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Pose-Aware PPE Compliance System

Core Idea: Merge YOLO-powered PPE detection with pose-region mapping and OpenVINO edge-speed—plus live monitoring dashboard.

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Literature Review

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1. An effective deep learning approach enabling miners' protective equipment detection and tracking using improved YOLOv7	Zheng Wang et al.	2023	*Xi'an Univ. of Science & Tech.*	Tailored YOLOv7-PE for miners, real-time tracking in harsh environments
2. Integrating real-time pose estimation and PPE detection with cutting-edge deep learning…	Mohamed Imam et al.	2025	*Neurocomputing*	Combines pose + PPE detection, enhanced rescue ops, low false positives
3. A Deep Learning Approach to Detect Complete Safety Equipment…	Islam et al.	2024	arXiv	Full PPE detection in construction; ~87.7% mAP
4. Real-Time Personal Protective Equipment Compliance Detection	Lo et al.	2022	*IEEE*	Techniques across YOLOv3/4/7; YOLOv7 ~97% mAP @25FPS
5. Target Detection of Safety Protective Gear Using the Improved YOLOv5	Liu & Qin	2024	*IEEE Trans.*	YOLO-EA for small objects; precision ~98.9%, recall ~94.7%
6. Edge-based pose & PPE compliance in mining (Underground)	Imam et al.	2023	*IEEE Access*	YOLO-Pose-Edge; robust under low light, occlusion
7. A Combined Detection Algorithm for PPE Based on Lightweight YOLOv4	Ma et al.	2022	*Sensors*	CLSlim YOLOv4 (pruned); size ↓98%, speed ↑1.8×
8. Helmet Detection Using Improved YOLOv5s	Chen et al.	2023	*Journal of Real-Time Image Processing*	Attention-enhanced helmet detection @100+ FPS, ~94.7% mAP

Note: Readers, year, venue, and primary contribution captured for each.

Problem & Motivation

- PPE non-compliance causes injuries & financial loss.
- Manual monitoring is unreliable & slow.
- Automation demands real-time, accurate, explainable systems.
- Edge deployment is necessary for safety-critical sites.

Objectives

- Real-time PPE detection per body-region (head, torso, limbs).
- Pose-guided logical checks for misplaced gear.
- Utilize OpenVINO for fast inference on-device.
- Provide live alerting & employee dashboard logging.

