



Artificial Intelligence and Machine Learning in Occupational Safety and Health: A Review of Present Status, Opportunities and Challenges

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Abstract

This study aims to investigate the current state of the field of Artificial Intelligence (AI) and Machine Learning (ML) in Occupational Safety and Health (OSH) and to understand how AI and ML can be effectively used to improve workplace safety and health. The findings of this study support the potential of AI and ML in improving workplace safety and health, as well as identifying key challenges such as data privacy and security, ethical considerations, lack of standardization, and integration with existing systems. Overall, this study makes a significant contribution to the field of OSH by providing a comprehensive overview of the current state of the field and by highlighting the potential and challenges of AI and ML in enhancing workplace safety and health.

Keywords: - Artificial intelligence, machine learning & occupational safety and health

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1. Introduction

Workplace accidents and injuries continue to be a significant issue despite advancements in safety regulations and technology (Silva et al., 2020). To address this problem, there has been a growing interest in utilizing Artificial Intelligence (AI) and Machine Learning (ML) in occupational safety and health (Srinivasan et al., 2020). AI and ML can perform various human functions, learn from experience, and adapt to new entries and settings. These emerging technologies can achieve significant contributions and provide better competitive advantages as compared to conventional approaches. These technologies have the potential to predict and prevent hazards (Liu et al., 2020), improve training and education (Srinivasan et al., 2020), and increase the efficiency of safety management systems (Silva et al., 2020).

However, there is a lack of research on the practical applications of AI and ML in occupational safety and health (Silva et al., 2021). For addressing the identified gap, it is important to answer the following research questions:

- i. What are the areas of AI and ML application in the OSH background?
- ii. What are the future opportunities for AI and ML application in the OSH background?
- iii. What are the challenges to adoption of AI and ML in the OSH?

Therefore, it is crucial to conduct a critical analysis review of AI applications in OSH to comprehend the trends, potential, and challenges. The specific objectives of this study are to:

- i. Review the existing applications of AI and ML in OSH
- ii. Identify the opportunities for increased applications of AI in the OSH and,
- iii. Identify challenges affecting the adoption of AI in the OSH

Hence, the main motivation for this study is to provide the potential and benefits of how AI and ML can effectively be used to improve workplace safety and health. Additionally, this study aims to provide new knowledge of these emerging technologies that could be used to improve the safety and well-being of workers and to reduce the costs associated with workplace accidents and injuries (Silva et al., 2020).

The scope of this study includes a review of the current state of the field, an analysis of previous research on the use of AI and ML in workplace safety and health, a discussion of the benefits and limitations of using AI and ML in occupational safety and health. The limitations of the study include the focus on potential of AI and ML rather than a comprehensive evaluation.

2. Methodology

To identify the existing applications of artificial intelligence in OSH, an extent review of literature was conducted. Database queries were run on SCOPUS database and validated by data in other databases such as Institute of Electrical and Electronics Engineers (IEEE), Science Direct, WOS and Google Scholar for dates ranging from 2001 to 2023 (2 decades). The intention to comprehend the trends in the decades-long adoption of AI in OSH, as well as to identify the research gaps, opportunities, and obstacles, had an impact on the dates that were selected. The search strategy using keywords chosen of “machine learning” and “expert system” sequentially combining the primary interests of: “occupational safety”, “occupational health” and “work environment”. The combinations were as follows:

“machine learning” AND “occupational health”
“machine learning” AND “occupational safety”
“machine learning” AND “work environment”
“expert system” AND “occupational health”
“expert system” AND “occupational safety”
“expert system” AND “work environment”

The search of using keywords above from the database mentioned had extracted 16,603 articles. After assessing the 16,603 articles, 1690 articles were finally considered relevant and applicable which the articles are non-repetitive, English language and relevant to OSH and AI in construction. The articles were filtered to journal and conference paper. These details were taken from each article: OSH application area, methodology/techniques applied, and findings.

In Table 1, according to Occupational Accident Statistics by Industry Sector 2022, the industrial sector contributes to high number of fatal injuries followed by the agricultural, forestry and fishery sector in Malaysia. While the construction industry hits 148 number of fatal injuries reported to Jabatan Keselamatan dan Kesihatan Pekerjaan, Kementerian Sumber Manusia. Even though the sector of construction only ranked number 6 out of 9 in JKPP statistics website, researcher however interested and keen to look upon for this sector as a preliminary study for a new coming AI project related to construction industry. The search then was restricted to only construction industry and 690 articles were the filtered and finalized accordingly.

