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Implementation of Digital Twin Campus by Mixed Virtual Reality Design and Construction Technology

Chunhua Tang[1,a,*]

[1]School of Engineering and Built Environment, Edinburgh Napier University, Edinburgh, EH10 5DT, United Kingdom
a. 1721496167@qq.com
**corresponding author*

Abstract: This paper aims to realize digital twin campus by combining hybrid virtual reality technology, three-dimensional laser point cloud technology and BIM technology. First, Trimble TX8 3D scanner is used to collect the data of the target building, and then Trimble RealWorks is used to synthesize, splice, modify and measure the collected point cloud data. Then the synthesized point cloud model is imported into Revit as a reference, and the reverse modeling of point cloud is implemented in Revit, and the corresponding virtual 3D model of Glassroom is constructed. Because of the lack of the original drawings of the building, the second design and analysis of the target building are carried out, and the stability of the redesigned Glassroom structure is analyzed by using SAP2000. Finally, Trimble mixed virtual reality projection is used to make the digital double glass room.

Keywords: Digital twin campus, Mixed reality, Point Cloud, Trimble RealWorks, Trimble Connect

1. Introduction

In 2021, the cumulative global valuation of the Architecture, Engineering, and Construction (AEC) industry was estimated to be US$11.72 trillion [1]. Consequently, it means that the industry need to seek persistent methodologies and strategies aimed at optimizing the utilization of resources, augmenting productivity, reducing the cost of projects, curtailing the duration required for project delivery, and enhancing safety at the job site [2].

However, it is not that easy for the AEC to upgrade its technology because it faces numerous obstacles, such as a deficiency in investment for research and development, a decreasing trend in overall productivity, and the stagnation of technological development [3]. Moreover, the escalating complexity of engineering projects shows that the capabilities of Building Information Modelling (BIM) technologies might be inadequate despite their continuous advancement [4]. Therefore, this research aims to facilitate technological advancements in the AEC by integrating digital twin and mixed reality technologies. It will investigate the construction of a digital campus model and apply digital campus model in the AEC process using mixed reality technology.

This paper explores digital twin evolution, showing its growing importance in enhancing operational efficiency, and discusses 3D Laser Scanning's role in creating precise digital representations but notes the challenges in cost and data updating. Moreover, it expounded Mixed

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Virtual Reality's potential in improving communication, risk management, and project planning in construction, showcasing its transformative impact on the industry's efficiency and innovation.

2. Definition of the Digital twin

The original concept of digital twins, proposed by scholars such as Greaves and Vickers, introduced a framework with intrinsic properties [5]. The envisaged framework comprises three integral parts: a real space, a virtual space, and an intricate linkage mechanism facilitating the exchange of data and information between these two spaces [6]. This construct is named the Mirrored Spaces Model. The current evolution of digital twin (DT) technology is characterized by emphasis on modeling, data fusion, interactive collaboration, and service provision [7]. The use of digital twin technology is widely recognized in the field of digital simulation, especially in the manufacturing, aerospace, and automotive industries [8].

Digital twin have been gradually developed in various industries in recent years. Figure 1 shows the number of publications that were found on two literature databases containing "digital twin" (English only) in the article title, abstract, or keywords between 2011 and 2020, and publications have grown exponentially since 2016 [9]. The advantages of the digital twin framework are they can enable synchronous oversight, complex data scrutiny, and the emulation of various situational models (Figure 2), in the end, an elevation of operational efficiency and the refinement of decision-making processes in the construction domain [10]. That shows that digital twin (DT) has significantly enhanced the capabilities of construction, as it streamlines processes, minimizes maintenance expenses, enhances user interaction, and integrates various information technologies [11].

