Occupational Safety Using Object Detection

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Basic Introduction

- Object Detection is a computer vision task that refers to the process of locating and identifying multiple objects in an image. Deep learning algorithms like YOLO, SSD and R-CNN detect objects on an image using deep convolutional neural networks, a kind of artificial neural network inspired by the visual cortex.

Introduction To Project

- Occupational safety and training using OD is an idea aimed at enhancing workspace safety and productivity. By leveraging advanced computer vision techniques, we aim at creating a comprehensive system that can detect and prevent unsafe actions, identify potential hazards, and provide real time training and feedback to workers and everyone involved in the workspace.
- Through this project, we aim to improve the workspace safety, empower workers with real time guidance and create a data driven approach to safety and training. By combining these technologies, we aspire to foster a culture of safety that not only protects workers but also contributes to increased efficiency and productivity.

Objectives

- The primary objective of this project is to develop a system that can monitor and improve occupational safety in a workspace by detecting and preventing unsafe actions and provide a real time training and feedback to workers and everyone involved in the workspace.
- Use of Object Detection: It will play a crucial role in the project by helping identifying tools, equipment, objects and potentially hazardous situations in the workspace. Some of the specific benefits are:
- Personal protective equipment monitoring of the workers in the construction site or workplace.

Scope and requirements of the project

- The scope of the project encompasses the integration of object detection to enhance workplace safety and training. It includes the real time identification of hazards, safety violation detection, ergonomic assessment and immediate feedback to workers. The project seeks to provide data driven insights, a user-friendly interface, scalability to different industries and ongoing maintenance while adhering to ethical and privacy considerations. The ultimate goal is to foster a culture of safety in the workplace, preventing accidents, improving worker well being and enhancing overall operational efficiency.

In the current day and age, the project greatly benefits the workplace in several ways as it addresses critical safety and training need. Some of the requirements of the project are:

- Enhanced safety
- Tool and equipment tracking.
- Preventing collisions.
- Safe zones and restricted area.
- Accident prevention
- Workers well being
- Productivity and efficiency

Scope and requirements of the project

- Compliance with regulations
- Data driven decision making
- Adaptation to technology
- Remote work considerations
- Training and upskilling
- Customization
- Employee engagement
- Monitoring object interactions and environmental monitoring.
- Inventory management.
- Data for analysis and reporting.
- Cost reduction.
- Sustainability

Literature Survey

Reference	Year of publication	Conference or journal	Objective	Technique	Dataset	Evaluation	Result	Future work
Ren, S., He, K., Girshick, R., Sun, J	2016	Conference	object detection with region proposal networks	SPPNet, fast R-CNN VGG-16	PASCAL VOC 2007, PASCAL 2012	accurate	73.2% mAP on testing dataset	Object detection
anjan, R., Sankaranarayanan, S., Bansal, A., Bodla, N., Chen, J. C., Patel, V. M.	2018	Conference	Deep learning for understanding faces	CNN	VGGFace, MegaFace, CASIA-WebFace	accurate	TPE of 98.8%	Face detection
Xu, H., Lv, X., Wang, X., Ren, Z., Bodla, N., Chellappa, R	2018	Conference	Deep regionlets for object detection.	DCNN, deep regionlets COCO dataset	PASCAL VOC and Microsoft	accurate	mAP of 82.0%	Object detection
Oğuzhan,	2021	Conference	Object		Custom from	accurate	AP(%)	Object

Literature Review

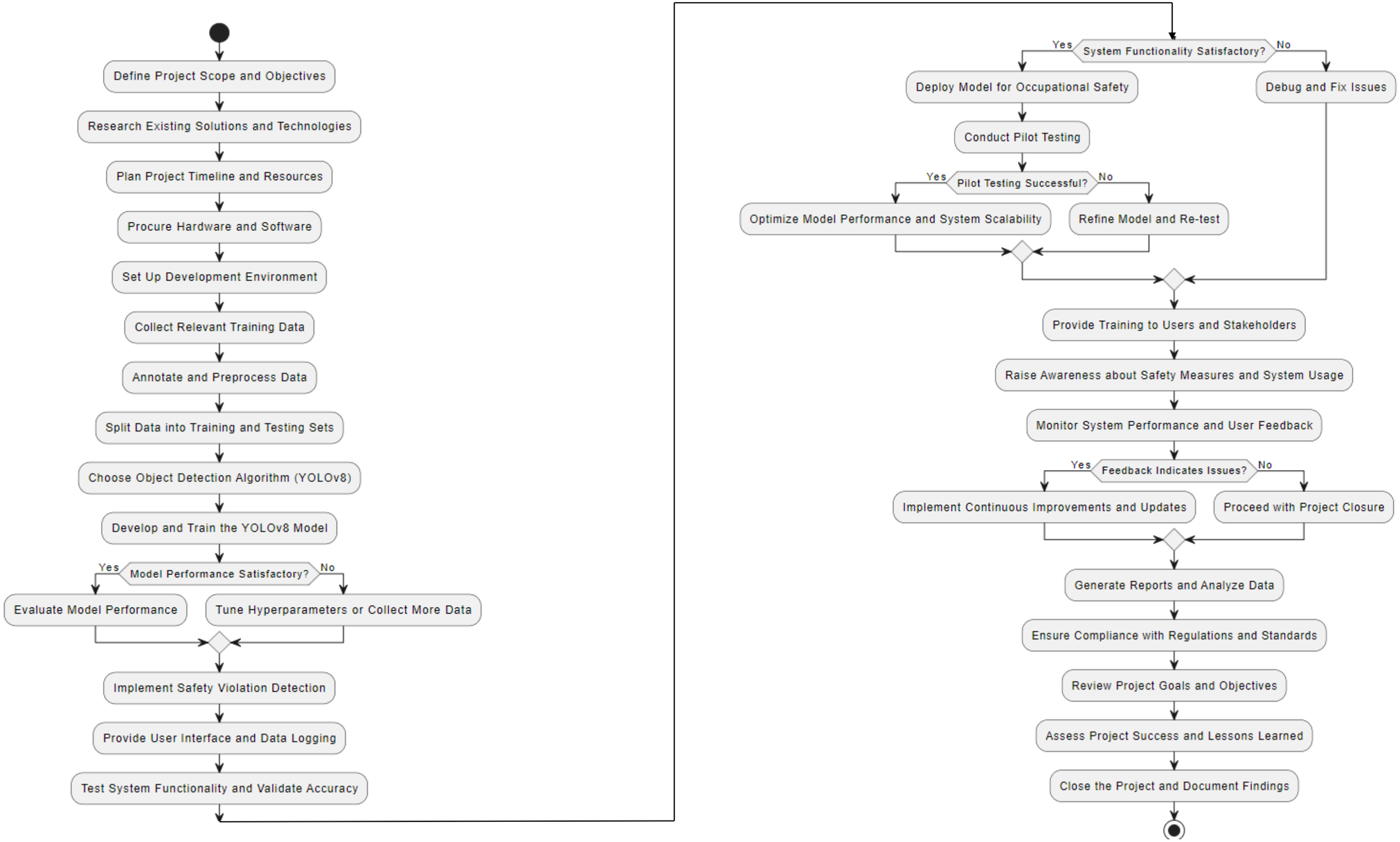
- After analyzing the literature available on the object detection in the form of conference papers and journals, we conclude that lot of work has been done in this field especially during the last few decade especially due to the advancement in artificial intelligence and deep learning technology.
- However, there are still some gaps in the literature regarding realizing the enormous true potential of object detection technology and the implications and benefits it can provide to the masses, however lack of funding and awareness could also play crucial role as such.
- The methodologies used like YOLO, CNN,R-CNN etc models were used to conduct the research on the topic and the results were fascinating and show great deal of benefit in an array of fields including security surveillance, public safety, vehicle automation etc.
- After concluding the literature review, we have got a clear and concise idea of how to approach this project regarding its research methodology, data collection, presentation and findings.

