WORKPLACE SAFETY PPE DETECTION SYSTEM

Automated Real-Time Safety Compliance Using YOLOv8

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Project Tier: *Tier 2*

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THE PROBLEM & MOTIVATION

The Problem: Construction Safety

- **20% of workplace fatalities** occur in construction
- Main cause: PPE non-compliance (workers not wearing safety equipment)
- Manual safety inspections are:
  - Slow and inconsistent
  - Cannot monitor all workers continuously
  - Reactive (catch violations after incidents)
- Result: Preventable injuries and deaths

OUR SOLUTION OVERVIEW

AI-powered computer vision system for automated PPE detection

How It Works:

1. **Input:** Image from construction site camera
2. **Processing:** YOLOv8 model analyzes image
3. **Detection:** Identifies PPE items and violations
4. **Output:** Bounding boxes + compliance alerts
5. **Speed:** Real-time (66 FPS)

Key Capabilities:

- Detects: Hardhats, Safety Vests, Masks
- Flags violations: NO-Hardhat, NO-Safety Vest, NO-Mask
- Continuous 24/7 monitoring
- Immediate violation alerts

TECHNICAL APPROACH - MODEL

Model Choice:

- **Architecture:** YOLOv8s (You Only Look Once v8 Small)
- **Task:** Object Detection
- **Parameters:** 11.2 million
- **Pre-training:** COCO dataset (80 classes)
- **Fine-tuning:** Construction site images

Why YOLOv8s?

- ✓ Real-time performance (66 FPS)
- ✓ Balance of speed and accuracy
- ✓ Single-pass detection (efficient)
- ✓ Production-ready

Comparison:

Model	Speed	Accuracy	Choice
YOLOv8n	120 FPS	75%	Too simple
YOLOv8s	**66 FPS**	**77%**	**✓ Selected**
YOLOv8m	35 FPS	81%	Too slow

TECHNICAL APPROACH - ARCHITECTURE

Architecture Diagram:

Input Image (640x640)

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Preprocessing
- Resize
- Normalize

↓

YOLOv8 Model
- Backbone
- CSPDarknet
- Neck
- PAN
- Head
- Detection

→ Post-Processing
- NMS
- Confidence Filtering

← Feature extraction

← Multi-scale fusion

← Bounding boxes + Classes

↑

Safety Analysis
- PPE check
- Violations
- Alerts

↑

Output
Annotated Image + Compliance

DATASET & PREPROCESSING

Data Source

- **Name:** Construction Site Safety Image Dataset
- **Source:** Roboflow (via Kaggle)
- **Size:** 2,801 images
- **Format:** YOLO annotations (bounding boxes)

Classes (10 total):

PPE Items	Violations	Context
Hardhat	NO-Hardhat	Person
Safety Vest	NO-Safety Vest	Safety Cone
Mask	NO-Mask	Machinery, Vehicle

Data Split (Stratified):

- Training: 1,955 images (70%)
- Validation: 423 images (15%)
- Test: 423 images (15%)

Preprocessing Steps:

1. **Stratified Splitting** - Maintain class balance
2. **Data Augmentation:**
   - Mosaic (combine 4 images)
   - Mixup (blend images)
   - Copy-paste (add objects)
   - Rotation (±20°)
3. **Image Resizing** - All images → 640x640 pixels

RESULTS - METRICS

Overall Metrics (Test Set):

