers as this have high impact on company values, like reputation, finance impact on workers accidents, violation registered on government affairs.



Government Regularity Affairs

The impact is multifaceted, influencing regulatory oversight, public health, economic policies, and legal frameworks. Governments are tasked with setting and enforcing PPE standards to ensure workplace safety, which reduces accidents and fatalities.

Introduction



Need for Automation

- Challenges in traditional PPE monitoring methods



PPE Usage Manual Detection

Inspectors need to check PPE compliance which is slow and prone to mistakes leading to delayed safety breach detection and higher accident risks from oversights resulting in costly labor expenses. Moreover, manual checks are less efficient, in large, dynamic environments where constant monitoring is required.



PPE Usage Auto Detection

Automatic detection of PPE uses advanced technologies like sensor-based, and computer vision and deep learning to monitor compliance in real-time, ensuring consistent and accurate safety checks. It reduces human error, provides immediate feedback, and enhances efficiency by covering large and complex environments effortlessly.

Introduction



Advances in Technology

- Introduction to deep learning and its role in enhancing PPE compliance

Sensor Based PPE Detection

Using sensor technology for detecting PPE involves utilizing tools such as RFID tags and GPS to track the presence and proper utilization of equipment in real time within safety procedures already in place to ensure adherence to safety measures. Nonetheless these systems can be expensive to install and maintain may face challenges with interference and might not be suitable, for all settings.

Deep Learning PPE Detection

Utilizing Deep learning improves the automated identification of PPE by using neural networks to precisely recognize and categorize safety gear instantly in different settings, with increased precision and flexibility while minimizing human involvement and errors risk but it demands significant computational power and extensive training data for optimal performance.

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Advances in Technology

- Identify the problem and what uses to overcome the problem in PPE Detection

Problem

The reliance on manual PPE inspections and periodic audits is insufficient in dynamic industrial environments, leading to delayed detection of safety breaches and increased risk of accidents. This gap necessitates the development of real-time automated systems to enhance safety compliance, reduce accidents, and improve overall workplace safety.



Solution

Utilizing Deep learning improves the automated identification of PPE by using neural networks to precisely recognize and categorize safety gear instantly in different settings, with increased precision and flexibility while minimizing human involvement and errors risk but it demands significant computational power and extensive training data for optimal performance.



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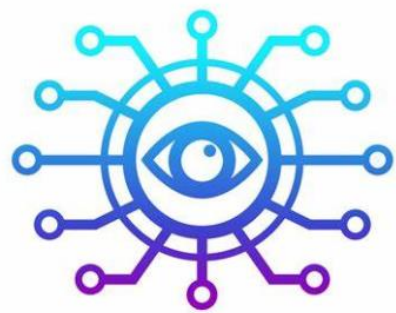
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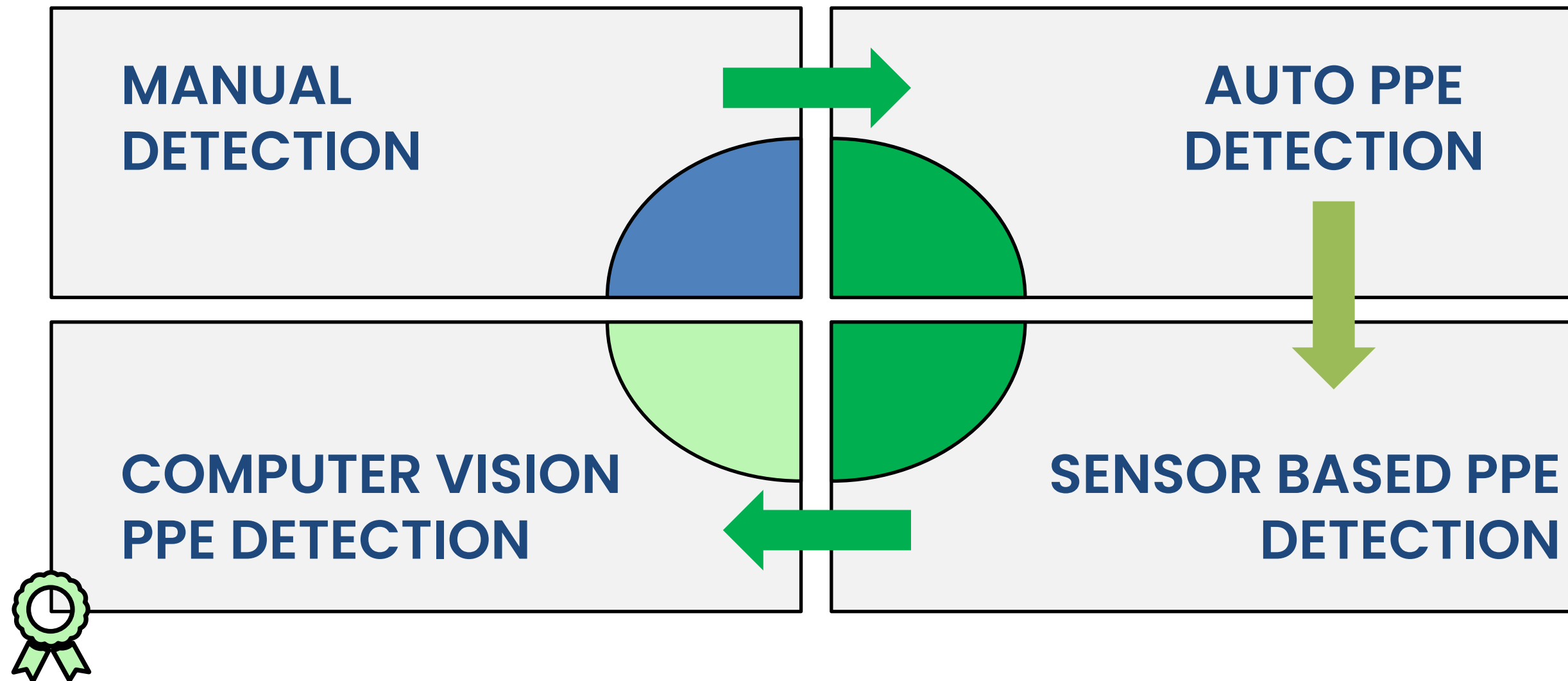
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State-Of-The-Art

Previous Work



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		Devices	Advantage	Disadvantage	Application
Sensor Based PPE Detection	RFID	RFID TAG per PPE equipment, Antennas, RFID Readers, Databases	real-time monitoring Integration with other monitoring system	High Cost, Sensors is sensitive to Metal environment subject to interference	used at the site entrance & exits
	GPS Tracker	GPS Devise Per PPE equipment, Database.	effective in large, open environments and can provide detailed location data over extensive areas	Used in Outdoor High Operation Cost	mining operations, GPS installed in PPE
	Bluetooth	Bluetooth sensors per PPE Detectors	Low Cost Indoor Environment	Limited in Range Subject to interference	used in manufacturing plants
	Proximity Sensors	Proximity sensors, TAGs per PPE	Real-time	High operation cost	chemical plants
	Pressure Sensors	Pressure-sensitive mats or floors detect the presence	Real-time	High Operation cost	Laboratories

Previous Work



Previous Work • Previous work USING YOLO Algorithm

Year	Goal	Algorithm	Dataset	Performance Measure
2018	Monitor PPE in nuclear facilities (Hard Hats, Full-face Masks)	YOLOv3 (two-phase training)	3,808 images (Real-world via webcam and web crawling)	Precision: 97.64%, Recall: 93.11%, FPS: 7.96
2019	Real-time PPE detection on construction sites	YOLOv3 with data augmentation	~2,500 images (Manually collected and web scraping)	mAP: 97%, Recall: 97%, F1-Score: 97%
2020	Enhance worker safety through real-time detection	YOLOv3, YOLOv4, YOLOv5	1,330 images (CHV dataset with 6 classes)	YOLOv5x mAP: 86.55%, YOLOv5s FPS: 52
2021	Detect helmets and heads in real-time	YOLOv5x with Power-law transformation	3,000 training, 1,000 testing (MakeML public dataset)	Accuracy: 92%, Precision: 92.4%, Recall: 89.2%, F1-Score: 90.8%
2022	Hybrid detection of PPE on construction sites	YOLOv4, YOLOv4-Tiny with CLSlim pruning	~25,000 samples (Security footage of construction site)	mAP loss: 2.1%, Inference speed: 1.8x, Compression: 98.2%
2022	Detect PPE in hazardous industrial areas using video streams	YOLOv4-Tiny, SSD MobileNet, CenterNet, EfficientDet	7,035 images (Public dataset), 215 & 236 images (Controlled)	YOLOv4-tiny mAP: 86%
2022	Real-time PPE monitoring using CCTV cameras	YOLOv4 with cognitive safety analysis	CCTV footage (Number not specified)	mAP: 80.19%, FPS: 80
2022	Improve helmet detection using one-stage object detector	YOLOv5 with ShuffleNetv2, MobileNetv3 backbones	7,041 images (Roboflow's "Hard Hat" dataset)	Precision: 94.2%, Recall: 91%
2022	Enhance safety at construction sites	YOLOv5 (multiple sizes: nano to extra-large)	7,063 images (Northeastern University, Harvard Dataverse)	mAP50: 95.8%, Precision: 93.9%, Recall: 91.2%, F1-Score: 92.5%
2022	Develop real-time PPE compliance detection models	YOLOv3, YOLOv4, YOLOv7	11,000 images	mAP: 97.29%, FPS: 25.02
2023	Computer vision-based PPE monitoring platform	YOLACT, DeepSORT for object tracking	1,288 images (Google Images, surveillance cameras, smartphones)	mAP50: 66.4, DeepSORT accuracy: 91.3%
2023	Develop robust PPE detection in challenging conditions	YOLOX-m with environmental augmentations	1,699 images (CHVG dataset)	mAP: 89.84%
2023	Real-time monitoring system for PPE compliance	YOLOv5	18,767 images (FUZ-PPE dataset)	mAP: 84.2%, FPS: 105
2023	Real-time detection of safety hardhats	Feature extraction, template matching, cascade classification	239 images (Construction sites)	Most effective: Cascade classifier, Real-time detection
2023	Detect PPE on offshore drilling platforms	RFA-YOLO with residual feature augmentation	10,000 images (ODPD), 6,600 samples (FCD), 2,000 images (PPED)	Accuracy: 93.1%, FPS: 13
2023	Real-time detection of hardhats in hazardous environments	SSD-MobileNet	3,261 images (Construction surveillance and web crawlers)	Precision: 95%, Recall: 77%
2023	Real-time PPE detection in industrial sites	YOLOv2	731 helmet images (ImageNet)	Effective real-time monitoring, Highlights potential for improving workplace safety