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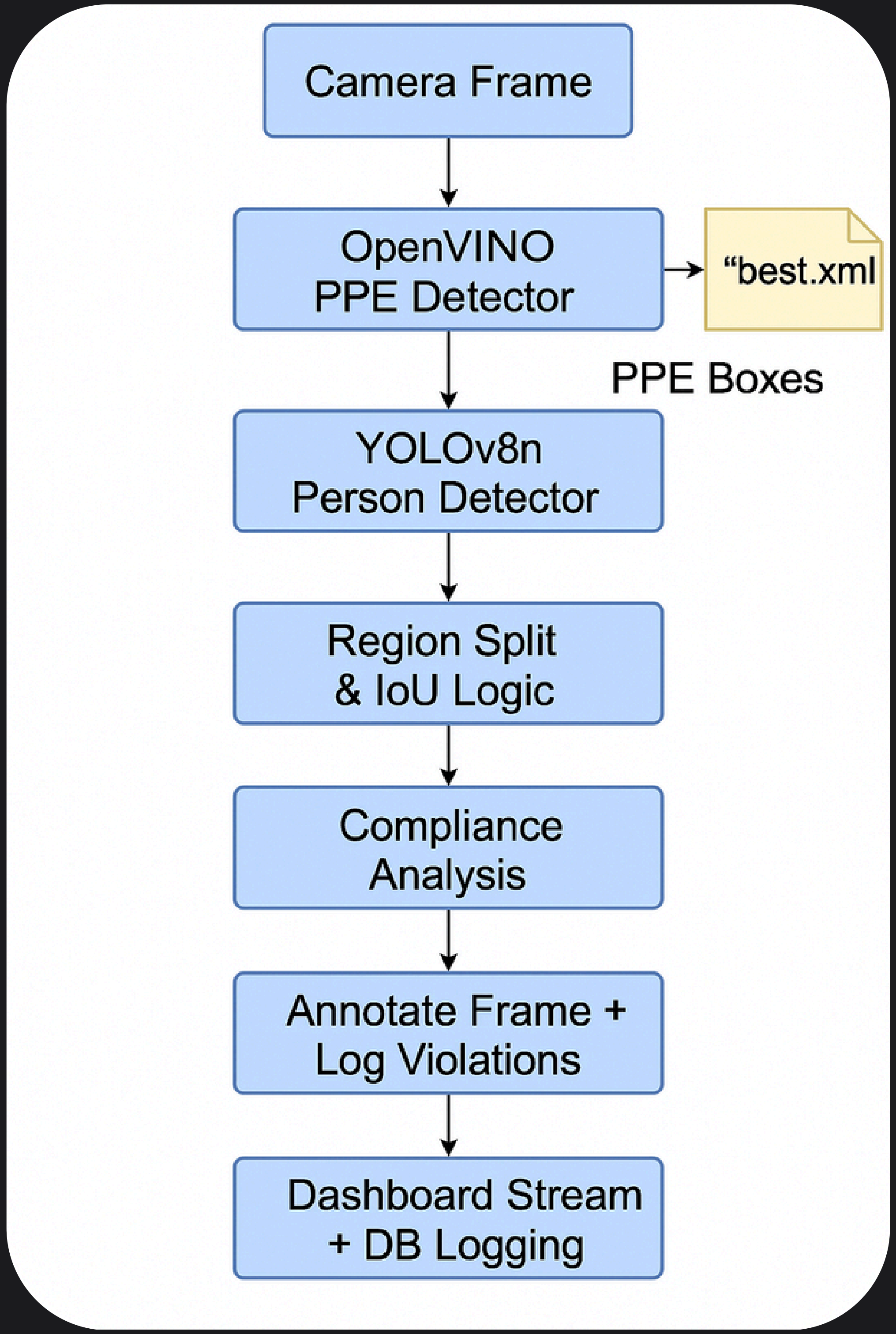
System Architecture



This pipeline performs real-time PPE compliance checks:

- Camera Frame: Captures live video input
- OpenVINO PPE Detector: Detects gear like helmets, gloves using an optimized model
- YOLOv8n Person Detector: Identifies people in the frame
- Region Split + IoU Logic: Matches PPE items to body parts (head, torso, legs)
- Compliance Analysis: Flags missing gear as violations
- Annotate & Log: Displays results and logs violations
- Dashboard & DB: Streams output and updates violation records

(Diagram visually illustrating the above pipeline)

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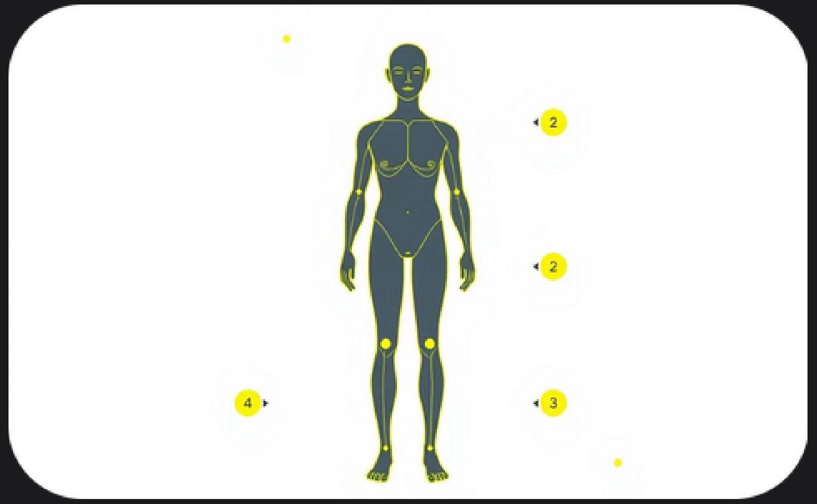
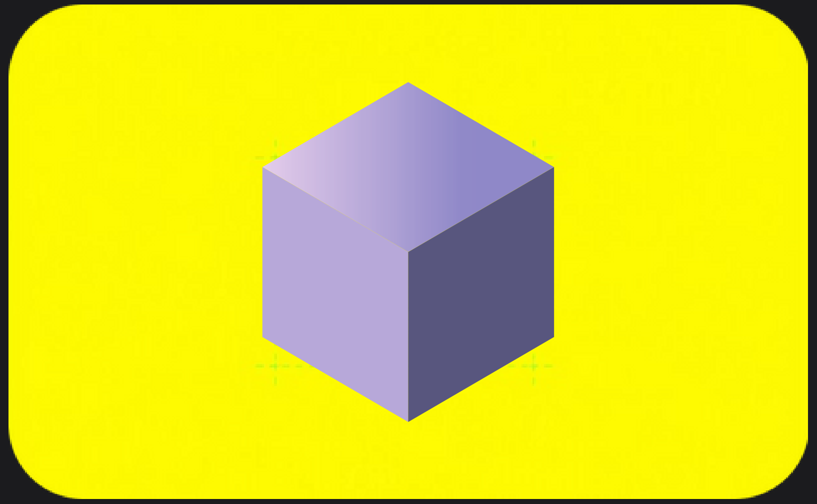
Core Algorithms & Logic



