

APPLICATION OF MACHINE LEARNING ALGORITHMS IN IDENTIFYING FALLS IN THE WORKPLACE

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Abstract

The construction industry is widely recognised as one of the most hazardous industries due to the complexity of its projects and the rapid implementation of investment. A significant contributing factor to injuries and fatalities in this sector is human falls. The prevalence of accidents at work, particularly those attributed to falls, necessitates the implementation of urgent preventive measures and innovative technological solutions.

The objective of the research outlined in this paper is the development of an algorithm capable of detecting human falls in real time. This solution is innovative in its application on construction sites, where its use will facilitate the identification of incidents related to human falls, as well as the provision of rapid assistance to the injured. In the case of such injuries, urgent medical intervention is in most cases crucial to save the health and life of the injured person.

The intelligent safety monitoring system is designed to utilise machine learning (ML) algorithms for real-time image analysis with the Python language and the implementation of the proposed algorithm. The YOLOv8 algorithm is specifically responsible for people detection. The proposed detection algorithm is predicated on a two-stage analysis: initial detection of human presence and subsequent verification of whether a human has fallen. In the event of a fall, the developed algorithm automatically generates an alert. The model was tested in construction areas in order to reproduce the natural environment of its target application. A set of images containing both cases of construction worker falls and situations in which no incident occurred was used.

Keywords: accident at work, accident prevention, construction, machine learning, human falls.

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1. Introduction

Workplace safety is a critical concern, particularly in the construction industry, which is characterised by a high incidence of accidents [1-3]. The construction sector is one of the world's major industrial domains [4]. Nevertheless, owing to the complexity of its projects and the rapid pace of execution, it is also regarded as one of the most hazardous sectors. For many years, the construction industry has grappled with elevated occupational accident rates in numerous countries [5]. Only in Poland, between 2016 and 2020, 24.7 thousand workers were injured and 240 fatalities were recorded in this sector [6].

The consequences of occupational accidents affect both individuals and organisations [7]. Such incidents generate tangible and intangible losses for both parties. At the individual level, these losses most often manifest as physical pain, suffering, and lack of financial liquidity [8, 9]. From an organisational perspective, intangible losses primarily include damage to corporate reputation, while tangible losses involve suspension of construction activities, compensation payouts, and other financial repercussions [10, 11].

Falls are one of the principal causes of injury and death in this field. Injuries resulting from falls pose a greater threat to life than most other types of trauma [12]. According to 2023 data from the Korean

Ministry of Employment and Labor, falls accounted for 59.8% of all occupational accidents in the construction sector [13]. Similarly, OSHA reports that falls are the leading cause of fatal incidents in U.S. construction, comprising approximately 43.5% of all work-related fatalities [14]. The situation in Poland is equally alarming: in 2023, slips, trips, and falls accounted for 31.42% of all non-routine incidents (Fig. 1a), making them one of the most prevalent categories of occupational injuries reported by the Central Statistical Office [6]. Although the number of such incidents has declined in recent years, there remains a clear correlation with the overall level of workplace safety (Fig. 1b). These events constitute a significant problem that demands targeted countermeasures and the development of innovative tools to reverse this adverse trend.

