SAFEFACEYOLO: Real-Time Workplace Safety Enforcement Via Integrated Helmet Detection And Facial Recognition

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Abstract- *Workplace safety is a critical concern in industries such as construction and manufacturing, where workers are exposed to hazardous environments. One of the major causes of accidents is the failure to wear personal protective equipment (PPE), particularly safety helmets. Traditional safety monitoring systems rely heavily on manual inspection, which is time-consuming, costly, and prone to human error, especially in large-scale sites with multiple ongoing activities. To address these challenges, this project proposes an automated system that integrates computer vision techniques for real-time helmet detection and worker identification. The system combines two key functionalities: helmet detection and face recognition. Helmet detection is performed using advanced object detection algorithms to identify whether workers are wearing safety helmets, while facial recognition is used to identify individuals by comparing extracted facial features with a pre-existing database. The proposed approach improves efficiency by eliminating the limitations of manual monitoring and enabling continuous surveillance. It also ensures better safety compliance by providing accurate and real-time detection under varying environmental conditions. The system is further evaluated based on performance metrics such as accuracy and recall rate across different visual scenarios found on construction sites. Overall, this integrated solution offers a reliable and intelligent approach to enhance workplace safety, reduce accidents, and support safety inspectors through automated monitoring and immediate detection of violations.*

Keywords: Alert System, Facial Recognition, Grassmann Algorithm, Helmet Detection, Personal Protective Equipment, Safety Monitoring, YOLO Algorithm.

I. INTRODUCTION

Workplace safety is a critical concern in hazardous environments such as construction sites and industrial areas, where workers are frequently exposed to risks from heavy machinery, elevated structures, and dangerous materials. One of the most essential safety measures in such settings is the proper use of personal protective equipment, particularly safety helmets, which help prevent serious head injuries and fatalities. However, ensuring consistent compliance with safety regulations remains a significant challenge when relying on traditional manual monitoring methods. These conventional approaches are often time- consuming, inefficient, and prone to human error, especially in large and dynamic workspaces where continuous supervision is difficult. As industrial operations expand, the limitations of manual inspection can lead to increased accident rates, financial losses, and legal consequences for organizations. To address these challenges, there is a growing need for intelligent and automated systems capable of monitoring safety compliance in real time. Recent advancements in deep learning and computer vision have made it possible to develop such solutions by enabling machines to analyze visual data and perform tasks that previously required human observation. Deep learning techniques have already demonstrated their effectiveness across various domains, including natural language processing, healthcare diagnostics, image translation, robotics, news analysis, and autonomous driving, highlighting their ability to process complex data and make accurate predictions. In the context of workplace safety, computer vision plays a vital role by enabling automated detection and monitoring through real-time video analysis. The proposed system leverages these technologies by integrating helmet detection and face recognition into a unified framework. Surveillance cameras capture continuous video data from the work environment, which is then processed using advanced algorithms to detect whether workers are wearing safety helmets and to identify individuals based on their facial features. The face recognition component compares extracted features with a pre-trained database to verify authorized personnel and detect unauthorized access to restricted areas. This dual functionality ensures both safety compliance and security within the workplace. Unlike traditional systems, the automated approach operates continuously without fatigue, handles multiple video streams simultaneously, and performs effectively under varying environmental conditions such as changes in lighting, angles, and background complexity.

Additionally, real-time alert mechanisms enable immediate notification of safety violations, allowing for quick corrective action. By reducing dependency on manual monitoring and enhancing accuracy and efficiency, this system provides a proactive and scalable solution for improving workplace safety, minimizing accidents, and supporting better operational management in industrial and construction environments.

II. METHODOLOGY

The proposed system architecture splits processed visual data into two parallel execution blocks: face recognition and helmet detection. Surveillance cameras continuously capture video streams, which are preprocessed via noise removal, resizing, and binarization.

A. Face Recognition using the Grassmann Algorithm

Facial recognition acts as the access control layer. Facial features are extracted from the frames using the Grassmann algorithm and compared against a pre-trained employee database. A Grassmann manifold $G_{n,p}$ is a set of p-dimensional linear subspaces of $\mathbb{R}^n$. The representation states that two matrices belong to the same equivalence class if their columns span the same p-dimensional subspace, represented as:

$$Y=\{YQ_p:Q_p \in O_p\}.$$

The system embeds the approximated tangent space, computes canonical angles, and generates feature vectors for matching.

