The Application of AI in Construction Safety Assurance

Zheyuan Xu *

School of International Education, Tianjin Chengjian University, 300384 Tianjin, China

* Corresponding Author Email: mailto:xuzheyuan001@outlook.com

Abstract. Construction safety is the cornerstone of ensuring the safety of people's lives and property. With the continuous development of the city, the number of large-scale engineering projects is increasing, and the complexity of the engineering construction environment is becoming increasingly prominent. In response to this problem, this paper systematically analyses the actual value of artificial intelligence in predicting and supervising building safety, including using machine learning algorithms to identify hidden dangers and monitoring violations in real time through computer vision. On this basis, this paper constructs an intelligent safety management system with a "human-machine" collaborative community, emphasizing the complementary integration of manual experience and intelligent technology. At the same time, this article points out the main problems facing the current stage. Finally, the prospects of future technological innovation are prospected, including the combination of digital twins, edge computing and 5G technology to promote the development of building safety management in a smarter, more accurate and more proactive direction, so as to more effectively ensure the safety of personnel and property on the construction site.

Keywords: Construction safety; artificial intelligence; intelligent safety management; digital twin; human-machine collaboration.

1. Introduction

Construction safety is an insurmountable "red line" of construction projects, and construction safety management is fluid, complex, and progressive [1]. The construction site environment is complex, but the current safety management method still relies on manual experience and phased inspection. This traditional method has a low level of technical application, low efficiency, and low attention to personnel, and cannot be applied to complex actual construction environments [2]. This leads to the weak safety awareness of relevant personnel, the lack of safety scientific safety management mechanism, and the lack of safety education and training in this model [1].

With the progress of the times and the development of science and technology, artificial intelligence technology has developed rapidly and gradually penetrated all aspects of people's lives. Therefore, with the help of the deep learning capabilities of new technologies such as artificial intelligence, it is crucial to establish a set of refined, efficient and accurate management systems for real-time supervision, prevention and control, and adjustment.

This article will discuss how to build a scientific, systematic and efficient construction safety management system in the practical application scenarios of construction safety assurance to ensure the safety of relevant personnel and property and ensure the smooth completion of engineering projects.

2. Application of AI in building construction safety and security

2.1. Computer vision supervision and AI perception system integration

The construction site environment is complex, with frequent flow of personnel and vehicles, and many related mechanical facilities. Although large-scale construction sites have established safety supervision systems, they are all in the stage of relying on personnel inspection and duty [2]. This model is far from guaranteeing the need for safety. The new model established through computer

vision supervision and artificial intelligence (AI) perception system will become the core technical method to ensure construction safety.

The computer vision supervision system has three main functions: low-level, middle-level and high-level. Bottom: Detect and track targets in dynamic scenes; At the middle level: identify and classify target behaviors; At the top level: Analyze and understand the behavior of the target [2,3].

AI perception system is an intelligent monitoring system based on artificial intelligence technology, which senses the behavior and environmental information of construction personnel in real time through cameras, sensors and other equipment [4].

Through the low-level functions of the computer, AI performs feature processing to complete the action classification and behavior state judgment at the middle level, Finally, after reasoning on the data, the system completes the final semantic understanding and makes decisions. 'A system structure' that integrates computer vision supervision and AI perception system as shown in Fig. 1 is formed. The system can carry out all-round and all-weather intelligent perception and early warning of the site.

