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Enhancing the Detection of Unsafe Acts and Conditions Using Face Recognition Technique in the Industry

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Abstract: This study proposes a dual faceted framework aimed at addressing this issue through advanced technological interventions. The first component focuses on the detection of unsafe acts by leveraging environmental sensors and behavioral monitoring systems. These systems utilize machine learning algorithms to analyze contextual data and flag actions or situations that deviate from predefined safety standards. The second component integrates face recognition technology for the identification of individuals associated with the detected unsafe acts. By delineating the detection of unsafe behaviors from the identification process, this approach maintains a clear functional separation, ensuring transparency and purpose specificity in the application of face recognition. The paper presents comprehensive methodologies, including the design and deployment of sensor networks, the development of behavior analysis algorithms, and the integration of biometric identification systems. Real world case studies demonstrate the effectiveness of the proposed approach in diverse settings such as construction sites, industrial plants, and public venues. Furthermore, this work critically examines ethical implications, with a particular emphasis on privacy concerns, potential algorithmic biases, and the need for regulatory oversight. Recommendations are provided to balance technological innovation with ethical responsibility, fostering the adoption of safety enhancing measures while safeguarding individual rights and freedoms.

Keywords: Face recognition Technology, Industrial safety, Manufacturing site, AI Detection, Unsafe Acts Detection, Behavioral Monitoring Systems, Human Behavior Analysis

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INTRODUCTION

Facial recognition technology has emerged as a powerful tool in the realm of digital forensics and crime prevention. This technology utilizes computer vision algorithms to analyze facial features, allowing for the identification of individuals from digital images or video footage [1][2].

The application of facial recognition in the context of identifying offenders involved in unsafe acts or conditions can be an asset for law enforcement and public safety efforts. The application of face recognition technology (FRT) in identifying unsafe acts within industrial environments has garnered significant attention in recent years. This literature review synthesizes current research related to the implementation, efficacy, and challenges of FRT in enhancing workplace safety [14]. The review will cover various aspects of FRT, including its technical basis, case studies illustrating its application in industrial settings, and the ethical and legal concerns surrounding its use. This body of work aims to provide insight into the potential benefits of FRT while also highlighting the consideration that must be given to ethical implications and worker privacy [13]. Face recognition technology relies on a combination of computer

vision, machine learning, and pattern recognition algorithms to identify individuals through facial features. Foundational studies have established the efficacy of these technologies in various applications, including security and surveillance [3]. Machine learning techniques, particularly deep learning, have significantly improved the accuracy and speed of face recognition algorithms [4]. For industrial applications, real time analysis of facial data is paramount, as immediate feedback is essential for identifying unsafe practices. Current technologies utilize convolutional neural networks (CNNs) to enhance classification tasks related to facial identification, yielding promising results for monitoring compliance with safety protocols [15].

