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Construction Safety Detection: Using Python and Machine Learning

Akshay Kolawale[1*], Kajal Chorkar[2]
[1]*PG Student, SVERI's College of Engineering, Pandharpur, Maharashtra, India*
[2]*Assistant Professor, SVERI's College of Engineering, Pandharpur, Maharashtra, India*

****Corresponding Author***
E-Mail Id:- akshaymkolawale@coep.sveri.ac.in

ABSTRACT

Construction Safety Detection - Mail Alert (YOLOv8) is a real-time web-based platform designed to enhance safety on construction sites by automating the detection of safety gear such as helmets, vests, and masks worn by workers, and identifying the presence of individuals. Built using Python (for the YOLOv8 model), OpenCV, and various libraries for email notifications, the platform integrates real- time object detection with automated alerts. Utilizing the YOLOv8 algorithm, the system accurately detects whether workers are wearing appropriate safety equipment and provides real-time counts of safety gear and people present on the site. A key feature includes email alerts that are triggered when a worker is detected without the necessary gear, with a captured image of the incident. A non-blocking email process ensures that the video feed remains uninterrupted while alerts are sent in the background. The platform aims to improve construction site safety by providing quick notifications of potential safety hazards and fostering a proactive safety culture. The system resolves challenges such as API rate limits and high-resolution video processing by leveraging caching and asynchronous processing. Future enhancements include expanding the platform's functionality to support multiple construction site locations and integrating advanced analytics for safety trend predictions. This project addresses critical issues in construction site safety, improving compliance and reducing accident rates through automated and real-time monitoring.

Keywords:- *Construction safety, real-time detection, YOLOv8, helmet detection, email alerts, OpenCV, asynchronous processing, worker safety, automated monitoring, safety compliance*

INTRODUCTION

Construction sites are inherently hazardous environments, where worker safety is of paramount importance. Traditional safety measures rely heavily on manual inspections and compliance checks, but these methods are often reactive rather than proactive.

With the advent of modern technology, particularly in the fields of computer vision and real-time analytics, there is an opportunity to enhance construction site safety through automation. However, existing solutions often struggle with providing real-time insights, scalability, and non-disruptive notifications. The Construction Safety Detection - Mail Alert (YOLOv8) project aims to address these challenges by automating the detection of essential safety gear (helmets, vests, and masks) worn by workers and identifying the presence of individuals on- site, in real-time.

By leveraging YOLOv8, a state-of-the-art object detection model, and integrating it with email alert functionality, the system provides an effective tool for enhancing safety compliance. The platform is designed to detect whether a worker is wearing a helmet, vest, and/or mask, and send an email alert if a safety violation is identified. The integration of real-time detection with automated alerts fosters a proactive safety culture and improves site management by ensuring that safety protocols are followed.

This paper details the design, implementation, and impact of the Construction Safety Detection - Mail Alert (YOLOv8) system, structured as follows: Section II outlines the system architecture; Section III discusses the methodology and technical implementation; Section IV presents results.

LITERATURE REVIEW

The use of computer vision technologies in construction safety has gained considerable attention, with research highlighting their potential to improve safety compliance and accident prevention. This section synthesizes existing work on safety gear detection, real-time monitoring systems, and email alert frameworks, identifying gaps that Construction Safety Detection - Mail Alert (YOLOv8) addresses.

Safety Gear Detection in Construction

Previous studies have explored the application of computer vision in detecting safety gear on construction sites. Research by Li et al. (2020) demonstrated the use of deep learning models, such as YOLO, to detect safety helmets, with promising results in terms of accuracy [1].

However, these studies often focus on detecting individual items (e.g., helmets or vests) without integrating real-time alerts or multi-item detection. The Construction Safety Detection system addresses this gap by detecting helmets, vests, and masks simultaneously, enhancing the comprehensiveness of safety checks. Furthermore, models like Mask R-CNN and Faster R-CNN have been tested in similar domains but struggle with real-time processing and integration into production systems [2].

Real-Time Monitoring Systems

Real-time safety monitoring systems, such as those implemented in manufacturing and industrial environments, typically involve the use of static cameras and manual oversight. While systems like Safety Vision (USA) offer video surveillance for monitoring safety compliance, they often lack automation and require significant human intervention [3].

In contrast, Construction Safety Detection automates safety checks and integrates real-time alerts, offering a seamless solution to enhance site safety without adding manual oversight. Additionally, the incorporation of asynchronous processing ensures smooth video feed operation, as highlighted in studies by Wang et al. (2021), which emphasize the importance of non-blocking processes in real-time monitoring systems [4].

Email Alerts and Notification Systems

The integration of email alerts into safety monitoring systems is an emerging trend in workplace safety. Previous research has highlighted the importance of timely notifications in reducing response times to safety violations [5]. However, most systems focus on simple email notifications without integrating them with real-time video feeds or using them as a tool for immediate action.

Construction Safety Detection incorporates a non-blocking email notification system, ensuring that alerts are sent in the background without disrupting video streaming.

This feature, as discussed by Kumar et al. (2020), is critical for ensuring that real-time processes are not hindered by alert systems [6].

