Smart Safety Monitoring System For Construction Sites Using Deep Learning

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Abstract: Construction sites are dangerous places, and not wearing proper safety gear can lead to serious accidents. Traditional monitoring methods often fail to ensure workers follow safety rules. This project solves the problem by creating an automated safety and hazard detection system using YOLOv8, a powerful object detection model, along with a Django-based web application. The system detects if workers are wearing essential safety gear like a helmet, mask, or vest, and also it detects safety cones, people, machinery, and vehicles in the construction site. If a worker is missing any required gear, an alarm sounds by playing an audio alert, prompting immediate action. By using computer vision and web technology, this system improves construction site safety, reduces the need for constant human supervision, and helps create a safer work environment.

Index Terms: Safety, Construction sites, Object detection, YOLOV8, Django, Safety gear.

I.INTRODUCTION

Construction sites are highly hazardous environments, with frequent accidents caused by falling objects, unsafe equipment handling, lack of personal protective equipment (PPE), and inadequate monitoring. Global safety reports highlight thousands of injuries and fatalities due to non-compliance with safety protocols. Traditional monitoring methods [3], [4], such as manual inspections, are time-consuming, error-prone, and inefficient in real-time hazard detection, often failing to address violations promptly. To overcome these limitations, an automated, intelligent, and real-time safety monitoring system is essential.

Recent advancements in computer vision and deep learning have revolutionized object detection and real-time monitoring. AI-based solutions, particularly YOLO (You Only Look Once) [1], [2], offer efficient alternatives to manual inspections by automating safety gear detection, hazard identification, and violation alerts. This project utilizes YOLOv8 [2], the latest YOLO version, to detect PPE like helmets, vests, and masks, as well as critical objects such as safety cones, machinery, and vehicles. Integrated with a Django-based web application, the system enables real-time monitoring, automated alerts, and remote management of construction sites.

The primary motivation is to reduce accidents, improve worker safety [2], [6], and assist site managers in enforcing compliance. Traditional methods like CCTV cameras provide passive surveillance without automated alerts, while manual inspections are error-prone [3] and labor-intensive. In contrast, YOLOv8 [2] offers faster, more accurate detection, enabling continuous monitoring without human intervention. This project aims to develop an AI-based system for automatic detection of safety violations, such as missing PPE, and trigger real-time audio alerts [3] for immediate corrective action.

The scope includes implementing a laptop-based detection system that processes live camera feeds or uploaded footage. Unlike traditional CCTV systems, this solution is lightweight, scalable, and accessible via a web interface. The Django-based web application serves as a centralized platform for remote monitoring, making it an effective tool for construction site management. By combining AI and web technologies, this system addresses critical safety challenges, offering an innovative and automated approach to ensuring worker safety and compliance.

The system's ability to provide real-time alerts [7] and remote monitoring ensures immediate corrective actions, reducing the risk of accidents and fostering a culture of safety awareness. It also minimizes the need for constant human supervision, enhancing efficiency and reducing operational costs. By leveraging advanced technologies, this project sets a new standard for construction site safety, contributing to safer working environments.

II.LITERATURE REVIEW

S. Shen and J. Yang (2024)

This study proposes an improved YOLOv5-based framework that enhances safety helmet detection through the integration of attention mechanisms and a lightweight GhostNetv2 backbone. The paper introduces two attention modules—Spatial Channel-wise Attention (SCNet) and Coordinate Attention (CA)—to improve the model's spatial awareness and focus on relevant regions within images. Additionally, a Gradient Norm Aware Minimization (GAM) optimizer is incorporated to boost generalization and training efficiency. The model is evaluated on various Kaggle helmet detection datasets and demonstrates a mean Average Precision (mAP) of 95.56% while reducing model parameters by more than 25% compared to standard YOLOv5. The framework is shown to outperform multiple existing architectures in terms of accuracy, speed, and efficiency. Ablation studies confirm the contribution of each component to overall performance. This research emphasizes the value of integrating attention and lightweight architectures to achieve high-accuracy helmet detection in complex real-world environments while maintaining computational efficiency.