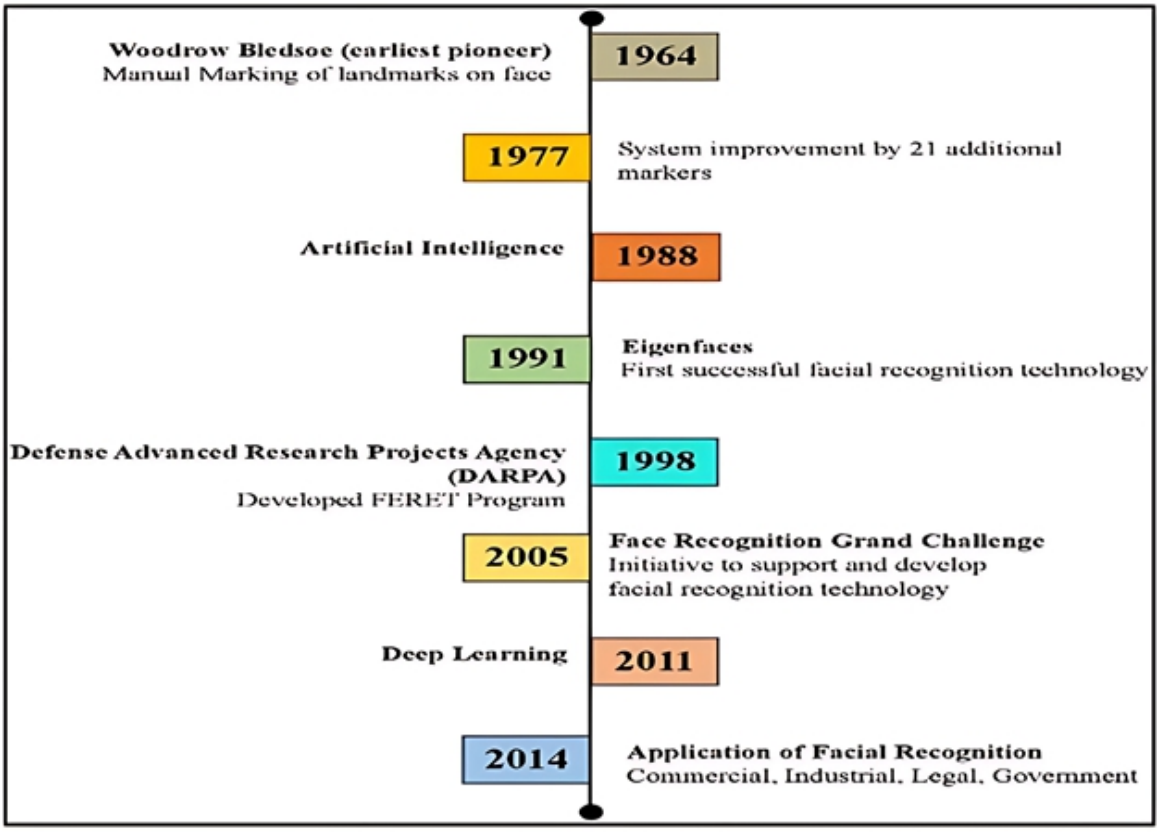

Figure 1: Framework of FRT [19]

Figure 2: PPE requirement in manufacturing plant [20]

LITERATURE REVIEW

Arso M. Vukicevic et al., (2023) Even while automation is used in manufacturing, it still needs people to do work, which can lead to musculoskeletal problems from doing the same risky jobs over and over again. It was suggested to use a deep learning based posture evaluation system that uses 3D pose estimate and mesh categorisation to get up to 98% accuracy. It makes it easier to keep an eye on safety by employing regular cameras instead of complicated data labelling or expert input. [16]

A. M. Vukicevic et al., (2022) Injury risks and costs rise when PPE misuse goes undetected. This study introduces a binary classification system using Higher HRNet and models like MobileNetV2 to monitor 18 PPE types across 5 body zones. It offers a scalable, low resource solution for digitizing PPE checks in self assessment and safety critical environments. [17]

J Purohit , (2022) Looked at how facial recognition on social media, notably auto tagging, makes people communicate and connect more. They said that more and more apps are adopting these kinds of technologies. Facial recognition improves gaming by allowing for personalised experiences that are based on each player's unique qualities and reactions. [6]

Kou et al. (2021) Looked into how facial recognition may get better by making it more accurate and reliable in different situations. They stressed the importance of combining different types of biometrics, such as iris, voice, and fingerprint data, to make authentication stronger. They also talked about how real

world facial recognition problems need better algorithms, more varied datasets, and stronger systems. [15]

Grover et al. (2020) Looked at how facial recognition is used in retail to make buying more personal by looking at how customers act, which increases engagement and sales. They also talked about similar benefits in healthcare, where reliable biometric identification systems help manage patients and keep them safe by reducing administrative mistakes. [14]

Buolamwini and Gebru (2018) Identified the crucial evolution of face recognition technology, highlighting its transitions from simplistic geometric methods in the 1960s to complex statistical approaches today. The initial face recognition systems were largely dependent on manually defined features, which limited their effectiveness across varying conditions such as lighting and facial orientation. [9]