Table 1. Statistics fatal injuries (January-November 2022)

Sector	Number of NPD	Number of PD	Number of Death	Total
Hotel & Restaurant	118	1	0	119
Facilities	178	2	9	189
Finance, Insurance, Real Estate & Business Services	345	4	24	373
Construction	87	2	59	148
Transport, Storage & Communication	234	4	10	248
Manufacturing	4273	183	58	4514
Wholesale & Retail Trade	114	3	2	119
Public Service & Statutory Authorities	74	3	0	77
Mining & Quarrying	27	2	8	37
Agriculture, Forestry & Fisheries	856	23	16	895
Total	6306	227	186	6719

Source from JKPP website

Indication:

PD-Permanent Disability

NPD- Not Permanent Disability

3. AI and ML Applications in OSH

One definition of AI is the investigation of an agent that is influenced by data. The process of environmental management, analyzing the data, and acting based on the data analysis. Fig. 1 detailed out the process of data collection to data analysis in AI. The procedure could be initiated with data collected from the environment via sensors. The ML algorithms are employed to analyze the data, and the results are then presented. The process of actuating by the actuators was accordingly to the work environment. Sensors and devices both act as part of the system. The autonomous portion of AI is referred to as AI, while ML is the algorithmic portion of AI.

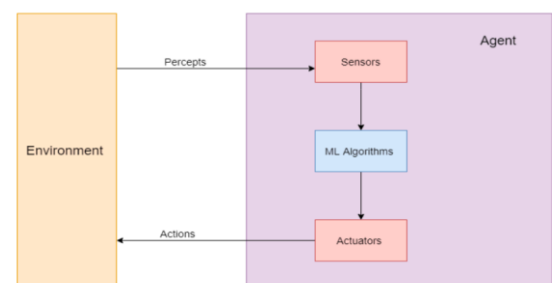


Fig. 1. Components of an AI system

In the 1990s, AI and ML were still in their early stages, with few publications utilizing the techniques. Throughout time the publications of AI and ML in OSH has been the principal area of interest since AI and ML impact on the bottom line is growing. This trend has been increasing rapidly in two years back attributed to the pandemic COVID-19 which hit the world. There were an increased number of OSH-AI & ML research trends in areas of medicine, medical, biomedical and pharmacology and pharmaceuticals as well.

A survey that has been carried out on 2021 by McKinsey & Company indicated findings which the adoption of AI in any backgrounds is steadily rising from 50% in 2020 to 56% in 2022. Since last year the AI adoption has increased in most emerging which includes China, Middle East and North Africa, Indian and followed closely by the Asia-Pacific. The figure steadily rises from 45% of AI adoption in 2020 to 57% in 2022 (McKinsey, 2021).

The survey which involves 39 respondents of adopted AI shown that the function of AI cases mostly used and applied in the area of service-operations optimizations (69%), new AI based enhancement products (56%), contact-center automation (56%), product-feature optimization (51%), predictive service and intervention (46%), customer service analytics (44%), creation of new AI-based products (44%), customer segmentation (41%), risk modelling and analytics (41%) and fraud and debt analytics (36%) (McKinsey, 2021).

The current state of AI and ML in Occupational Safety and Health (OSH) has a lot of potential applications such as in predictive analytics, autonomous systems, training and education, safety management systems, and workplace monitoring. These technologies can help organizations predict potential hazards, develop autonomous systems for dangerous tasks, enhance training and education, improve data analysis and risk management, monitor the workplace for potential hazards, and track worker behavior and performance.

4. Opportunities of AI in OSH

Currently, AI and ML are being used in a variety of ways to enhance occupational safety and health. One of the most common applications of ML is in the construction industry in preventive maintenance or injuries among workers by predicting the risk of injuries. Several machine learning models were developed to identify and prevent and predict the risk. A study from Koc et al., produced a machine learning (ML)-based novel which identifies the most vulnerable body parts of construction workers using a dataset. The study can help safety managers in evaluating susceptible body parts of construction workers prior to accidents. This can help to reduce the risk of injury among construction workers by adopting the utilization plan developed from the analysis of the model (Koc et al., 2023). A study from Zhu et al., developed predictive models of construction fatality

characteristics, including nature of injury, part of body, source of injury and event or exposure among the construction's workers. The ML model developed, benefits most of the construction workers since it able to establish and generate relevant emergency response plans and first aid facilities and services that correspond to the most likely nature of injury, part of body, source of injury and event or exposure among the workers (Zhu et al., 2023). This can allow organizations to take steps to address these risks and improve the overall health and well-being of their workers. In addition, AI and ML are also being used to analyze incidents and accidents that have occurred in the workplace, to identify the root causes and prevent similar incidents from happening in the future.