B. Helmet Detection using YOLO

- In parallel, the You Only Look Once (YOLO) algorithm analyzes the input frames to detect the presence of safety helmets.
- **Grid Division:** The image is divided into a grid of cells.
- Bounding Box and Class Prediction: The algorithm predicts bounding boxes, confidence scores, and class probabilities (e.g., human, helmet).
- Non-Maximum Suppression (NMS): NMS is applied to remove redundant or overlapping bounding boxes, finalizing the detection results.

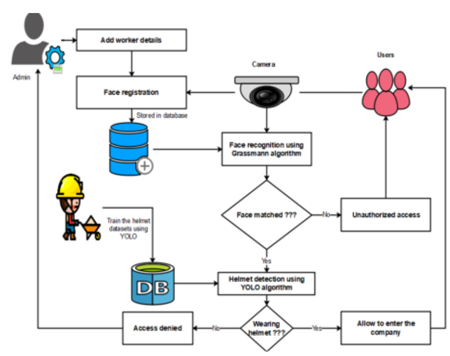
C. Decision and Alert Module

If a worker is identified without a helmet, or if an unauthorized face is detected, the system triggers immediate alerts. Notifications are sent to supervisors via SMS and Email, and local alarms can be sounded to enforce immediate corrective action.

III. BACKGROUND AND RELATED WORKS

The SAFEFACEYOLO system addresses the critical safety concerns in high-risk industries like construction and manufacturing, where the failure to wear personal protective equipment, particularly safety helmets, remains a leading cause of accidents. While traditional safety monitoring depends on manual inspections that are often inefficient, costly, and prone to human error, this project introduces an automated solution using advanced computer vision to integrate real-time helmet detection with facial recognition. This approach builds upon existing research in deep learning, specifically leveraging various iterations of the YOLO algorithm and Convolutional Neural Networks (CNNs) to overcome challenges like low resolution and occlusion. Furthermore, it incorporates industrial IoT concepts and worker identification techniques seen in related works—such as contour and color feature analysis and multiscale detection methods like SAS-YOLOv3-tiny—to provide a continuous, accurate surveillance system that ensures safety compliance across diverse and complex environmental conditions.

IV. WORKING PRINCIPLE



The system operates by capturing real-time video and splitting the visual data into two parallel processes: one to check for safety compliance (helmets) and one to verify worker identity (faces).

Step 1: Data Acquisition (Camera Capturing)

- Surveillance cameras are strategically placed in critical workplace areas (e.g., construction sites, manufacturing floors).
- These cameras continuously capture real-time video streams or images of the workers.

Step 2: Preprocessing

- Before analysis, the captured frames are refined to improve quality.
- This involves resizing the image, reducing noise, and applying binarization to separate the foreground (the workers) from the background scenes.

Step 3: Parallel Processing Core

Once the image is clean, the system feeds it into two distinct machine-learning modules simultaneously:

A. Face Recognition (The Access Control Layer)

- The system uses the **Grassmann algorithm** to extract unique facial features from the workers in the frame.
- These extracted features are converted into vectors and compared against a pre-existing, trained database of authorized employees.
- This step determines if the individual is an authorized worker or an intruder.

B. Helmet Detection (The Safety Layer)

- Simultaneously, the **YOLO (You Only Look Once)** algorithm analyzes the same image to detect safety helmets.
- YOLO divides the image into a grid of cells and predicts bounding boxes for objects it finds.
- It calculates a "confidence score" to determine how likely it is that the detected object is a helmet.
- It then applies Non-Maximum Suppression (NMS) to remove duplicate or overlapping bounding boxes, finalizing the detection.

Step 4: Decision and Alert System

- The system combines the results from both modules. It checks two conditions: *Is this an authorized worker?* and *Are they wearing a helmet?*.
- If a violation is detected (e.g., an authorized worker without a helmet, or an unrecognized face), the system immediately triggers the Alert Module.
- Alerts are sent out as SMS notifications or physical alarms to notify security personnel or supervisors so they can take immediate corrective action.