Doshi-Velez and Kim (2017) stressed the need for explainable AI in facial recognition, urging the development of systems that clearly show how decisions are made. They emphasized transparency to build trust, address ethical concerns, and ensure responsible use, especially in sensitive areas like security and biometric identification. [18]

PROBLEM IDENTIFICATION

Unsafe acts and conditions are leading contributors to workplace and public space accidents, accounting for approximately 88% of such incidents. While current safety monitoring systems can detect violations of safety protocols, they often lack the capability to accurately identify the individuals responsible. This gap in accountability hinders effective enforcement of safety measures and limits the potential for corrective action. There is a critical need for an integrated system that not only detects unsafe behaviors but also reliably identifies the offenders, while addressing ethical concerns such as privacy and bias.

OBJECTIVE

1. To develop a dual faceted framework that separates the detection of unsafe acts from the identification of individuals using face recognition technology.
2. To design and implement a multi modal detection system incorporating environmental sensors, wearable devices, and AI based behavioral monitoring.
3. To integrate advanced face recognition algorithms (e.g., CNNs, Face Net, MTCNN) for accurate and real time identification of individuals involved in unsafe acts.
4. To evaluate the effectiveness of the proposed system through real world case studies in diverse environments such as industrial plants, construction sites, and public health facilities.
5. To address ethical and legal considerations related to the use of biometric data, ensuring compliance with privacy regulations and minimizing algorithmic bias.

RESEARCH METHODOLOGY

For this study, we chose manufacturing sites in high risk sectors such as heavy industry, assembly lines, and chemical processing settings with documented incident histories and a strong commitment to safety and advanced technology adoption. These locations featured reliable IT infrastructure and integrated security systems, ensuring effective real time data capture from AI powered cameras. Data collection combined

quantitative metrics from the FRT system including PPE compliance, safety violations, and response times over a three month period, with qualitative feedback from participant focus groups and interviews about user experiences and privacy concerns. Prior to observation, all employees participated in mandatory safety training, and standardized protocols for incident reporting and behavioral monitoring by trained safety officers were followed. For analysis, we applied statistical tools like GraphPad for quantitative assessment, and thematic analysis for qualitative insights, with all findings carefully validated and compared across time periods. The comprehensive results were presented in a clear report, informing future safety strategies and promoting ongoing improvement in workplace safety culture.

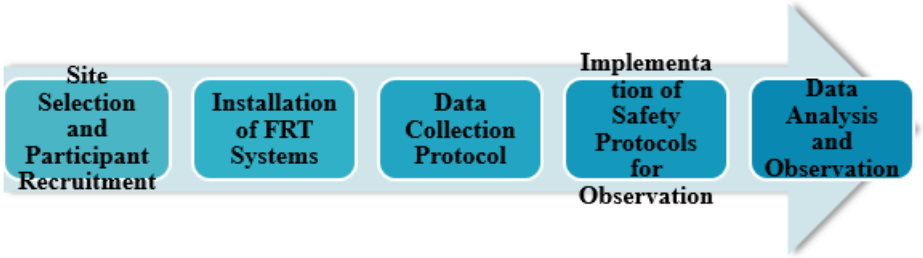

Figure 3: Methodology flow chart

Facility Characteristics:

a. Industry

b. Willingness and Infrastructure

c. Environmental Factors

d. Personnel and Training

e. Regulatory, Ethical, and Privacy Considerations

f. Continuous Improvement and Feedback Loop

Implementation of Safety Protocols for Observation

1. **Safety Training:** Prior to the study commencement, all participants underwent a mandatory safety training program, focusing on the importance of PPE, adherence to safety protocols, and the implications of non-compliance.
2. **Behavioural Observations:** Trained safety officers conducted observational studies during regular shifts, noting instances of compliance and violations. These observations served as a supplementary dataset for analysing the effectiveness of FRT.
3. **Incident Reporting:** A standardized workflow was introduced to report incidents of non-compliance, allowing for seamless integration of data from various sources.