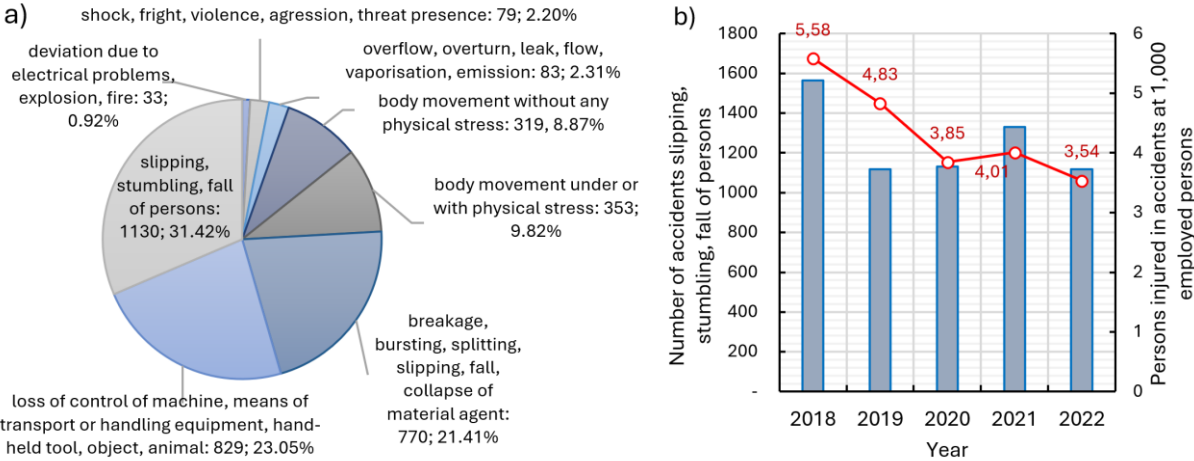


Fig. 1. (a) Persons injured in accidents at work by deviations in Polish construction industry in 2023; (b) Number of events deviating from normal conditions as a result of slipping, tripping or falling, together with the accident rate according to data from the Central Statistical Office.

A high incidence of occupational accidents in the construction industry, particularly those involving human falls, necessitates urgent preventive measures and the implementation of innovative technological solutions. The authors of this work contend that machine learning can play a pivotal role in enhancing on-site safety. In recent years, machine learning algorithms have grown in importance as tools for data analysis and risk prediction [1, 15]. Owing to their capacity to process large datasets and identify complex patterns, these techniques can improve workplace safety through the early detection of potential hazards [15, 16].

Several machine learning based solutions aimed at reducing fall-related accidents are already in use worldwide. For example, Fang et al. [17] applied Faster R-CNN and a deep convolutional neural network (CNN) trained to detect both workers and their safety harnesses; however, the CNN's harness-detection accuracy was relatively low, a shortcoming the authors attributed to a limited training dataset. Shanti et al. [4] focused on real-time monitoring of Personal Fall Arrest System (PFAS) compliance, developing a YOLOv3-based algorithm that detects two PFAS components - harness use and lifeline attachment - with 91.26 % accuracy and approximately 99% precision. Another study [18] proposed an AI-driven ladder-inspection model implemented in Python using NumPy and OpenCV; this system evaluates ladder "fitness for use" by analysing structural rigidity before work commences, offering a faster and continuous alternative to traditional inspection methods. Fang et al. [17] further introduced an automated vision-based methodology employing two CNN models: Faster R-CNN for worker localisation (99% accuracy, 95% precision) and a deep CNN for identifying unfastened harnesses (80% accuracy, 98% effectiveness). This dual-model approach enables proactive detection of unsafe behaviours on construction sites.

Despite these advances, no prior research has targeted the real-time detection of worker falls. To fill this gap, the authors of the present article have undertaken the development of such an algorithm. The objective of this study is to design a fall-detection algorithm capable of identifying human falls in real time. This innovative solution, when deployed on construction sites, will enable rapid response and

medical assistance - an essential factor in mitigating the severe, multi-organ injuries often associated with such incidents - by analysing and estimating human body posture to detect falls as they occur.

Based on the conducted literature review, it can be concluded that, to date, no studies have specifically addressed the development of a solution for real-time detection of worker falls. To fill this identified research gap, the authors of the present article have undertaken the challenge of designing such an algorithm.

The primary objective of this research was to develop an algorithm capable of detecting human falls in real time. This solution is innovative in that its deployment on construction sites will enable rapid response and prompt medical assistance to the injured, an essential factor in cases of multi-organ trauma frequently associated with fall incidents. The proposed algorithm is designed to identify a fall through analysis and estimation of human body posture.

2. Methodology

The designed data-flow model of the intelligent safety monitoring system employs machine learning (ML) algorithms for real-time image analysis. Implementation was conducted in Python using the OpenCV library. Person detection is handled by the YOLOv8 algorithm (yolov8s.pt).

You Only Look Once (YOLO) is a real-time object-detection algorithm based on convolutional neural networks (CNNs) [19, 20]. It features a low computational overhead, enabling rapid inference with satisfactory accuracy on live video streams [21]. YOLOv8 adopts an anchor-free architecture with a decoupled head, which separates object-localisation, classification, and regression tasks into independent branches—thereby enhancing overall model precision [19]. In its output layer, a sigmoid activation estimates the probability of an object being present, while a softmax activation assigns detected objects to their respective classes.