Formulation of workflow of the project

This project involves several component and an overview of these components are:

- Object detection
- Real time monitoring and processing component
- Safety violation detection component
- Training and guidance component
- User interface component

Formulation of workflow



Relevancy of algorithms with respect to the project

Algorithms are of utmost relevance to the project “Occupational safety and training using object detection and human posture recognition”. The algorithms form the core of the technology that enables the real time monitoring of workplace safety and provision of immediate feedback and training.

➢ **Object detection algorithms:**

- YOLO (You Only Look Once): YOLO is a real-time object detection algorithm known for its speed and accuracy. It can detect multiple objects in a single pass.
- Faster R-CNN (Region-based Convolutional Neural Network): Faster R-CNN is a popular algorithm for object detection that uses a region proposal network to identify objects within images.
- SSD (Single Shot MultiBox Detector): SSD is another real-time object detection algorithm that is capable of detecting objects at multiple scales.

Relevance: Object Detection algorithms are essential for identifying tools, equipment, objects and potential hazards within the workplace.

Relevancy of algorithms with respect to the project

➢ **Machine Learning and Deep Learning Algorithms:**

- Convolutional Neural Networks (CNNs): CNNs are fundamental for image analysis tasks, including object detection and human pose estimation.
- Recurrent Neural Networks (RNNs): RNNs can be used for sequence modeling, which is relevant when tracking human pose over time.
- Transfer Learning: Transfer learning techniques, such as using pre-trained models (e.g., ResNet, VGG), can accelerate the training of object detection and pose estimation models.

Relevance: These algorithms are used for training and fine-tuning object detection and pose recognition models.

Relevancy of algorithms with respect to the project

➢ **Safety Violation Detection Algorithms**

- Custom Rule-based Algorithms: Develop custom algorithms that define rules for detecting safety violations, such as identifying unsafe postures or improper tool usage.
- Anomaly Detection: Use anomaly detection techniques to identify unusual or unexpected patterns in worker behavior that may indicate safety violations.

Relevance: These algorithms are designed to detect violations and are central to the project's mission of proactive safety managements.

➢ **Real-time Processing Algorithms:**

- Streaming Data Processing: Implement algorithms for real-time data streaming and processing to handle data from cameras and sensors efficiently.
- Queueing Systems: Utilize queueing systems to manage and prioritize data processing tasks for timely response to safety violations.

Relevance: These algorithms are crucial for analyzing data from cameras and sensors in real time

Relevancy of algorithms with respect to the project

➢ **Data Analysis and Reporting Algorithms:**

- Statistical Analysis: Employ statistical algorithms to analyze safety data and derive insights into trends and patterns.
- Machine Learning for Predictive Analytics: Apply machine learning algorithms to predict potential safety hazards based on historical data.

Relevance: These algorithms extract insights form the collected safety data.

➢ **Algorithm Optimization Techniques:**

- Parallelization: Implement parallel processing techniques to optimize algorithms for real-time performance.
- Quantization: Reduce model size and computational requirements through quantization techniques, making them suitable for edge devices.

Relevance: Ongoing algorithms optimization ensures that the system operates efficiently and accurately.

