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Utilizing the High Maturity Level of Digital Twin for Construction Resource Monitoring

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ABSTRACT

This article presents an approach to utilize the high maturity level of digital twin for construction resource monitoring. The digital twin is used in construction projects as a systematic representation of physical objects into virtual models of construction. While the resource monitoring system is used as a decision-making tool to optimize resource leveling optimization. A high maturity level is needed to provide an interoperable ecosystem for the construction monitoring process. The state-of-the-art literature review and gap identification are used through various studies related to the research objectives. The result shows that the integration of Building Information Modeling (BIM), geographic information system (GIS), machine learning (ML), and monitoring dashboard is needed for the digital twin resource monitoring model for controlling resource utilization on the project. A platform ecosystem is also required to effectively obtain an efficient decision making process for project construction. The study contributes to the framework of digital twin for aerial construction.

KEYWORDS: Construction, Digital Twin, Monitoring, Resource

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1. INTRODUCTION

Resources monitoring is needed to oversee the project construction (Cheng & Teizer, 2013; Fapohunda & Chileshe, 2014; Guven & Ergen, 2021). While resource optimization is needed to obtain effective and efficient construction activities (He et al., 2021; Jiang et al., 2022; Kusimo et al., 2019; Teizer et al., 2020). The effective term relates to the construction operation, meanwhile the efficient is about the cost spent on the whole project. Then effective and efficient collectively are the terms to optimize the construction resources. Thus, construction monitoring is expected to achieve a generative approach to meet the solutions to the resource's problems (Fapohunda & Chileshe, 2014).

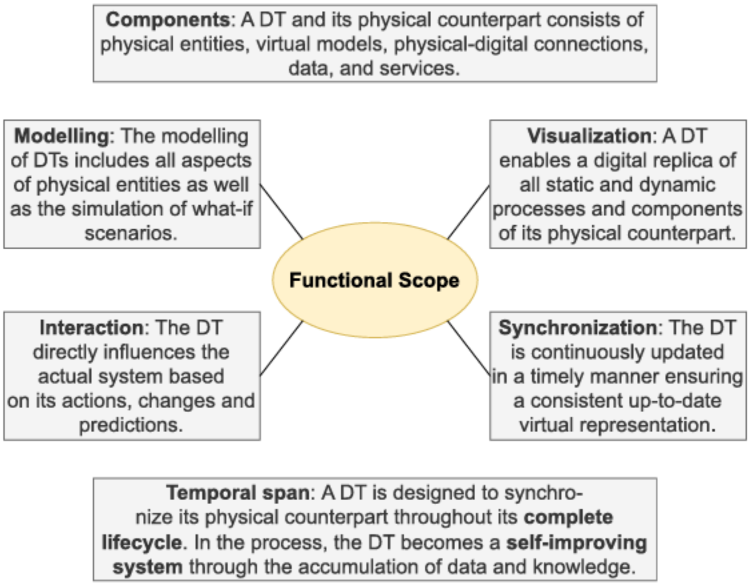
Digital twins are used in construction to provide a digital representation of construction implementation (Akanmu et al., 2021). This process is used in monitoring to quickly generate an overview and observation of the construction progress position. In addition, through digital twins, a dynamic analysis for the upcoming operational steps can also be generated through the simulation approach (Amer & Golparvar-Fard, 2021; Münker et al., 2021; Vivi et al., 2019). Specifically, it is used for construction resource utilization.

However, various digital twin ecosystem provisions used for monitoring construction are still vary (Duarte-Vidal et al., 2021; Gara et al., 2021). Some gaps must be completed through a unified maturity level of the monitoring ecosystem. Moreover, a high maturity level is required to provide a proper ecosystem (Woodhead et al., 2018). Thus, the digital twin is a systemic object that provides connectivity between subsystems in a whole systematic process (Akanmu et al., 2021). A high maturity level of the construction monitoring ecosystem can achieve optimal and reliable construction monitoring results. This study aims to formulate a high maturity level of the digital twin ecosystem of construction projects. This maturity level is used as the basis for the development of digital twin models environment in construction monitoring.

