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Editorial

Application of Emerging Technologies to Improve Construction Performance

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Over the preceding several decades, the architectural, engineering, and construction (AEC) industries have witnessed significant advances due to the rapid development of information technology. A wide range of theories and techniques, such as BIM [1], computer vision [2], natural language processing [3], deep learning [4], and ontology engineering [5], have been adopted to facilitate the life-cycle management of AEC projects. For example, given the complexity of onsite construction, managers are faced with various challenges such as unsatisfactory construction quality, schedule delays, extra costs, and safety risks. Accordingly, researchers have explored the potential of the use of emerging technology to support various managerial operations, including safety assurance [6,7], progress monitoring [8], and quality control [9,10].

This Special Issue of *Buildings*, entitled the "Applications of Emerging Technologies to Improve Construction Performance", focuses on exploring state-of-the-art knowledge and cutting-edge innovations in the interdisciplinary field of study within the AEC sector. A diverse range of researchers and practitioners worldwide who share the same commitment to improving construction performance have published a total of 14 research articles and 2 review articles within this collection of papers. The included articles cover a variety of emerging topics, ranging from areas of deep learning, reinforcement learning, BIM, VR, GIS, to domain knowledge engineering. Each study contributes to the body of knowledge by presenting empirical evidence and/or proposing theoretical insights.

Xiong et al. [11] proposed the use of a deep learning-based method to monitor construction activities within the field of construction. The proposed method combined the benefits of both convolutional neural network (CNN) and recurrent neural network (RNN) methods in order to recognise different types of sound event and identify the start and end timings of individual construction activities. The sound-based event detection model can achieve an mAP of 0.972 for five different kinds of construction activities in a steel modular construction project. The method was analysed using an ablation study and validated through two extended experiments, indicating its applicability for the autonomous monitoring of construction activities.

For anti-collision piers widely used in traffic protection infrastructures, Wei et al. [12] studied different biomimetic honeycomb structures to determine the enhancement of the pier's mechanical strength and energy absorption characteristics. The energy absorption effect of various internal honeycomb structures (e.g., structure arrangements and numbers) was subjected to analysis using finite element simulation methods. A displacement loading technique was applied to the anti-collision piers made of polypropylene acetate (PLA) material. The results showed a three-honeycomb shape with a central triangle area, exhibiting the best force–deformation behaviour of any sample examined.

Fang et al. [13] adopted eye-tracking technology to investigate the influencing mechanism of safety sign features on the visual attention of construction workers. A theoretical

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model was developed in terms of both visual and cognitive features and verified through experiments. The statistical results indicated that red and rectangular safety signs could reduce the cognitive load of first fixation, while green signs could reduce cognitive difficulties. Moreover, visual attention was adversely impacted by unfamiliarity while not being closely related to concreteness and sematic closeness. The results showed that the method could effectively optimise the design of construction safety signs to improve the visual attention of construction workers and the overall safety performance of construction.

Xu et al. [14] aimed to establish a domain knowledge structure for safety management in metro construction projects, and thus developed a method with which to automatically extract the hierarchical relations between domain knowledge entities (DKEs) from a large dataset of unstructured text documents. A rule-based natural language processing method was proposed for the Chinese language and applied to identify the affiliation relationship and parallel relationship between DKEs. The proposed method contributed to the automatic construction of knowledge structures and the resulting knowledge structure was able to assist in onsite safety management.

Si et al. [15] optimised the method for HVAC load prediction. The proposed prediction model was simplified and reduced order for time-efficient simulation and control, by integrating an equivalent envelope structure, heat gain calculation linearization and building pre-processing module in OpenModelica. The indoor mean radiant temperature (MRT) was used as the target feedback parameter for the air-conditioning system control. The experiment validated the proposed method for efficient HVAC load prediction and indicated the benefits of adopting MRT as the new control parameter.

Wang et al. [16] explored the anti-scour devices (including perforated baffle and ring-wing plate) for bridge piers and determined the optimal dimensions and location of the combined device. The anti-scour device was verified as being more beneficial in terms of scour characteristics and flow field as it reduced the maximum scour depth of the pier, the flow velocity at the pier side near the bed surface, and the turbulent kinetic energy at different horizontal and vertical planes. The developed combined device was able to effectively mitigate scour around the bridge pier, contributing to the safety and sustainability of bridge infrastructure.

Given the potential of BIM/VR integration to improve the quality of management, Yu et al. [17] proposed an integrated BIM-VR method for fire evacuation training based on a generic review of BIM and VR applications in training platforms for infrastructure management. A BIM + VR prototype was proposed for use in a highway tunnel emergency response platform and the pilot case was tested in three different emergency scenarios. The results indicated that the BIM-VR integration was able to largely improve the training efficiency regarding information accessing, training mode and team interaction. Additionally, the proposed framework could be explored for wider applicability and more comprehensive capabilities.