V. SYSTEM IMPLEMENTATION

The system was implemented using a client-server architecture:

- **Front-End:** HTML, CSS, and JavaScript were used to build an administrative dashboard for managing the worker database.
- **Back-End:** Python and Flask act as the core backend, integrating OpenCV for camera operations, the Luxand FaceSDK for facial recognition tracking, and PyTorch/TensorFlow for the YOLOv5 implementation.
- **Database:** MySQL Server handles the storage of employee profiles, attendance logs, and alert records.

VI. MODULE DESCRIPTION

6.1 MODULE LIST

- Framework Construction
- Camera Capturing
- Face Recognition
- Helmet Classification
- Alert System

6.2 MODULE DESCRIPTION

6.2.1 FRAMEWORK CONSTRUCTION

People are essential resources in the construction industry, so their safety should be a top priority. Accidents occasionally occur during the construction of large projects, making construction sites one of the most dangerous places to work. Accidents can result in injuries from cars, trucks, or objects falling from a height. Such injuries can result in the death of an individual (worker), which can cause damage to the worker’s family and the builder. Therefore, appropriate protective measures should be taken to address this risk. Worker safety is a top priority in any industrial setting. Neglecting to wear safety helmets poses a significant risk to workers, making it crucial to develop an automatic surveillance system that can detect individuals without helmets. This system would not only enhance safety but also reduce the labour-intensive task of manually monitoring violations. The use of safety helmets is essential for reducing injuries in construction sites. However, due to various factors, helmets are not always worn correctly. Therefore, an automatic safety helmet detection system based on computer vision is of utmost importance. Safety is of paramount importance in industrial and construction environments, where workers face multiple hazards. One critical aspect of ensuring worker safety is ensuring the proper usage of safety helmets. Failing to wear helmets can lead to severe accidents and even fatalities. In this module, admin can create the GUI for store the user details. User details contains the information such as Employee id, name, mobile number and so on. These details are trained as employee database.

6.2.2 CAMERA CAPTURING

The process of camera capturing in system involves strategically placing surveillance cameras throughout the workplace to monitor employee face and ensure compliance with safety regulations. These cameras are typically positioned in key areas where safety helmets are required, such as construction sites, manufacturing floors, or industrial warehouses. Once installed, the surveillance cameras continuously capture images or video footage of the monitored areas. These cameras may be fixed in position or equipped with pan, tilt, and zoom capabilities to provide comprehensive coverage of the workspace. The captured images or video frames are then fed into the system for analysis. This analysis involves processing the visual data using advanced computer vision algorithms to detect the presence of safety helmets on individuals within the monitored areas. The surveillance cameras play a crucial role in providing real-time data to the Helmet Detection module, enabling the system to identify instances where employees are not wearing safety helmets as required. If a violation is detected, the system can trigger alerts to notify security personnel or supervisors, prompting them to take appropriate action to address the issue promptly. In this module, enable the camera to analyze the safety helmets. Implement binarization steps to separate the foreground from background scenes.

6.2.3 FACE RECOGNITION

Face recognition have gained a great deal of popularity because of the wide range of applications such as in entertainment, smart cards, information security, law enforcement, and surveillance. It is a relevant subject in pattern recognition, computer vision, and image processing. Human's face is a prominent feature in machine learning and computer vision system. A face conveys various information including gender, age, ethnicity etc. Face information is applicable in many sectors like biometric authentication and intelligent human-computer interface. Since our main concern of this paper is gender classification from human faces so a proper localization of human face area is necessary. For both face detection and gender classification purpose selection of color space for detecting skin region is a main concern. Extracting two sets of data for both male and female and separate them accurately is a challenging job. So, we need to select a better classifier to improve the classification performance. Face identification is a one-to-many matching process that compares a query face image against all the template images in a face database to determine the identity of the query face. The identification of the test image is done by locating the image in the database that has the highest similarity with the test image. The identification process is a "closed" test, which means the sensor takes an observation of an individual that is known to be in the database. This module is known as login phase or testing phase. Input is in the form of real time video capturing. Matching the features using Grassmann algorithm. The temporal information in video sequences enables the analysis of facial dynamic changes and its application as a biometric identifier for person recognition. There are different ways to form the feature vector for training the classifier. Some of them even use whole image as a feature vector and perform classification which needs high computation. So here feature vector is made from important values of the image from each filter Energy, mean and standard deviation forming a 40-value feature vector for every image. By applying the Grassmann algorithm—a facial features extraction technique—the system places cameras in strategic locations throughout critical sections of the workplace. A solid foundation for further identification is provided by this algorithm, which makes it possible to extract distinguishing facial traits. In this module, construct the face features vectors and also recognize the employees.