M. Çiftçi, M. U. Türkdamar, and C. Öztürk (2024)

This research focuses on detecting personal protective equipment (PPE) such as helmets, masks, and safety vests using deep learning techniques, specifically YOLOv5 and YOLOv8 [2]. The authors conducted three experiments to compare the performance of different YOLO models on datasets with varying class complexities. The system was trained on a dataset containing ten classes, including safety-related gear and construction-related elements like machinery and vehicles. YOLOv8 [2]n outperformed YOLOv5n in terms of accuracy, especially in detecting equipment in a multi-class scenario. The research used Ultralytics' YOLO framework for training and evaluation, applying performance metrics like precision, recall, F1-score, and mAP. Results showed that YOLOv8 [2] provided higher detection accuracy, especially in 2-class settings. The study also used k-fold cross-validation to confirm the robustness of YOLOv8 [2]. Overall, this approach proves highly effective for real-time monitoring and enhancing safety standards at construction sites, offering a reliable and scalable solution for occupational hazard prevention through automated object detection.

R. Jyothika, S. Salapur, and S. Sridharan (2022)

This research presents a deep learning-based safety helmet detection system to improve monitoring efficiency on construction sites. The study addresses the challenges of manual supervision and proposes an automated method using the YOLOv3 object detection algorithm. The system monitors live video feeds from construction areas and alerts non-compliant workers and supervisors through a buzzer and SMS notification when safety helmets are not detected. The model utilizes a dataset collected in real-time and processes it using OpenCV [3], [4] for image pre-processing and feature extraction. YOLOv3 was chosen for its ability to detect multiple objects accurately and quickly using convolutional neural networks. The study includes data collection [2], [6], pre-processing, and detection modules, and emphasizes the role of frame-by-frame helmet detection in reducing accidents. Results show that the system achieved an accuracy of 92%, significantly improving over previous methods. The research supports the idea that integrating real-time detection systems in construction environments can enhance safety compliance and reduce workplace injuries.

K. Dhakal (2021)

This research presents a computer vision-based safety system aimed at enhancing worker protection in construction environments, particularly around heavy machinery like excavators. The system uses stereo vision with near-infrared (NIR) monochrome cameras and reflective safety vests to detect and track workers in real time. The detection process relies on contour extraction and segmentation, where reflective vest regions are highlighted using adaptive thresholding techniques. The system identifies workers by analyzing bounding boxes and centroids around detected blobs in the image frames. The study focuses on creating a cost-effective yet efficient safety system capable of alerting excavator drivers when workers are in close proximity. It emphasizes the need for real-time detection in varying light conditions and evaluates performance in indoor and outdoor scenarios. The proposed solution demonstrates strong accuracy in moderate lighting but shows limitations under direct sunlight. It suggests that computer vision and basic machine learning techniques can significantly reduce accidents, providing a foundation for further improvements using deep learning models in future work. This approach reflects the growing role of intelligent vision systems in occupational safety.

M. Cromsjö and L. Hallonqvist (2020)

This research investigates the development of an automated system for detecting personal protective equipment (PPE), specifically reflective vests, in a paper mill setting using image recognition. The study explores the feasibility of using Microsoft Azure's Custom Vision service to train object detection models that can identify whether workers are wearing required safety gear. A prototype system was developed using .NET Core, OpenCV [3], [4], and Azure services, capable of real-time monitoring and sending alerts when PPE non-compliance is detected. The research highlights the impact of training data quality, including variations in lighting, distance, background, occlusion, and angles, on model performance. Privacy and employee acceptance of such surveillance technologies were also studied through interviews, revealing that transparency, ethical considerations, and perceived purpose of monitoring play vital roles in system acceptance. The results demonstrate that cloud-based image recognition systems can be effective in promoting occupational safety while also emphasizing the need for careful deployment respecting worker privacy.

III.RESEARCH METHODOLOGY

The proposed methodology for the Smart Safety Monitoring System for Construction Sites Using Deep Learning involves a systematic approach to ensure real-time detection of safety violations and effective monitoring. The process begins with data collection [2], [6], where images and videos from construction sites are gathered, focusing on workers wearing and not wearing safety gear such as helmets, masks, vests, and as well as other objects like safety cones, machinery, and vehicles. These images are then annotated using tools like LabelImg to create a labeled dataset for training.

