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Automation of Historical Buildings: Historical Building Information Modeling (HBIM) based Virtual Reality (VR)

Keltoum OUMOUMEN[1,a *], Fatima ABOUBANE[1,b], Younes ECH-CHARQY[1,c]

[1]Energy, Engineering, Materials and Systems Laboratory (LGEMS), Department of Civil Engineering, National School of Applied Sciences, Ibn Zohr University, Morocco

[a]keltoum.oumoumen@edu.uiz.ac.ma, [b]fatima.aboubane@edu.uiz.ac.ma, [c]y.echcharqy@uiz.ac.ma

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Abstract. Every civilization's constructed legacy, identity, and history require the cooperation of several specialists and a historical database to be preserved and passed on to future generations. The difficulties of maintaining and preserving these old buildings have been successfully handled by the integration of contemporary technology. Historical Building Information Modeling (HBIM), a branch of BIM that deals with the complexity of built heritage, acquires, manages, models, and documents specific data. Virtual reality (VR) provides the benefits of intuition, realism, and teamwork. Combining HBIM and VR improves historical building visualization, analysis, comprehension, and communication, resulting in a more effective conservation process. This paper, reviews the capabilities of VR and HBIM technologies, focusing on their impact when combined in heritage conservation practices. The aim is to determine the current state of development of VR technology in the field of existing historical buildings and to identify the challenges and limitations of its application.

Introduction

The built heritage, the identity of every civilization, witnessing every country's rich cultural and architectural history [1], needs great efforts of preservation to protect this richness from extinction and help pass it on to future generations. Given the uniqueness of each historic building, the requirement for the collaboration of several specialists, and a historical database and records, the heritage conservation process becomes complex [2]. Calling for the digitization of the maintenance phase using advanced technologies such as building information modeling (BIM) and virtual reality (VR).

While BIM, an innovative method of information and data management of a building lifecycle, fulfills usual, new, and Smart construction needs. Historic buildings, characterized by complex shapes and irregular materials carrying symbolic meanings and originating from historic changes [2] require a sub-field of BIM designated the "Historic Building Information Modeling" to provide the missing historical aspect in the standard BIM [3]. The HBIM intervenes to treat existing buildings and to preserve the architecture and structure of heritage buildings without affecting their identity. The VR technology complements HBIM by offering intuitive, realistic, and collaborative simulations improving the heritage building's visualization, analysis, understanding, and communication.

To study the usefulness of Virtual Reality technology and its development in the field of existing buildings, this paper was structured as follows, the research generalities including definitions of the HBIM and VR technologies are presented in Section 2, and the data collection methodology and publication distribution are detailed in Section 3. Section 04 contains a discussion of the challenges of VR implementation in the field of existing building conservation and its future developments. The conclusion is finally mentioned in Section 5.

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Generalities

VR

Virtual Reality (VR) including various applications and experiences giving to users virtual immersive environments (VIE), is derived from the "Man-Machine Graphical Communication System", and it is a part of the continuum RV [4] divided into four levels: Reality Environment (RE), Augmented Reality (AR), Augmented virtuality (AV) and Virtual Environment (VE). Achieving the VR level depends on the VE quality, its visuality and immersion, and the level of the user's sensation and feedback realism. The VR use in the AEC industry was dedicated to design, safety, project management, site layout optimization, collaboration, and understanding of complex designs [7]. This field's research has been developing since 1995, determining future directions including adaptive design, information systems, integrated human factors in construction training, facility management, and industry adoption, along with types of VR devices such as stationary, head-based, and hand-based displays[8]. Performance evaluation of hardware components and their effect on the VR experience is an area of continuous study [9].

HBIM

The HBIM is the extension of the BIM technology for existing historical buildings, focusing on the accurate collection and management of the various types of information and data related to built heritage [10], including structural, architectural, technical, and historical which are characterized by their complexity, uniqueness, and inter-project differences. First identified in 2009 by Murphy et al [10] to establish a vast database serving to heritage management, preservation, and communication. It includes essential data for heritage building preservation, such as geometric data, architectural syntax, materials characterizing, degradation representation and typologies, damage study, and environmental parameters [11]. The HBIM technology enables this data to be documented and integrated into a digital computer model accessible to all stockholders of the project, offering benefits in terms of sustainable preservation, lifecycle assessment, 3D visualization, and structural analysis. The HBIM process includes data acquisition, data processing, and the creation of a parametric database, producing a complete HBIM model.

Research methodology and publications distribution

This study was achieved by analyzing 57 research papers related to the intersection of VR with BIM and 13 papers on its intersection with HBIM. These papers included journal articles, conference papers, and academic documents from the Science Direct database. The paper selection process involved different steps, starting with keyword searches for "VR", "Virtual Reality", "BIM" and "HBIM", subsequently refined based on an examination of keywords, titles, and abstracts as shown in Fig 1.

The analysis revealed an increasing publishing trend relating to VR in the context of BIM picking in 91 articles in 2022. In contrast, VR publications in HBIM were comparatively limited, starting in 2018 and increasing gradually to seven articles in 2022, as illustrated in Fig 2.