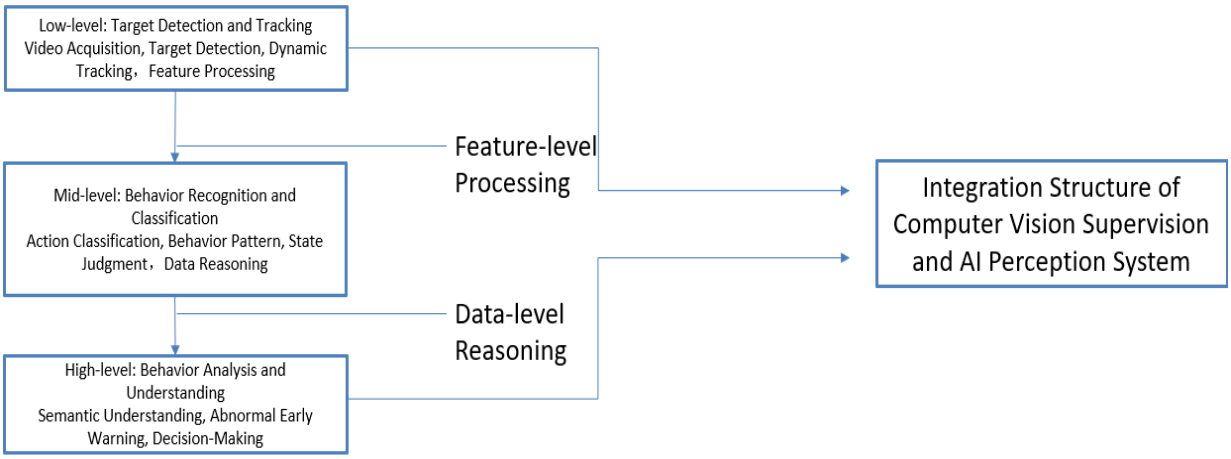


Fig. 1. Computer vision supervision and AI perception system structure system. (Picture credit: Original).

To solve the problem of personnel safety standards, the system can collect images through the camera and use AI learning algorithms to identify and classify targets. If the personnel do not comply with the safety regulations, such as the construction personnel do not wear safety helmets, reflective vests and other illegal behaviors, the system will immediately make a decision and upload it to the management cloud in a timely manner. This will facilitate the timely intervention of safety officers, and if an accident occurs, it will also facilitate the traceability of the cause and clarify the responsibility.

At the same time, the number of vehicles entering and exiting the construction site of large construction sites is large, and the traffic safety problems at the construction site are becoming increasingly significant. For this reason, the intelligent traffic monitoring system (ITS) based on computer vision integrates electronic communication, automation control, and network information technology [5]. First, the vehicle in the image is obtained by the camera, The surveillance data is obtained by digital image processing and pattern recognition analysis of the video stream [5]. The knot uses AI perception to identify the vehicle sensing status, conducts real-time command of the vehicle, and establishes an intelligent vehicle approach system [6]. The system delineates the storage yard of different transport vehicles outside the construction site according to the type of vehicle, and designates the unloading area in the construction area, and the specific operation process is as follows: the corresponding construction post reports all materials through the system, and automatically allocates off-site vehicles to enter, and plans its entry route at the same time, avoiding the redundancy and disorder when the vehicle enters the construction site and the hazard to the safety of personnel and property due to overspeed and overloading of vehicles. The flow diagram of the system is shown in Fig. 2.

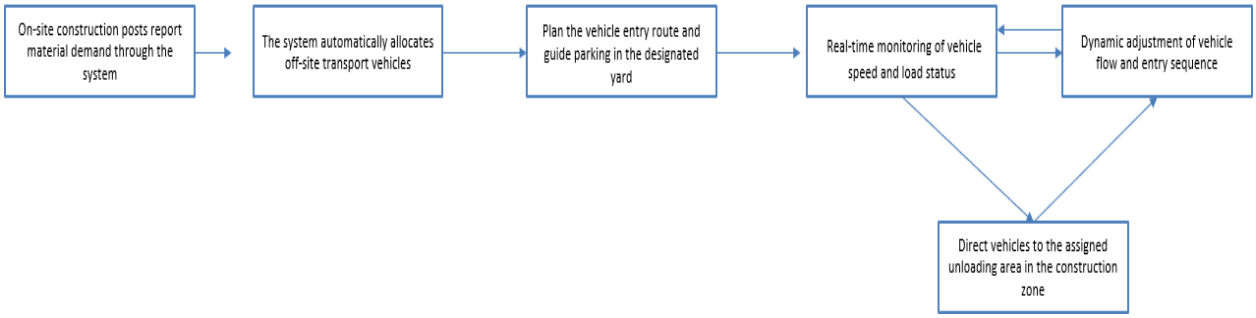


Fig 2. Flow chart of intelligent traffic control system.
(Picture credit: Original)

For the safety problems that may be caused by large machinery, in this mode, it can detect whether there are personnel staying in the operating radius of the machinery, avoid potential safety hazards that may be caused by blind spots, and identify whether large equipment is operating in a standardized manner.

2.2. IOT and AI analytics converge

In the current construction safety management, it involves personnel, materials, equipment and other dimensions, such factors may make the project management system appear disorderly, and if it is not dealt with, various safety incidents will inevitably occur [7].

Internet of Things (IOT) is a closed-loop mechanism that supports information interaction and feedback, it mainly adopts technologies such as perception layer, network layer, and application layer [8]. In the construction process of smart construction sites, Through the integration of IOT and artificial intelligence, a new data collection and decision-making model for construction safety management is established. Faced with the disorderly management system caused by personnel, materials, equipment and other dimensions, IOT technology can digitize the "people, materials, machines" and other elements on the scene [7]. At the same time, AI analyzes and judges these data. In this way, a complete process from perception to cognition, from early warning to treatment has been formed. Position, image, etc. are collected at the perception level such as locators and sensors, guided by 5G technology, information is transmitted to the application level of AI, big data and other applications to realize the application of smart construction sites.

