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Applications of smart technologies for automatic near miss detection in the industrial safety

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Abstract

Smart technologies are been extensively used in manufacturing processes in order to increase overall performance; an increasing focus is outlined also for supporting occupational and industrial safety. Applying smart technologies in the safety domain could contribute to increase performance of several processes starting from workers tracing, environmental monitoring and dynamic risk analysis. This study aims to evaluate potentialities of adopting these technologies in a specific critical process, i.e. near miss management. Near miss events could be defined as a hazardous occurred event, with the capability to lead to an accident if it had not been interrupted; they represent a relevant source of information for developing effective activities to prevent incidents. An automated detection system based on smart technologies will allow increasing the reliability of this process. The study analyses potential contributions of smart technologies in supporting an efficient prevention process with a focus on near miss detection based on a literature review analysis. Further developments will be oriented to define also an economic analysis to evaluate life cycle costs of applying smart technologies for near miss automatic detection.

Keywords: safety management, smart technology, automatic near miss detection, near miss management

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1. Introduction

The adoption of smart technologies in manufacturing is wide spreading all over the world: an emerging field of both research and industrial practices is in the safety domain. A recent impulse has been forced by the COVID19 pandemic diffusion, where smart technologies have revealed for effective in such workplace to prevent its diffusion [1]. Smart technologies could support a more effective information acquisition and communication between workers and the hazardous elements at workplace thus providing a more dynamic risk analysis [2]. Data collected through sensors can also be more easily and quickly shared between workers and supervisors thus providing an enhanced awareness of actual risk at workplace [3], [4]; furthermore, smart technologies could also contribute to increase process safety effectiveness especially in preventing major accidents [5]. Thus, as several applications are developing mainly focusing on safety levels as well as worker conditions monitoring, less effort has been focused on supporting preventive actions to reduce the likelihood of an accident: in this field, one traditional issue to be applied is a near miss management system [5], [6]. Near miss are occurred events that have not caused harm, but have the potential to cause injury or ill health; as they are usually characterized by the same direct causes and/or contributing factors of an incident. Thus, near-miss reporting and investigation identify and control safety or health hazards before they cause a more serious incident [7], [8]. One critical process in a near miss management system is the reporting and collection step: workers or supervisors usually reports occurred events manually at their workplace; next, information are usually moved to a safety expert for the analysis of causes and critical factors. This is complex activity due to several factors: recognizing a near miss requests an effort in training workers to collect data about event and, also to recognize them as a near miss. Thus, some reported events could not be really classified as a near miss event as they represent hazardous conditions and/or behaviors that a small capability to escalate in an incident. Furthermore, the predisposition of workers in reporting information about hazardous conditions is often a critical point, as it requires an high involvement in this process. A possible solution – currently enabled by smart technologies - is an automatic detection system, which provides reliable feedback about the occurred near miss events. Although the reliability of the process in this case could be high, some criticalities could be evaluated in this application starting from the evaluation of the most effective technologies to be adopted in the specific context to the complexity of the solution provided. This study proposes a critical analysis of adopting smart technologies for supporting automatic near miss detection systems. The paper is organized as follows: in section 2, potential applications of smart technologies in supporting more effective preventing activities in the safety domain is discussed; next, a state of the art of current application for near miss automatic detection is proposed aiming to evaluate current contribution of smart technologies in safety prevention.

2. Potentialities of adopting smart technologies to support effective preventive actions at workplace

Smart technologies could be applied efficiently for supporting accident prevention at workplace. The industrial workplace is utilizing smart technologies –ranging from Internet of Things (IoT) to augmented and virtual reality tools- to improve safety at several workplaces from construction to manufacturing to process industries. Usually, smart technologies consist of various sets of tools for acquiring, analyzing, and communicating data to enhance a specific industrial process. Real time as well as historical events involving safety issues can be communicated to safety managers and workers in a very simple way with a reduced economic effort. These analytics allow companies to identify trends, find training opportunities and improve the behavior of employees through data-driven decisions.
Thus, a qualitative analysis – based on safety experts interviews- about the main current potentialities of smart technologies based on fields of applications in the occupational safety domain. The idea is to start outlining the safety problem and, next, evaluating most promising technologies to be adopted to support problem resolution.. The basic idea is not to evaluate all possible applications of smart technologies but to outline the ones that are been used and have the highest potentiality of adoption. Based on these hypotheses, main fields of applications of these technologies for supporting occupational safety management are analyzed as follows:

- *Monitoring of workers conditions*: the main target is to evaluate – usually in real time - a worker's physiological state that could lead to health problems, thus preventing higher severe conditions and/or a quick emergency response. For this purpose, the most effective tool could be wearable sensing technology [9]. The compresence of different type of sensors and wireless communication systems provided in

different supports (e.g. from smart clothes to smart watches) provides flexibility and adaptability to several working conditions. In addition, based on a specific risk type, evaluation of hazardous behaviors or activity could be also a potential field of application;

- *Workplace monitoring*: the main purpose is to evaluate in real time the actual hazardous conditions of such a workplace for automatically alert workers of unsafe external conditions. Sensors networks and IOT technologies could provide the capability to connect and exchange data about machines, plants and workplace aiming to point out in advance potential hazardous conditions. Furthermore, digital twin tools can provide interactive maps of work place enabling dynamic support between the work environment and remote supervisors [10]. Finally, also warble technologies could be adopted in such conditions;
- *Proximity detection between workers and machine:* the main target is to map workers or machine locations (e.g. during normal or emergency conditions) and provide alerts nearby potentially hazardous conditions [11]. The most promising technologies are Radio Frequency Identification (RFIDs), which, for example, can measure a worker's proximity to moving equipment and alert them for possible collisions;
- *Situational awareness increasing and training*: the target is to increase the worker awareness about hazardous conditions trough immersive training activities. Two main smart technologies can be used: Augmented and Virtual Reality. The first one provides the capability to increase worker awareness by "adding" useful information to the physical environment; the latter offers immersive situational training without the risks associated with real-life procedures. These technologies also supply additional information about worker behavior, which can be used by safety experts to evaluate effective preparedness level of workers in such a condition.

By summarizing, main capabilities of smart technologies applied in the safety domain are that they could support effective preventive approach as by closely monitoring such an environment they could pre-empt and alert workers to potential hazardous conditions before they escalate in more severe ones. In addition, smart technologies are responsive: when an event occurs, these systems could provide a quick alert to emergency teams thus supporting a more coordinate a quick and effective response. Finally, they are informative as they allow to collect and analyze a huge quantity of data, thus providing a more ex post analysis to reduce and/or eliminate risks.

A summary of the critical analysis is proposed in table 1.

Table 1. Smart technologies and potential applications in the safety domain

Potential field of application	RFID	Wireless Sensor	Wearables	Augmented and virtual reality
Physiological monitoring of workers conditions		X	X	
Workplace monitoring	X	X	X	
Proximity detection	X			
Situational awareness increasing and training				X

It has to be noted that this analysis does not consider all the possible combinations of smart technologies and safety problems, but according to experience and current state of the art, it proposes a starting point for future discussion, as performances of technologies are fast growing thus allowing more applications in different fields not yet evaluated. These critical analysis outlines the potentialities of adopting smart technologies for supporting preventing activities in the safety domain: in the following section, a state of art analysis about the application of smart technology in one of the most effective prevention activity - such as near miss management – is proposed.

3. A literature analysis of current applications in near miss automatic detection

Recent papers have proposed applications of smart technologies for supporting near miss automatic detection. Thus a literature review has been carried out using the Scopus database. Key words adopted for the search have been "near miss detection"; "smart technologies near miss" and "industry 4.0 near miss"; last ten years – from 2011 to May 2021- have been considered for the analysis. Conference as well as journal papers have been evaluated. As the topic is very specific, few papers have been founded in the database: their detailed analysis is proposed as follows.

First observation about results obtained is that the industrial sector where the majority of the studies have been developed is the construction sector. One main reason is that construction is a hazardous sector with a high injury rate all over the world [12]. Another issue to be considered is that the construction sector is affected by "standardized well known" risks: one critical major risk is falling from a height; other typical risks come from being struck by vehicles and heavy moving objects. This is mainly due to the presence of repetitive tasks and equipment characterizing construction processes. This condition is allowing to support efficiently the adoption of smart technologies as evaluating innovative technologies for detecting repetitive near miss events could be easier compared to more complex activities. Most of papers proposed prototypal applications: this outlines how is preliminary the adoption of these technologies for supporting an automatic near miss detection process.

Following, a detailed analysis about current applications proposed in the scientific literature.

