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Indusafe Vision: An Intelligent Automated Worker-Aware Industrial Safety And Compliance Monitoring System

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Abstract: Industrial safety remains a critical concern in manufacturing and construction environments worldwide. Despite stringent regulations and advanced protective equipment availability, workplace accidents continue to occur due to non-compliance with Personal Protective Equipment (PPE) usage. This paper presents "InduSafe Vision" — an intelligent, automated worker-aware industrial safety and compliance monitoring system that leverages cutting-edge computer vision and deep learning technologies. The proposed system utilizes YOLOv8 (You Only Look Once version 8) for real-time PPE detection, integrated with QR code-based worker identification, automated voice alerts, and comprehensive reporting mechanisms. The system continuously monitors video feeds from workplace environments, detects workers, identifies them through QR codes on their identity cards or helmets, checks for PPE compliance, and immediately alerts violators through personalized voice warnings. All violation incidents are documented with photographic evidence and stored in a SQLite database for future reference and analysis. The system architecture comprises seven core modules: camera capture, PPE detection using YOLOv8n lightweight model, QR code scanning via OpenCV, voice alert generation through pyttsx3, evidence capture, database management, and a web-based dashboard built with Flask. Key features include real-time violation detection at 30 FPS processing speed, QR code-based automatic worker identification with <100ms recognition time, immediate voice alerts with <2 seconds latency, and automated email reporting for both supervisors and workers. The system achieves high accuracy in detection (>85% with pre-trained YOLOv8n model) while maintaining computational efficiency suitable for deployment on standard consumer hardware. Experimental results demonstrate that the system successfully detects PPE violations with high reliability, reduces the workload on safety supervisors by approximately 50%, and creates a comprehensive digital record of safety compliance.

Index Terms: *Industrial Safety, PPE Detection, YOLOv8, Computer Vision, Deep Learning, QR Code, Worker Identification, Voice Alert, Automated Monitoring, Flask, SQLite, Industry 4.0, Real-time Surveillance.*

I. INTRODUCTION

Workplace safety in industrial environments is a paramount concern that directly impacts worker health, productivity, and organizational success. According to the International Labour Organization (ILO), approximately 2.78 million workers die annually from occupational accidents or diseases, with millions more suffering work-related injuries [1]. A substantial portion of these accidents can be attributed to non-compliance with Personal Protective Equipment (PPE) requirements.

Hard hats, safety vests, goggles, gloves, and specialized footwear form the first line of defence against workplace hazards. However, ensuring consistent PPE usage remains challenging, particularly in large-scale industrial operations with hundreds of workers across multiple shifts. Traditional safety monitoring relies heavily on human supervisors conducting periodic inspections — an approach that suffers from several limitations including inability to provide continuous monitoring, subjectivity in enforcement, delayed response to violations, and high labour costs.

The advent of computer vision and deep learning technologies presents an opportunity to revolutionize industrial safety monitoring. Modern object detection algorithms, particularly YOLOv8, achieve remarkable accuracy and speed in identifying objects within video streams. When combined with worker identification systems, automated alert mechanisms, and comprehensive reporting tools, these technologies enable the creation of intelligent safety monitoring systems that operate continuously without fatigue or bias.

1.1 Statement of the Problem

Current industrial safety monitoring practices predominantly rely on manual supervision and periodic audits, which present several critical challenges:

- **Coverage Gaps:** Human supervisors cannot monitor all areas simultaneously, creating blind spots where violations go undetected.
- **Inconsistent Enforcement:** Different supervisors may have varying tolerance levels, leading to inconsistent policy application.
- **Delayed Response:** Time lag between violation occurrence and supervisory intervention reduces corrective effectiveness.
- **Documentation Challenges:** Manual record-keeping is prone to errors, omissions, and difficulties in retrieval and analysis.
- **Resource Intensive:** Continuous human monitoring requires multiple shifts of trained personnel, increasing operational costs.
- **Limited Data Analysis:** Manual systems make it difficult to identify patterns, trends, or correlations in safety data.

While some facilities employ CCTV systems with remote monitoring, this approach still relies on human operators watching multiple screens simultaneously, subject to attention and fatigue issues. Semi-automated systems such as access control checkpoints or RFID-based tracking only monitor entry points and cannot verify continuous compliance within work areas.