Previous Work



Previous Work • Previous work USING CNN Algorithm

Year	Goal	Algorithm	Dataset	Performance Measure
2022	Ensure PPE compliance and prevent head injuries	YOLO-based detectors, CNN, Decision Trees	1,500 annotated images, 4,700 instances (Pictor-v3)	mAP: 72.3%, FPS: 11
2022	Detection of head-mounted protection gear	YOLOv5, MobileNetv2 SSD, Faster R-CNN	12,682 images (University of Belgrade, Roboflow, Pictor PPE)	Precision: 92%, Recall: 61.1%, Hardhats Precision: 100%, Recall: 96%
2023	Ensure worker safety by detecting PPE	R-CNN architecture	1,129 images (MIT database), 333 additional images	Accuracy: 70%
2023	Facial recognition and PPE detection for restricted access	Faster R-CNN with data augmentation	Kaggle dataset	mAP: 99% at 3m, 89% at 5m
2023	PPE compliance using position-guided anchoring	Position-guided anchoring, CNN-based classifiers	932 images (CPPE dataset)	F-score: 97% (hardhats), 95% (vests)
2023	Enhance construction safety via worker tracking and hazard prediction	R-CNN and CNN-based models	Surveillance video frames (Construction sites)	mAP: 92%, AP: 95%, Safety position precision: 87%
2023	Detect hardhat violations and issue alarms	CNN with MobileNet backbone, residual blocks	Custom dataset (Construction workers with/without hardhats)	AP: 87% (negative), 89% (positive), FPS: 62

Previous Work



Previous Work • Conclusion

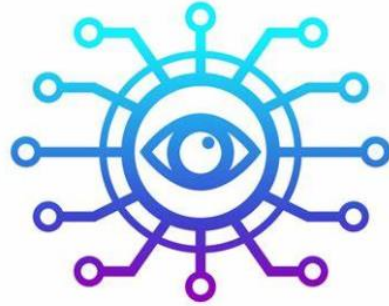
		Accuracy	Inference Time	Model Complexity	Localization Accuracy	Scalability	Training Time
Computer Vision PPE Detection	CNN-based Detectors	Higher accuracy, better for complex scenes	Slower, not suitable for real-time applications	High complexity, requires more resources	Very accurate in localizing objects	Less scalable without significant changes	Longer training times
	YOLO	Competitive accuracy, improving with each version	Fast, designed for real-time detection	Lower complexity, more efficient	Improved localization, but still behind CNN-based models	Highly scalable with minor modifications	Relatively efficient training

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Problem Definition

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Methodology

Describe the dataset, and Model Implementation and Evaluation



Questions

Q&A Opened space



Previous Work

List previous techniques and advances ones, and provide high level comparison.



Results and Discussion

Present Performance KPIs, showing Visual examples & Model performance main KPIs

Objective



Objective

- Develop a real-time object detection model for PPE using YOLO



Sub-Objectives

- Select appropriate object detection algorithms.



Evaluate the model's performance

- Evaluate the model's performance based on accuracy, precision, and recall.

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Methodology



Dataset Construction

- Describe dataset construction, and



Model Training

- Training the YOLOv8 model using the prepared dataset.

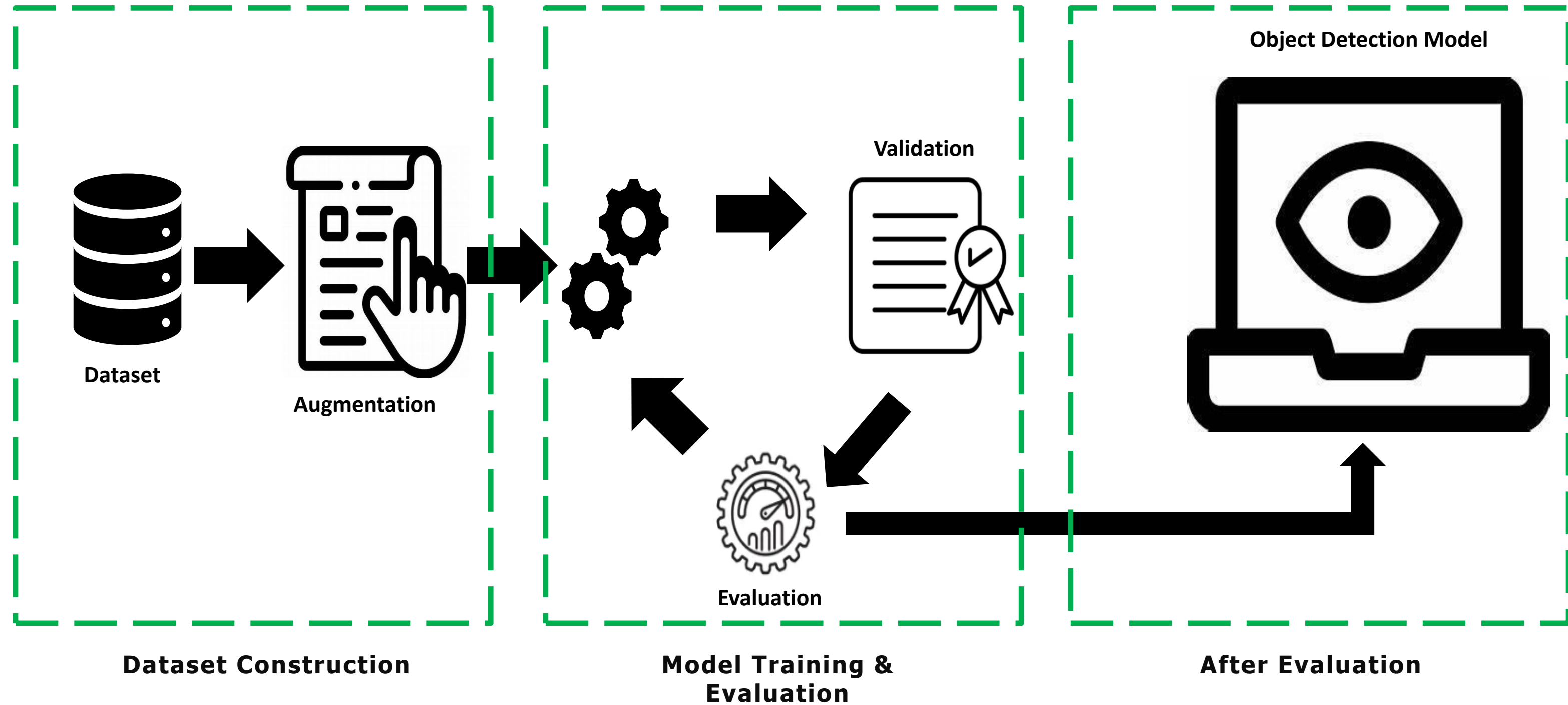


Evaluation

- Performance assessment using metrics like mAP, precision, recall, & F1 score.

Methodology

Methodology Complete Cycle.



Methodology



Dataset Construction

- Develop a real-time object detection model for PPE using YOLO

Collection

- images are collected from roboflow website, including real-world environments and publicly available datasets

Annotation

- These images are annotated with bounding boxes around PPE items like helmets, vests, gloves, and safety goggles.

Augmentation

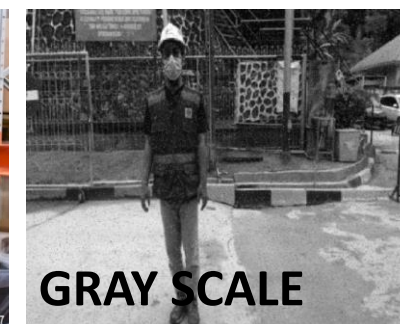
- Data augmentation techniques such as rotation, scaling, and flipping are applied to enhance the dataset's diversity and improve model robustness.



