frontiers | Frontiers in Built Environment

TYPE Editorial
PUBLISHED 16 January 2023
DOI 10.3389/fbuil.2023.1130115

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Building Information Modelling (BIM), a section of the journal Frontiers in Built Environment

RECEIVED 22 December 2022
ACCEPTED 10 January 2023
PUBLISHED 16 January 2023

CITATION
Yitmen I, Kovacic I and Tagliabue LC (2023), Editorial: Cognitive digital twins for facilitating construction 4.0: Challenges and opportunities for implementation. *Front. Built Environ.* 9:1130115. doi: 10.3389/fbuil.2023.1130115

Editorial: Cognitive digital twins for facilitating construction 4.0: Challenges and opportunities for implementation

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KEYWORDS

cognitive, digital twins, construction 4.0, building information modelling, internet of things, artificial intelligence

Editorial on the Research Topic
Cognitive digital twins for facilitating construction 4.0: Challenges and opportunities for implementation

Cyber-physical systems (CPS) comprising interconnected and integrated smart systems can transform the Architecture Engineering Construction (AEC) industry and contribute to the development of Construction 4.0. Digital Twin (DT) construction is a new mode for managing production in construction that leverages the data streaming from a variety of site monitoring technologies and artificially intelligent functions to provide accurate status information and to proactively analyze and optimize ongoing design, planning, and production. DT integrates historical and real-time data obtained from physical systems with physics-based models and advanced analytics to create digital counterparts with high integrity, awareness, and adaptability to provide predictive services to planning and construction entities.

Although the current level of advancement in enabling technologies and the state-of-the-art applications and implementations of DT in the AEC industry regarding real-time monitoring, performance prediction, and decision-making, there still exist several key knowledge gaps that must be addressed through continued research to make DT more capable, reliable, and practical for real-world applications. Even if a considerable amount of engineering data increases unprecedently in the planning and construction of a project, the adoption of DT, IoT and AI techniques still lag behind the process in other industries. Therefore, there is immense interest in implementing a variety of DT, IoT and AI methods in the construction engineering and management domain to seize the valuable opportunity of digital evolution for better performance and profitability.

This Research Topic provides knowledge into Cognitive DT models for facilitating Construction 4.0 focusing on challenges and opportunities. This manuscript Research Topic comprises DT incorporating cognitive abilities to detect complex and unpredictable actions and reasoning about dynamic process optimization strategies to support decision-making in smart planning and construction. This Research Topic offers contributions of AI enhanced DT for the incorporation of IoT, Big data, smart sensors, machine learning and communication technologies, all connected to a novel paradigm of self-learning hybrid models with proactive cognitive capabilities.

So far, four manuscripts have been published in the Research Topic. The next parts of the editorial provide a brief summary of each of the manuscripts published.

Kosse et al. propose a framework for a digital twin for the industrialized production of precast concrete elements in series production based on the asset administration shell (AAS) from the context of Industry 4.0. For this purpose, relevant production processes are identified, and their information requirements are derived. Data models and corresponding AAS for precast concrete parts will be created for the identified processes. The functionalities of the presented digital twin are demonstrated using the use case of quality cntrol for a precast concrete wall element. The result shows how data can be exchanged with the digital twin and used for decision-making.

El Mokhtari et al. present the development of a Cognitive Digital Twin (CDT), populated by construction information, facility management data, and data streamed from the Building Automation System (BAS). Advanced machine learning was enabled by access to both real-time and historical data coupled with scalable cloud-based computational resources. Streaming data to the cloud has been implemented in existing architectures; to address security concerns from exposing building equipment to undesirable access, a secure streaming architecture from BACnet equipment to our research cloud is presented. Real-time data is uploaded to a high-performance scalable time-series database, while the ontology is stored on a relational database. Both data sources are integrated with Building Information Models (BIMs) to aggregate, explore, and visualize information on demand. A case study of a Digital Twin (DT) of an academic building where various capabilities of CDTs are demonstrated through a series of proof-of-concept examples.

Gourlis et al. present a holistic modeling and simulation framework, utilizing modular digital twins (DTs) of all elements that may constitute a given industrial unit. The integration of multiple DTs of these subsystems in a hybrid (continuous and discrete) simulation forms a holistic DT ecosystem of an existing facility. The particular focus of the study is the building representation in this DT ecosystem for energy-efficient production. Based on a methodology including hybrid simulation, Building Information Modelling (BIM), and visual programming, a semi-automated data acquisition workflow was proposed. The hybrid simulation is based on Discrete Event System Specification (DEVS) formalism, where the building is incorporated as a building energy model (BEM). Within the abstracted representation of the overall system, the manuscript explores the possibilities of parametrizing the DT of the building, interconnected with the rest of the factory elements, by acquiring information directly from existing BIM models. Through a comparative case study, the proposed workflow is compared to a manual one in terms of integrity and benefits.

Meschini et al. present a methodology for the development of a BIM-GIS web-based platform (i.e., AMS-app) providing the real-time visualization of the asset in an interactive 3D map connected to analytical dashboards for management support. Two buildings of the University of Turin are adopted as demonstrators, illustrating the development of an easily accessible, centralized database by integrating spatial and functional data, useful also to develop future CDTs. As a first attempt to show the AMS app potential, crowd simulations have been conducted to understand the buildings' actual level of safety in case of fire emergency and demonstrate how CDTs could improve it. The identification of data needed, also gathered through the future implementation of suitable sensors and Internet of Things networks, is the core Research Topic together with the definition of effective asset visualization and monitoring methods.

The studies in current Research Topic reflect the substantial improvements and provide exciting new insights and state-of-the art knowledge for actions toward development of CDT for facilitating Construction 4.0. The Research Topic editors are grateful to the review editors and associated editors.

Author contributions

IY, IK, and LT conceived and edited the Research Topic. All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

Acknowledgments

The authors would like to thank the reviewers who contributed to this Research Topic. Particular thanks go to the board of the Frontiers Publishing house for their supports of this Research Topic.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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