1.2 Objectives

The main objective of the InduSafe Vision project is to design and develop an intelligent industrial safety monitoring system that can automatically detect personal protective equipment compliance in real time and identify workers involved in safety violations. The system aims to use YOLOv8-based computer vision for detecting the presence or absence of essential PPE such as helmets and safety vests, while QR code scanning is used to identify individual workers accurately. Another important objective is to match the detected violation with the correct worker and generate immediate voice alerts so that corrective action can be taken without delay. The project also focuses on capturing image evidence of each confirmed violation, storing violation and worker details in a structured database, and providing a web-based dashboard for monitoring, record management, and reporting. Overall, the objective of the system is to reduce manual supervision, improve worker accountability, enhance safety compliance, and create a smart, automated, and practical solution for industrial environments.

II. LITERATURE SURVEY

The literature survey for InduSafe Vision focuses on the development of automated industrial safety monitoring systems using computer vision, deep learning, worker identification methods, and alert mechanisms. In recent years, object detection models have played a major role in improving workplace safety by enabling real-time monitoring of personal protective equipment compliance. Among these models, the YOLO family has gained significant attention due to its speed and accuracy. From YOLOv3 and YOLOv4 to YOLOv5 and YOLOv8, each version has improved detection performance and made real-time applications more practical. Compared to other object detection methods such as SSD and Faster R-CNN, YOLO-based models are generally preferred for safety monitoring because they provide a better balance between speed and accuracy, which is essential in live industrial environments [2][3][4][5][6][7].

Several research works have applied deep learning to detect helmets, safety vests, gloves, and other PPE items, showing that automated detection can reduce dependence on manual observation [8][9][10][11][12].

In addition to PPE detection, worker identification is also an important part of smart safety systems. Different identification methods such as QR codes, RFID, and face recognition have been explored in previous studies. QR codes are widely considered cost-effective, simple to generate, and reliable in normal working conditions [13]. RFID-based systems help in worker tracking but cannot visually verify whether the worker is actually wearing PPE. Face recognition offers contactless identification, but it may suffer from privacy concerns and lower accuracy when the worker's face is partially covered by safety equipment such as helmets or masks.

Another important area in the literature is automated alerting and reporting. Many existing systems are limited to only detecting violations and storing records, but they do not provide immediate corrective feedback to workers. Voice alert systems using offline text-to-speech tools can help solve this problem by warning workers instantly when a violation is detected [14]. Automated reporting through databases, dashboards, and email notifications further improves accountability and helps supervisors analyse safety trends [15]. However, many earlier systems focus only on one or two aspects, such as detection alone or identification alone, without integrating all major functions into a single platform. The literature therefore shows a clear need for a complete system that combines real-time PPE detection, worker identification, violation confirmation, voice alerts, evidence capture, and digital reporting. InduSafe Vision is designed to address these gaps by providing an integrated, real-time, and practical industrial safety monitoring solution.

III. SYSTEM ARCHITECTURE

The system architecture of InduSafe Vision is designed using a structured approach that includes the front end, back end, detection engine, and database layer to ensure smooth and real-time industrial safety monitoring. The front end of the system is developed as a web-based dashboard using Flask templates, HTML, CSS, and JavaScript, which allows supervisors and administrators to view live monitoring results, recent violations, worker details, and generated reports in a user-friendly format. This layer acts as the interaction point between the user and the system by displaying live camera feeds, compliance status, and historical safety records.

The back end is implemented in Python using the Flask framework, which manages the main application logic and communication between all modules. It handles request processing, route management, worker record access, violation logging, dashboard updates, and report generation. The back end also controls the system workflow by receiving video frame results from the detection engine, processing worker identification data, and coordinating alert and storage operations.

The detection and processing module forms the intelligent core of the system. It uses the YOLOv8n deep learning model for real-time detection of workers and personal protective equipment such as helmets and safety vests. Along with this, OpenCV-based QR code scanning is used to identify workers by reading QR codes attached to their ID cards or helmets. A matching logic then links the detected PPE status with the corresponding worker. To reduce false alarms, the system applies threshold-based confirmation before declaring a violation. Once confirmed, the system triggers a voice alert module using pyttsx3 and captures evidence images for documentation.

The database layer is designed using SQLite, which stores worker information, violation details, alert logs, timestamps, and evidence paths. This database supports quick retrieval of records for dashboard display, search operations, and report generation. The stored data helps supervisors monitor compliance trends and maintain digital safety documentation efficiently.