ANNOTATION



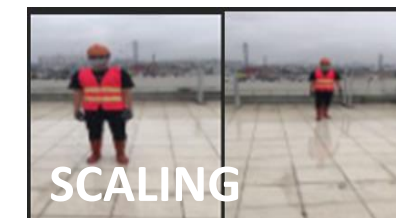
NOISE



GRAY SCALE



FLIPPING



SCALING

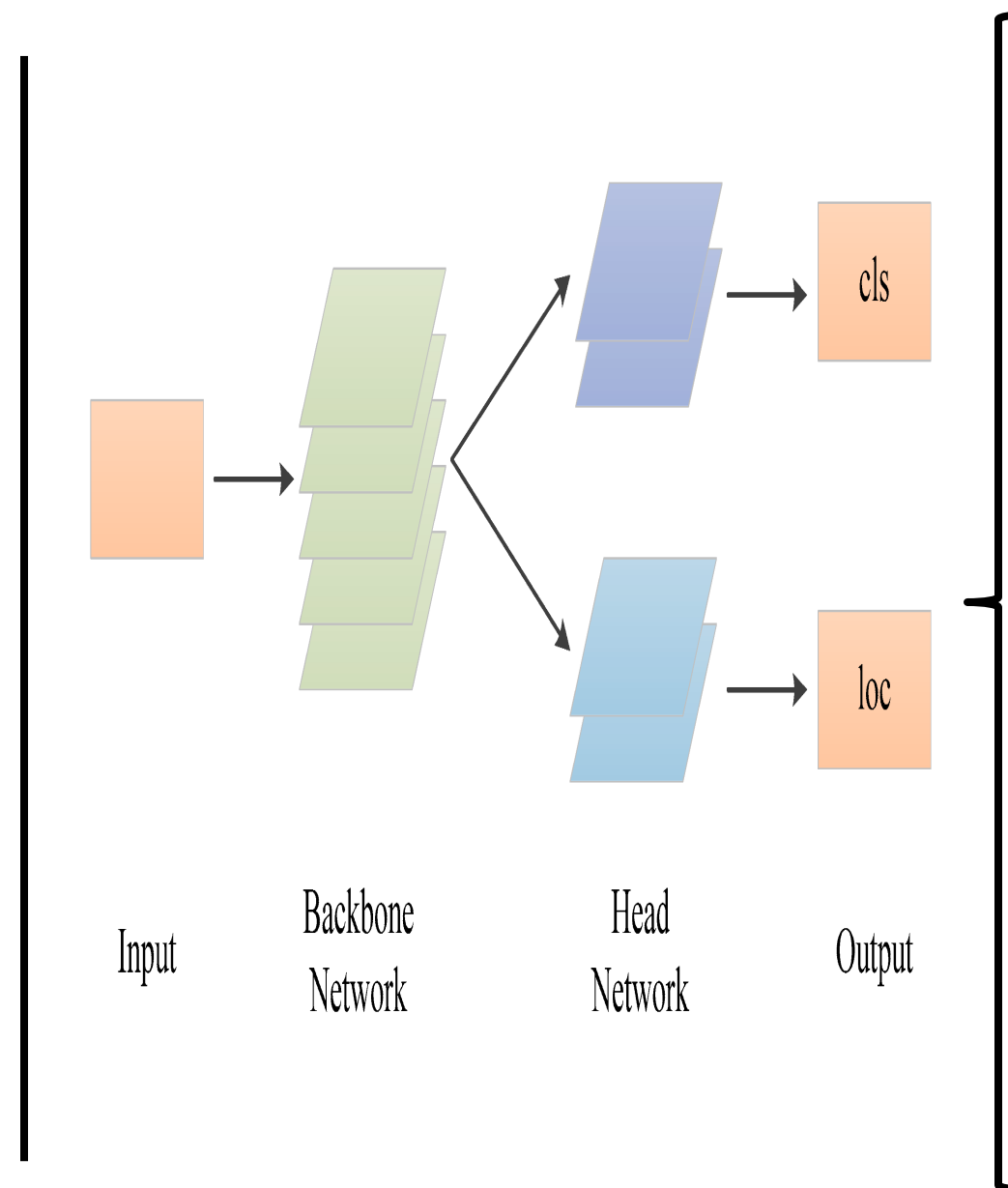
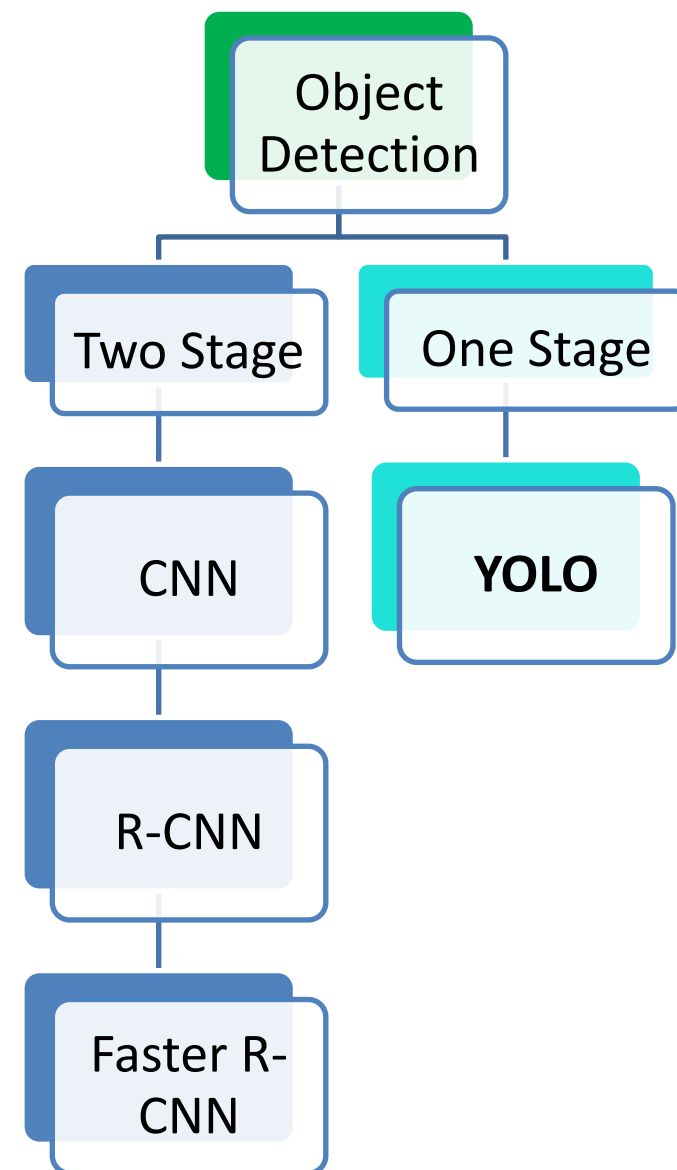
Methodology



YOLOV8 Model

- Develop a real-time object detection model for PPE using YOLO

Object Detection based on detection Stage count



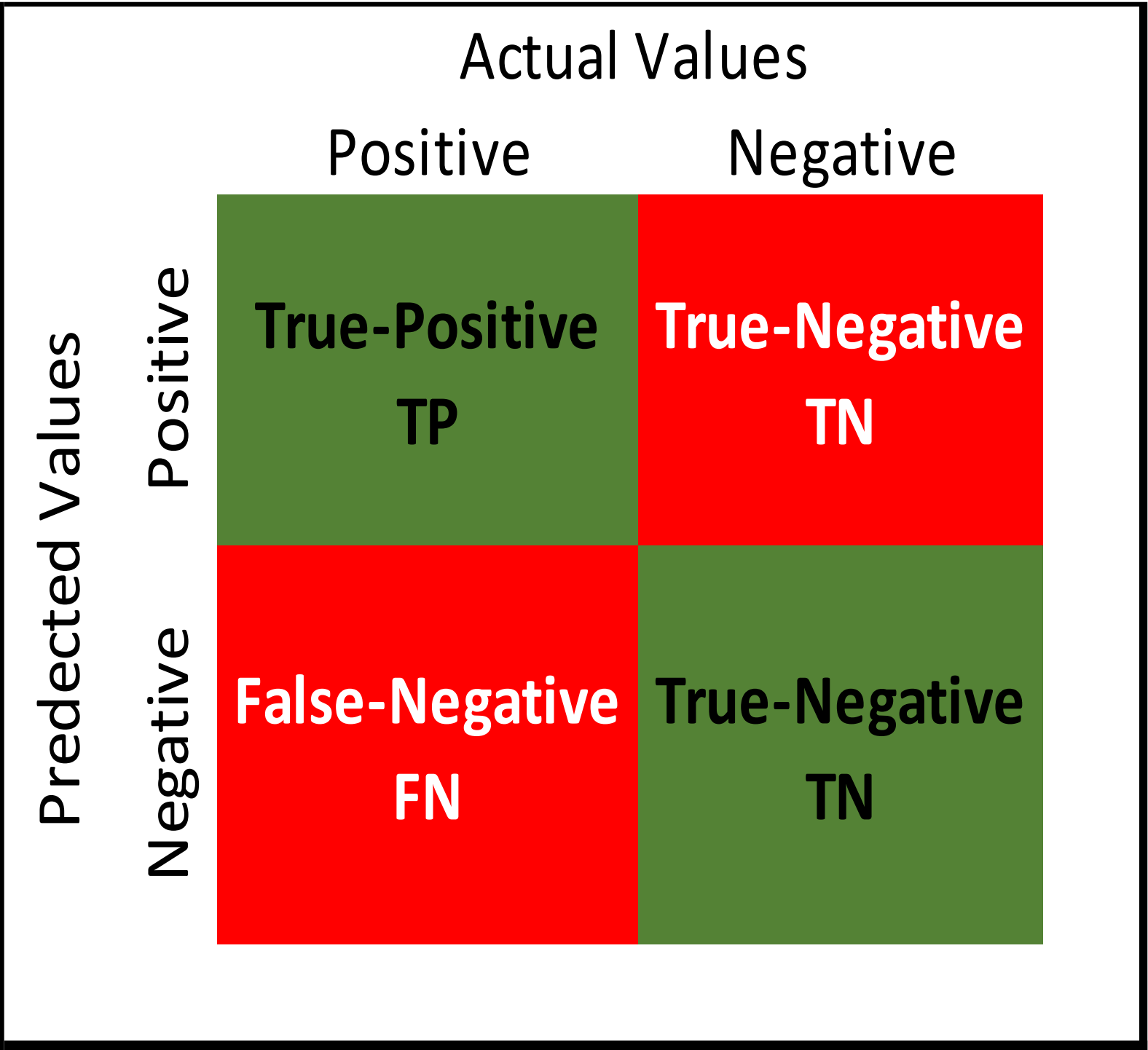
- 1. Input and Preprocessing:** The image is resized and normalized, preparing it for feature extraction.
- 2. Backbone:** Extracts features using convolutional layers from the input image, generating feature maps.
- 3. Neck:** Aggregates features from multiple scales, making the model robust to objects of various sizes, and So, the neck is crucial for refining and improving the features before they are passed on to the head for the final detection tasks.
- 4. Head:** After the neck, the head of the network takes the refined features and produces the final outputs, including the object class (classification, or "CLS") and the object location (localization, or "LOC").