AI and ML are also being used to monitor human behavior in the workplace, such as identifying workers who may be at risk of developing a particular illness or injury. A researcher reported the ML-based human behavior monitoring can be used to identify and address unsafe behaviors in the workplace, such as not wearing personal protective equipment (Liu et al., 2020). A study from Márquez et al. incorporate the adoption of AI and the Internet of Things (IoT) to provide information of the construction workers by using wearable smartwatch. The wearable smartwatch is able to constantly monitor the worker's health in real-time, through temperature, falls, noise, impacts, or heart rate meters, activating an audible and vibrating alarm when an anomaly is detected. The smartwatches able to correct the unsafe human or workers activity behavior and improve safety working environment in the construction sites (Márquez et al., 2021). After two months, the researcher Márquez et al., then came a crossed a new idea of developing a Smart Personal Protective Equipment (PPE), a wearable technology which information able to reduce the rate of accidents and occupational illness among construction workers. The Smart PPE employs three pieces of: a helmet, a bracelet, and a belt, which process the collected information using artificial intelligence (AI) techniques (Márquez et al., 2021).

A study by Srinivisan et al, reported that AI and ML have the potential to improve workplace safety and health by predicting and preventing hazards, improving training and education, and increasing the efficiency and effectiveness of safety management systems (Srinivisan et al., 2020). For example, AI-based predictive maintenance can be used to identify and predict equipment failures before they occur, reducing the risk of accidents and injuries (Srinivisan et al., 2020).

Another application of AI and ML in OSH is in hazard detection, where the technology is used to identify potential hazards in the workplace or construction area, such as human intrusion judgement in static dangerous areas, the influence of human posture, intrusion direction, and falling from heights. This can help to improve the safety of workers by allowing organizations to take proactive measures to mitigate these hazards. A study from Mei et al., developed a computer vision-based intrusion detection method mainly aimed at static hazardous areas. The proposed method able to effectively address the defects of manual supervision in engineering

safety management, reducing the probability of accident occurrence and enhancing safety at construction sites (Mei et al., 2023). Regarding an accident that considered the most common cases reported in construction industry, falling from heights. A study from Shanti et al., developed a novel system integrating deep learning and drones to monitor workers in real-time when performing at-height activities to protect workers on jobsites from falling (Shanti et al., 2022). A study from Ozcan et al. applied the use of detection systems using wearable devices, e.g., smartphones, and tablets, equipped with cameras and accelerometers to prevent workers from falling from heights. The proposed models can show a significant decrease in the number of falls during daily activities (Ozcan et al., 2016).

Lastly, AI and ML are also being used to monitor the health of workers and to identify and predict the occurrence of occupational illnesses and diseases. For example, a study by Ng et al., produced a ML algorithm to facilitate a productive and efficient healthcare service in the private sector. A reliable and explainable system for predicting sick time and rehabilitation plans named Smart Work Injury Management System (SWIM) able to provides prediction using multi-dimensional data and machine learning approaches. The comprehensive system developed is also able to translate the machine learning result into a human-readable form that can support modern work injury case management (Ng et al., 2023).

Based on the discussion above, it is likely that the information in various digital technologies like IoT sensors, smart algorithms and portable gadgets are employed to prevent and address issues of safety, health and risk injuries among workers. These requirements are inevitably met by the application of advanced AI methods (e.g., the application of ML) to facilitate and promote safety-related prevention. Table 2 mapped the opportunities of AI or ML in construction services which relevance to OSH.