Use eye coordinates to determine the initial affine registration parameters for each image.

- Sample the affine registration manifold by perturbing the affine parameters
- Compute the k nearest neighbours from the registration manifold
- Apply color equalization and filter features values
- Construct the tangent space
- Embed the approximated tangent space and compute canonical angles

6.2.4 HELMET CLASSIFICATION

First, a large dataset of images containing individuals wearing safety helmets in various poses and lighting conditions is collected. Each image/frame is then annotated to specify the location of the safety helmet(s) within the image. The annotated dataset is used to train the YOLO model to recognize safety helmets in images. During training, the model learns to detect the presence and location of safety helmets based on features such as color, shape, and texture. Once trained, the YOLO model may undergo optimization techniques to improve its performance, such as adjusting hyperparameters, fine-tuning layers, or employing data augmentation to enhance generalization. After training and optimization, the YOLO model is deployed to perform inference on new images or video streams captured by surveillance cameras in the workplace. The model analyzes each frame in real-time and identifies the presence and location of safety helmets. Detected safety helmets are typically overlaid with bounding boxes to visually indicate their location in the image. Additionally, post-processing techniques may be applied to filter out false positives and improve detection accuracy. If an individual is not wearing a safety helmet where required, the system may generate an alert to notify relevant personnel. In this module implement object detection system using YOLO algorithm. Then detect the objects and draw bounding box on that object. Verify the features which are contain the helmet objects. If helmet object not occurred means, forward to next module.

The You Only Look Once (YOLO) algorithm is a neural network-based real-time object detection system that runs in a single forward pass. The following are the main steps in the YOLO algorithm:

Division of the Input Image: The input image is separated into a grid of cells. The YOLO model's architecture dictates the size of this grid (YOLOv3 utilizes a 13x13 or 19x19 grid, for example).

Bounding Box Prediction: Multiple bounding boxes (typically two or three) are predicted for each grid cell. These bounding boxes provide dimensions like width, height, and the x and y coordinates of the box's centre, together with a confidence score that indicates the likelihood that an object is inside the box.

Class Prediction: The model forecasts the class probabilities for every bounding box. Softmax activation is used for this, and each class score indicates the likelihood that an object falls into a specific class (e.g., human, car, etc.).
Confidence Score Calculation: The highest-class probability multiplied by the objectness score (which indicates the likelihood of an object being present) yields the confidence score for each bounding box.

Non-Maximum Suppression (NMS): This technique is used to remove redundant or less certain bounding boxes for the same object. In order to do this, the bounding boxes are sorted according to their confidence scores, and boxes that exhibit significant overlap with a box with a higher confidence are suppressed.

Thresholding: To remove low-confidence detections, bounding boxes with confidence scores below a particular threshold are removed.

Output: The maintained bounding boxes, together with the confidence ratings and class labels that correspond with them, make up the final output. The objects found in the input image are represented by this data.

6.2.6 ALERT SYSTEM

Alerts can be delivered through various channels, depending on the organization's preferences and requirements. Common delivery methods include email notifications, SMS alerts. In this module, recognized user details are extracted from database which is extracted from trained database. And send the notification about unauthorized access or no helmet detection. Notification in terms of SMS or Alarm.