Methodology

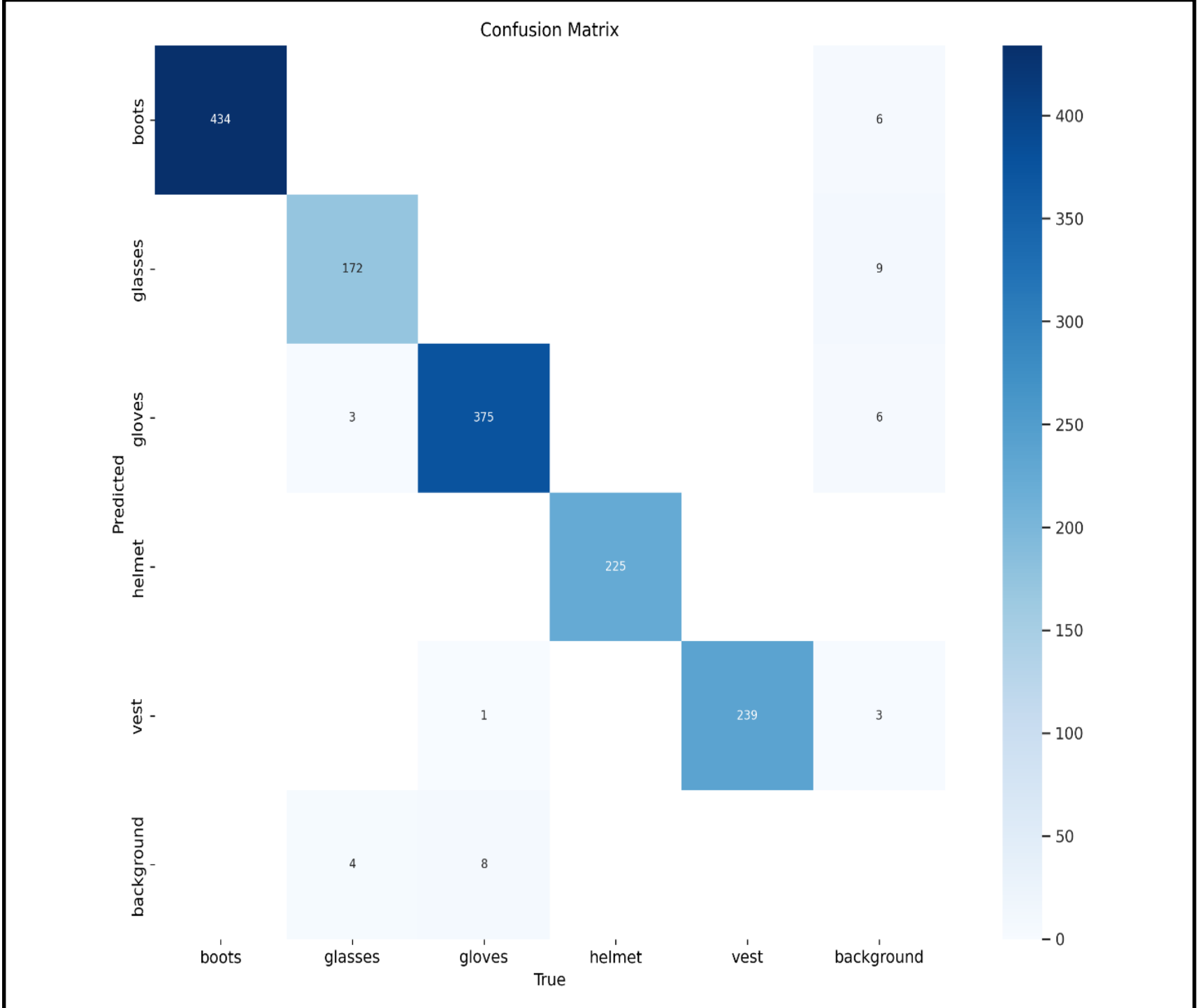


Evaluation

- Confusion Matrix, it is table layout allows visualization of the performance of an algorithm



Theoretical Confusion Matrix



Model Performance Confusion Matrix

Methodology



Evaluation

- Performance assessment using metrics like mAP, precision, recall, & F1 score.

Model Training for PPE Detection: Model training involves feeding the annotated dataset into a deep learning model, YOLOv8, on Google Colab platform using GPU acceleration.

The model learns to detect PPE items by iterating over the data multiple times (epochs) in our case we are using 50 epochs and optimizing its accuracy, precision, and recall.

Below training Model Results

Class	Images	Instances	Recall	mAP50
all	236	1461	98.20%	98.40%
boots	212	434	100.00%	99.50%
glasses	176	179	93.70%	95.90%
gloves	205	384	97.10%	97.70%
helmet	211	225	100.00%	99.50%
vest	228	239	100.00%	99.50%

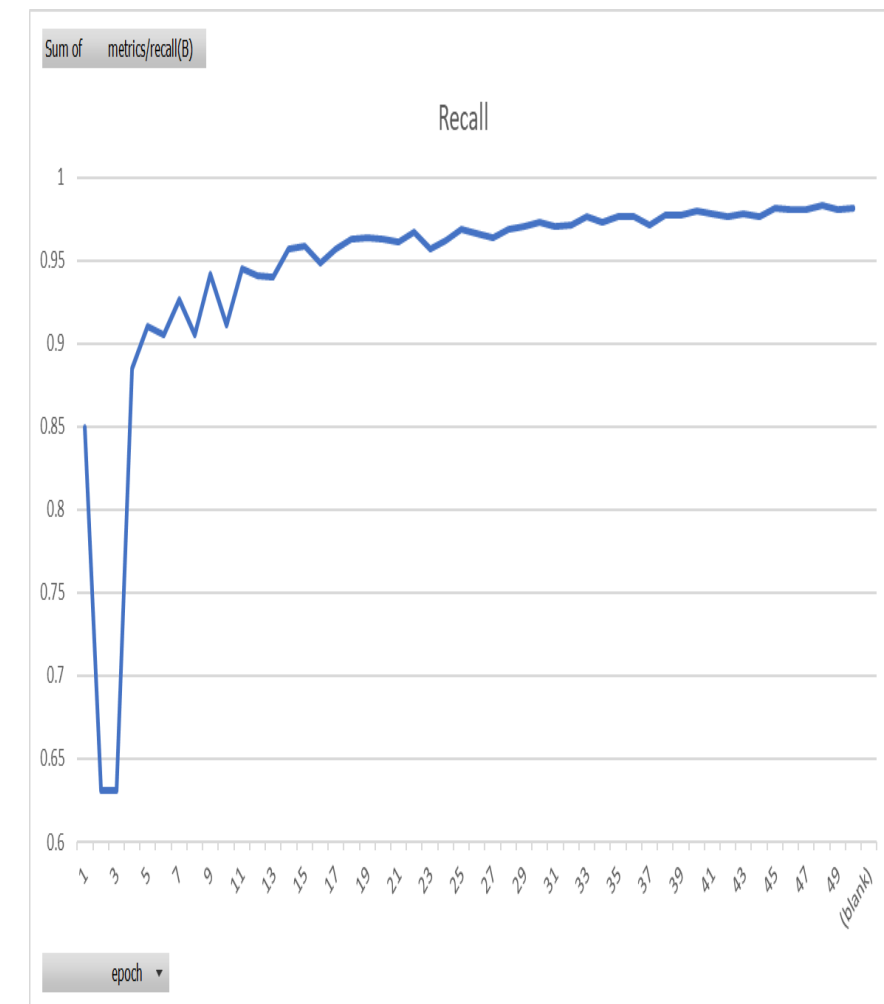
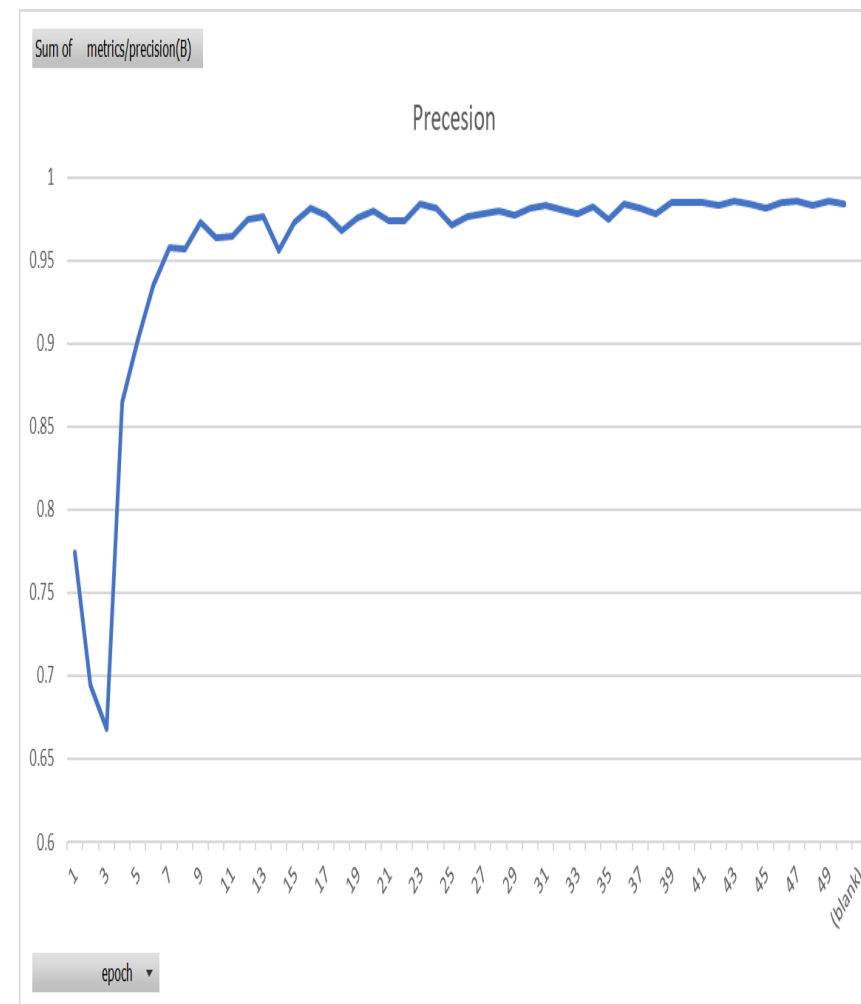
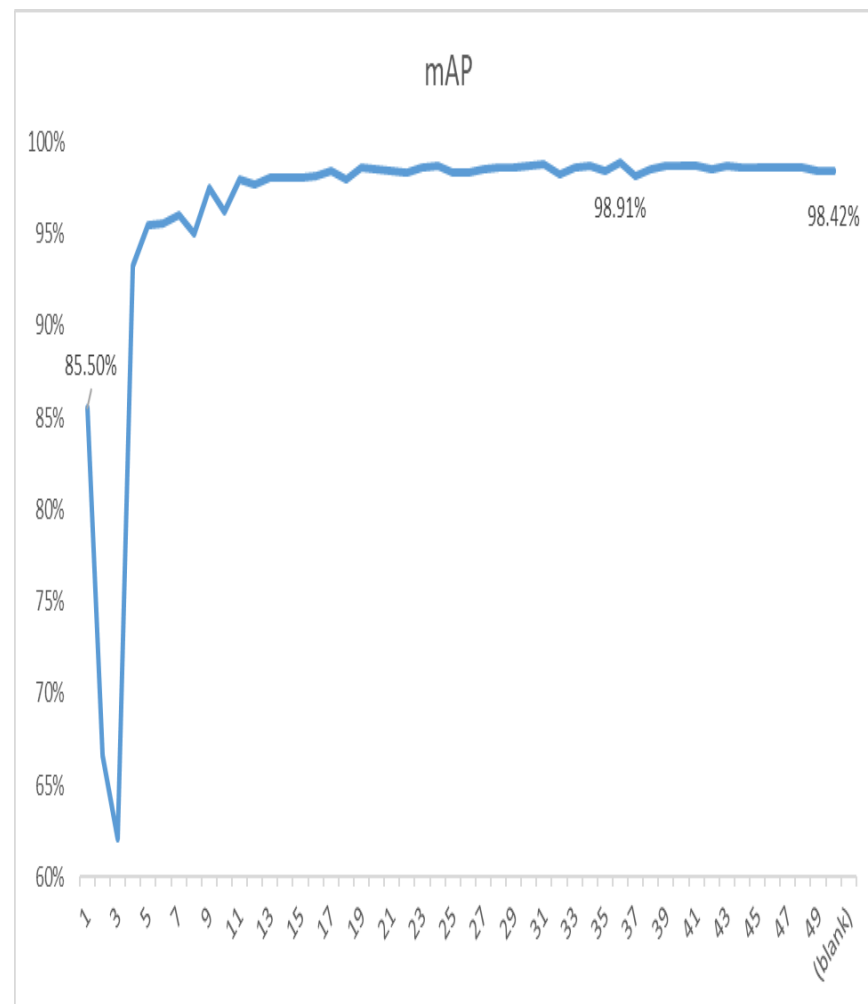
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- Performance assessment using metrics like mAP, precision, recall, & F1 score.



