Helmet Detection Using Two-Stage YOLOv11 Pipeline

Group Members:

- **Muneeb ur Rehman Khan (2024-MSDS-115)**
- **Rehman Kabir (2024-MSDS-120)**
- **Shamroz Ali (2024-MSDS-122)**

Project Overview:

This project aims to automate the detection of helmet usage in environments where personal protective equipment (PPE) is mandatory, such as construction sites, factories, and traffic control zones. The focus is on enhancing safety compliance monitoring using real-time computer vision.

Problem Statement:

Manual monitoring of PPE compliance is time-consuming, inefficient, and prone to human error—especially in large or complex environments. Traditional detection techniques like HOG, Haar cascades, or SVMs fail to adapt well to dynamic conditions and perform poorly on small or partially occluded objects like helmets.

Research Gap:

Most existing solutions apply object detection to the entire image, leading to high false positives, especially for small PPE items. Some approaches attempt to use classifiers post-detection or employ slicing techniques (like SAHI), but they compromise real-time performance or accuracy.

Proposed Solution:

We introduce a **two-stage YOLOv11-based detection pipeline**:

Stage 1: Person Detection:

- A YOLOv11 model is trained specifically to detect human figures.
- Only regions with detected persons are passed to the next stage, filtering out irrelevant background regions.

Stage 2: Helmet Detection

- A second YOLOv11 model is trained to detect helmets.
- This model operates only within the regions of the image containing persons.
- If a helmet is detected on a person, they are marked as "PPE compliant".
- Otherwise, they are marked as "Not PPE compliant".

Advantages:

- High Accuracy (>98%): By focusing only on person regions, helmet detection becomes more accurate.
- Low False Positives: Restricting the detection area reduces the risk of detecting helmets in the background or on machinery.
- Real-Time Performance: YOLOv11 ensures fast inference suitable for live camera feeds.
- Modular & Scalable: The framework can be extended to detect other PPE (e.g., vests, goggles) without retraining the person detection model.

Tools & Technologies

- **YOLOv11**: Used for both stages of detection.
- **Python**: A Core programming language for implementation.
- **OpenCV**: This is for image processing and drawing bounding boxes.
- **PyTorch/TensorFlow**: This is for model training and inference (based on your environment).

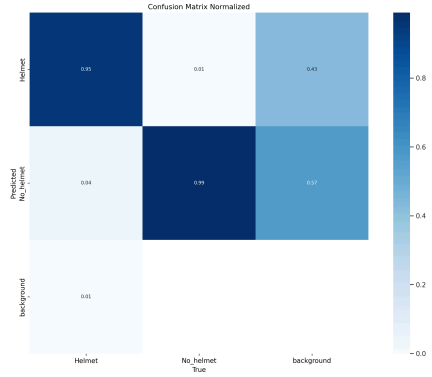
Dataset:

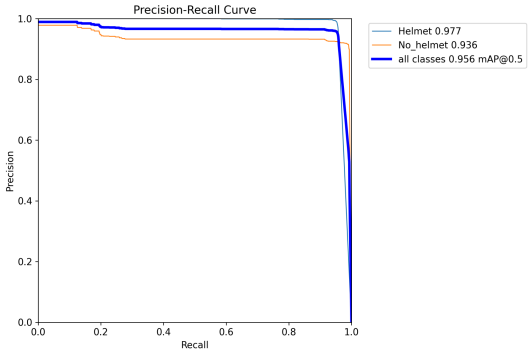
- **Person Detection**: Pretrained on the COCO dataset or a custom dataset with labeled persons.
- **Helmet Detection**: Trained on a custom dataset containing images of people with and without helmets, labeled accordingly.

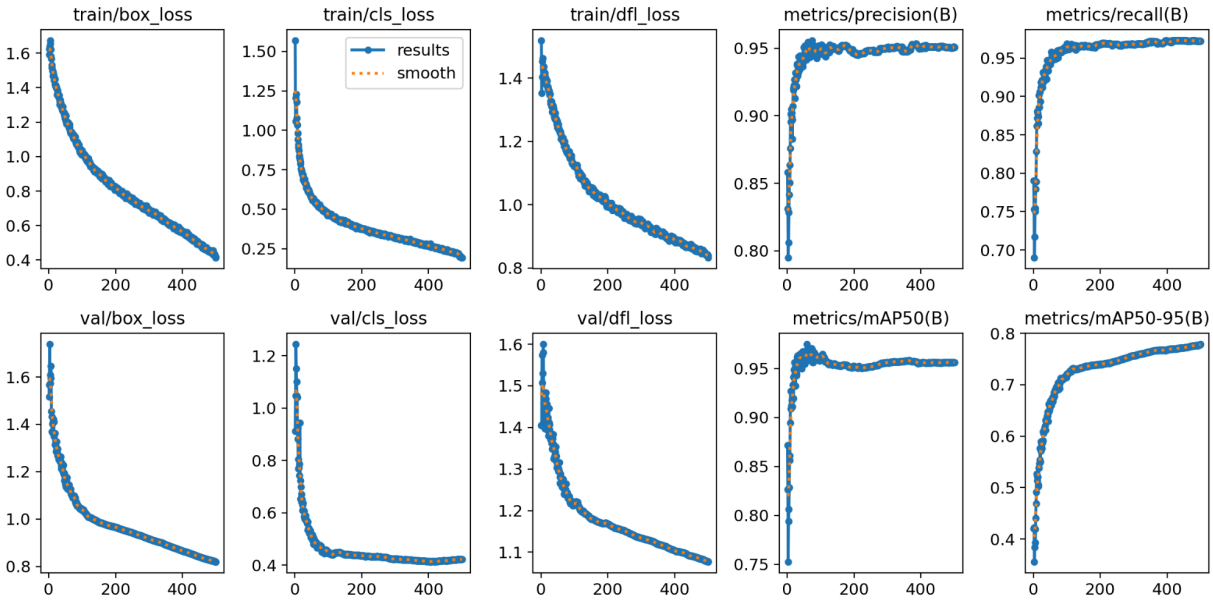
Evaluation Metrics:

- Precision, Recall, and mAP (mean Average Precision) are used for model evaluation.

- False Positive Rate is monitored to ensure real-world reliability.







Future Work:

- Expand detection to additional PPE like safety vests and goggles.
- Deploy on edge devices for field implementation.
- Integrate with alert systems to notify non-compliance in real time.