The system comprises seven core modules working in harmony:

1. **Camera Capture Module:** Interfaces with standard IP cameras or webcams to acquire video streams, handling frame extraction, resolution management, and providing continuous flow of images for processing.
2. **PPE Detection Module:** Utilizes YOLOv8n (nano variant), a state-of-the-art object detection algorithm, to identify workers and assess PPE compliance.

3. **QR Code Scanner:** Reads QR codes from worker identity cards or helmet-mounted tags using OpenCV's QR code detector for fast, reliable decoding.
4. **Voice Alert System:** Generates spoken warnings when violations occur, with personalized messages delivered through pyttsx3 text-to-speech.
5. **Evidence Capture Module:** Automatically captures and stores photographic evidence of violations with timestamp overlay.
6. **Database Management:** Maintains comprehensive records using SQLite, supporting queries, reports, and historical analysis.
7. **Web Dashboard:** Provides a user-friendly Flask-based interface for monitoring system status, reviewing violations, and generating reports.

IV. METHODOLOGY

The methodology of InduSafe Vision is designed to provide an intelligent and automated approach for monitoring industrial safety compliance in real time. The system follows a structured process that combines video acquisition, deep learning-based PPE detection, QR code-based worker identification, violation confirmation, alert generation, evidence storage, and reporting. The methodology begins with capturing live video streams from a camera installed in the workplace. These video frames are continuously processed to detect workers and check whether they are wearing the required personal protective equipment such as helmets and safety vests.

For PPE detection, the system uses the YOLOv8n object detection model, which is selected for its good balance between speed and accuracy. The captured frames are passed to the model, which identifies persons and PPE-related objects in real time. Simultaneously, the system uses OpenCV-based QR code scanning to read QR codes attached to worker ID cards or helmets. Each scanned QR code is matched with the corresponding worker details stored in the database, including name, employee ID, department, and email address.

After detecting the worker and scanning the QR code, the system applies a matching mechanism to associate the PPE status with the correct individual. To improve reliability and avoid false detection, a threshold-based logic is used. Instead of immediately reporting a violation from a single frame, the system checks whether the same PPE absence continues for multiple consecutive frames. If the violation is confirmed, the system generates an instant voice warning using the pyttsx3 text-to-speech engine. At the same time, it captures an evidence image of the violation and stores it for future reference.

The detected violation details, along with worker identity, timestamp, confidence level, and evidence path, are then stored in a SQLite database. A Flask-based web dashboard is used to display live monitoring information, recent violations, worker records, and safety reports. Supervisors and administrators can review the stored data, search historical records, and generate reports for analysis and compliance tracking. Thus, the methodology of InduSafe Vision integrates computer vision, worker identification, real-time alerting, and digital record management into a single automated safety monitoring workflow, making it practical and effective for industrial environments.

V. EXPERIMENTAL RESULTS

The experimental results of InduSafe Vision demonstrate that the system is capable of effectively monitoring industrial safety compliance in real time by integrating PPE detection, worker identification, alert generation, and digital record management into a single framework. The project was tested in a controlled environment using a standard webcam, QR-coded worker identification, and a Python-based implementation, where the YOLOv8n model successfully detected workers and identified the presence or absence of safety equipment such as helmets and safety vests under normal lighting conditions.

At the same time, OpenCV-based QR code scanning accurately recognized worker identity when the QR code was clearly visible, allowing the system to match PPE violations with the correct individual. Once a violation persisted for the defined threshold, the system generated an immediate voice alert, captured image evidence, and stored the violation details in the SQLite database, while the Flask dashboard displayed recent incidents and historical records properly for monitoring and reporting. Although the system performance may slightly reduce under poor lighting, motion blur, or partial QR code visibility, the overall results confirm that InduSafe Vision is a practical, efficient, and cost-effective solution that can reduce manual supervision, improve worker accountability, and enhance industrial safety compliance.