In terms of personnel management, hazardous areas can be delineated, if it is determined that someone has entered the dangerous area during the construction process, the system will send out an alarm signal to remind personnel to pay attention to the surrounding risk situation and report to the safety officer to take necessary interventions. At the same time, IOT integrates positioning, sign detection and other sensors to monitor personnel location, body temperature, heart rate, working status and other information in real time, AI performs pattern analysis on data. If the worker is stationary for a long time, the AI will analyze the personnel who may faint, and the system will alarm them. Avoid defects that are difficult to fully cover in ordinary inspections, and achieve accurate and fast, from passive to active processing.

Application in environmental detection. By collecting dust, noise, temperature and humidity and pollutants at the construction site, AI algorithms can judge whether the current environment meets the operating standards in real time and then combines it with meteorological information to predict environmental risks in the future.

2.3. UAV technology intelligent inspection

Working at heights has long been considered a high-risk occupation due to its high accident rate and mortality rate [9]. Traditional manual inspections are limited by factors such as limited field of view, insufficient coverage, high risk and inaccessibility, and often have regulatory blind spots. The construction industry is currently looking for innovative technologies to reduce accidents and accelerate the digital transformation of safety management [9-11].

Drones can cover the entire life cycle of a building [9]. With the rapid development of artificial intelligence and drone technology, drone intelligent inspection technology has become a revolutionary tool in the field of high-altitude safety [10].

In high-altitude work, drones can hover over high-altitude work hazardous areas such as scaffolding, installation of curtain walls, and steel structure ceilings. Capture the job screen through the camera, combined with AI image recognition algorithms, the system can automatically identify whether the safety rope and scaffolding of the operator are worn and laid in a standardized manner, and whether the edge protection is in place. Compared with manual inspection, drones are faster and more efficient, compared with the fixed end, the movement of the Unmanned Aerial Vehicle (UAV) allows it to shoot from multiple angles to avoid misjudgment caused by occluding the viewing angle [9].

In the inspection of large-scale equipment, the traditional inspection of high-altitude equipment such as tower cranes requires manual climbing, which takes a lot of time and increases the risk of falling from a high altitude. The drone can fly directly around the equipment, photograph the wear of steel wires and structural deformation, and transmit the images back to the management platform, and AI automatically marks abnormal parts and generates reports. For dangerous areas such as deep foundation pits, drones can also quickly obtain terrain change data to assist in assessing the risk of landslides and collapses [8].

In terms of collaborative management of schedule and safety, UAV regularly take aerial photography to generate orthophotos and 3D models of the construction site, enhance the spatiotemporal nature of progress information, and reduce the subjectivity of progress information, managers can superimpose and compare models in different periods to intuitively understand the progress of the project and identify potential safety hazards [9, 11, 12].

2.4. VR personnel training

In the construction safety and security system, personnel safety awareness and emergency response capabilities are the key links in preventing accidents. Traditional safety training mostly uses classroom narration and other forms, the content is boring, the participation of personnel is low, and the training effect is difficult to guarantee [13].

The introduction of Virtual Reality (VR) technology provides an immersive, interactive solution for safety training, it is becoming an important means to improve the safety quality of employees [14, 15].

The VR training system realistically restores various dangerous scenes by constructing high-precision environmental on-site 3D virtual scenes [14]. Trainees can be in a virtual construction environment and experience the occurrence of typical accidents such as falling from a height, hitting objects, electric shock, and collapsing. Different from traditional methods, VR strengthens the learning experience of personal experience, personally feeling the serious consequences of illegal operations, to form a deep memory at the psychological level.

In terms of practical skills training, the VR system can simulate standardized operation processes such as scaffolding erection and temporary power wiring. The trainees perform virtual operations through interactive devices such as handles, and the system recognizes the standardization of actions in real time and gives guidance and feedback. For example, when simulating high-altitude work, the system will prompt workers where and how to fasten their seat belts correctly; in simulated fire scenarios, workers need to choose appropriate fire extinguishing equipment according to the type of fire source and standardize the operation.

3. Conclusions

Artificial intelligence, Internet of Things, drones and VR technology are deeply integrated into the field of construction safety assurance, promoting the transformation of construction safety

management from the traditional civil air defense mode to the technology-based machine defense mode.