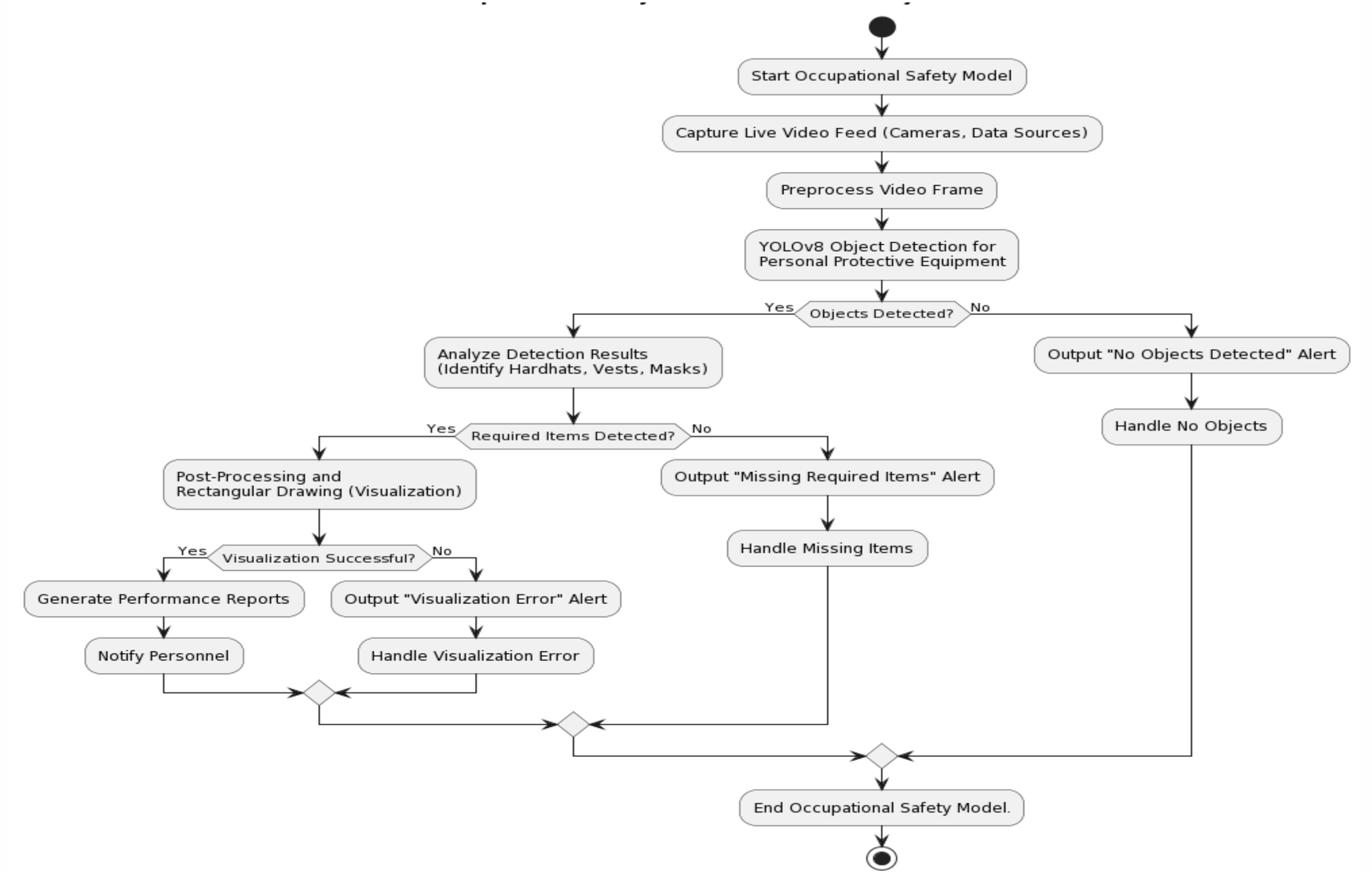
Design Description

- According to a survey done in 2017 by Kang et al. found that about 70% of all incidents involved a lack of PPE. Construction workers who do not use PPE are three times more likely to be injured than those who do (Lette et al., 2018). Melzner et al. (2013) suggested that wearing PPE contributes to a roughly 30% reduction in fall accidents.
- The main goal of this project is to prevent such accidents by ensuring proper Occupational safety and training using Object Detection. It is an idea aimed at enhancing workspace safety and productivity. By leveraging advanced computer vision techniques, we aim at creating a comprehensive system that can detect the personal protective equipment of the workers in the workplace and create a safe workplace.

- This project aims to target the construction workplace safety of workers.

- The scope of this project goes beyond just PPE detection of the workers and to enhance workplace safety and training. It includes the real time identification of hazards, safety violation detection, ergonomic assessment and immediate feedback to workers. The project seeks to provide data driven insights, a user-friendly interface, scalability to different industries and ongoing maintenance while adhering to ethical and privacy considerations. The ultimate goal is to foster a culture of safety in the workplace, preventing accidents, improving worker well being and enhancing overall operational efficiency.

Basic working flowchart of the YOLOv8 Object Detection Model



Screenshots of the code for object Detection

PPEDetection.py

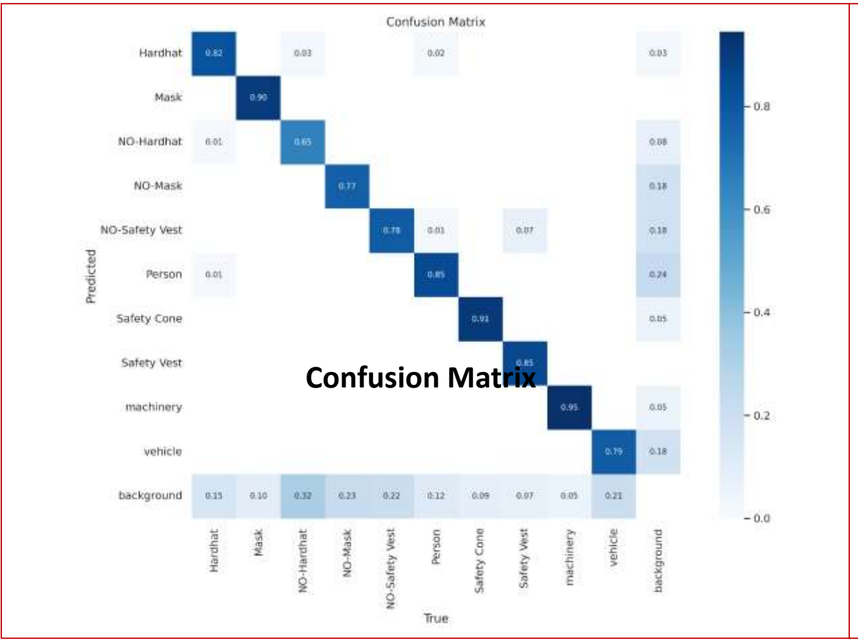
```python
from ultralytics import YOLO
import cv2
import cvzone
import math

cap = cv2.VideoCapture(0)  # for webcam
cap.set( propId: 3,  value: 1280)  # width
cap.set( propId: 4,  value: 720)  # height

# cap = cv2.VideoCapture("../Videos/ppe-2.mp4")  # for video

model = YOLO("ppe.pt")

classNames = ['Hardhat', 'Mask', 'NO-Hardhat', 'NO-Mask', 'NO-Safety Vest', 'Person', 'Safety Cone',
              'Safety Vest', 'machinery', 'vehicle']

myColor = (0, 0, 255)  # red and green is (0,255,0)
while True:
    success, img = cap.read()
    results = model(img, stream=True)  # uses generators therefore efficient
    for r in results:
        boxes = r.boxes
        for box in boxes:
            # for simple box
            # x1, y1, x2, y2 = box.xyxy[0]
            # x1, y1, x2, y2 = int(x1), int(y1), int(x2), int(y2)
            # print(x1, y1, x2, y2)
            # cv2.rectangle(img, (x1, y1), (x2, y2), (255, 0, 255), 3)

            # for fancy rectangle
            x1, y1, x2, y2 = box.xyxy[0]
            x1, y1, x2, y2 = int(x1), int(y1), int(x2), int(y2)
            w, h = x2 - x1, y2 - y1

            # corner rectangle
            # cvzone.cornerRect(img, (x1, y1, w, h))

            # confidence
            conf = math.ceil((box.conf[0] * 100)) / 100

            # class name
            cls = int(box.cls[0])
            currentClass = classNames[cls]
            print(currentClass)
            if conf > 0.5:
                if currentClass == 'NO-Hardhat' or currentClass == "NO-Safety Vest" or currentClass == "NO-Mask":
                    myColor = (0, 0, 255)
                elif currentClass == 'Hardhat' or currentClass == "Safety Vest" or currentClass == "Mask":
                    myColor = (0, 255, 0)

                else:
                    myColor = (255, 0, 0)

                cvzone.putTextRect(img,  text: f' {classNames[cls]} {conf}',
                                   pos: (max(0, x1), max(35, y1-5)), scale=1, thickness=1, colorB=myColor,
                                   colorT=(255, 255, 255), colorR=myColor, offset=5)

                cv2.rectangle(img,  pt1: (x1, y1),  pt2: (x2, y2), myColor,  thickness: 2)

    cv2.imshow( winname: "Image", img)
    cv2.waitKey(1)
```