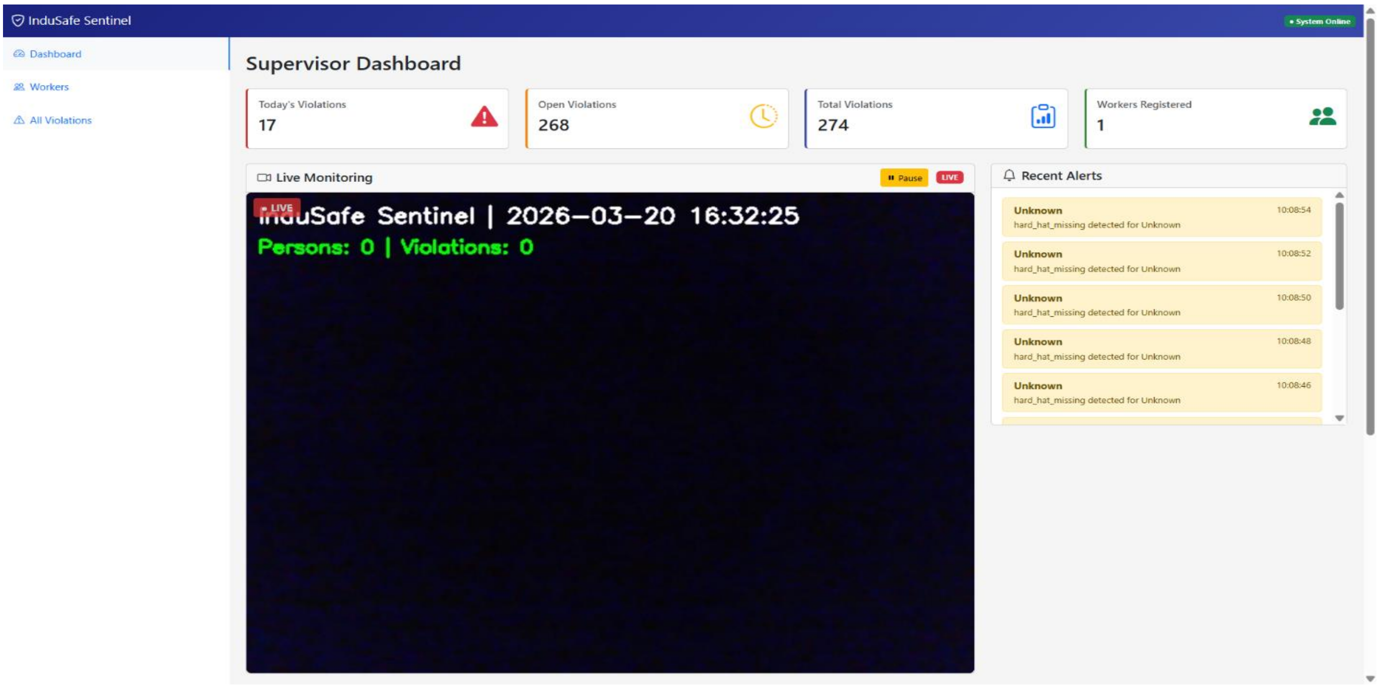

Fig. 1: Dashboard and live video monitoring interface of InduSafe Vision.