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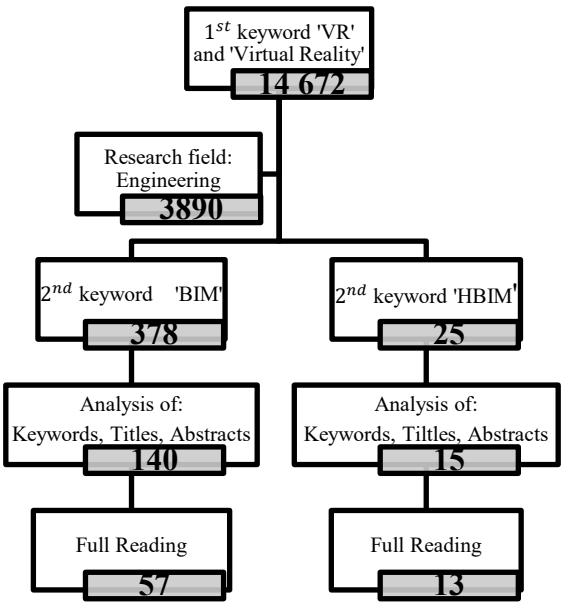

Figure 2: Paper extraction methodology

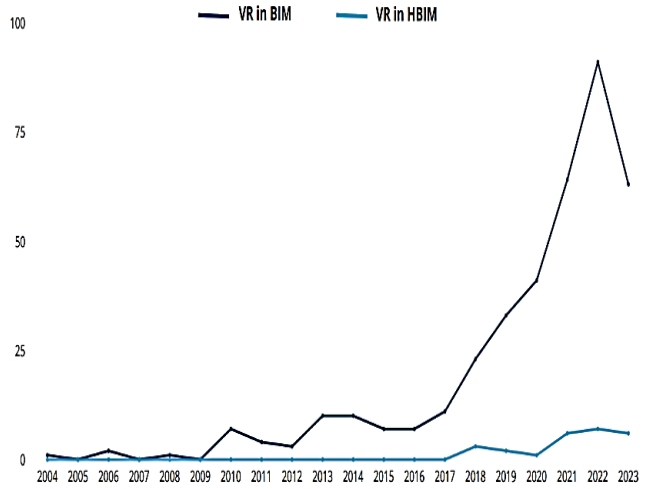

Figure 1: The VR literature progress in the BIM and HBIM context

Discussion

The application of VR in the Architecture, Engineering, and Construction (AEC) industry has varied purposes in the context of BIM compared to the context of HBIM. In the context of BIM, VR is largely applied in areas such as design, construction safety, training, building management, stakeholder coordination, and energy optimization. While the VR in the context of HBIM is currently used specifically for virtual representations, risk management, operation, and maintenance of historical buildings. The historical buildings, being a unique construction with special architectural features, materials, construction methods, and history, conserving the historic integrity of these buildings has more of stakeholder's interest and priority over other applications. As well as this uniqueness generates difficulty in applying modern techniques, lack of detailed information required, and limits to structural modification, in addition to the need for a substantial renovation budget, specialized tools and expertise, and detailed regulations.

HBIM technology creating detailed models of historical buildings, serving two main purposes: operation and maintenance. In the operational phase, it focuses on the use of story-telling for educational and tourism purposes, while in the maintenance phase, it aims to provide predictive maintenance of structural and architectural aspects, although this area requires more research and development. VR technology, while valuable for visualizing building elements, is more widespread as well in the operation phase than in the maintenance phase. Its integration into HBIM makes it possible to move from short-term objectives to a long-term approach aimed at understanding the building's behavior over time, with detailed models in the structural and MEP fields. To achieve this, a comprehensive digitization process is suggested, using a centralized model and collaborative platforms such as BIM 360, with continuous updates by architectural, structural, and engineering professionals for efficient maintenance. VR plays a crucial role in simplifying the interpretation of technical details for those unfamiliar with the HBIM method, but several challenges need to be overcome, divided into three main phases: the HBIM process itself, the transfer of data to VR platforms, and the lack of compatible VR platforms with civil engineering needs.

VR applications in BIM and HBIM face similar challenges, such as high device costs, software limitations, data complexity, interoperability issues, data management and security issues, and

standardization issues. This underlines the importance of further research into virtual reality simulation and the effective preservation of historic buildings using VR.

Conclusion

The application of VR technology in the context of historic building information modeling (HBIM) presents both opportunities and challenges for the use and preservation of historic buildings. It enables visualization and interaction with historic buildings, offering benefits in education, tourism, and maintenance through VR presentations. However, it faces challenges related to the complex structural and architectural aspects, unique materials, and historical significance of these buildings, as well as issues of data collection, interoperability, standardization, and expertise. These challenges also have an impact on the development of VR application areas such as structural maintenance.

To fully exploit the potential of VR in HBIM and extend its applications, further research, and development are essential. This includes automating historic documentation processes, developing standard data and formats specific to historic buildings, and improving the accessibility of the technology and associated tools.

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