The collaborative application of the above technologies does not exist in isolation but empowers each other and forms a closed loop. Computer vision and the Internet of Things provide the foundation of data perception, drones expand the dimension of supervision, AI gives data analysis and prediction capabilities, and VR strengthens the shaping of human behavior.

The full establishment of this system still faces some problems and limitations. Examples include battery and drone cruise technology, flight stability issues, restrictions on applicable items, and restrictions on government laws. In the future, with the further development of 5G, digital twins, edge computing and other technologies, construction safety management will eventually move towards a more intelligent, accurate and systematic direction, laying a solid safety foundation for the high-quality development of the construction industry.

References

[1] C. Zhou, Analysis of Key Problems and Countermeasures in Safety Management of Construction Projects, Build. Mater. Dev. Orient. **24**(1), 97–99 (2026). DOI: 10.16673/j.cnki.jcfzdx.2026.0027.

[2] X. Chen, Research on Key Technologies of Visual Supervision System for Large-scale Construction Sites, Master Thesis, Nanjing University of Aeronautics and Astronautics (2016).

[3] K.Q. Huang, X.T. Chen, Y.F. Kang and T.N. Tan, Review of Intelligent Video Surveillance Technology, J. Compu. **38**(6), (2015).

[4] Y.L. Zhang, J.X. Liu, A.N. Liu and X. Liu, Practical Application of AI Behaviour Perception System in Ship Safety Management, Pearl River Water Transp. (20), 137–141 (2024). DOI: 10.14125/j.cnki.zjsy.2024.20.042.

[5] W. Wang, M.H. Yao, Intelligent Traffic Monitoring System Based on Computer Vision, J. Zhejiang Univ. Technol. **38**(5), (2010).

[6] F. Garcia, D. Martin, A. De La Escalera and J.M. Armingol, Sensor Fusion Methodology for Vehicle Detection, IEEE Intell. Transp. Syst. Mag. **9**(1), 123–133 (2017). DOI:10.1109/MITS.2016.2620398.

[7] W.J. He, Y. Yang, Application of Internet of Things Technology in Construction Safety Management of Construction Projects[C/OL]//New Quality Productivity Drives the Development of Secondary Industry and Bidding and Procurement Innovation Forum, Beijing, China, (2025) 8–12, pp. 5.

[8] G. Ren, F.N. Li, T.C. Li, A.M. Yao, T. Meng and Z.Q. Chen, Construction and Engineering Application of Multi-dimensional and Multi-level Safety Intelligent Supervision Platform for Deep Foundation Pits: A Case Study of Beijing Urban Sub-central Station Comprehensive Transportation Hub Project, Constr. Sci. Technol. (15), (2025). DOI: 10.16116/j.cnki.jskj.2025.15.012.

[9] A.K. Singh, S.R. Mohandes, S.H. Muhodir, W. Zhang, M.F. Antwi-Afari and P. Shakor, Exploring Barriers to Unmanned Aerial Vehicle (UAV) Technology for Construction Safety Management Using Mixed-Methods Approach, Buildings **15**(12), 2092 (2025).

[10] J. Ma, W. B. Jiang, Application of UAV AI Inspection Technology in Construction Site Quality and Safety Management, Constr. Sci. Technol. (23), 117–119 (2024). DOI: 10.16116/j.cnki.jskj.2024.23.027

[11] L.F. Li, Application of Multi-rotor UAV Technology in Engineering Construction Management, Master Thesis, Shandong Jianzhu University (2020).

[12] J.L. Carrivick and M.W. Smith, Fluvial and aquatic applications of Structure from Motion photogrammetry and unmanned aerial vehicle/drone technology, WIREs Water **6**(1), e1328 (2019). DOI:10.1002/wat2.1328.

[13] X.Y. Miao, H. Liu, D. Wang and H.J. Li, A Brief Analysis of the Effectiveness of VR Technology Safety Training in the Construction Field, Stone (11), 123–125 (2024). DOI: 10.14030/j.cnki.scaa.2024.0556

[14] J.S. Chen, C.H. Chen, Application of VR Technology in Safety Training in Chemical Construction Projects: A Case Study of Company H, Straits Sci. (3), 108–111, 116 (2025).

[15] Y. Tan, W. Xu, S. Li and K. Chen, Augmented and Virtual Reality (AR/VR) for Education and Training in the AEC Industry: A Systematic Review of Research and Applications, Buildings **12**(10), 1529 (2022). DOI:10.3390/buildings12101529.