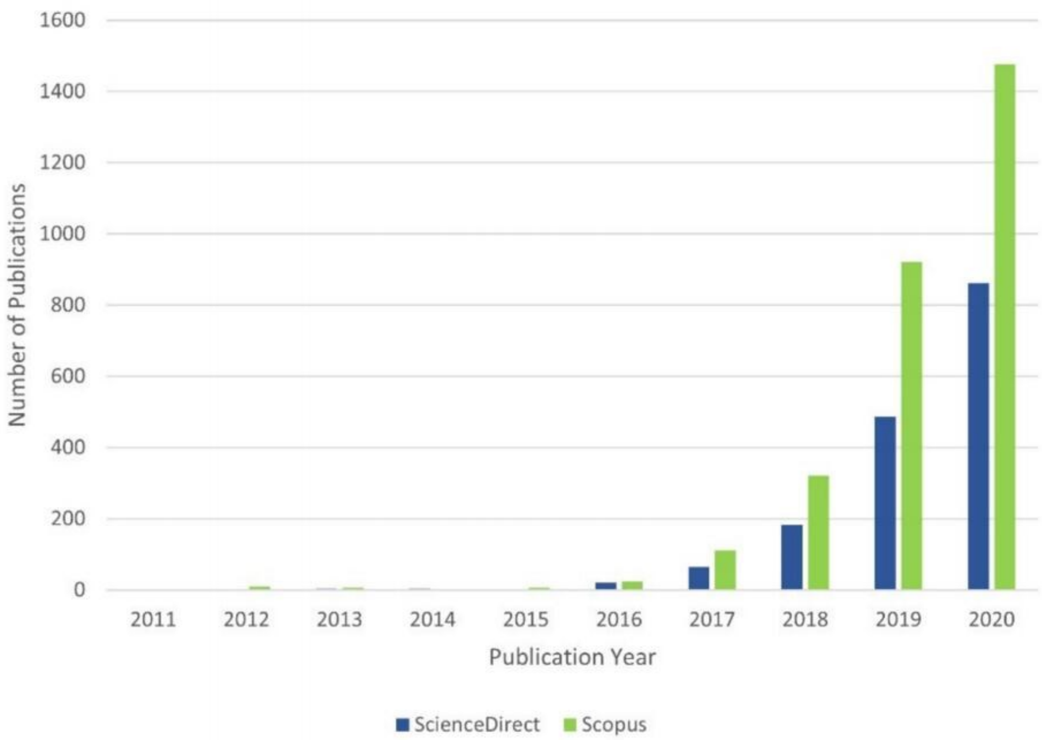

Figure 1: Number of publications relating to digital twin between 2011 and 2020 [9]

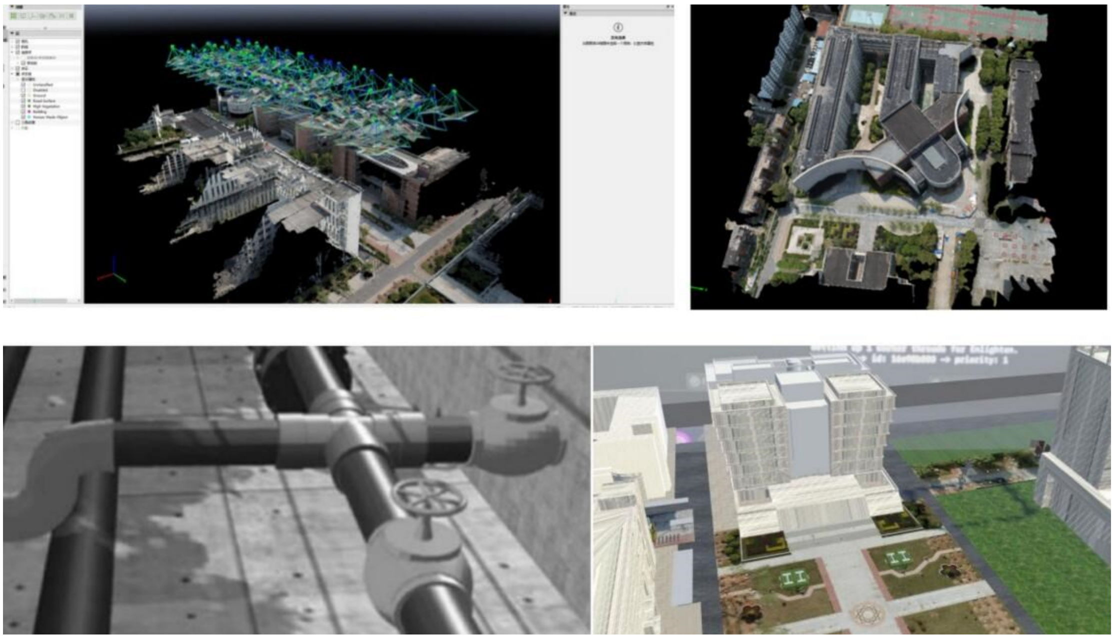

Figure 2: Digital twin campus model [12]

Digital twins have been gradually used in construction in recent years. However, the historical development of the digital twin (DT) concept is relatively new. Due to its relatively late development history, the development of digital twins in infrastructure and construction is in its infancy [13]. Therefore, the current methods of constructing digital twin buildings are also insufficient.