2. LITERATURE REVIEW

Digital Twin (DT)

The concept of creating digital twins for physical assets or processes marks a crucial milestone in the journey of digitization and has advanced over the past two decades alongside the technologies that make it possible, such as sensor technology, the Internet of Things (IoT), cloud computing, Big Data analytics, and artificial intelligence (AI). Since Grieves introduced the idea at an industry workshop in 2002, there have been numerous definitions of digital twins, often tailored to specific domains. However, most definitions agree that digital twins serve as virtual replicas of actual systems (AS), capable of being continuously updated with real-time data throughout their lifecycle and interacting with the physical system, ideally in an automated manner (Klar et al., 2024).



Source: (Klar et al., 2024)

FIGURE 1. Digital Twin Characterization

3. METHODS

Research is performed through a qualitative approach. Literature study and state of the art identification is conducted to obtain the research objective. The research process flow is given in the following Figure 1.

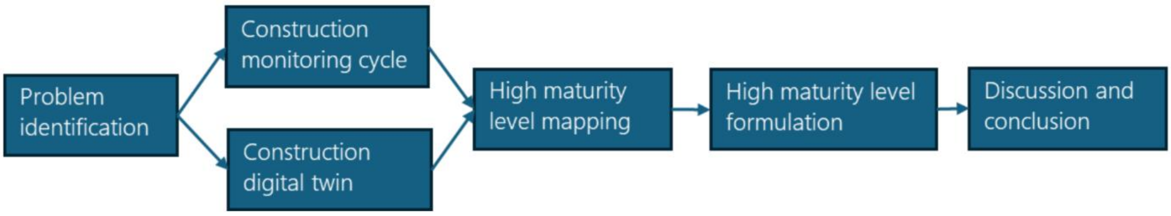


FIGURE 2. Research Flow

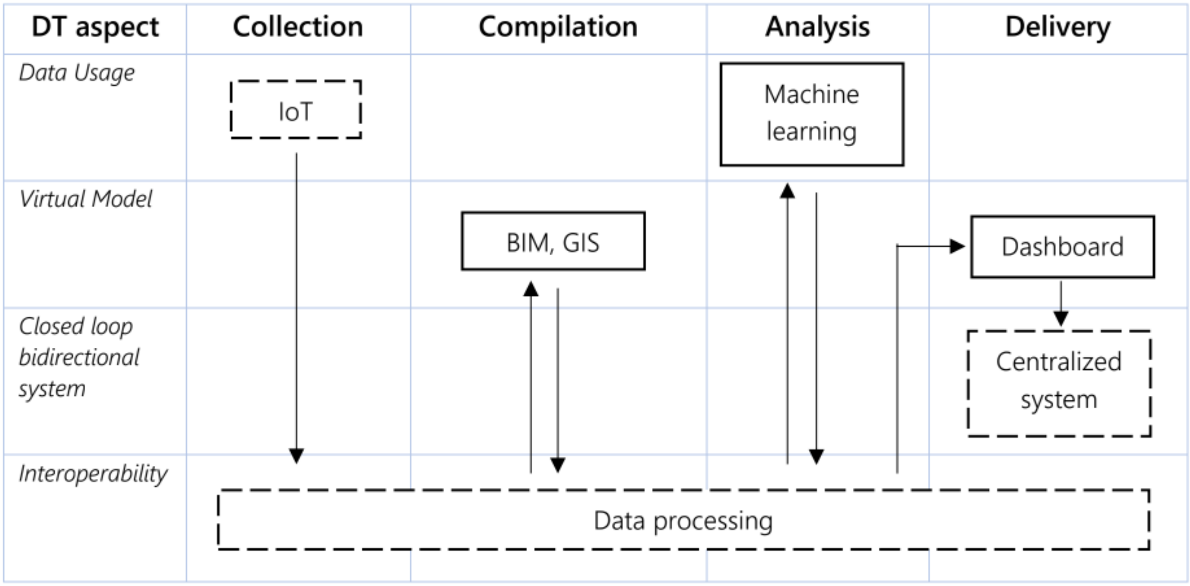
Study consists of two research questions followed by two research objectives. The first objective comes from the research question of how the monitoring cycle of construction activities. While the second objective comes from the question of what the technical requirements are to generate a high maturity level of digital twin in accordance with the monitoring cycle of the project construction. Then to answer these two questions, it includes identifying the monitoring cycle of the project construction and formulating the technical requirements to generate a high maturity level of digital twin. The formulation of both objectives is carried out through literature review and identification of systemic relationship between the components and parameters of the system. Discussion and conclusion are given at the end of the study.

