**PPE Safety Agent – Personal Protective Equipment Detection System**

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**Abstract**

**Personal Protective Equipment** (PPE) plays a vital role in ensuring the safety of workers in high-risk environments such as **construction sites, factories, mining areas, chemical plants, and warehouses**. However, many workers often neglect wearing essential safety gear like helmets, jackets, gloves, or safety glasses, which increases the chances of accidents and injuries. This negligence not only threatens individual safety but also affects overall workplace productivity and compliance with safety standards.

To address this issue, our project proposes a PPE Safety Agent powered by **computer vision**. The system will continuously monitor individuals to verify if they are wearing the required protective equipment. In cases where any PPE item is missing, the system will automatically capture the image, send an email alert to both the supervisor and project manager, and trigger an alarm at the location.

**Introduction & Problem Statement**

**Background of the Problem**

Workplace safety is a major concern in industries such as construction, manufacturing, and mining. Despite strict safety regulations, **non-compliance with PPE rules** leads to frequent accidents, injuries, and sometimes fatalities. Supervisors often cannot continuously monitor every worker, especially in large sites, which increases risks.

**Why It Is Important**

Ensuring PPE compliance is critical for worker safety and reducing workplace hazards. Timely detection of missing PPE can prevent

**Problem Definition / Objectives**

* Detect whether workers are wearing **required PPE** (helmets, jackets, gloves, glasses).
* Automatically **alert supervisors** and **project managers** if PPE is missing.
* Provide a **visual and audio alert** to increase compliance.
* Reduce accidents and **improve overall safety** at industrial sites.

**Proposed Methodology**

The PPE Safety Agent system follows a **step-by-step Machine Learning (ML) pipeline**, ensuring accurate and reliable detection of PPE items. The methodology includes **data gathering, preprocessing, feature extraction, model training, evaluation, deployment, and alert system**.

**1. Dataset Collection**

* Collect images of workers **with and without PPE** from construction sites, factories, and industrial areas.
* PPE items include: **helmets, jackets, gloves, and safety glasses**.
* Annotate the dataset using tools such as **LabelImg** to mark bounding boxes around each PPE item.

**2. Data Preprocessing**

* Resize images into a fixed input size (e.g., 224×224).
* Normalize pixel values (0–1).
* Apply **data augmentation** (rotation, flipping, brightness changes) to increase dataset diversity.
* Split into **training, validation, and testing sets**.

**3. Feature Extraction**

* **For CNN (from scratch):** Convolution layers extract low-level (edges, textures) and high-level (PPE shapes) features.
* **For pretrained models:** Backbone networks like ResNet (used in YOLO/Faster R-CNN) extract features automatically.

**4. Model Training Approaches**

**(A) Using Pretrained Models (Transfer Learning)**

* Models such as **YOLOv8, Faster R-CNN, SSD, RetinaNet** are commonly used for object detection.
* These models come with **pretrained weights** (trained on COCO/ImageNet datasets).
* Fine-tune them with the PPE dataset for faster convergence and high accuracy.

**(B) Building Model From Scratch**

* Design a **custom CNN architecture**:
  + Convolution + Pooling layers for feature extraction.
  + Dense layers for classification.
  + Output layer for PPE classes + bounding boxes.
* Initialize weights **randomly** (no pretrained models).
* Train fully on the custom PPE dataset.
* Loss functions:
  + **Cross-Entropy Loss** (classification).
  + **Localization Loss** (bounding box accuracy).

**5. Evaluation**

* Test the trained model on validation data.
* Metrics:
  + **Accuracy** (correct predictions).
  + **Precision, Recall, F1 Score** (PPE detection quality).
  + **mAP (Mean Average Precision)** for object detection.

**6. Deployment**

* Save the trained weights (CNN or pretrained detector).
* Deploy using **Python (TensorFlow/PyTorch + OpenCV)**.
* Integrate with **live CCTV/Webcam feed** for real-time monitoring.

**7. Alert System**

When PPE is missing:

* Capture the image.
* Send an **email alert** to the supervisor/project manager.
* Trigger a **local alarm** to ensure immediate compliance.

**Flow Chart**

[Camera / CCTV Feed]

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[Image Preprocessing]

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[Custom CNN Model (From Scratch)]

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[PPE Detection]

▼

[Missing PPE?]

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Yes No

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[Capture Image + Alert System] [Continue Monitoring]

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[Email to Supervisor + Local Alarm]

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[Project Manager Notification]

**Expected Working**

* Continuous monitoring of workers in real-time.
* High-accuracy detection of helmets, jackets, gloves, and glasses.
* Instant alert system to **ensure immediate compliance**.

**Conclusion**

The **PPE Safety Agent** aims to enhance workplace safety by ensuring PPE compliance. By using computer vision and automated alerts, the system can significantly reduce accidents, improve safety standards, and assist supervisors in monitoring large industrial areas effectively.

**References**

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