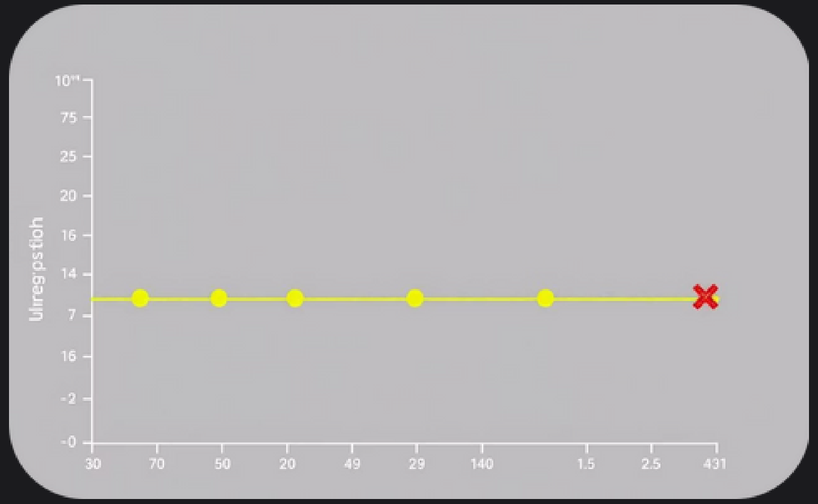
Region Partitioning

Dividing the detected person into distinct body regions: head, torso, and legs.



Box-IoU Checks

Utilizing Intersection over Union (IoU) to assess the overlap between detected PPE items and their corresponding body regions.



Thresholding

A 0.25 IoU threshold determines successful PPE detection within each region, ensuring adequate coverage.

Compliance Checklist

A dynamic checklist evaluates PPE status for each body part, resulting in a final "Safe" or "Unsafe" compliance label.

These algorithms are scripted and implemented using OpenCV for image processing, Ultralytics YOLO for object detection, and OpenVINO for optimized inference.