Figure 4: Sample Photos

RESULT

The data collected during the experimental phase demonstrates that Facial Recognition Technology (FRT) can significantly enhance safety measures in industrial environments, as evidenced by improved PPE compliance, fewer safety violations, and faster alert responses. However, safety observation photos from the facility reveal ongoing gaps in PPE usage, emphasizing that while FRT offers clear benefits, continuous monitoring and intervention remain essential. These findings highlight the need for ongoing efforts to reinforce safety behaviors and ensure consistent compliance, ultimately supporting the development of a strong safety culture within the workplace.

Figure 5: FRT pics for PPE (Personal Protective Equipment

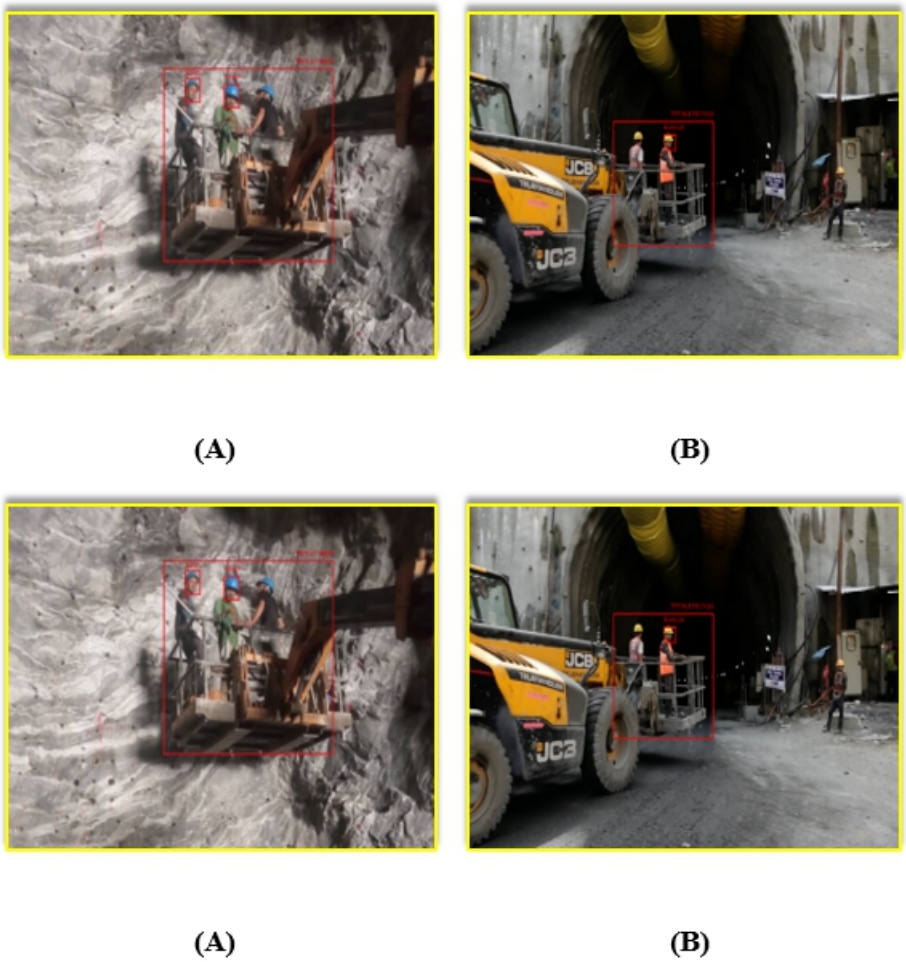

Figure 6: (A) & (B): FRT pics for person's face

Here are the results of Observation from December 2024 and January 2025 with AI camera fixed for detecting unsafe acts at production unit.