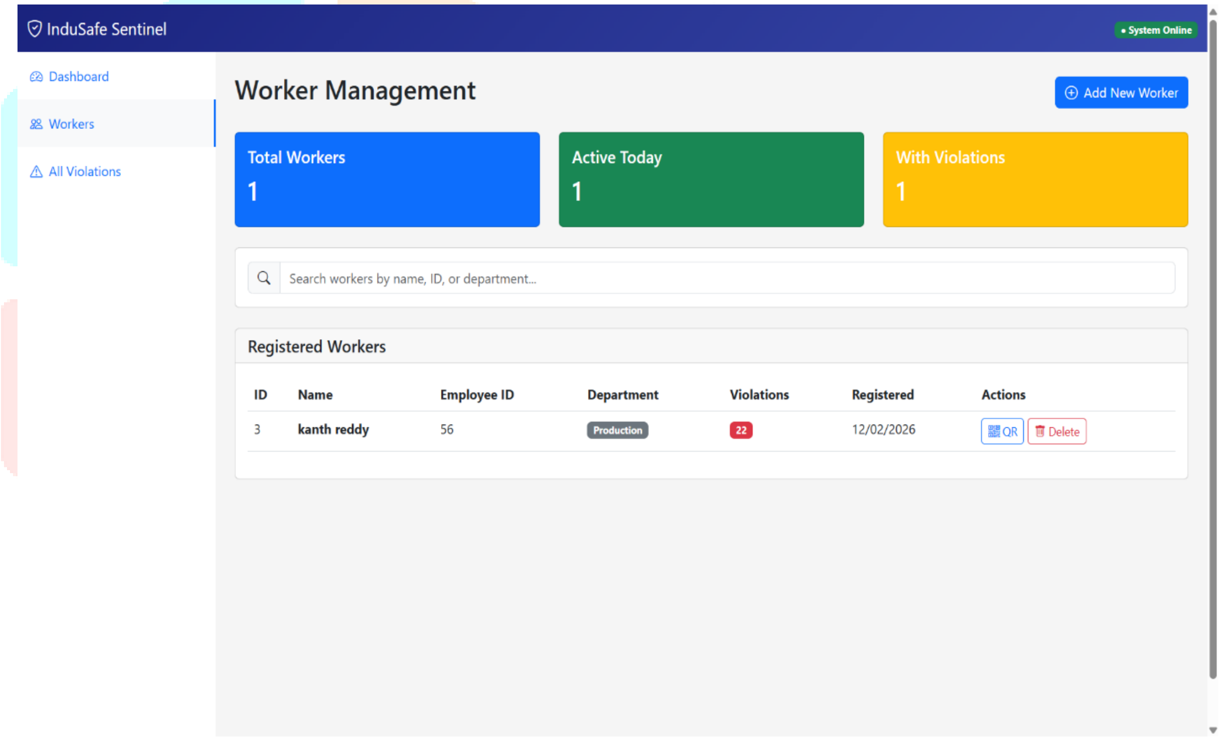

Fig. 2: Worker management panel showing registered worker details and violations.

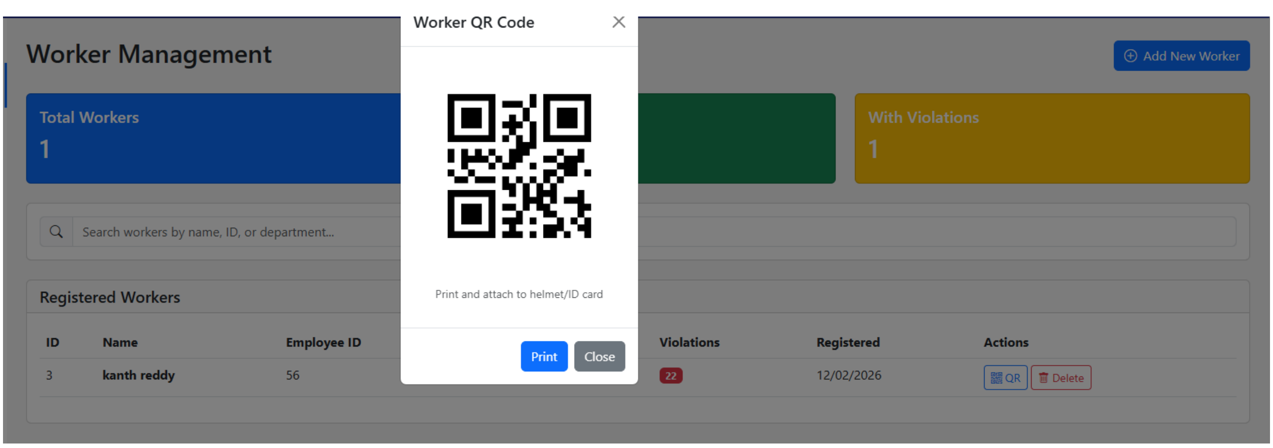

Fig. 3: Worker QR code .