Precision=TP/ (TP+FP)

Recall= TP/ (TP+FN)

F1 score= (2* Precision*Recall)/ (Precision+ Recall)

$$\text{mAP} = \frac{1}{N} \sum_{i=1}^N \text{AP}_i$$

Mean Average Precision Formula

KPIs Metrics for YOLOv8 Object detection algorithm vs epochs

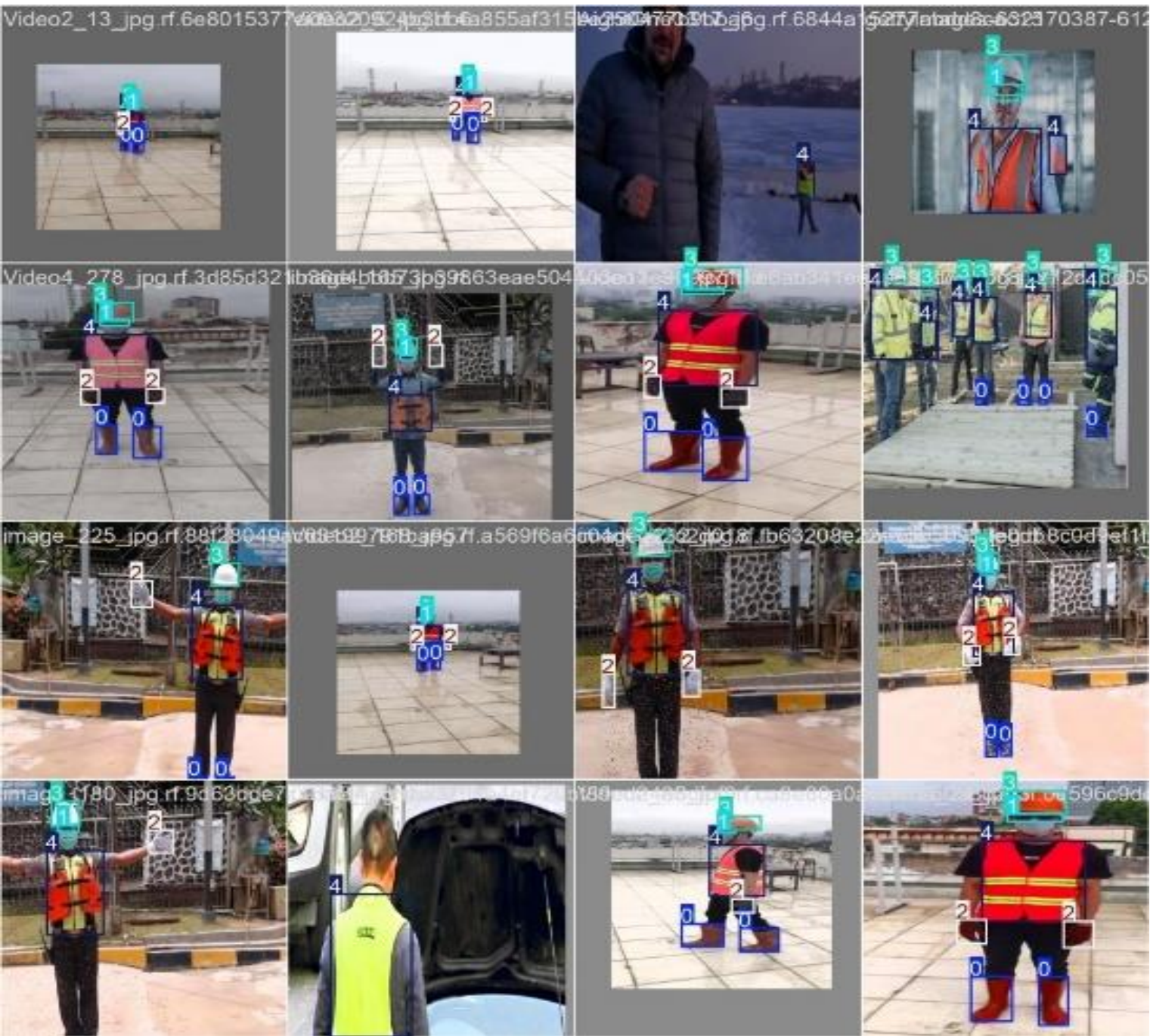
Methodology



Evaluation

- Training Batched and Validation Pictures

Training



Validation Class & Confidence Rate



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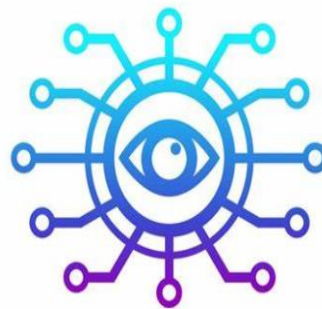
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Results and Discussion

The YOLO version 8 model is showing results in detecting different types of personal protective equipment, During the test, YOLOv8 was applied to a videos stream to detect objects like helmets, safety vests, and other PPE type. The video was processed frame by frame, with YOLOv8 making predictions about the presence and location of these objects in real time.

Confidence Ratio

The confidence ratio, also known as the confidence score, is a measure of how certain the model is about its prediction. It ranges from 0 to 1, where 1 indicates complete confidence in the detection and classification of an object.

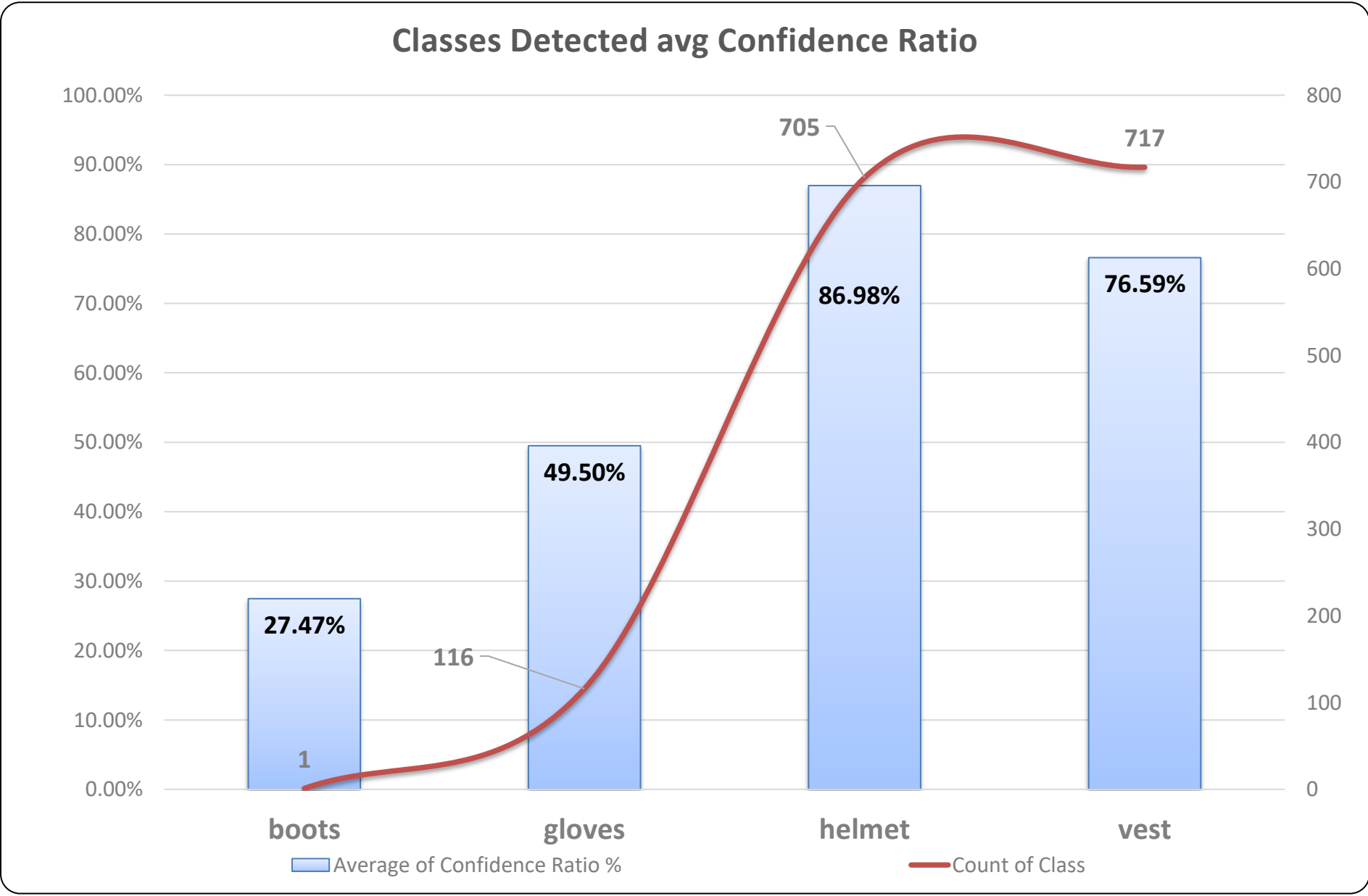
- **High Confidence (close to 1):** The model is highly certain that the detected object is correctly classified and the bounding box is accurate.
- **Low Confidence (closer to 0):** The model is less certain about its prediction, which might indicate that the object is partially obscured, in a challenging position, or the image quality is poor.