Table 1: Safety Observation Captured by AI Camera for the month of Dec 2024

Category	Behavioral Safety (BS)		Emergency Control (EC)	PPE		
	People Gathering (PG)	Phone Usage (PU)	Person Unconscious (PU)	Gloves(G)	Helmet(H)	Vest (V)
Safety Observation	**47**	**23**	**0**	**121**	**48**	**13**

Table 2: Safety Observation Captured by AI Camera for the month of Jan 2025

Category	Behavioral Safety (BS)		Emergency Control	PPE		
	People Gathering (PG)	Phone Usage (PU)	Person Unconscious (PU)	Gloves(G)	Helmet(H)	Vest (V)
Safety Observation	**21**	**11**	**1**	**34**	**26**	**21**

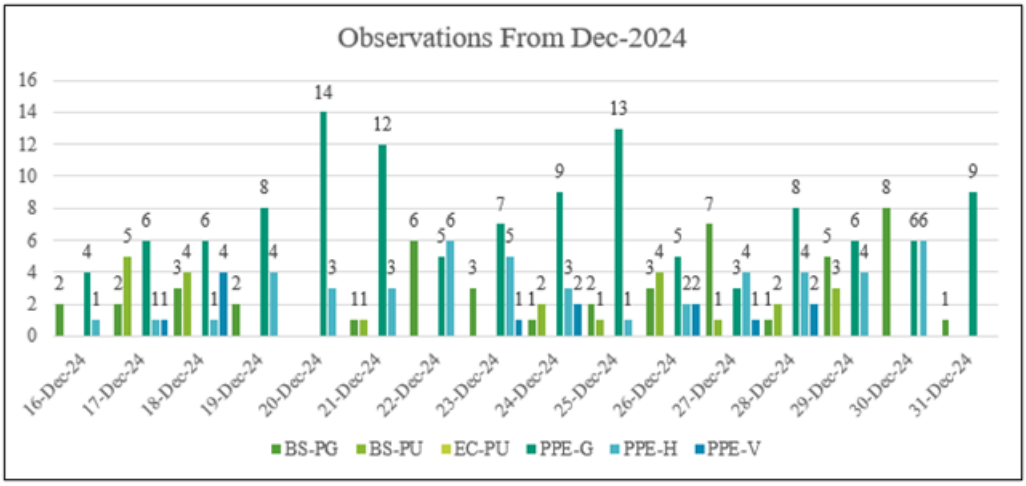

Figure 7: Observation from Dec 2024

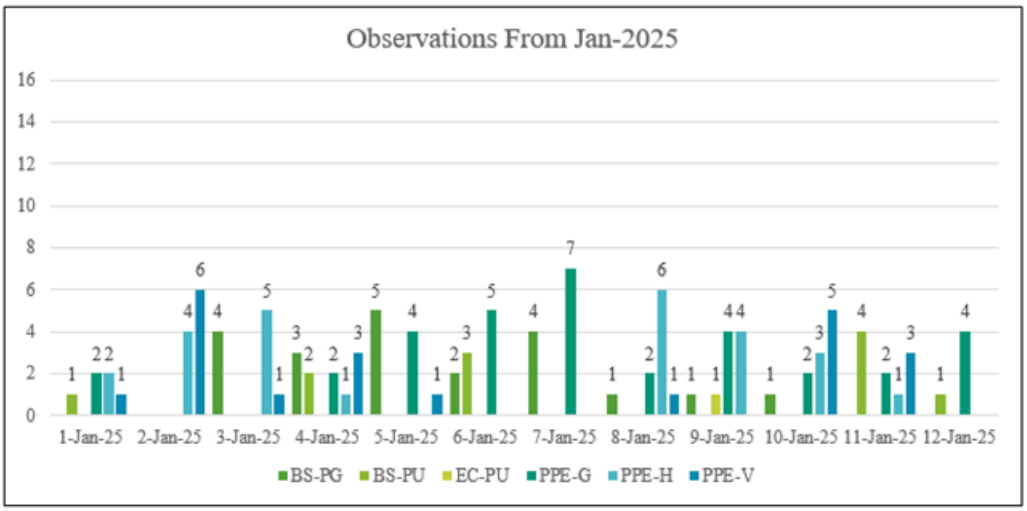

Figure 8: Observation from Jan 2025

The findings of the safety observation study within the medium sized manufacturing facility reveal critical insights into the current state of safety behaviors and compliance, highlighting both strengths and areas for improvement. The observed data across various safety categories underscores the importance of continuous monitoring and intervention strategies to foster a robust safety culture.