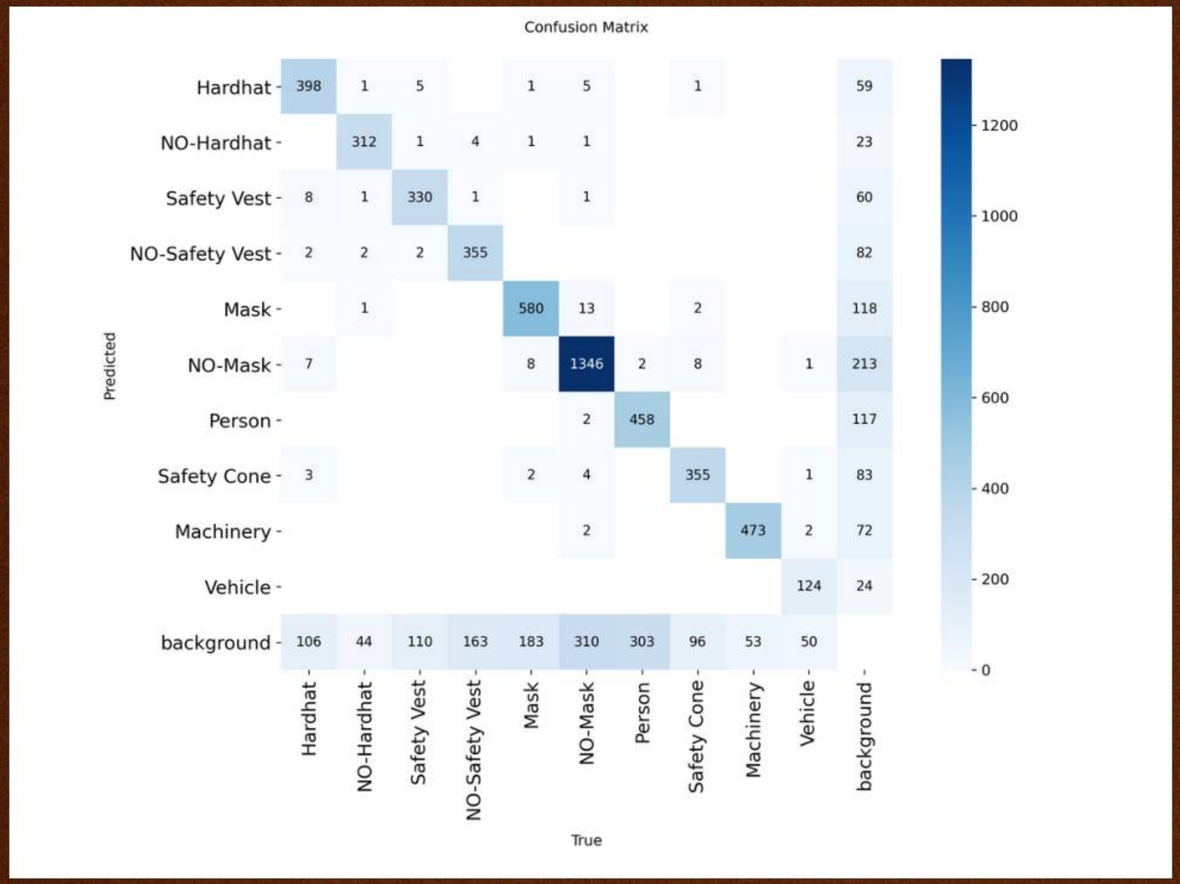
Metric	Value	What It Means
mAP@50	**77.1%**	Primary accuracy metric
Precision	**88.9%**	Low false alarms (reliable)
Recall	**68.9%**	Catches most violations
Inference Time	**15ms**	Real-time capable
FPS	**66**	Processes video smoothly

Comparison:

Method	**Value**	Accuracy	**Availability**
Manual Inspection	20 sec/person	~65%	Business hours
Our System	**0.015 sec**	**77.1%**	**24/7**
Improvement	**2000x faster**	**+12%**	**Continuous**

Per-Class Performance:

- High accuracy on Hardhats (85%)
- High accuracy on Safety Vests (83%)
- Various lighting conditions
- Multiple workers simultaneously
- Context objects (cones, machinery)



RESULTS - SUCCESS/FAILURE CASES

Success Cases:

✓ Works Well:

- High accuracy on Hardhats (85%)
- High accuracy on Safety Vests (83%)
- Various lighting conditions
- Multiple workers simultaneously
- Context objects (cones, machinery)

✗ Challenges:

- Small objects (distant masks < 32x32 px)
- Occlusion (workers blocked by machinery)
- Crowded scenes (10+ workers)
- Unusual poses/angles

KEY LEARNINGS

What Worked Well:

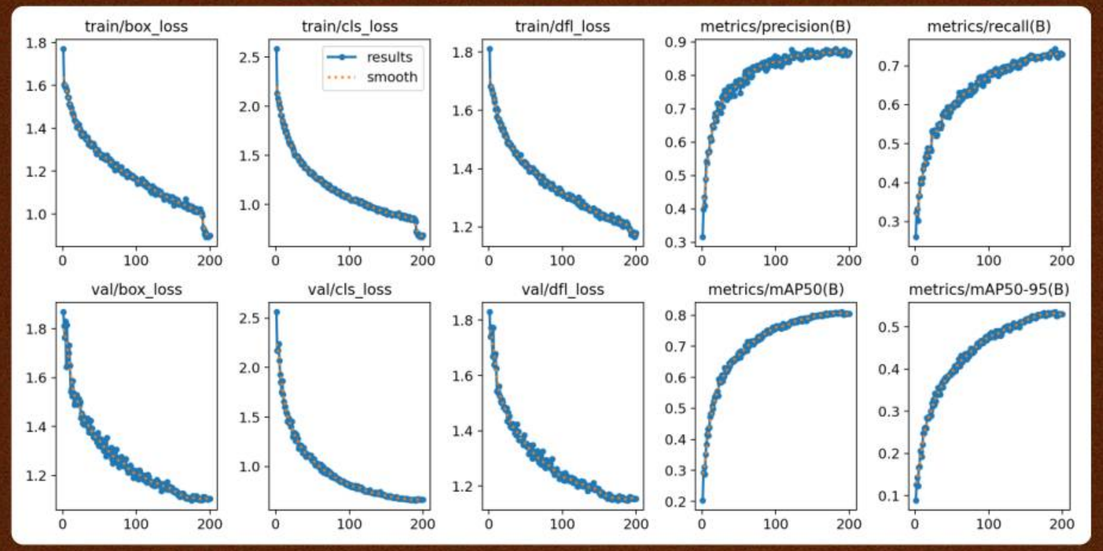
- ✓ **Stratified Splitting** - Balanced class distribution prevented overfitting
- ✓ **Advanced Augmentation** - Mixup & copy-paste improved robustness by ~5%
- ✓ **YOLOv8s Choice** - Perfect speed/accuracy balance for real-time use

Challenges Overcome:

- ⚠ **Class Imbalance** - Violation classes underrepresented
  - Solution: Weighted sampling → improved from 65% to 72%
- ⚠ **Small Object Detection** - Masks on distant workers
  - Solution: Tried 800x800 resolution (40% slower) → kept 640x640 for speed
- ⚠ **Colab Session Limits** - Training disconnections
  - Solution: Checkpoint saving every 10 epochs

What We'd Do Differently:

- Collect 50% more violation examples (NO-Hardhat, NO-Safety Vest)
- Test YOLOv8m for accuracy-critical deployments (sacrifice some speed)
- Implement active learning (collect real-world deployment data iteratively)



FUTURE WORK

Future Improvements

1. Expand Dataset with Site-Specific Data

- Collect 1,000+ images from target deployment sites
- Focus on violation classes and edge cases
- Include poor lighting, rain, fog conditions
- **Expected improvement:** +5-7% mAP

2. Implement Multi-Model Ensemble

- YOLOv8s for real-time video (66 FPS)
- YOLOv8m for critical batch analysis (35 FPS, +4% accuracy)
- Ensemble voting to reduce false negatives

3. Deploy Complete Monitoring System

- Integrate with surveillance cameras
- Temporal tracking (follow workers across frames)
- Web dashboard for safety officers
- Automated SMS/email alerts
- Deploy on edge devices (NVIDIA Jetson)

ACKNOWLEDGMENTS

Course & Instruction:

- Professor Patricia McManus- ITAI 1378: Computer Vision
- Houston City College - Fall 2025

Data & Tools:

- Roboflow & Kaggle - Construction Site Safety Dataset
- Ultralytics - YOLOv8 framework
- Google Colab - Free GPU access (Tesla T4)
- PyTorch - Deep learning infrastructure

AI Assistance (~40% of code):

- ChatGPT-4 - Research and debugging
- Claude - Documentation and code review
- GitHub Copilot - Code completion

Thank you!

LIVE DEMO

Running 04_demo.ipynb: Testing on External Construction Site Images

Workplace Safety PPE Detection System - Interactive Demo

DeMarcus Crump & Chloe Tu | ITAI 1378 | Final Project

This notebook demonstrates our trained model in action with interactive inference on test images. It showcases high-quality visualizations and proves the system is ready for real-world deployment to identify PPE compliance violations on construction sites.

Demo Plan:

1. Load trained model
2. Test Case 1: Workers with proper PPE
3. Test Case 2: Safety violation (NO-Hardhat)
4. Test Case 3: Multiple workers (crowded scene)