In practical terms, a threshold is often set (e.g., 0.5 or 0.6) to filter out predictions with low confidence scores, which helps reduce false positives.

In our test we include some of the processed frames, and confidence ratios for each detected class.

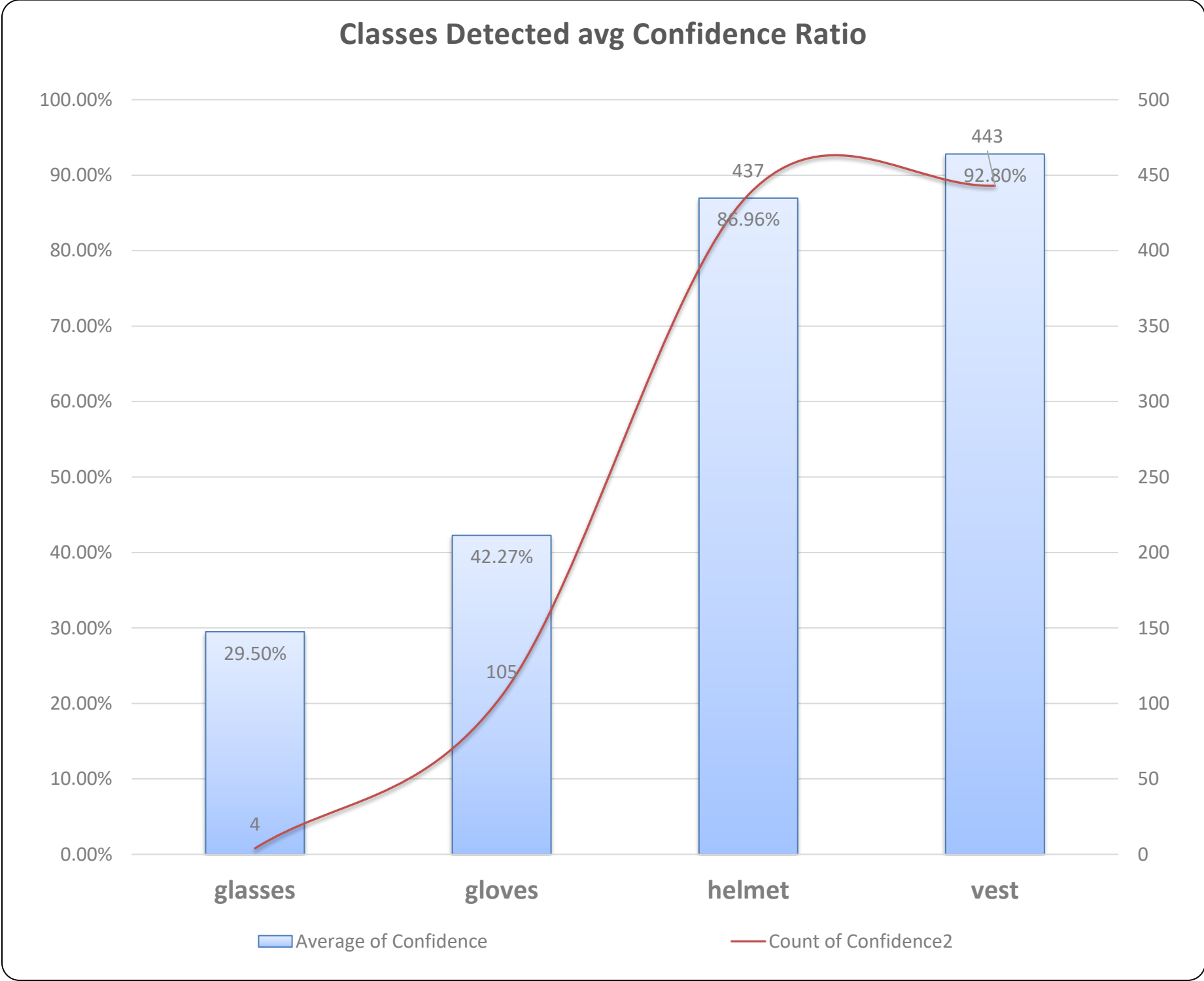
Results and Discussion

Test #1



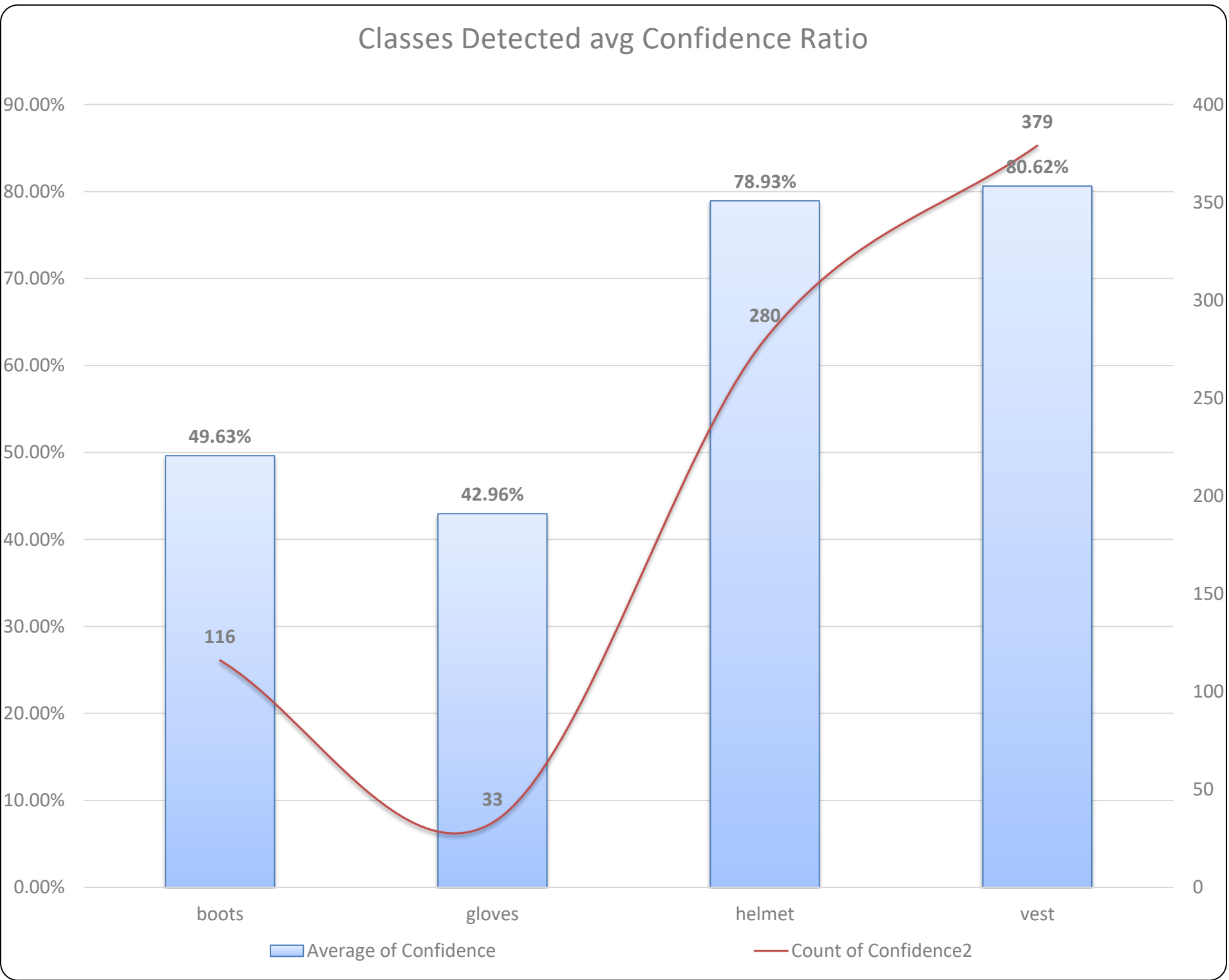
Results and Discussion

Test#2



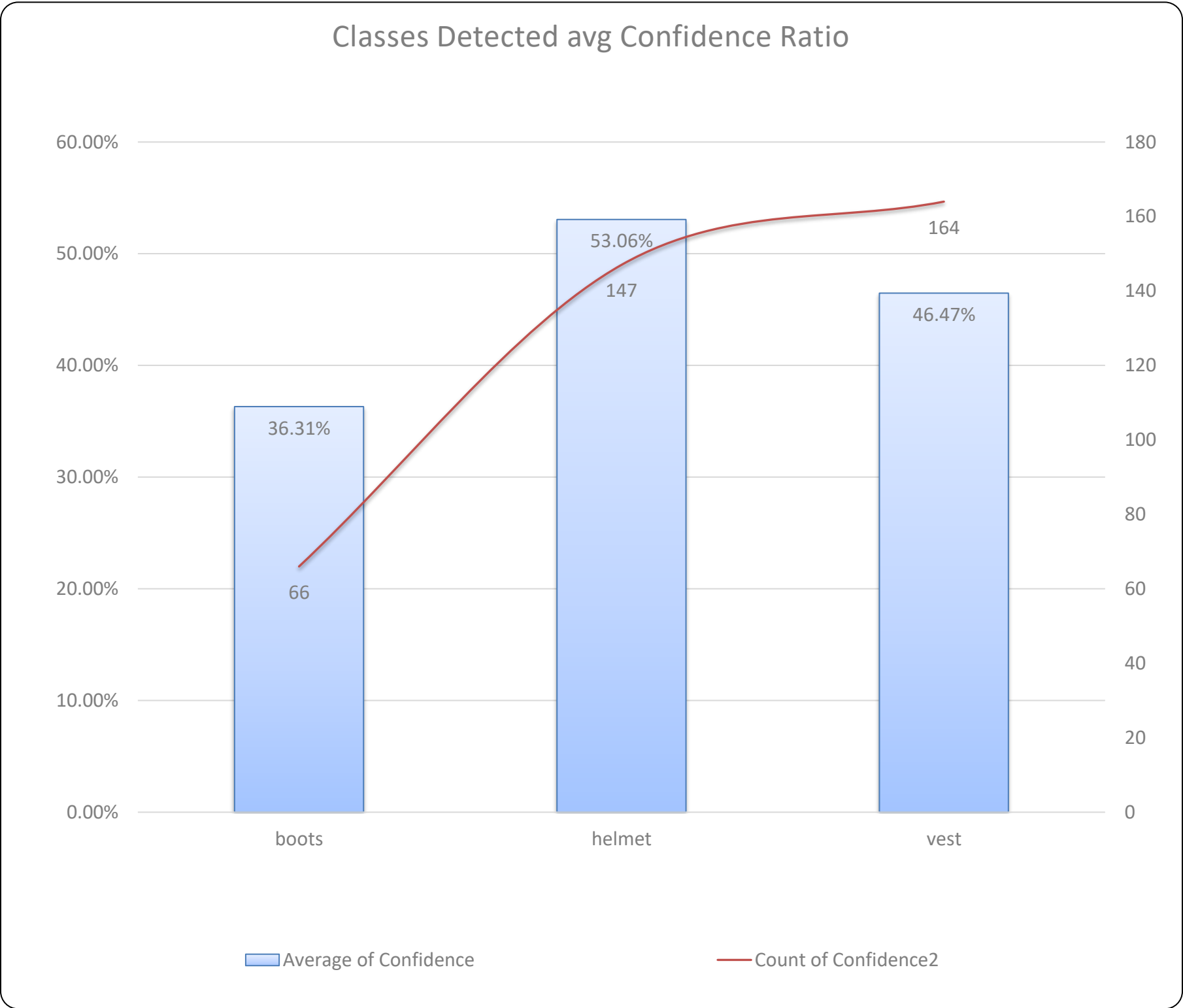
Results and Discussion

Test#3



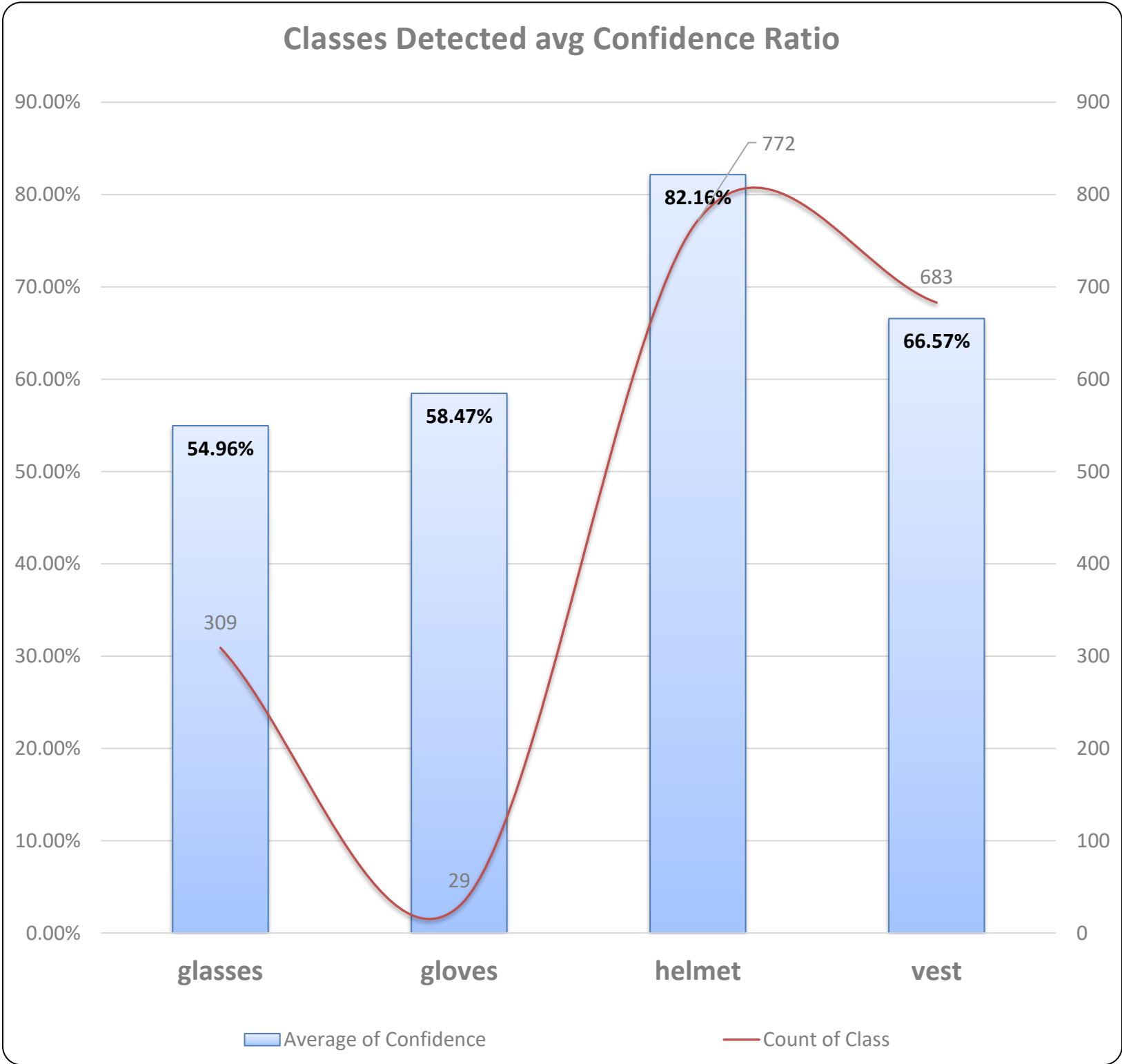
Results and Discussion

Test#4



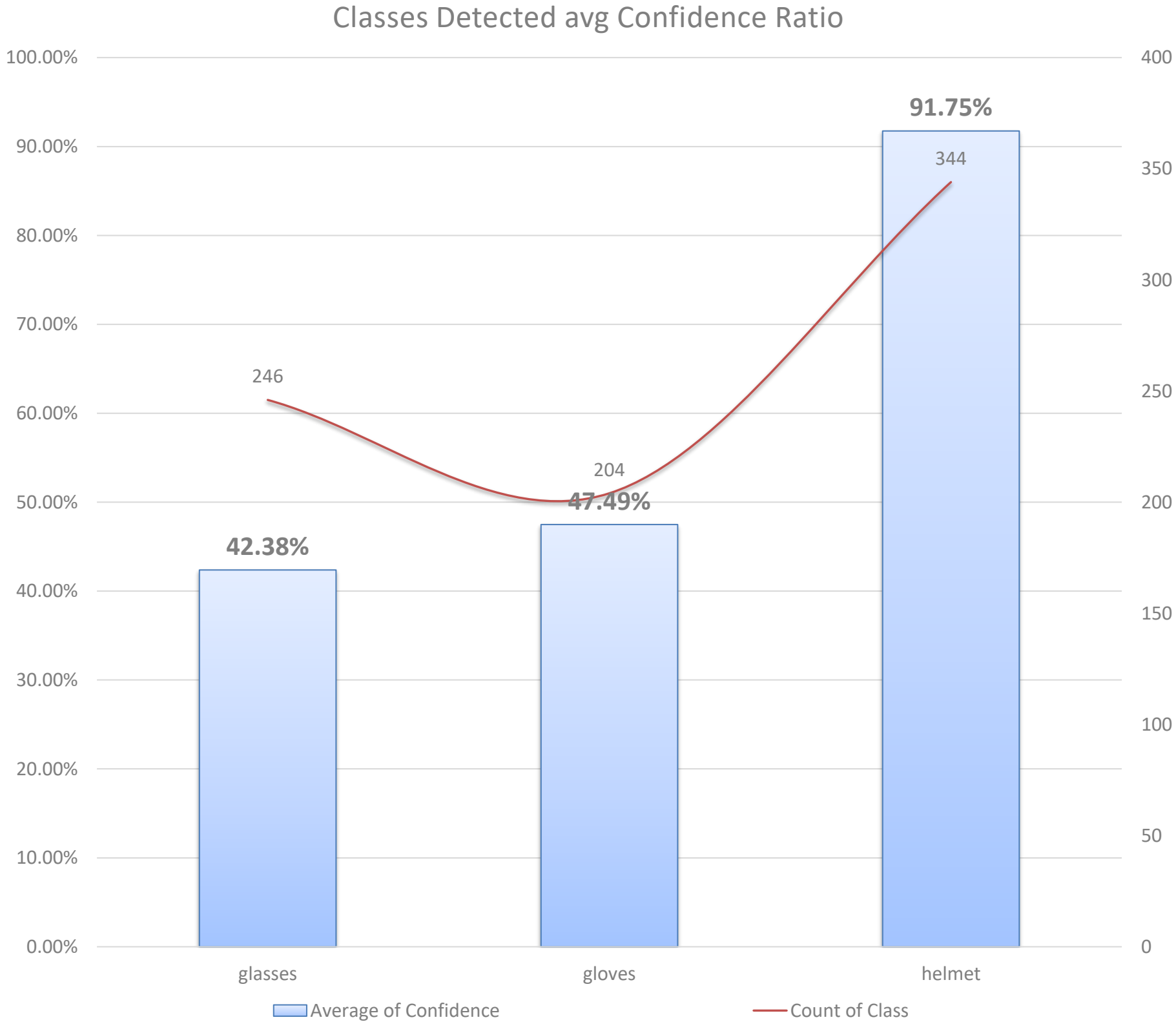
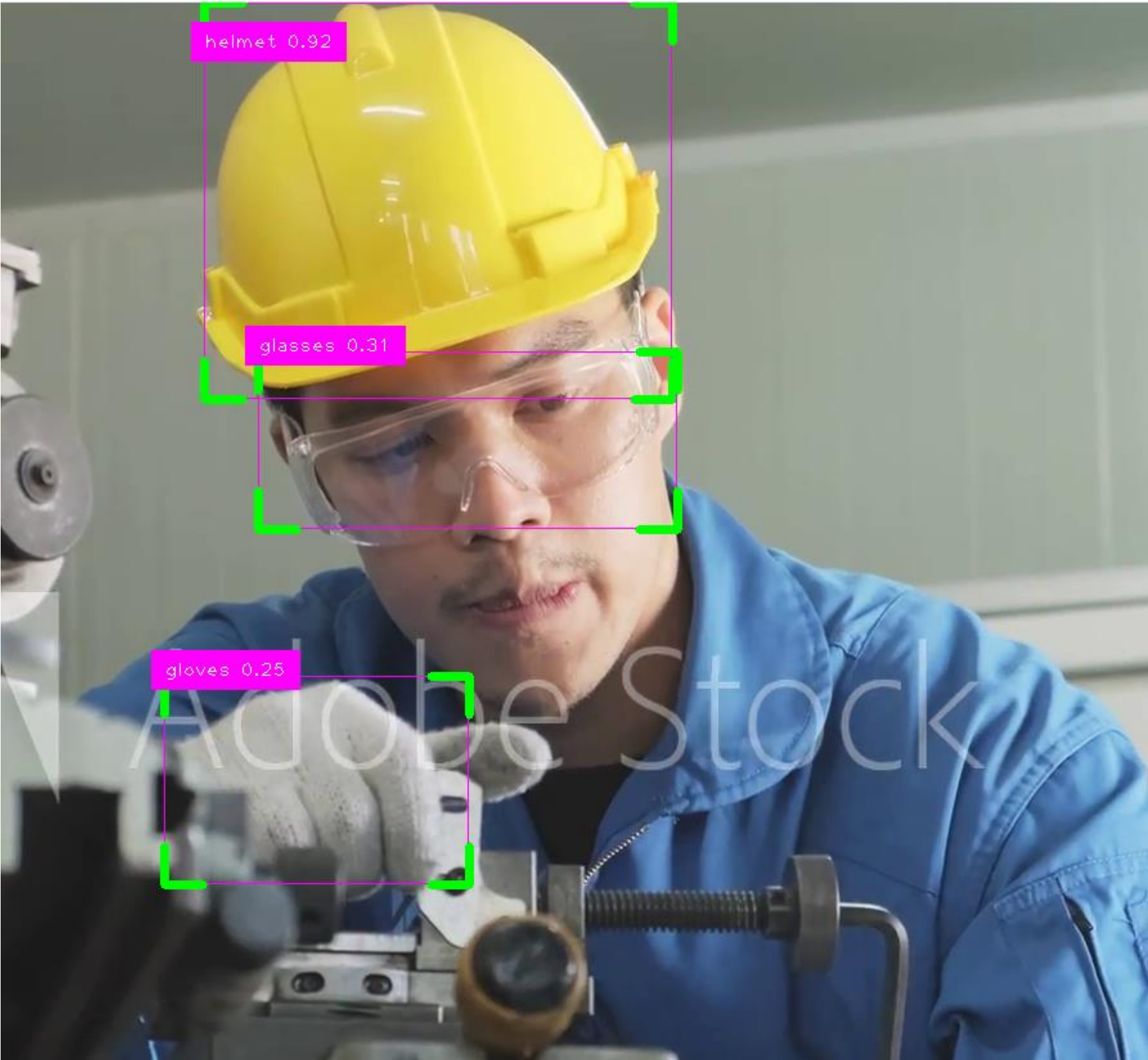
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Test#5



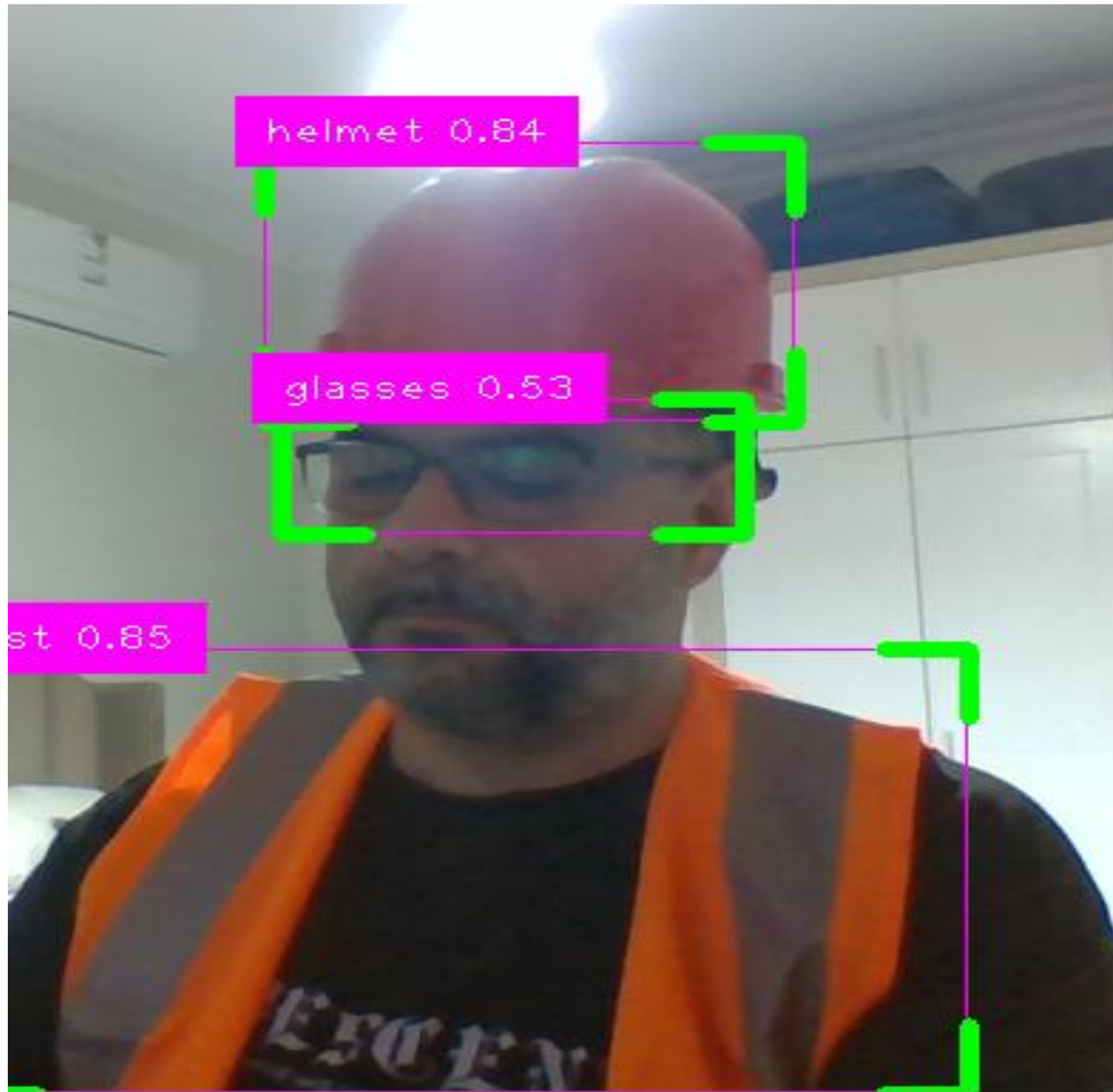
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Test#6



Results and Discussion

Test#7 Live CAM