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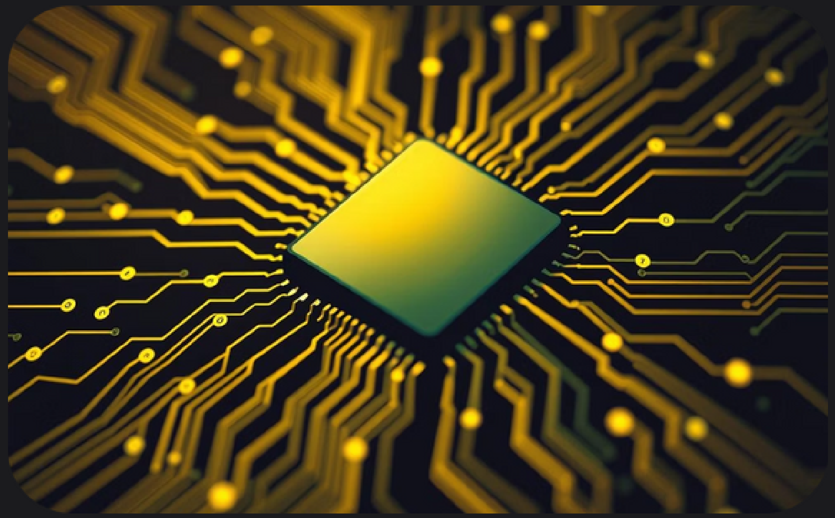
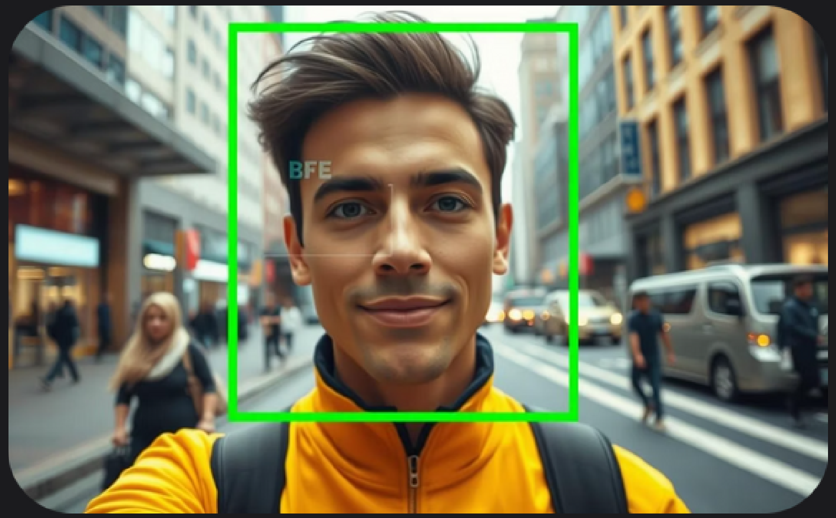
Implementation Details

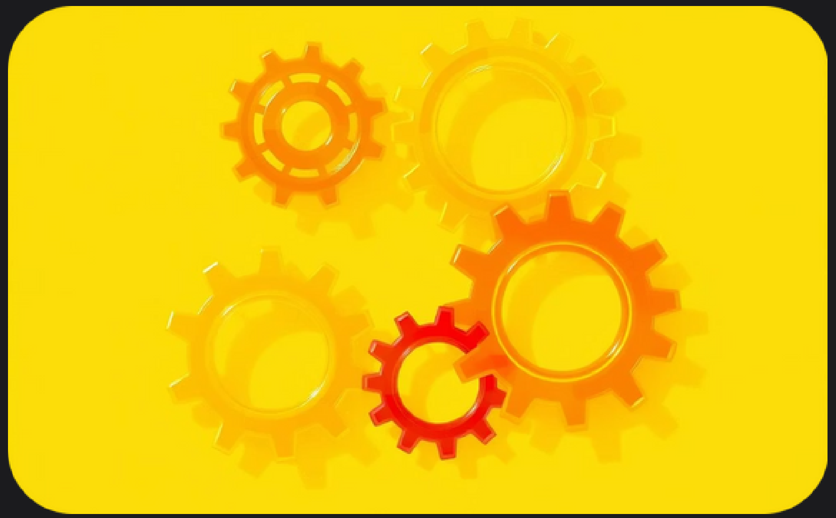


OpenVINO: PPE inference (best.xml) @ ~2.4 ms/frame.

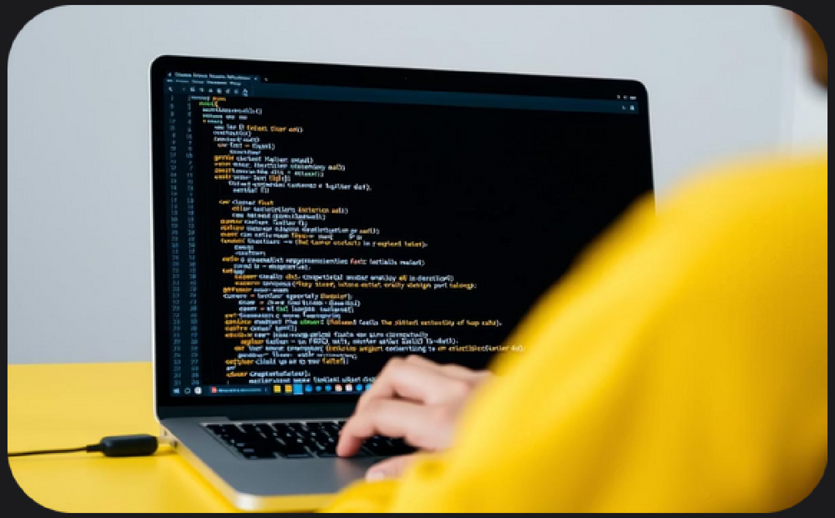


YOLOv8n: Person detection @ ~30 FPS.