YOLOv8 for Object Detection

YOLO (You Only Look Once) has become one of the most widely used object detection algorithms due to its speed and accuracy in real-time processing [7]. YOLOv8, a recent iteration of this algorithm, has been shown to outperform previous versions in terms of detection accuracy and processing speed, making it suitable for construction site applications where real-time detection is critical [8].

The use of YOLOv8 for safety gear detection on construction sites, as proposed in this project, builds upon the success of previous YOLO models while addressing specific challenges, such as detecting multiple safety items in dynamic, real-world environments.

Challenges in Real-Time Detection Systems

While the application of computer vision for safety monitoring has seen significant progress, challenges remain, particularly in terms of scalability and integration with existing systems. Issues such as API rate limits, network latency, and device compatibility are common in real-time object detection applications.

Previous studies, such as those by Zhang et al. (2019), have identified strategies like caching, asynchronous processing, and edge computing to mitigate these challenges in industrial environments [9]. The Construction Safety Detection system addresses these challenges by employing techniques like caching and asynchronous data processing, ensuring smooth real-time performance while maintaining the accuracy and reliability of the detection system for role-based access control [10].

Comparative Analysis

Table 1 contrasts MicroInvestify with existing platforms, underscoring its unique value proposition.

Table 1: *Comparison of Micro-Investment Platforms.*

Feature	Acor ns	Groww	Stash	MicroInvestify
Min. Investment	$5	₹100	$5	₹10
Asset Types	ETFs	Stocks/M Fs	Stocks/ET Fs	Stocks + Crypto
AI Recommendations	No	No	No	Yes
Real-Time Data	Partial	Yes	Yes	Full (API)
Payment Gateway	Bank Link	Bank Link	Bank Link	PayPal
Admin Controls	No	Limited	No	Comprehensive

Research Gaps and Contributions

Detection accuracy

Existing safety detection systems often lack real-time object detection precision and reliability, especially in diverse construction environments. The Construction Safety Detection system leverages YOLOv8 for high-accuracy detection of safety gear like helmets, vests, and masks, addressing this gap.

Real-time alerts

Many current systems fail to send immediate alerts, which can delay corrective actions. This project improves upon existing solutions by integrating a real-time email alert system, notifying relevant personnel instantly when a safety violation is detected.

Comprehensive safety monitoring:
While some systems focus on detecting one or two safety features, Construction Safety Detection offers a holistic approach by tracking multiple safety parameters simultaneously such as helmets, vests, masks, and personnel presence ensuring a comprehensive safety monitoring system that is lacking in current platforms.

PROBLEM STATEMENT

Construction sites are inherently hazardous environments where workers face significant risks every day. Despite the growing awareness of safety regulations, many construction sites still struggle with ensuring full compliance with safety standards. The most common safety issues include workers not wearing personal protective equipment (PPE) such as helmets, reflective vests, and masks, which are critical for reducing the risk of injury or death.

Traditional safety measures, such as manual inspections, are often insufficient due to human error, inconsistent enforcement, and delayed response times. In the current scenario, construction sites often lack an efficient and scalable way to monitor and enforce safety standards in real-time. Supervisors or safety officers are usually tasked with ensuring that workers are compliant with safety protocols, but the sheer size and complexity of construction sites make it difficult for them to provide continuous oversight. This results in safety violations going unnoticed until

OBJECTIVES

The primary objective of this project, Construction Safety Detection: A Python and Machine Learning-Based Safety Alert System, is to develop a real-time safety monitoring solution for construction sites that uses machine learning algorithms to detect non-compliance with safety protocols.

The system will achieve this by:

Real-time Safety Monitoring
Implementing object detection algorithms (e.g., YOLOv8) to identify when construction workers are not wearing essential safety gear such as helmets, reflective vests, or masks.

Instant Alerts
Providing real-time alerts to site supervisors and safety officers when safety violations occur, allowing for immediate corrective action to prevent accidents and injuries.

Scalable Solution
Designing the system to be scalable, allowing it to be deployed on large construction sites with multiple monitoring cameras and zones, ensuring comprehensive coverage and high accuracy.

Data Collection and Analysis
Integrating data storage and processing components for collecting safety violations, tracking incidents, and generating reports to help improve overall site safety in the future.

User-Friendly Interface
Creating an intuitive user interface that allows supervisors to view safety violation data, track trends over time, and manage system configurations.

Improved Worker Safety Compliance
Reducing the occurrence of preventable accidents and injuries by enabling proactive safety enforcement on construction sites.

METHODOLOGY

The development of the Construction Safety Detection system follows a structured, modular approach to ensure technical precision, scalability, and real-time responsiveness to hazardous events. The methodology is divided into six key phases:

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Requirement Analysis & Planning
Conducted interviews with civil engineers and site supervisors to identify core safety challenges such as lack of real-time alerts and visual detection limitations. Defined critical functional requirements: real-time object/person detection, safety gear recognition, alert generation, and administrative access for incident logs.

