Clustrex Data Private Limited

Case study

PPE Object Recognition Using YOLO

Overview

Personal Protective Equipment (PPE) is crucial for ensuring worker safety in industries such as construction, manufacturing, and healthcare. Manually monitoring PPE compliance is time-consuming and prone to error. To address this, we explore the use of **YOLO (You Only Look Once)**, a real-time object detection system that can detect and localize multiple PPE items like helmets and goggles to enhance workplace safety.

Problem Statement

Ensuring workers are wearing the required PPE, such as helmets, goggles, is a critical challenge in industrial environments. Manual checks are time-consuming and prone to human error. An automated system capable of detecting PPE violations in real-time could significantly improve compliance and prevent accidents.

Objective

To develop an automated solution using YOLO for real-time detection of PPE (helmets, goggles) to ensure compliance with safety regulations.

Methodology

1. Data Collection

A dataset was curated from open-source sources (e.g., COCO) and industrial sites, featuring images of workers wearing and not wearing PPE in various postures, lighting conditions, and angles.

2. Annotation

Images were manually labeled with bounding boxes around PPE items (helmets, goggles) using tools like labelme. The dataset was split into training, validation, and test sets.

3. Model Selection (YOLO)

YOLO's real-time object detection capability made it a strong choice. The following versions were evaluated:

- **YOLOv7**: Balanced speed and accuracy, excelling at detecting small and large objects.
- **YOLOv8**: Improved real-time performance, ideal for edge devices.
- **YOLOv9**: The latest version, offering better detection performance with an efficient backbone.

YOLOv9 was selected for its superior speed and accuracy, critical for real-time PPE detection.

4. Training

The training process involved feeding the annotated images into the YOLO model. Key considerations included:

- **Transfer Learning**: Leveraging a pre-trained model on the COCO dataset to speed up training and improve accuracy.
- **Fine Tuning**: Performed fine tuning over the trained model to enhance accuracy.
- **Data Augmentation**: Applying techniques like horizontal flipping, rotation, and color jittering to increase the diversity of the training data.
- **Loss Functions**: YOLO uses a multi-part loss function that includes objectness loss, classification loss, and localization loss.

The model was trained for multiple epochs with batch normalization and early stopping to prevent overfitting.

5. Testing and Evaluation

The trained YOLO model was tested on the validation dataset, and its performance was evaluated using metrics such as:

- **Mean Average Precision (mAP)**: Measures the accuracy of the bounding boxes for PPE items.
- **Frame Per Second (FPS)**: Measures the real-time performance of the model.
- **Confusion Matrix**: To analyze false positives and false negatives for each PPE item.

Results:

- mAP: 92% for helmet detection, and 84% for goggles.
- FPS: 45-50 on an Nvidia GPU, which meets the real-time processing requirement.

Deployment

The YOLOv9 model was deployed in real-world environments using edge devices with Nvidia GPUs for inference. Cameras were placed in high-traffic areas to monitor workers in

real-time. Alerts were triggered for PPE violations, and data was integrated into the safety compliance framework.

Challenges Faced

- **Occlusion**: Workers sometimes obscured parts of their PPE, behind machinery, leading to false negatives.
- **Lighting Variations**: Changes in lighting conditions (indoor, outdoor, night) affected detection accuracy.
- **Complex Postures**: Workers bending or crouching caused the model to misclassify or miss PPE items.

To address these, the dataset was further augmented with more challenging scenarios, and additional fine-tuning of the model was performed.

Results

The deployment of the YOLO-based PPE detection system resulted in:

- A reduction in PPE non-compliance incidents.
- Improved safety audit scores.
- Real-time alerts reduced the need for manual inspections, saving man-hours per week.

Conclusion

YOLO-based PPE detection has proven to be an efficient solution for improving safety compliance in industrial settings. Real-time alerts have enhanced workplace safety, and the system's scalability suggests future expansions to detect additional PPE items (e.g., steel-toed boots) and improve robustness under varying conditions.

Future Scope

- **Integration with Drones**: Using drones with YOLO models to monitor large-scale sites.
- **Advanced Analytics**: Gathering data on PPE compliance trends for safety improvements.