The developed software executes in a continuous loop: for each frame, the falling_detecting() function is invoked to assess the image for indications of a worker’s fall. First, the YOLOv8 model localises all persons in the frame and computes their bounding-box dimensions. To prevent false positives arising from kneeling or crouching postures, the algorithm applies a geometric criterion: a fall is flagged when the bounding-box width is at least twice its height. Fig. 2 illustrates the block diagram of the proposed human-fall detection system.

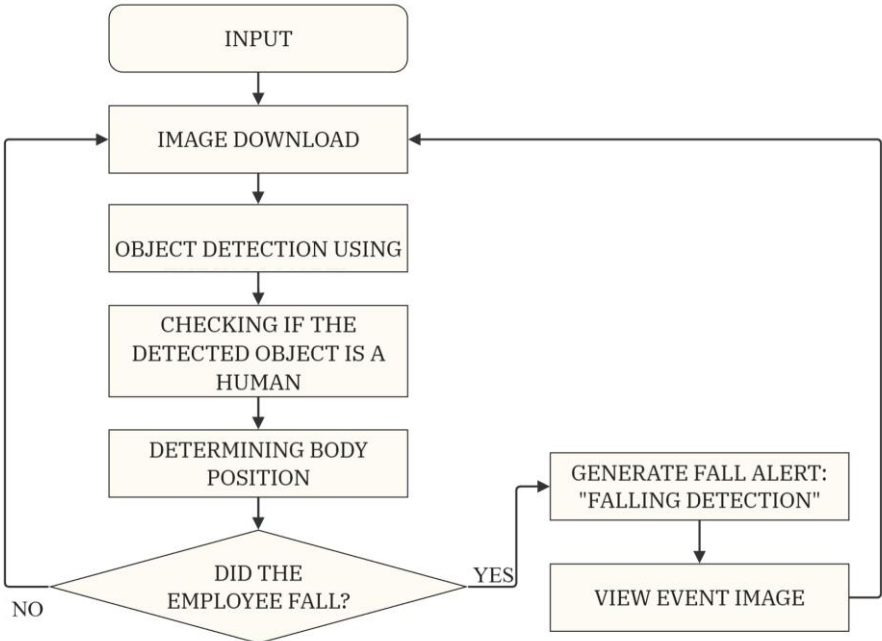


Fig. 2. Block diagram of a human fall detection system

The program first identifies the human silhouette, marking it with a blue frame, and then analyses its dimensions. If no fall is detected, the employee is marked with a green frame. However, if a fall is detected, the system generates a red frame with a warning message “FALLING DETECTION” The algorithm is available in the repository [22].

3. Results

The system was evaluated under real-world construction-site conditions to faithfully replicate its intended deployment environment. For validation, a dataset containing both fall incidents and non-incident scenarios was used. Representative results from these tests are presented in Fig. 3. Individuals framed in green bounding boxes denote workers who did not experience a fall, whereas those framed in red are workers detected in fall incidents and are marked with a fall-detection alert.



Fig. 3. Output frames from the image-analysis process using the developed algorithm: (a) no human fall detected; (b) human fall detected.

4. Discussion

As noted in the introduction, documented cases already exist of machine learning techniques being applied in the construction sector to enhance workplace safety, particularly for identifying hazards such as missing harnesses [17] or protective helmets [23]. Similarly, image-recognition methods have been employed to detect personal protective equipment [24]. However, the authors of this article did not identify any scientific publications addressing systems capable of detecting worker falls. Consequently, the present study represents the first innovative effort to tackle this issue and to propose an appropriate, fully functional solution.

The developed system exhibits promising performance, as illustrated in Fig. 3. The model accurately classifies both fall incidents and non-fall scenarios. Nonetheless, further improvements are required - most importantly, validation of its efficacy on video sequences rather than solely on static images.

5. Conclusions and Future Research

An algorithm for real-time detection of worker falls has been developed, based on the YOLOv8 architecture and implemented in Python. The proposed detection framework operates via a two-stage analysis: first, identifying the presence of a person; second, verifying whether a fall has occurred. Upon confirmation of a fall event, the system automatically issues an alert.

The current version of the system presents certain limitations that will be addressed in subsequent studies. Future work also includes the development of a user interface, underpinned by an Application

Programming Interface (API) and a web-based platform, to enable real-time deployment of the safety-monitoring system on construction sites. This interface will provide access to a historical log of fall alerts, thereby facilitating efficient post-event analysis by occupational health and safety personnel.

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