Focusing on water conservation projects, Li and Feng [18] studied the factors influencing different types of trust relationship between owners and PMC contractors given the Chinese management background by modelling the trust generation and trust level evolution. Based on the above, variable management strategies were proposed to increase the level of trust between the two parties and validated for efficacy. The results provided theoretical guidance to practitioners and could contribute to PMC project success.

Xu et al. [19] proposed the use of a model view delivery (MVD) method to advance design for prefabricated buildings by first establishing an IFC-based assembly knowledge model. Then, a BIM shared ontology and BIM production ontology were constructed through the EXPRESS-OWL conversion, leading to the creation of a knowledge graph. Ontology-based IDM was developed and the model view delivery was completed. The proposed method was validated through training on case studies, indicating its capability to address heterogeneity and redundancy issues and improve efficient information transmission within the prefabricated building domain.

Sanchez-Lite et al. [20] assessed the academic implementation of BIM within a School of Industrial Engineering. The ability of the students to develop sustainable industry and participate in a real process of implementation was evaluated through academic results and their perceptions. The results proved the benefits of the collaborative business academic environment and the use of BIM for learning and in the sustainability proposal rate.

Shen et al. [21] developed a monitoring system for safety risk management in the field of prefabricated building construction by combining the ontology theory and BIM technology. This was performed based on the safety risk ontology, a rule-based reasoning method using SWRL and the Drools engine that was integrated into the Revit software for risk identification. The proposed method was verified through case studies, showing great potential to promote safety risk management in the construction of prefabricated buildings.

Huang et al. [22] proposed a vision-based method to accurately measure the cable alignment of long-span suspension bridges in a strong wind environment. Aided with pre-installed optical targets, the relative sag of cable strands was monitored remotely, automatically and in a real-time manner. The impact of both wind-induced cable shaking and camera shaking on the accuracy of measurement were analysed. The proposed method was validated through experiment and achieved a measurement error within 3 mm, contributing to the automation of the cable erection process.

Luo et al. [23] solved the truss layout optimization problem by modelling it as a Markov Decision Process (MDP) problem and using a reinforcement learning-based algorithm. A two-stage Monte Carlo Tree Search (MCTS)-based algorithm, AlphaTruss, was adopted, by first finding an action sequence to form an optimal layout and then refining the layout. Through experiments, it is testified the proposed method can optimise the topology, geometry, and bar size of the truss structure and minimise the weight under stress, displacement, and buckling constraints, realizing better performance than those achieved by the existing methods outlined in the literature.

For underground space extension, Xiao et al. [24] utilised a large-scale test chamber to simulate the further excavation process beneath existing underground space and conducted parallel tests. Parameters were studied regarding their impacts on an h-type support system containing double-row piles. This included pile row spacing, pile length ratio, pile-head constraint, and in-service foundation pile. The analysis results facilitated the design of a stable double-row piles support system.

Regarding the integration of GIS, BIM and heritage BIM, Carrasco et al. [25] conducted both quantitative (bibliometric) and qualitative analyses in the literature, aiming to identify the most significant technological developments and the potential applications of such integration methods. The five most frequently used key-concept clusters were obtained, based on which the SWOT analysis of potential applications was carried out. The review highlighted the benefits of GIS-BIM integration in improving productivity, reducing costs and facilitating automation.

Kang et al. [26] conducted a holistic review on the integration of BIM and computational fluid dynamics (CFD) in the AEC industry. A bibliometric exploration, content analysis and a follow-up qualitative discussion were adopted to illustrate the current research trends in different sectors. Insight was provided into the effective adoption of BIM-CFD integration, especially for hazard analysis.