VII. EXPERIMENTAL RESULTS AND VALIDATION

Verification and validation are critical phases in ensuring the system is both developed correctly and performs effectively in practical scenarios. During verification, the focus is on confirming that each module—such as camera capturing, pre-processing, facial recognition via the Grassmann algorithm, and YOLO-based helmet detection—functions precisely according to the specified design. This includes rigorous code-level, module, and integration testing, as well as evaluating data flow and database matching using sample datasets. Once the system's internal correctness is verified, validation assesses its real-world viability by deploying it in simulated or actual environments like construction sites. Validation evaluates performance metrics such as accuracy, precision, recall, and response time across varying lighting, angles, and environmental conditions. Ultimately, this comprehensive process ensures that the system not only accurately identifies workers and detects helmet usage without technical errors, but also provides a user-friendly, efficient solution with reliable alert mechanisms to successfully improve workplace safety and regulatory compliance.

VIII. CHALLENGES

The document outlines several challenges driving the need for the SafeFaceYOLO system, beginning with the limitations of traditional manual safety monitoring, which is costly, time-consuming, prone to human error, and difficult to manage across large-scale, dynamic workspaces. Ensuring consistent safety compliance is inherently difficult because workers frequently fail to wear protective helmets due to negligence, discomfort, or a lack of supervision. From a technical standpoint, existing monitoring methods and conventional object detection techniques struggle to accurately detect helmets under varying lighting conditions, different sizes and orientations, and complex background environments. Furthermore, the literature survey notes that implementing automated computer vision and deep learning solutions introduces its own set of challenges, including the need for high computational resources , the requirement for large training datasets , high implementation costs for IoT infrastructure, privacy concerns regarding facial recognition , and sensitivity to occlusions.

IX. CONCLUSION

The proposed system for helmet detection and face recognition provides an effective and intelligent solution to enhance workplace safety in construction and industrial environments. Ensuring the proper use of personal protective equipment, especially safety helmets, is essential to reduce the risk of serious injuries and accidents. Traditional safety monitoring methods, which rely heavily on manual supervision, are often inefficient, time-consuming, and prone to human errors. This project successfully addresses these limitations by introducing an automated system that continuously monitors workers in real time using advanced computer vision techniques. By integrating helmet detection and face recognition into a single framework, the system not only verifies whether workers are following safety protocols but also identifies individuals accurately. The use of the YOLO algorithm enables fast and precise detection of safety helmets, while the Grassmann algorithm enhances facial feature extraction and identification. This combination ensures a reliable and efficient monitoring process even in complex and dynamic environments. The system is capable of handling variations in lighting, worker positions, and background conditions, making it suitable for real-world applications. Another significant advantage of the system is its ability to provide immediate alerts whenever a violation is detected, such as when a worker is not wearing a helmet or when an unauthorized person enters the site. This real-time alert mechanism allows supervisors to take prompt action, thereby preventing potential accidents and improving overall safety compliance. Additionally, the automated nature of the system reduces the need for continuous human intervention, lowering operational costs and increasing productivity.

X. FUTURE ENHANCEMENT

The proposed system for helmet detection and face recognition can be further enhanced by incorporating more advanced technologies and features to improve its efficiency, scalability, and real-world applicability. One of the key future enhancements is the integration of more robust deep learning models that can provide higher accuracy in challenging conditions such as low lighting, occlusions, and crowded environments. Upgrading the current algorithms to more advanced versions of object detection and facial recognition models can significantly improve performance and reduce false detections. Another important enhancement is the inclusion of additional personal protective equipment (PPE) detection, such as safety vests, gloves, masks, and boots. By expanding the system's capabilities beyond helmet detection, it can provide a more comprehensive safety monitoring solution. This would allow organizations to ensure complete compliance with safety regulations rather than focusing onsingletype of equipment. The system can also be improved by integrating cloud computing and Internet of Things (IoT) technologies. With cloud integration, data collected from multiple sites can be stored, analyzed, and accessed remotely, enabling centralized monitoring and management. IoT-enabled smart cameras and sensors can further enhance real-time data collection and system responsiveness. This would be particularly useful for large-scale industrial environments with multiple locations. Another potential enhancement is the development of a mobile or web-based application that allows supervisors and safety officers to receive real-time alerts, monitor live feeds, and access reports from anywhere. This would increase the usability and accessibility of the system, making it more convenient for management to take immediate action when violations occur. Additionally, implementing data analytics and reporting features can help in identifying patterns, tracking safety compliance over time, and making informed decisions to improve workplace safety policies.

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