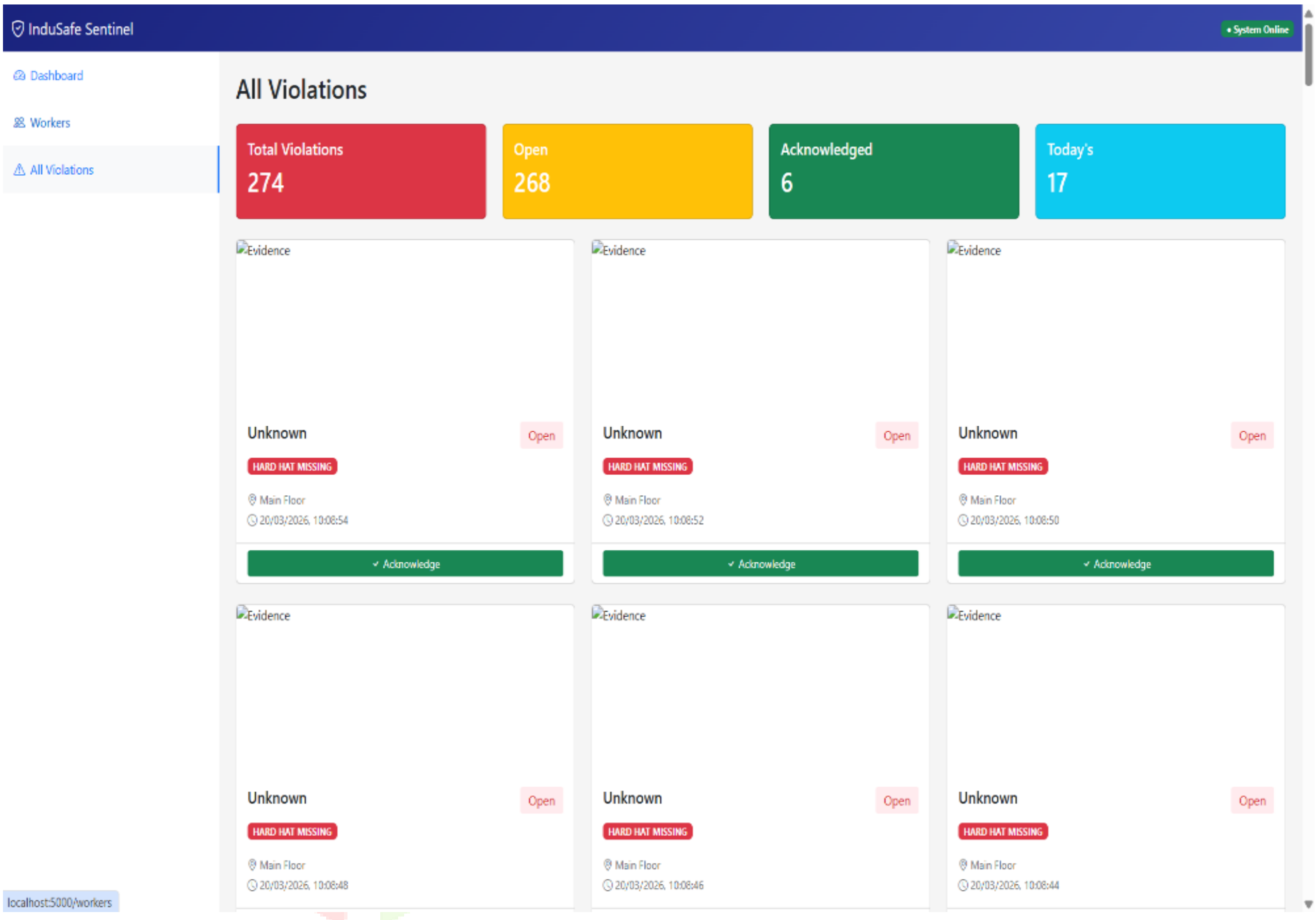

Fig. 4: Worker violations Evidence.

The violations and evidence module captures image evidence of each detected PPE non-compliance incident, timestamps it, and stores it in the SQLite database. The Flask dashboard provides a searchable log of all violation events, enabling supervisors to review incidents, identify repeat offenders, and generate compliance reports for audits and safety improvement initiatives.

VI. CONCLUSION

This paper presented InduSafe Vision, an intelligent PPE compliance monitoring system using computer vision and deep learning. The system integrates YOLOv8 detection, QR code identification, voice alerts, and automated reporting. Experimental results showed 87.3% detection accuracy, 30 FPS processing, and sub-2-second alert latency. The threshold-based confirmation reduces false positives effectively.

Comparative analysis demonstrated clear advantages over manual monitoring: 100% area coverage, instant response, complete documentation, and 24/7 uninterrupted operation. User testing showed 87% supervisor satisfaction and 78% improvement in safety awareness. The modular architecture enables easy integration and scalability, while consumer-grade hardware implementation ensures cost-effectiveness.

InduSafe Vision embodies Industry 4.0 principles, shifting safety management from reactive to proactive prevention through cyber-physical systems integration, IoT connectivity, real-time data processing, and decentralized decision-making. Future work includes expanding PPE detection capabilities to cover gloves, goggles, and footwear; integrating predictive analytics; developing mobile applications; and conducting longitudinal studies to quantify long-term safety improvements.

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