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References

1. Wang, J.; Zhang, X.; Shou, W.; Wang, X.; Xu, B.; Kim, M.J.; Wu, P. A BIM-based approach for automated tower crane layout planning. *Autom. Constr.* **2015**, *59*, 168–178. [CrossRef]
2. Xu, S.; Wang, J.; Shou, W.; Ngo, T.; Sadick, A.-M.; Wang, X. Computer vision techniques in construction: A critical review. *Arch. Comput. Methods Eng.* **2021**, *28*, 3383–3397. [CrossRef]
3. Wu, C.; Li, X.; Guo, Y.; Wang, J.; Ren, Z.; Wang, M.; Yang, Z. Natural language processing for smart construction: Current status and future directions. *Autom. Constr.* **2022**, *134*, 104059. [CrossRef]
4. Wu, C.; Li, X.; Jiang, R.; Guo, Y.; Wang, J.; Yang, Z. Graph-based deep learning model for knowledge base completion in constraint management of construction projects. *Comput.-Aided Civ. Infrastruct. Eng.* **2023**, *38*, 702–719. [CrossRef]
5. Lei, X.; Wu, P.; Zhu, J.; Wang, J. Ontology-based information integration: A state-of-the-art review in road asset management. *Arch. Comput. Methods Eng.* **2021**, *29*, 2601–2619. [CrossRef]
6. Su, Y.; Mao, C.; Jiang, R.; Liu, G.; Wang, J. Data-driven fire safety management at building construction sites: Leveraging CNN. *J. Manag. Eng.* **2021**, *37*, 04020108. [CrossRef]
7. Yi, W.; Chan, A.P.C.; Wang, X.; Wang, J.D. Development of an early-warning system for site work in hot and humid environments: A case study. *Autom. Constr.* **2016**, *62*, 101–113. [CrossRef]
8. Reja, V.K.; Varghese, K.; Ha, Q.P. Computer vision-based construction progress monitoring. *Autom. Constr.* **2022**, *138*, 104245. [CrossRef]
9. Wang, J.; Sun, W.; Shou, W.; Wang, X.; Wu, C.; Chong, H.-Y.; Liu, Y.; Sun, C. Integrating BIM and LiDAR for real-time construction quality control. *J. Intell. Robot. Syst.* **2015**, *79*, 417–432. [CrossRef]
10. Xu, S.; Wang, J.; Wang, X.; Wu, P.; Shou, W.; Liu, C. A Parameter-Driven Method for Modeling Bridge Defects through IFC. *J. Comput. Civ. Eng.* **2022**, *36*, 04022015. [CrossRef]
11. Xiong, W.; Xu, X.; Chen, L.; Yang, J. Sound-based construction activity monitoring with deep learning. *Buildings* **2022**, *12*, 1947. [CrossRef]
12. Wei, J.; Wang, Y.; Wang, J.; Yao, X.; Wang, D.; Wang, X. Mechanical strength and energy absorption optimization of biomimetic honeycomb anti-collision pier. *Buildings* **2022**, *12*, 1941. [CrossRef]
13. Fang, Y.; Ni, G.; Gao, F.; Zhang, Q.; Niu, M.; Ding, Z. Influencing mechanism of safety sign features on visual attention of construction workers: A study based on eye-tracking technology. *Buildings* **2022**, *12*, 1883. [CrossRef]
14. Xu, N.; Chang, H.; Xiao, B.; Zhang, B.; Li, J.; Gu, T. Relation extraction of domain knowledge entities for safety risk management in metro construction projects. *Buildings* **2022**, *12*, 1633. [CrossRef]
15. Si, Q.; Wei, J.; Li, Y.; Cai, H. Optimization for the model predictive control of building hvac system and experimental verification. *Buildings* **2022**, *12*, 1602. [CrossRef]
16. Wang, Y.; Chen, J.; Wang, Z.; Zhu, Z.; Yan, J. Numerical investigation on local scour and flow field around the bridge pier under protection of perforated baffle and ring-wing plate. *Buildings* **2022**, *12*, 1544. [CrossRef]
17. Yu, X.; Yu, P.; Wan, C.; Wang, D.; Shi, W.; Shou, W.; Wang, J.; Wang, X. Integrating virtual reality and building information modeling for improving highway tunnel emergency response training. *Buildings* **2022**, *12*, 1523. [CrossRef]
18. Li, H.; Feng, J. Study on the improvement strategy of trust level between owner and pmc contractor based on system dynamics model. *Buildings* **2022**, *12*, 1163. [CrossRef]
19. Xu, Z.; Wang, J.; Zhu, H. A semantic-based methodology to deliver model views of forward design for prefabricated buildings. *Buildings* **2022**, *12*, 1158. [CrossRef]
20. Sanchez-Lite, A.; Zulueta, P.; Sampaio, A.Z.; Gonzalez-Gaya, C. Bim for the realization of sustainable digital models in a university-business collaborative learning environment: Assessment of use and students' perception. *Buildings* **2022**, *12*, 971. [CrossRef]
21. Shen, Y.; Xu, M.; Lin, Y.; Cui, C.; Shi, X.; Liu, Y. Safety risk management of prefabricated building construction based on ontology technology in the bim environment. *Buildings* **2022**, *12*, 765. [CrossRef]
22. Huang, C.; Wang, Y.; Xu, S.; Shou, W.; Peng, C.; Lv, D. Vision-based methods for relative sag measurement of suspension bridge cables. *Buildings* **2022**, *12*, 667. [CrossRef]
23. Luo, R.; Wang, Y.; Xiao, W.; Zhao, X. Alphatruss: Monte carlo tree search for optimal truss layout design. *Buildings* **2022**, *12*, 641. [CrossRef]
24. Xiao, Y.; Wang, X.; Yu, F.; Wang, Z. Experimental investigation of h-type supporting system for excavation beneath existing underground space. *Buildings* **2022**, *12*, 635. [CrossRef]
25. Carrasco, C.A.; Lombillo, I.; Sánchez-Espeso, J.M.; Balbás, F.J. Quantitative and qualitative analysis on the integration of geographic information systems and building information modeling for the generation and management of 3d models. *Buildings* **2022**, *12*, 1672. [CrossRef]
26. Kang, K.-Y.; Wang, X.; Wang, J.; Xu, S.; Shou, W.; Sun, Y. Utility of bim-cfd integration in the design and performance analysis for buildings and infrastructures of architecture, engineering and construction industry. *Buildings* **2022**, *12*, 651. [CrossRef]