4. RESULTS

The formulation of maturity level is defined from the functional cycle of construction monitoring needs to the digital twin framework (Boje et al., 2020; Khallaf et al., 2022; Xu et al., 2014). Mapping is then to be determined through the relationship between functional cycle and key aspects related to the development of digital twin ecosystems. It is found that the construction monitoring function includes progress collection, progress compilation, progress analysis, and progress delivery (Duarte-Vidal et al., 2021; Kusimo et al., 2019; Whyte, 2019). While the Identification of the digital twin development key aspects includes data usage (Li et al., 2023; Mêda et al., 2021), the virtual model (Adel et al., 2022; Rafsanjani & Nabizadeh, 2023), closed loop bidirectional system (Pan & Zhang, 2021; Sacks et al., 2020), and the system Interoperability (Duarte-Vidal et al., 2021; Noardo et al., 2020). Thus, the functional mapping result to the key aspects is given on the following Table 1 and followed by the schematic result overview in the following Figure 2.

TABLE 1. Construction Functional Mapping to Digital Twin Key Aspects

DT Aspect	Collection	Compilation	Analysis	Delivery
Data usage	Internet of Things (IoT) based data collection	The use of data storage system and data warehousing	Using Machine learning (ML) in data analysis	Able to develop data based scenarios through dashboards (Knowledge base decision making)
Virtual model	Progress data from IoT is directly connected to the input of data processing and virtual model	Member detailing data and location coordinates directly construct aerial models. So that the virtual model is integrated with the data	ML analytics system that attaches directly to the platform	Monitoring is available through the Aerial model virtual view platform using BIM and GIS
Closed loop bidiretional system	There is a systematic relationship on data collection to feedback on site through forward and backward relationships using IoT and actuators	There is feedback propagation to the site from the control center	Perform analysis and model construction based on actual information and directly perform generative analysis for prediction simulation quickly and dynamically using ML	The command center becomes the connecting center between the system forward from the site and the backward system back to the site
Interoperability	IoT connected to data storage platforms	Data storage connected to data warehousing	Data warehousing connected to ML	ML conclusions connected to dashboards and DT virtual models



(Note: continuous lines indicate the core ecosystem for digital twin resources monitoring and the dashed lines indicate the supporting unit for providing feeds for the ecosystem))

FIGURE 3. Schematic of Digital Twin Maturity Mapping

The high maturity level formulation is obtained from the mapping Figure 2. The involvement of machine Learning, BIM, GIS, and dashboard are needed to develop a hi maturity level of construction digital twin. While it also requires the involvement of IoT and data engineering as the supporting unit for providing the data feeds for the ecosystem. However, the systemic closed two-way ecosystem integration of these aspects will result in a compact process as well as the ecosystem will be able to deliver a dynamic process on construction resources monitoring.

The provision of a digital twin ecosystem has no application standard yet (Akanmu et al., 2021). It is due to various studies conduct customized operational application for providing the twin regarding to each operational need. However, the objective of monitoring is a standard approach to optimize aspects of cost, duration, and quality (Reja et al., 2022; Teizer et al., 2020). Regardless of how the method is applied, the utilization of digital twins will certainly be able to streamline several steps to obtain an integrated system (Gara et al., 2021; Zhang et al., 2022). So that the process for achieving the monitoring goals will be much better. A systemic review of maturity level formulations is necessary because technology will evolve over the time. So, we need to rely on the functionality over the technology (Deng et al., 2022). The technology will be able to adjust along with systemic development. In the future, with a certain maturity level, construction will have a standard core system where improvements in terms of technology can be done more flexibly and interchangeably.

5. CONCLUSIONS

The formulation of a high maturity level of construction digital twin ecosystem is generated from the project construction cycle and is the key to digital twin development. Result shows that the integration Machine Learning, BIM, GIS, and Dashboard are needed for developing the high maturity level of digital twin resource monitoring model for controlling resource utilization on the project.

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