Core Implementation

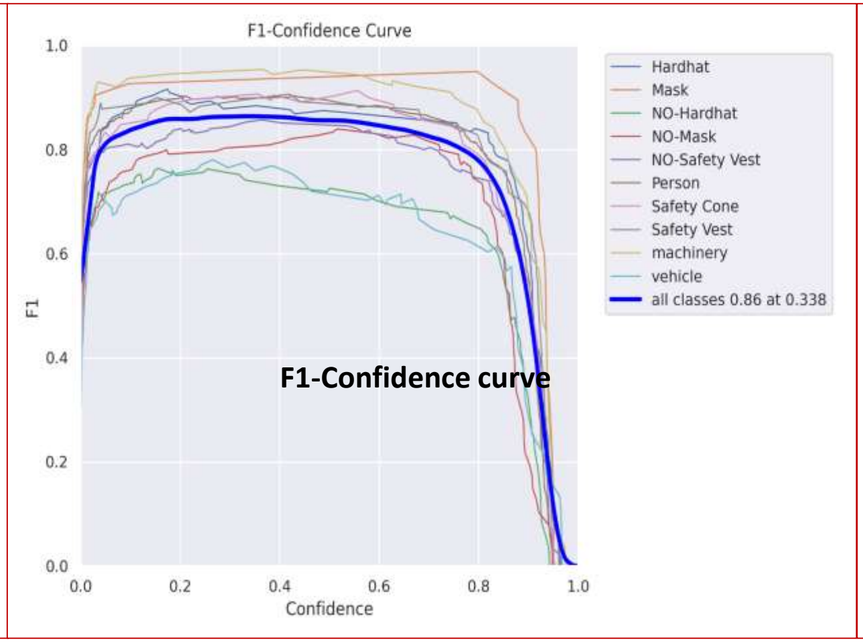
- Data collection and processing.
- Model Architecture (YOLOv8)
- Model development and training.
- Inference
- Fine-tuning the mode.
- Camera integration.
- Evaluation.
- Deployment.
- Testing and validation.
- Real time object detection.
- Deployment and maintenance.

Resultant Outcomes and figures of the YOLOv8 Trained model

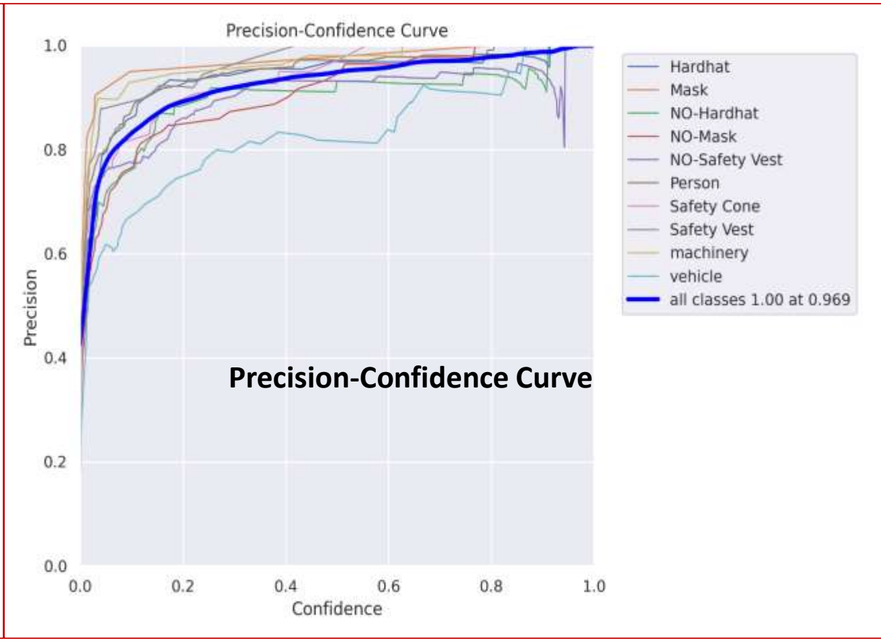
The training of YOLOv8 model was done for 50 epochs and was completed in 3.1 hours. After the following results were obtained:



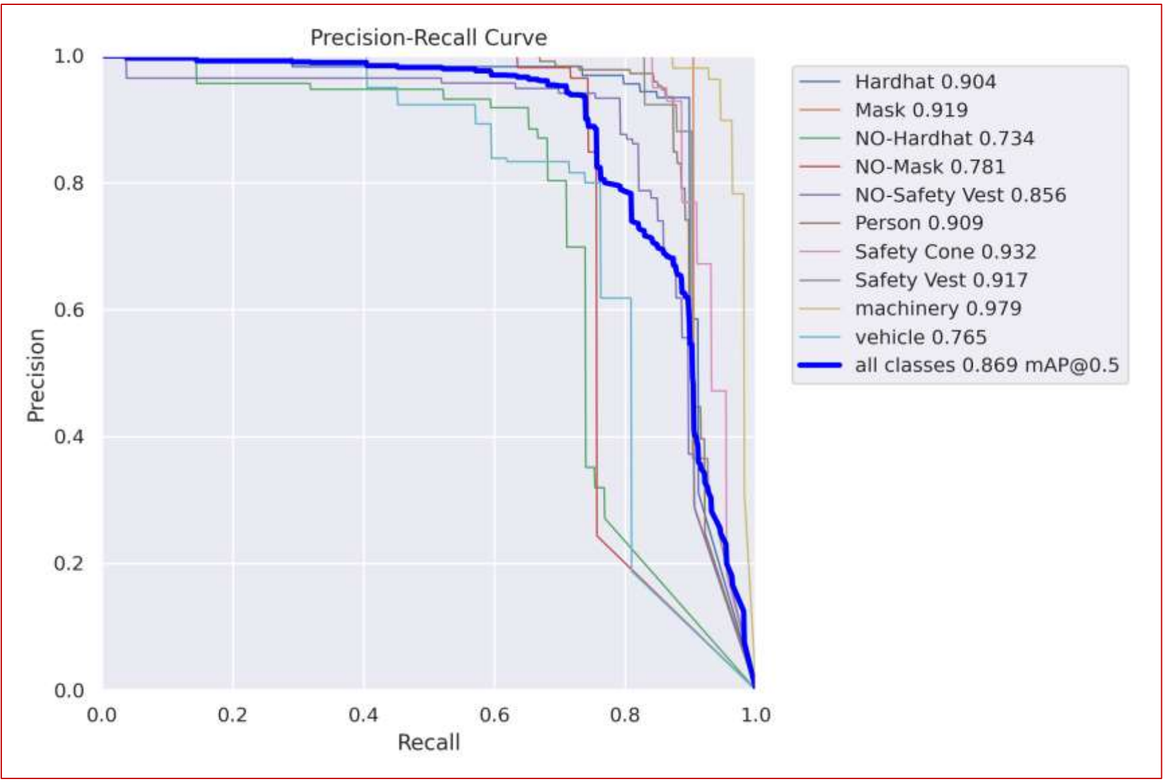
Confusion Matrix



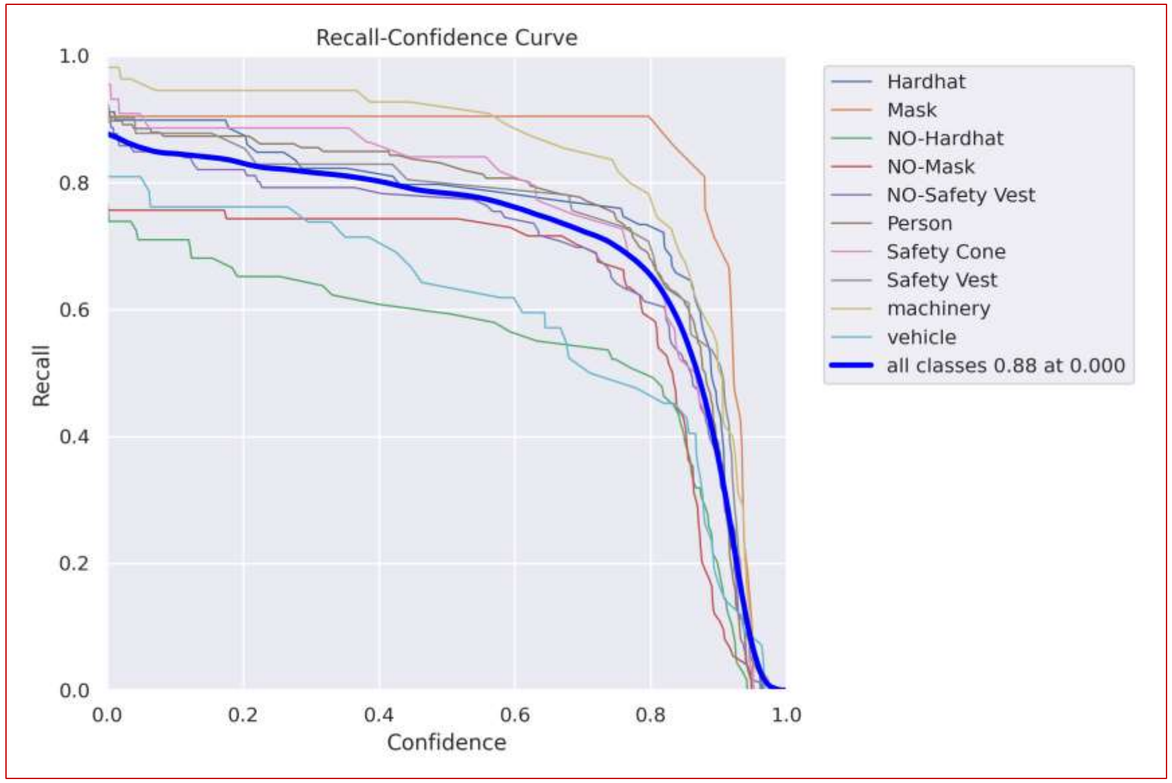
F1-Confidence curve



Precision-Confidence Curve

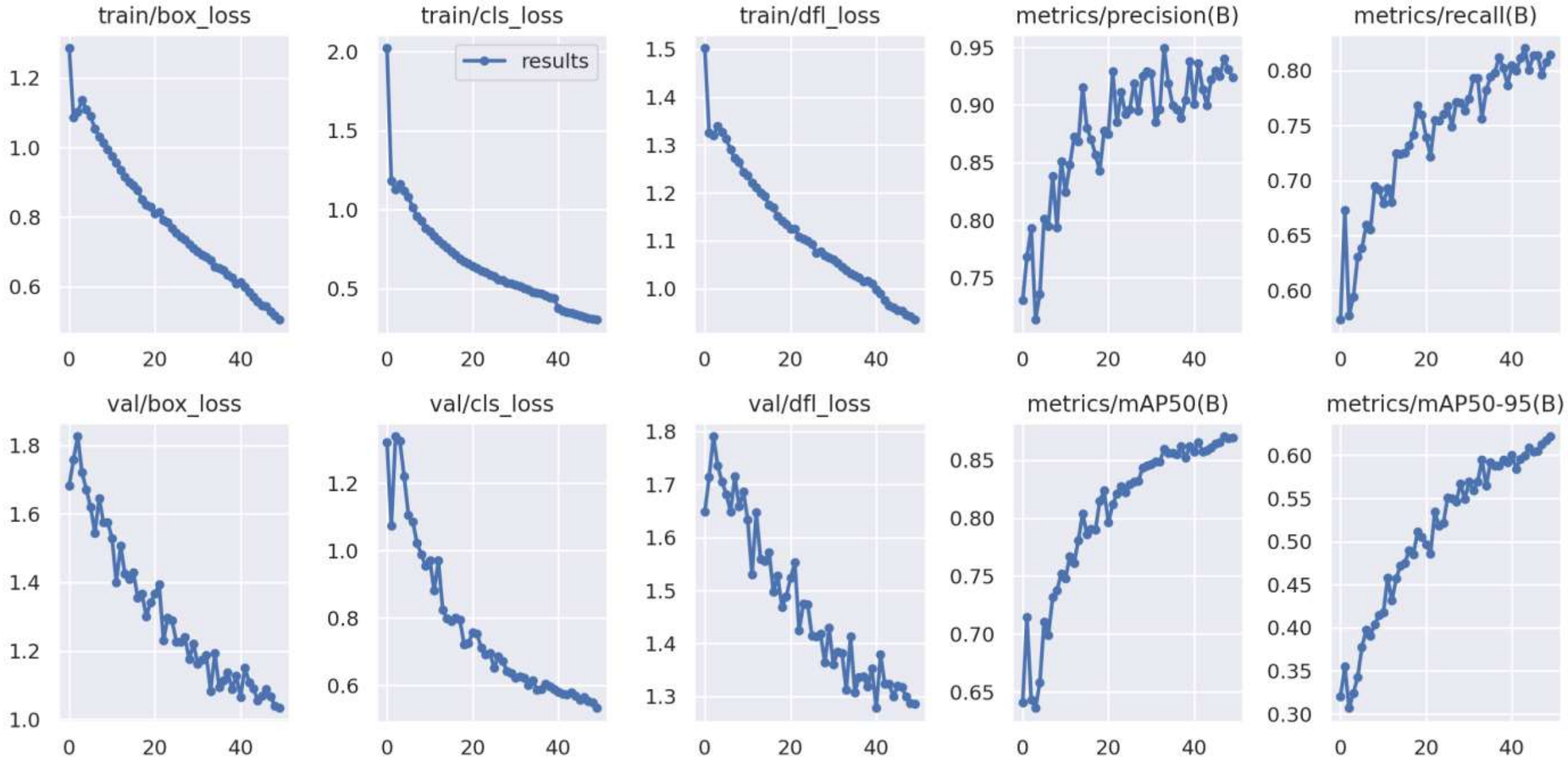


Precision-Recall Curve

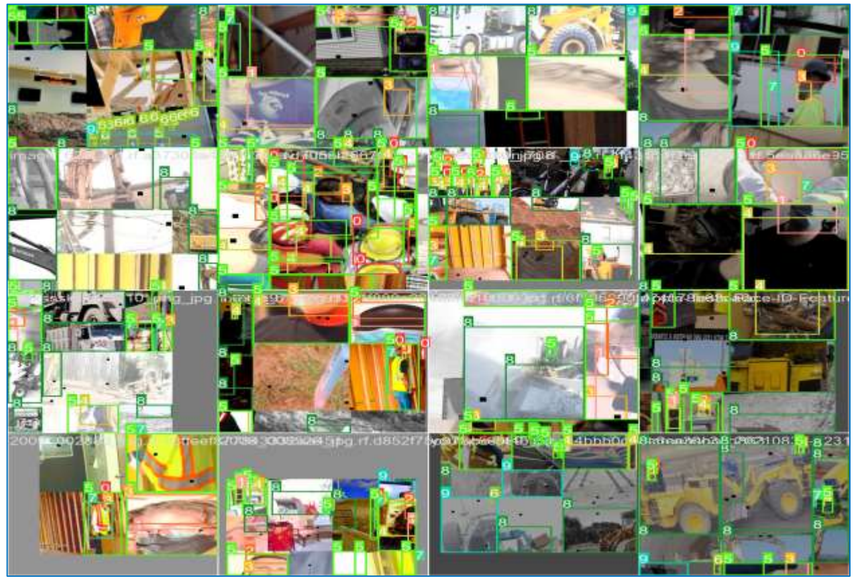


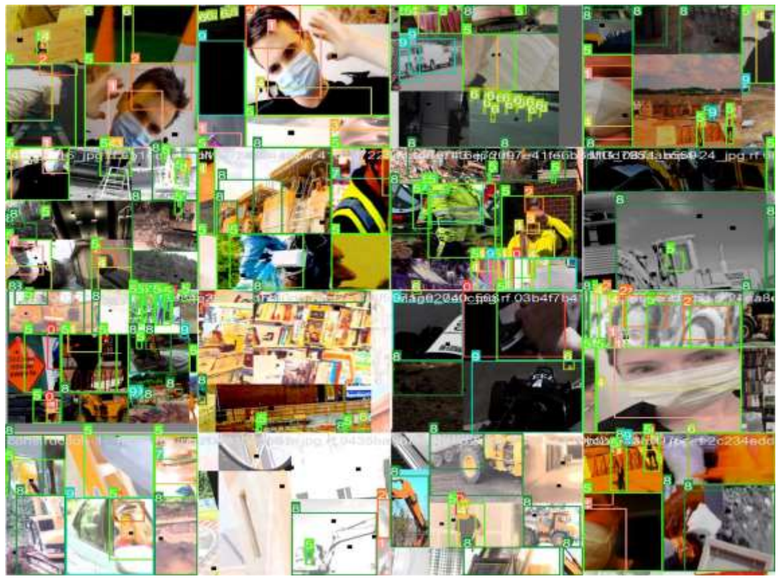
Recall-Confidence Curve

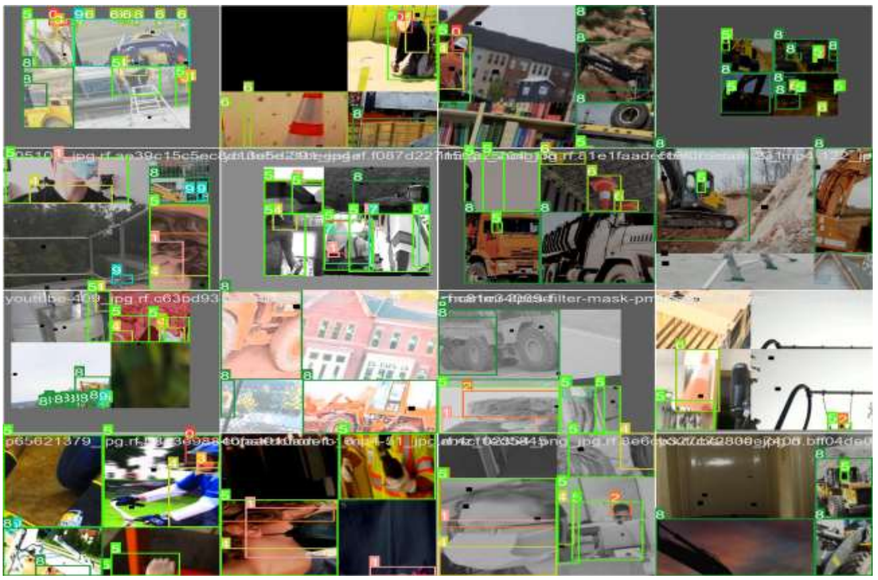
Some more important figures and graphs

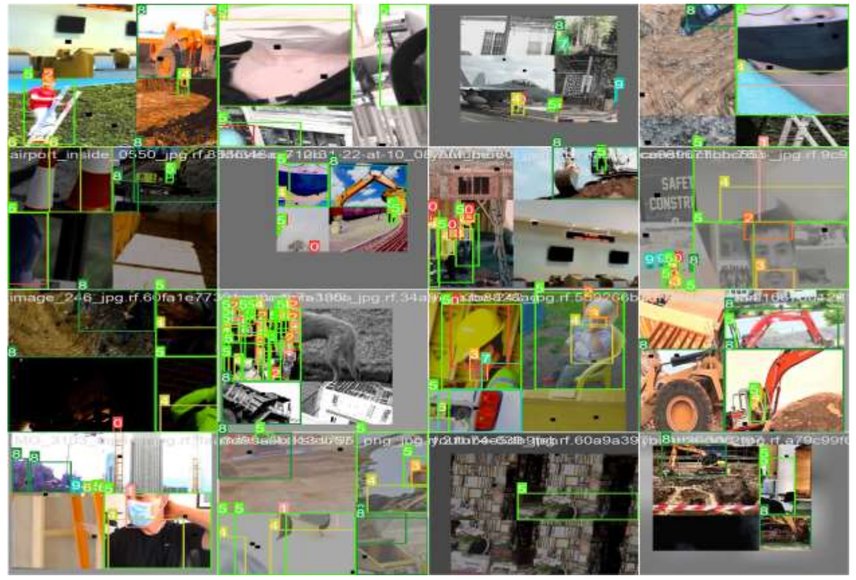


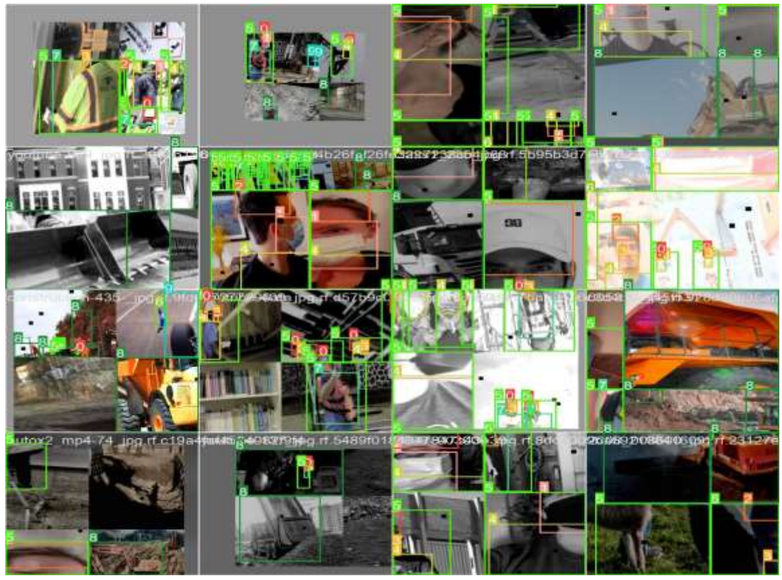