Some papers focused ***on monitoring of worker conditions*** based a specific risk in the construction activity -fall accidents-; wearable technologies have been evaluated for potential applications aiming to detect near miss events due to this risk. In [13] authors adopted wearable technology for detecting near miss events due to falls for a specific target of workers, i.e. ironworkers. In detail, authors proposed the use of Inertial Measurement Unit (IMU) sensor data based systems to automatically detect data about potential near-miss events during worker walking; next, a semi-supervised algorithm used this data to evaluate potential near-miss events. Similarly, [14], [15], [16] discussed the development of an automated detection system composed by IMU inertial measurement technologies for data acquisition and threshold-based approach to detect actual near miss falls to be applied for the same cluster of workers. Differently from these works, [17] proposed the adoption of mobile technologies and artificial neural networks (ANNs) for automatic detection of fall near miss events. Starting from a hypothesis that postural instability and loss-of-balance are the main causes of fall at construction sites, authors proposed to use triaxial accelerometers embedded in smartphones for data acquisition and ANNs for event identification.

Other studies focus on ***proximity detection*** risks. In [18], authors proposed an automatic detection system for near miss events based on proximity between workers and heavy construction equipment. The system adopted GPS and RFID technologies to evaluate near miss events due to hazardous proximity: this information also allowed to assess critical factors that could lead to an accident due to this specific risk. Similar approach is proposed in [19] where a real time location tracking system is described to firstly evaluate risks due to workers-on-foot in construction site (e.g. access in hazardous areas, proximity with hazardous equipment): the target is to control the spatial–temporal conflicts between workers and the identified hazards. The proposed technology is the ultra wide band systems. The scope of the proposed system is not limited only to near miss detection as it also aims to automatically identify the critical areas of hazards on a specific construction site, and finally, to define such a proximity hazard indicator based on information acquired by the technological system. A review of potential technologies that could be adopted to automatize this specific near miss events is also proposed.

Two papers proposed a wider approach for automatic near miss detection, which involves a more complex architectutr does not focus on a specific risk type. [20] discussed a complex real time model for tracking and interrupting near miss events by acting dynamically on immediate factors causing these events. An integration of different technologies is proposed for designing the real time detection systems: ultrasonic technologies is used for outdoor as well as indoor location tracking, different types of sensors are used to monitoring environment actual conditions, RFID for access control and data storage, and finally, a wireless network manages communication between each device and the cloud software. Similarly, in [21], a technological architecture based on integration of different smart technologies for data acquisition is discussed; an economic feasibility analysis is also proposed aiming to evaluate the actual applicability of the technological solution in specific construction areas. Results obtained from the literature review are synthethized in table 2.

Table 2. Literature review results synthesis

Paper	Field of application	Specific risk problem	Adopted smart technologies
[13]	Monitoring of worker conditions	Fall risk detection	Wearable technology

[14]	Monitoring of worker conditions	Fall risk detection	Wearable technology
[15]	Monitoring of worker conditions	Fall risk detection	Wearable technology
[16]	Monitoring of worker conditions	Fall risk detection	Wearable technology
[17]	Monitoring of worker conditions	Fall risk detection	Wearable (mobile) technology
[18]	Proximity detection	Interference risk detection	RFID
[19]	Proximity detection	Interference risk detection	RFID
[21]	Workplace monitoring, proximity detection,	Environmental monitoring, access control	RFID, wireless sensors
[20]	Monitoring of worker conditions	PPE control	RFID, wireless sensors

4. Conclusions

The study proposes a critical assessment about the application of smart technologies in the safety field: the focus is on evaluating how these technologies could support a more effective design and management of prevention activities in industrial safety. After evaluating how specific smart technologies – i.e. from sensor based systems to virtual and augmented reality systems – could contribute to support prevention activities to reduce/eliminate accidents and injuries at workplace, a state of the art analysis has been proposed on a critical activity: automatic near miss detection. Near miss events are weak signals provided by the day-by-day activity of an organization outlining its actual safety level. They represent critical pillars of the safety management system, as they could contribute to improve safety parameters, hazard control and risk reduction to minimize the likelihood of a serious incident in the future. The literature analysis has outlined that several prototypical applications have been developed to support an automatic and a reliable near miss detection process. These applications are basically developed for "well-known" risks (e.g. fall from height) affecting specific industrial sectors (i.e. the construction sector). However, these experiments could represent a relevant starting point for amplifying the adoption of smart technologies in near miss detection.

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