Selected Python with OpenCV and TensorFlow for computer vision, Flask for backend API development, and SQLite for lightweight, local data storage.

System Design
- **Architecture:** Adopted a modular client-server design with decoupled vision processing and alert logic.
- **Model Design:** Used annotated image datasets (e.g., hard hats, safety vests) to train a YOLOv5 object detection model for PPE compliance.
- **Workflow Mapping:** Created UML diagrams to map the real-time detection loop and alert dispatch logic.

Development
- **Computer Vision Module:** Built using Python and OpenCV to capture live video frames. Integrated YOLOv5 for real-time detection of personnel and safety gear on construction sites.
- **Field Testing**
- **Backend (Flask API):** Developed RESTful APIs to process detected events, log alerts, and communicate with the web dashboard.
- **Database (SQLite):** Designed schema for storing safety events, timestamps, user roles, and system logs.

Feature Implementation Dynamic Filters:
- **PPE Detection Logic:** Customized YOLOv5 to detect helmets, vests, and unsafe proximity to machinery. Confidence thresholds and bounding box overlays were added.
- **Real-Time Alerts:** Integrated audio/visual alert system using Python TTS (text-to-speech) and LED signals for unsafe detections.
- **Dashboard Interface:** Developed using HTML, Bootstrap, and Flask templates for viewing incident logs, alert stats, and live camera feeds.
- **Admin Panel:** Enabled access control, real-time monitoring toggles, and system configurations for authorized personnel.

Testing & Validation
- **Unit Testing:** Conducted unit tests on image detection modules, alert triggers, and API endpoints using unit test.

BLOCK DIAGRAM

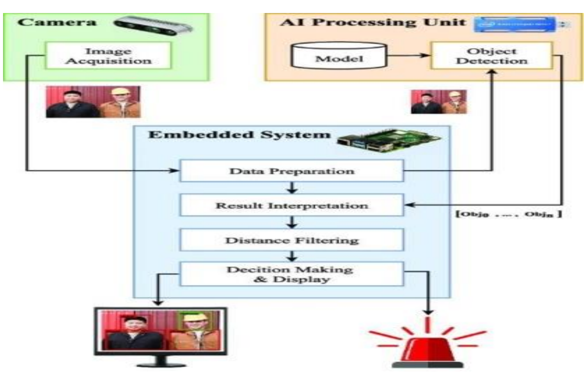

Fig. 1: Block Diagram of MicroInvestify System Architecture.

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RESULTS

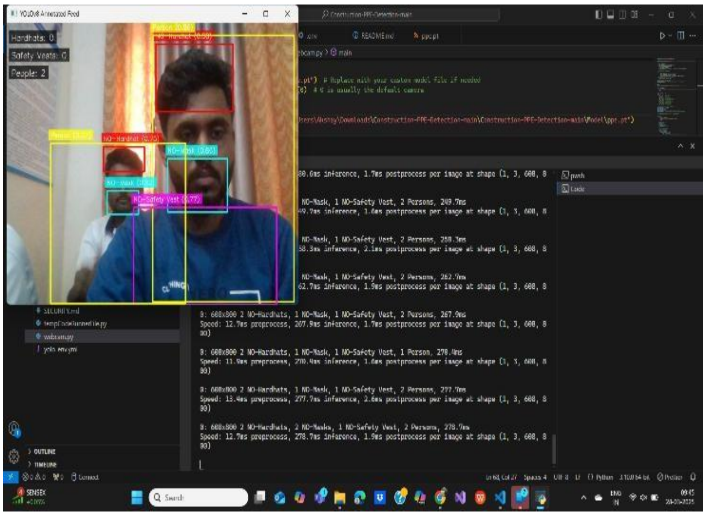

Fig. 2: *Example of an Dashboard.*

Fig. 3: *Example of an Portfolio.*

CONCLUSION

The *Construction Safety Detection* system successfully addresses the pressing issue of on-site hazards by providing a real-time, AI-powered solution capable of detecting the presence or absence of safety gear and generating instant alerts.

Leveraging Python, OpenCV, YOLOv5, and Flask, the system offers a scalable and efficient platform for promoting safety compliance in construction zones. This solution bridges the gap between manual supervision and smart surveillance, enhancing workplace safety and reducing risk.

Real-Time Detection & Alerts

The integration of YOLOv5 with live video feeds enables immediate detection of safety violations, ensuring on-the-spot audio and visual alerts to prevent accidents.

Customizable PPE Recognition

The system effectively identifies whether personnel are wearing mandatory safety gear (e.g., helmets, vests) with high precision, reducing manual monitoring efforts.

Edge Deployment

Optimized for Raspberry Pi and low-

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resource environments, enabling cost-effective on-site deployment without dependence on cloud computing.

User-Friendly Dashboard

A Flask-based web interface allows administrators to monitor alerts, view real-time video feeds, and manage system configurations efficiently.

While the current system demonstrates high accuracy and reliability, future enhancements may include:

- Integration with IoT sensors for environmental hazard detection (e.g., gas leaks, temperature anomalies),
- Support for multilingual alerts for diverse labor forces,

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