Train Batch images







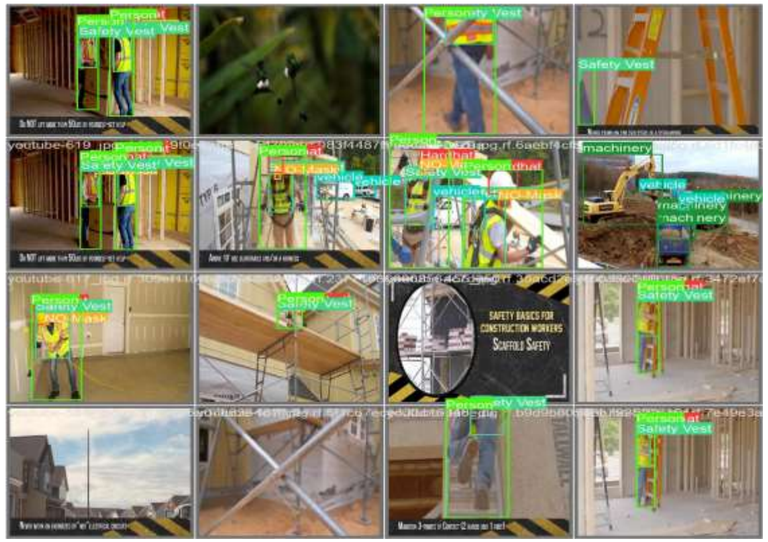




Valid Batch images

Validation label 01

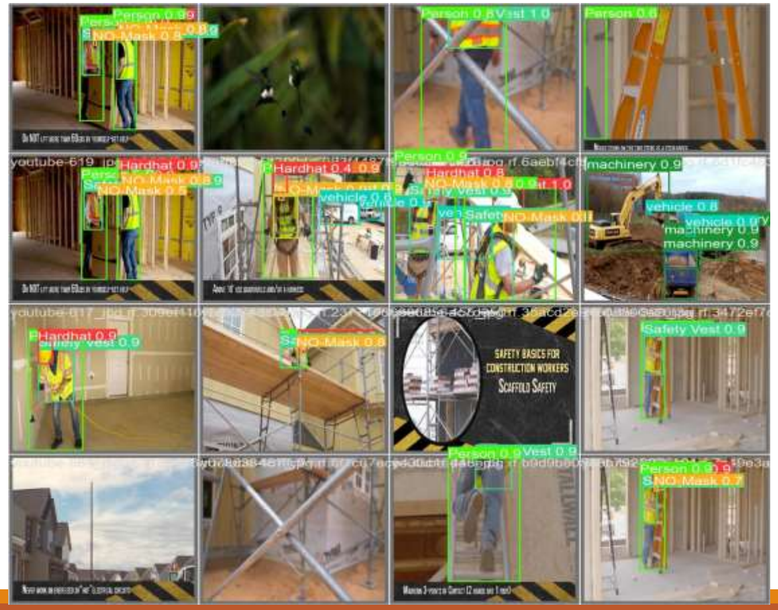
Validation label 02



Validation label 03

Validation Prediction 01

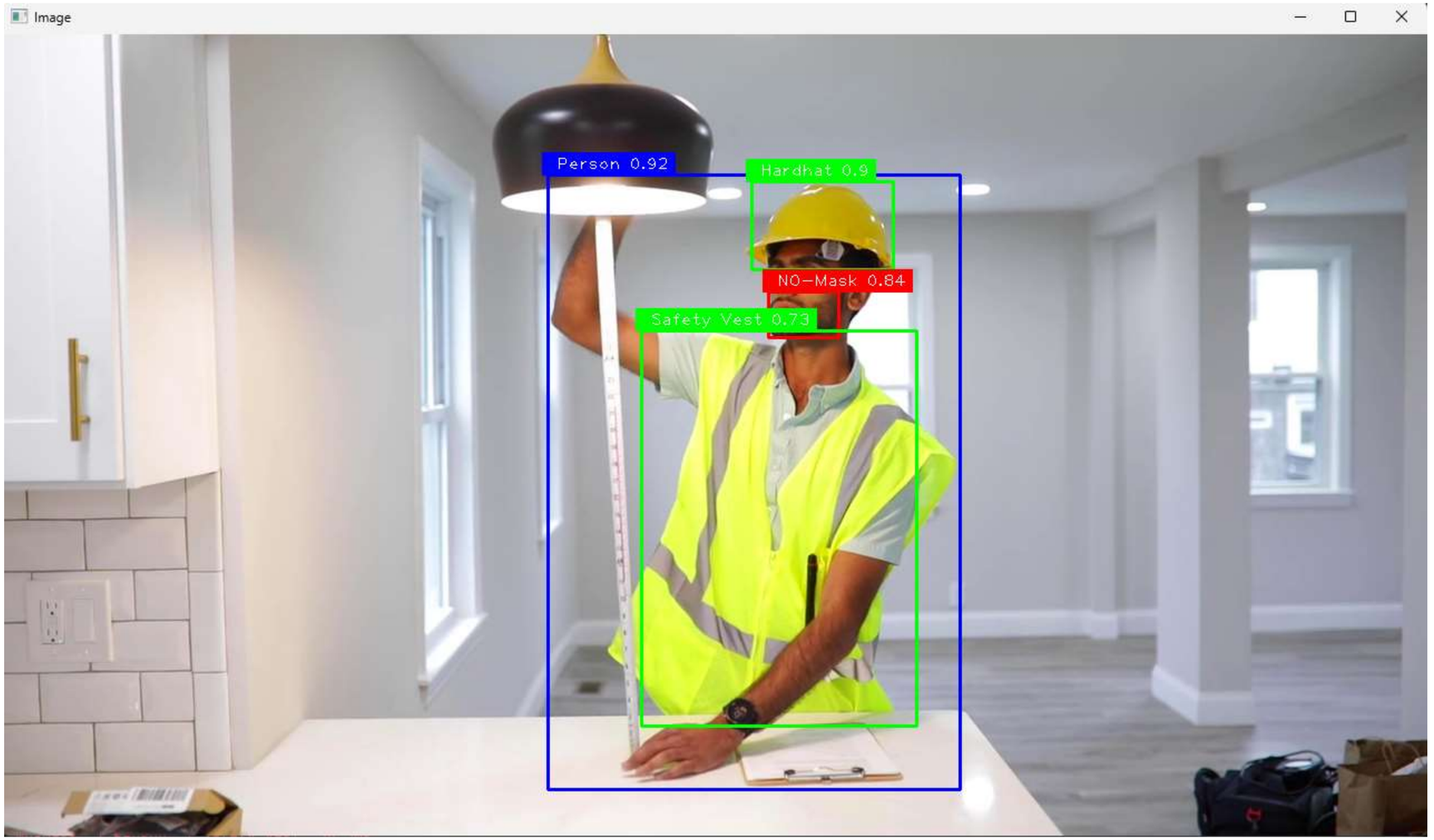
Validation Prediction 02



Validation Prediction 03

Below are the resultant screenshots of object detection done by the yolov8 model on videos on this device.

Sample Video 1



Sample Video 2

Sample Video 3

The resultant images show:

- Rectangular boxes are drawn on the people and desired PPE equipment to be detected if detected with class name and confidence level.
- The blue box is drawn if person is detected.
- The green box is drawn if the desired PPE equipment like hardhat, mask, vest is detected.
- The red box is drawn if the desired PPE equipment is not detected.

Future Work

- Train the model for more epochs.
- Train the model on a larger dataset.
- Compare this YOLOv8 model with other models.
- Create ID tracking of workers and save bounding boxes of workers not wearing proper PPE.
- ML App deployment with alarm triggering.
- Multi-Object Detection.
- Semantic segmentation.
- Integration with IOT devices.
- Augmented Reality (AR) support.
- Automated reporting and analytics.
- Mobile application, website integration.
- Machine learning for anomaly detection and Cloud based solution.
- Collaborative tools and customizable alerts and notifications.
- Internationalization and localization.

Thank You