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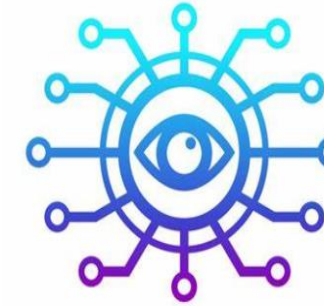
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The YOLOv8-based PPE detection system effectively enhances workplace safety with high precision and real-time capabilities, though challenges like processing speed in complex environments persist. Future work will focus on optimizing the model for various industrial scenarios and improving real-time performance on lower-end hardware.

- This research utilized AI and Computer Vision, specifically the YOLOv8 architecture, to enhance workplace safety by ensuring the proper use of Personal Protective Equipment (PPE).
- The model effectively addressed the problem of PPE noncompliance by providing real-time detection with an impressive 98.9% mAP accuracy on validation data.
- The findings underscore the potential of AI in promoting sustainability, improving employee well-being, and reducing costs for industries.
- Further improvements in model performance can be realized by expanding the training datasets, thereby enhancing detection accuracy across diverse scenarios.

Conclusion and Future Work

The future works related to this research can be summarized as follows:

- Future research should focus on expanding the dataset to include more varied and complex environments to improve model generalization.
- Exploring lightweight versions of the model for deployment on edge devices could enhance its practical application in real-time safety monitoring.
- Integrating the model with existing safety management systems and exploring additional deep learning techniques could further refine the system's effectiveness and efficiency in diverse industrial settings.

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