Artificial Intelligence (AI) Applications in Construction Safety

Construction safety

The construction industry is among the most dangerous industries, as one in five worker deaths is related to construction job sites. Construction projects are unique, with different rationales and requirements. Safety issues exist within each step of the construction phase at each project. Various applications of AI in construction safety are explored in this study, as well as their benefits and challenges.

AI-based safety monitoring system

Using AI, construction sites can be monitored in real-time and safety risks identified. A number of sources of data can be analyzed by AI algorithms in order to identify hazardous conditions, unauthorized access, and safety violations. These sources include surveillance cameras, drones, and IoT devices. Machine learning algorithms detect patterns and anomalies and alert safety managers when safety hazards occur. The proactive monitoring reduces the likelihood of accidents and injuries by allowing timely action to be taken.

Predictive models for risk assessment

Predictive analytics can be used on construction sites to assess and identify safety risks. AI algorithms can identify potential safety hazards based on historical data, weather conditions, and information specific to a project. Using this information, construction teams can plan better safety protocols, allocate resources more effectively, and take preventative measures. In addition to optimizing construction schedules for minimizing risky situations and improving overall safety, predictive analytics can also be used to improve overall safety.

PPE compliance verification and intelligent recognition

Personal Protective Equipment (PPE) compliance can be determined via AI-powered systems analyzing visual data captured by cameras and wearables on the job site. AI-based systems detect and evaluate worker PPE, such as hard hats, safety glasses, gloves, and vests. Using AI algorithms, AI algorithms can evaluate whether individuals follow PPE protocols in real-time by comparing video data with predefined safety guidelines. Images of different PPE equipment and scenarios can be used to train machine learning algorithms. With this training, the AI system can recognize specific PPE items in complex environments with shadows or different lighting conditions.

Virtual/augmented/mixed reality training

Construction safety training has been reimagined with AI-driven virtual/augmented/mixed reality (VR/AR/XR) technology. Workers can practice safety procedures, identify hazards, and respond to emergency using VR/AR/XR simulations. By engaging in these simulations, workers gain hands-on experience without exposure to potential hazards. With AI, training progress can be tracked, learning can be evaluated, and instruction can be customized to address specific safety weaknesses.

Robotics and autonomous equipment

Robotics and autonomous equipment powered by AI can improve safety on construction sites. These technologies can reduce hazardous situations caused by negligence or fatigue in part due to their ability to automate repetitive and hazardous activities. Moreover, AI algorithms can enable these machines to collaborate safely with human workers, thereby preventing accidents. By integrating safety sensors into autonomous equipment, potential dangers can be detected and addressed, further enhancing site safety.

AI techniques
The AI techniques in construction safety can generally be classified into two main areas: (1) decision-making methods and algorithms and (2) learning methods.

Decision-making methods and algorithms: Search methods and optimization theories are used when we have enough information to tackle decision-making, and the problem is solved by the selection of the best action (concerning some constraints and criteria) from a set of alternatives. Examples include linear programming, genetic algorithms, and ant colony optimization. Game theory can be applied when multiple participants collaborate to accomplish a task. Stochastic models are used when the environment is not perfectly predictable, and decisions are partly influenced by user feedback and partly influenced by regulations, standards, and guidelines. Last, when decision-making can be modeled as sequential decision problems in uncertain environments, decision-making algorithms such as Markov decision processes can be used.

Learning methods: Learning methods are classified into knowledge-based, reasoning, and planning methods (learninghow to adapt to changing conditions), learning probabilistic methods (e.g., Bayesian learning), and machine learning (e.g., supervised learning or reinforcement learning). This study will enable us to understand potential applications of decision-making and learning methods of the AI domain in AEC.

AI limitations and challenges
AI has numerous benefits for construction safety as well as several limitations and challenges. Some of the key challenges include:
- Availability and quality of data

In order to train and make accurate predictions, AI algorithms require high-quality data. There may be a lack of structure, fragmentation, or incompleteness to data in the construction industry.
- Deficiencies in standardization

There is no standardization of documents, terminology, and procedures. When data sources and systems do not adhere to uniform standards, integration becomes difficult.
- Resistance to change and adoption

The construction industry is resistant to change and new technologies, including AI adoption. Resistance to change and AI adoption can be for various reasons, such as cost consideration, misconception about how AI works, or the fear of losing jobs.
- Managing complex and multidimensional environments

Construction job sites are complex in nature with many factors affecting project activities, such as inclement weather, changes in project specifications, and unique site conditions. AI algorithms may struggle to adapt to these environments and address unforeseeable scenarios effectively.

Conclusions
AI can enhance construction safety practices. Construction industry can significantly enhance safety compliance, mitigate risks, and promote a safety culture by leveraging machine learning into their projects. To ensure optimal worker safety, AI applications should be complemented by comprehensive training, regular audits, and human oversight. By automating the verification process, monitoring in real-time, identifying problems, and providing information, AI can improve construction safety practices at job sites.