The YOLOv8 [2] model is selected for its high speed and accuracy [2] in real-time object detection. The model is trained on the annotated dataset, which is split into training (70%), validation (20%), and testing (10%) sets, and optimized for accuracy and speed. Once trained, the model is integrated with OpenCV [3], [4] for real-time video processing and detection. An audio alert system is implemented to trigger predefined sound files when workers are detected without safety gear, ensuring immediate corrective action. A Django-based web application is developed to provide a user-friendly interface for real-time monitoring and management, with SQLite used as the database to store violation logs, user data,and system configurations.

The system captures live video feeds from construction site cameras and processes them frame-by-frame using the YOLOv8 [2] model to detect safety gear violations. Detected violations are logged and displayed on the web dashboard, which also provides live video feeds and detection results for remote monitoring. The system is tested in controlled and real-world environments to evaluate its accuracy, speed, and reliability, with performance metrics such as detection accuracy (mAP), processing speed (FPS), and response time being measured. Finally, the system is deployed on construction sites, with cameras and speakers installed for real-time monitoring and alerts, and site supervisors and workers are trained to use the system effectively. This comprehensive methodology ensures a robust, scalable, and efficient system for improving construction site safety using deep learning and web technologies.

IV.RESULTS OF THE RESEARCH

Figure 1: Project flow diagram

The proposed safety detection system was successfully implemented using advanced machine learning techniques and frameworks like YOLOv8 [2], TensorFlow, and OpenCV [3], [4]. The system effectively detects the presence or absence of key safety gear such as helmets, vests, and masks on construction workers in real-time. Additionally, it recognizes other essential elements like safety cones, machinery, vehicles, and people at the construction site, enabling a comprehensive safety monitoring solution.

The user interface, as demonstrated in the landing, registration, and login screens, ensures easy access for both administrators and users. After login, the home screen offers quick navigation to key functionalities such as real-time detection, viewing database records, and logging out. The integration of the Django framework has ensured a smooth flow of data between the frontend and backend, while the camera module initiates live detection through a simple and intuitive interface.

Figure 2: Registration page

Once the detection starts, the system continuously monitors video input and flags any violation where a worker is found not wearing required gear. An audio alert is triggered instantly, enabling supervisors or safety officers to take immediate action.

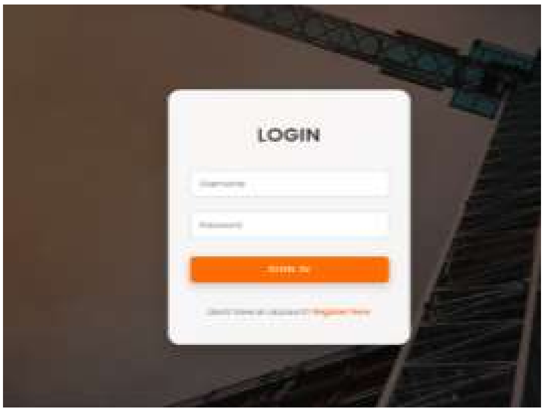

Figure 3: Login page

Figure 4: Home page

The results show that the system works with high accuracy [1], [2], [6] under various lighting and environmental conditions, thanks to the YOLOv8 [2] model's speed and precision. This automation not only improves safety standards but also reduces the burden on human supervisors. Additionally, by maintaining digital records of detected violations, the system supports accountability and data-driven decision-making on site.

Figure 5 : Camera button page

Figure 6: Detection page

V.CONCLUSION

The proposed safety monitoring system efficiently enhances safety measures at construction sites by integrating advanced object detection technologies. Unlike traditional systems, it is capable of detecting multiple safety gears such as helmets, vests, and masks, along with other essential elements like safety cones, vehicles, and machinery. The use of real-time detection and audio alerts [3] ensures that supervisors are immediately notified in case of any safety violations. With the ability to store and manage detection data, it provides a comprehensive monitoring solution.

The system also supports remote monitoring, making it highly practical for large construction areas. By leveraging powerful libraries and frameworks like TensorFlow, YOLO, Django, and OpenCV [3], [4], the system delivers accurate and fast performance. The user-friendly interface and database integration add to its functionality and ease of use. This project not only promotes a safer working environment but also reduces the risk of accidents significantly. It bridges the gap between automation and safety in construction. Overall, the project is a step forward in ensuring workplace safety [4], [7] through intelligent monitoring systems.

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