Webcam demo includes bounding boxes, safety labels.



Modular for extension: violations, alerts, API-chaining.



Integrated in Python (Jupyter/Script).

UI & Dashboard Overview

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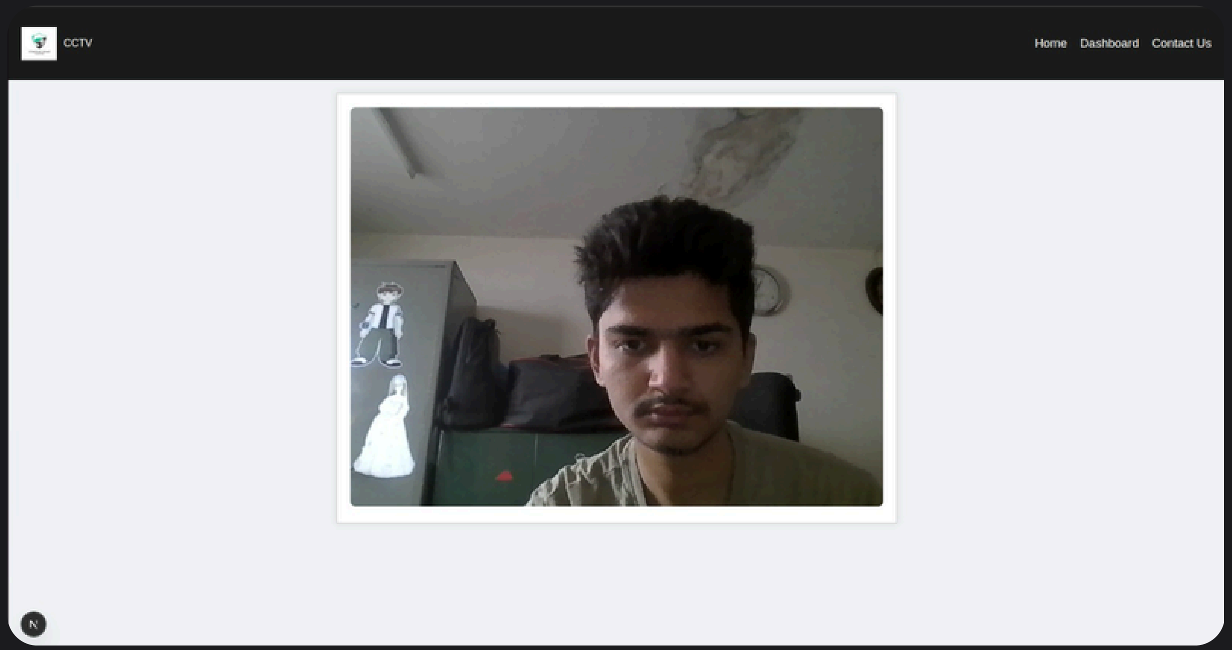
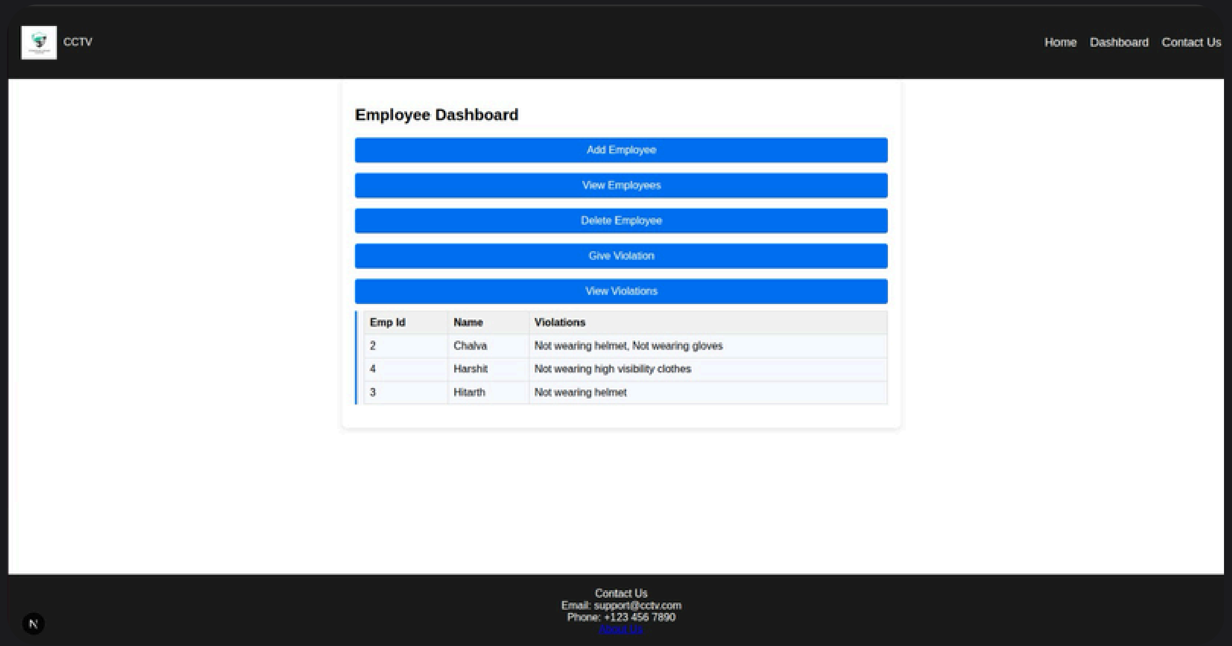
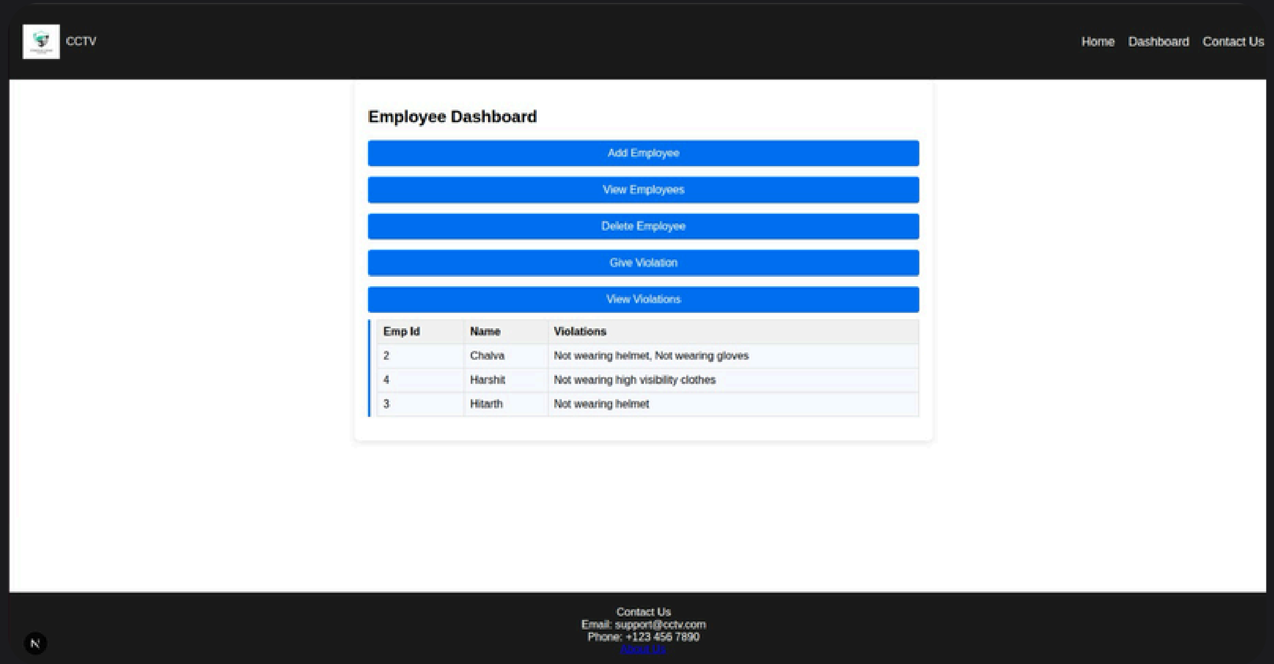