Now a comparison of the data for December 2024 and January 2025

Table 3: Comparison of Data of Dec 2024 and Jan 2025

Category	Dec 2024	Jan 2025
Behavioral Safety (BS)	47	21
Emergency Control (EC)	23	11
PPE	0	1
People Gathering (PG)	121	34
Phone Usage (PU)	48	26
Person Unconscious (PU)	13	21
Total Observations	252	114

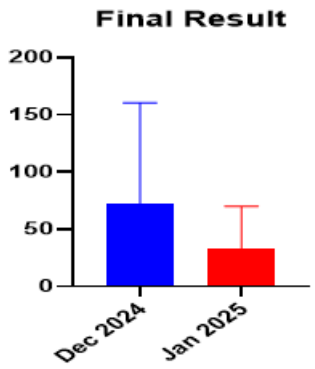

Figure 9: Comparison of Dec 2024 and Jan 2025 data

The comprehensive analysis of safety observations over two consecutive months provides nuanced insights into workplace safety behaviors and areas warranting further attention. Notably, there has been a significant reduction in the total number of observations from 252 in December to 114 in January reflecting either genuine improvement in safety practices or potential limitations in reporting and monitoring. The most marked improvement is seen in the Behavioral Safety (BS) category, which declined from 47 to 21 observations. This suggests that recent safety initiatives and awareness campaigns have positively influenced employee behavior and adherence to safety protocols. Similarly, the sharp decrease in Phone Usage (PU) observations from 48 to 26 indicates heightened awareness of the dangers posed by distractions in the workplace, potentially due to more stringent policies or reinforced training efforts.

However, the analysis also highlights critical concerns that warrant closer examination. Emergency Control (EC) observations have dropped from 23 to 11, raising questions about whether this is due to fewer incidents or a diminishing emphasis on emergency preparedness and reporting. This emphasizes the ongoing need to sustain regular emergency drills and readiness training to avoid complacency. Additionally, while PPE compliance remains a vital aspect of workplace safety, the observation of a single PPE violation in January compared to none in December points to the necessity for continuous reinforcement and monitoring of PPE usage protocols.

Another area of concern is the significant decrease in People Gathering (PG) observations from 121 to 34. While this may reflect positive measures to prevent overcrowding and ensure physical safety, it also necessitates a balance between maintaining safety and fostering collaborative work environments. Most notably, the increase in incidents involving unconscious persons from 13 to 21 signals emerging health or fatigue related challenges among employees. This underlines the urgent need for proactive health monitoring, wellness programs, and strategies to mitigate occupational stress and fatigue.

CONCLUSION

The reduction in unsafe behaviors reflects improved employee awareness, yet declines in emergency and safety reporting may indicate underreporting or complacency. A rise in health related incidents highlights the need for wellness initiatives. To sustain progress, ongoing training, transparent reporting, and strong employee engagement are vital for a lasting safety culture.

FUTURE SCOPE

Looking ahead, future safety systems can be enhanced by integrating predictive analytics to anticipate high risk behaviors and enable proactive interventions. Expanding the framework to multi site and cross industry applications such as logistics, healthcare, and energy will require customizing detection parameters to address specific risks. The addition of real time biometric health monitoring through wearable devices can help identify early signs of fatigue or health issues, further safeguarding employee well being. Improved user interfaces for feedback and training, advanced AI driven anomaly detection, and privacy focused design enhancements will all contribute to more effective and trusted solutions. Incorporating gamification and reward systems can motivate consistent safety compliance, while integration with automated emergency response protocols can dramatically improve response times during incidents. These advancements collectively promise to elevate workplace safety, engagement, and overall organizational resilience.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest related to this research work.

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