3. 3D Laser scanning technology

In recent years, some methods of digital twins have emerged, particularly most of the methods implemented through BIM [14]. 3D Laser scanning technology is a good data collection method, which, coupled with advanced point cloud synthesis software systems, gradually attracts attention in the field of constructing digital twin buildings. The main operating principle of 3D Laser scanning is that it can quickly capture object shapes and provide high-density 3D point clouds by performing high-speed measurements. 3D point clouds are created on geometric samples on the object's surface and can be converted into informational images by applying complex software systems [3]. Therefore, this technology demonstrates considerable utility in the identification of objects with irregular geometries [15].

There are many advantages of 3D laser scanning. 3D laser scanning technology facilitates the generation of accurate three-dimensional digital representations, thereby enhancing the efficacy of architectural refurbishment and design processes. The 3D scanning (Figure 3) used in this research can capture field data at least a rate of 500,000 points per second, helping to paint a thorough picture of sophisticated architectural features. Compared with traditional civil engineering surveying methods, this capability that can precisely map sophisticated structural corners (often difficult to quantify with traditional tools) mean it can increase the efficiency of digital twin model building and make the final digital twin model more exact. In addition, the 3D scanner used in this research needs to use a 100mm Scanner Sphere when scanning. These positioning spheres will become reference sites in the point cloud synthesis software. The fixed-point method using a stationary positioning ball as a base station can be spliced into an accurate visual 3D model, which is more accurate than directly identifying different images because the extraction of elements is more obvious.

Figure 3: The 3D scanning

However, the adoption of 3D laser scanning technology among construction management professionals across various projects has not reached the level of prevalence with Building Information Modelling (BIM) [16]. One factor is that 3D laser scanning is so expensive. The other factor is that the inability to update original data promptly due to the lack of timely data synchronization can negatively affect building management during the subsequent repair and maintenance of structures (whether second, third or any subsequent event). In addition, the process of building maintenance or renovation requires empirical investigation and remeasurement at the actual site. That means that this intervention may affect the normal use and management of the building.

4. Mixed Reality in Civil Engineering

Mixed reality (MR) is a synthetic environment that can project elements of virtual space into real space and combine them with real objects in real space to build the 4D information model [17]. Mixed Reality (MR) represents a technological innovation that combines components from both Virtual Reality (VR) and Augmented Reality (AR), creating an artificial environment that seamlessly integrates the virtual realm with the physical realm. MR facilitates heightened immersion across multiple areas, encompassing areas like traditional gaming, tabletop role-playing games (TTRPGs), interactive, cooperative spaces, and the representation of data. The application of Virtual Reality (VR) systems proves beneficial within the realms of Architecture, Engineering, and Construction (AEC) [18]. It can be speculated that MR can provide enhanced immersive experiences in building construction. Moreover, by merging virtual and real-world elements, MR can create an interactive and evolving space for users to experience and engage with.

Mixed virtual reality (MR) offers several advantages in the construction industry. It facilitates better dialogue and teamwork among those involved in the project, leading to enhanced performance and increased efficiency [19]. MR supports 3D visualization of complex structures, aiding in design flexibility [20]. Moreover, it streamlines the management of resources, the detection of risks, and the adoption of digital processes, resulting in enhanced planning and implementation of projects [21]. Because MR can be used for data sharing, efficient communication, and helping workers understand and guide their operations, additionally, it enables simulation and real-time interaction, enhancing work efficiency and improving disaster management and prevention. The implementation of MR in construction can lead users to a better understanding of projects, cost reductions, and enhanced user experience. These benefits contribute to the automation and digitalization of the construction sector, promoting efficiency and productivity.

However, Mixed VR also has flaws. Most commercial AR/VR/MR software lacks an automated pipeline from engineering design documents to the digital model, preventing real-time communication between designers and other project stakeholders. The VR helmet used in this study will combine with the digital twin model to realize the application of mixed virtual reality in construction and solve problems with technological updates in the civil engineering industry.

5. Conclusion

This research discusses how the digital twin campus can be realised by combining virtual reality, 3D laser scanning and BIM technologies. The main goal of this research is to test the feasibility of a digital twin campus and to test the effectiveness of a hybrid combination of multiple technologies. Finally, the digital dual campus will be realised through virtual reality, 3D laser scanning and BIM technologies. However, literature on Mixed Reality (MR) applications in this sector is notably scarce, showing that its potential is yet to be fully realized. And the practical cases about digital twins are also rare, so the cases and documents that can be referenced are still insufficient, and the practical design plan of this study is not perfect.

In conclusion, the civil engineering industry is poised to enter a new era marked by increased levels of intelligence and automation. The integration of digital twin and mixed reality technologies is expected to revolutionize the sector, enhancing efficiency, safety, and productivity. This research will provide innovative research solutions and insights and is expected to contribute to the technological upgrading of the civil engineering industry.

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