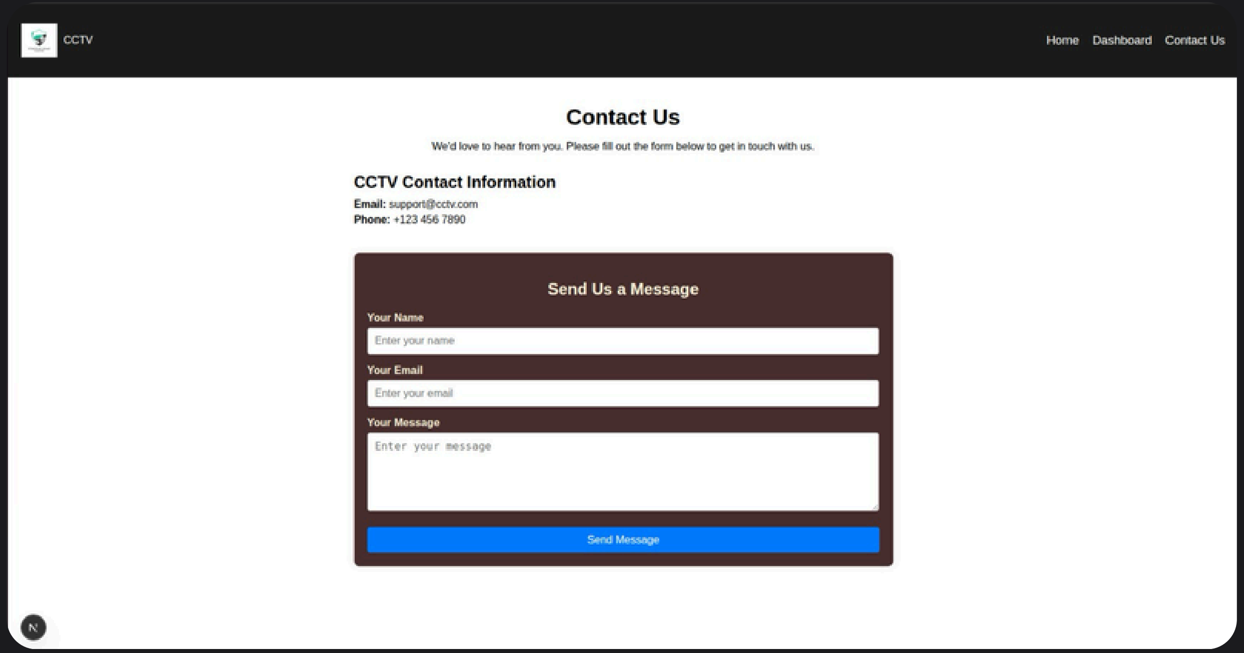
Live webcam feed with "Safe"/"Unsafe" overlay.



Employee Dashboard: add/view/delete employees.



Violation Log Table: captures time, ID, missing PPE.



Contact Form for support or incident reporting.

Results & Evaluation

0.762
PPE mAP@0.5
Detection accuracy

0.774
Precision
Detection accuracy

0.608
Recall
Detection accuracy

30 FPS
Speed
Helm detection + compliance check

0.096
Gloves Recall
Identified as low, needs retraining

<5ms
Latency
Edge-ready on CPU-only setups

```
Running validation...
val: Scanning D:\ppe_dataset\labels\valid.cache... 717 images, 0 backgrounds, 0 corrupt: 100%|
val: D:\ppe_dataset\images\valid\Video2_167_jpg.rf.b7df0fd15e39d5158427deef2d4bc20f.jpg: 1 duplicat
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
                   all        717       2410      0.774      0.608      0.762      0.507
              hard_hat        717        877      0.689      0.815      0.803      0.538
           safety_vest        717        776      0.725      0.765      0.804      0.524
                gloves        717        354      0.852      0.096      0.603      0.411
                 boots        717        403      0.829      0.757      0.837      0.554
Speed: 0.3ms preprocess, 2.4ms inference, 0.0ms loss, 0.7ms postprocess per image
Results saved to runs\detect\dataset_verification_run

Validation Metrics:
mAP50: 0.762
mAP50-95: 0.507
Precision: 0.774
Recall: 0.608
```

Results & Evaluation

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