Table 2: Opportunities of AI in construction

Study	AI/ML applied	Tasks	OSH Relevance or Outcome
Koc et al., 2023	Inclusive modelling algorithm	Distinguishes the vulnerable workers' body parts that exposed to injury according to variable of age, working days and number of workers	Help safety managers in evaluating susceptible workers' body parts and reduce the risk of injuries
Zhu et al., 2023	Neural Networks (NN), Support Vector Machines with Linear Kernel (SVMLK), Decision Tree	Identifies 30 explanatory variables that comprehensive related with injuries	Allow organization to take steps to address the risks of injuries

		(DT), Random Forest (RF), Stochastic Gradient Boosting Model (SGBM)		
Liu et al., 2020	Algorithm	Identifies and address unsafe behaviors in the workplace	Reduce the unsafe working behaviors in the working site	
Márquez et al., 2021	Smart watch sensor	Identifies and measures the parameters and working environment that contributes to risk of injuries	Valuable for risk prevention and medical-health anticipation among workers	
	Smart PPE	Monitoring the state of workers and the working environment to ensure safe conditions	Reduce anomalies in the workplace and provide support for the care of personnel.	
Mei et al., 2023	Computer vision-based intrusion detection	Infusion judgement with care of influence human posture and intrusion direction	Detect defects manual supervision in engineering safety management, reducing probability of accident occurrence	
Shanti et al., 2022	Drones combine with algorithm	Monitor workers in real-time and protect workers on job-sites from falling	Reduce the severity of falls when performing at-height activities	
Ozcan et al., 2016	Smartphone and tablet equipped with camera and accelerometer	Fall Detection system	Reduce the severity of falls by informing other people to deliver help	
Ng et al., 2023	Algorithm	Reduce waiting list for occupational rehabilitation services	Minimal delays in recovery and returning to work and help organization predicting the sick leave and rehabilitation plan	

5. Challenges of AI in OSH

The rosy pictures of AI and ML can be imagined from their potential and opportunities. However, it must be realized that due to the complexity of integration AI and ML can also represent many challenges and

ongoing issues. Silva et al (2020), has identified several challenges associated with the use of AI and ML in occupational safety and health. The challenges include data privacy and security, ethical considerations, lack of standardization, and integration with existing systems (Silva, Silva, & Silva, 2020). Additionally, organizations and practitioners may be limited by a lack of knowledge, resources, and expertise in these technologies (Silva, Silva, & Silva, 2021). Hence, to overcome these challenges the government could also establish or develop the standard and legislative guidelines or the best practices (Gomoi and Stoicu-Tivadar, 2010; Bhaduri et al., 2011) to address the ethical considerations and data privacy and security issues associated with AI and ML in OSH. The organizations and practitioners also should consider investing in the development of expertise in AI and ML to take advantage of the opportunities presented by these technologies. The issues regarding privacy protection (Wang et al., 2020; Zhou et al., 2021) on how AI can save, process, edit and share information or data in considerations of permission from the client or user has been brought up by the researcher.

Srinivasan and Kumar (2020), the use of AI-based predictive maintenance can be limited by the availability and quality of data, and the complexity of the equipment being monitored. The key consideration is data privacy and security, as the collection and storage of data can raise concerns about the protection of participants' personal information. Measures such as anonymous data collection and secure storage of data must be implemented to ensure the privacy of participants is protected. Similarly, the study by Liu, Yuan, and Wang (2020) highlights the challenges associated with monitoring human behavior in the workplace, such as privacy concerns and the need for accurate and reliable data.

Furthermore, as highlighted in the study by Silva, Silva, and Silva (2020), the use of AI and ML in OSH raises important ethical, legal, and societal considerations, such as issues of data privacy and security, bias, and accountability. The study recommends that organizations and practitioners should consider these ethical considerations when adopting AI and ML in their safety and health programs. Another important consideration is informed consent, where participants must be informed of the purpose of storage and data collection, their rights as participants, and any potential risks or benefits associated with their participation. They must also give their informed consent to participating. Confidentiality is another important consideration, where participants' information must be kept confidential and not shared with any third party without the participants' consent. Fairness and non-discrimination must also be considered, where it must be conducted in a fair and non-discriminatory manner, and any potential biases in data must be identified and addressed.

6. Conclusion

In conclusion, the research highlights the potential benefits of these technologies in improving workplace safety and health. However, it also identifies key challenges and limitations associated with their use. Organizations and practitioners should consider these challenges and limitations when adopting AI and ML in their safety and health programs. Additionally, more research is needed to fully understand the impact and limitations of AI and ML in OSH, and to develop guidelines and best practices for their use. This research makes a valuable contribution to the field of occupational safety and health by providing a comprehensive overview of the current state of the field, highlighting the potential and challenges of AI and ML in enhancing workplace safety and health, and providing guidance for organizations and practitioners.

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