BIM-Based Repair History Management for Architectural Heritage

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Wooden architectural heritage, which is typically heavily influenced by climatic factors such as temperature and humidity, relies on information contained in records and reports, including past repairs and physical measurements, to analyze the cause of damage and determine potential repair and conservation measures.

architectural heritage | historic building information modeling | repair history database

1. Introduction

Wooden architectural heritage, which is typically heavily influenced by climatic factors such as temperature and humidity, relies on information contained in records and reports, including past repairs and physical measurements, to analyze the cause of damage and determine potential repair and conservation measures. In particular, architectural heritage management and conservation plans that rely on records from the past that remain undigitized for long periods of time suffer from fragmentation and missing information over time [1]. This, in turn, makes it difficult to restore and preserve cultural heritage in its original form, and can lead to a decline in cultural value as well as subsequent economic losses [2].

The use of digital technologies, such as building information modeling (BIM) systems, can serve as a solution to this issue by replacing manual records and managing construction data throughout a building's lifecycle. BIM systems can also function as integrated management systems, linking geometry and attribute information for efficient data processing [3]. Especially for wooden structures, the continuous accumulation of information and data-driven decision making are critical for maintenance and preservation. Recent incidents, such as the fires at South Korea's Sungnyemun Gate and France's Notre Dame Cathedral, underscore the global necessity for digitally integrated maintenance systems.

BIM has emerged as a new area of interest in the cultural heritage domain, and it is commonly known as historic or heritage building information modeling (HBIM). Since its introduction by Murphy et al. [4], HBIM has been extensively developed with innovative applications at various levels in the fields of archaeology and architectural heritage. Despite significant advances in the past decade, the integration of conservation-driven heritage data management remains incomplete [5]. To enable the sustainable archiving of architectural heritage data, an advanced management system that combines a geometrical model with preservation-related data is necessary to support the operation and maintenance phases effectively. Identifying and digitally documenting the current state and properties of heritage building components, along with all pertinent semantic information in a singular HBIM

model, will establish a collaborative information management platform that optimizes the operation, preservation, and reconstruction stages [6]. This not only helps stakeholders make effective decisions throughout the lifecycle, but also furnishes a comprehensive overview.

2. Framework for BIM-Based Repair History Management for Architectural Heritage

Heritage structures demand appropriate preservation and safeguarding measures to retain their intrinsic worth and significance. Notably, the utilization of conservation and restoration techniques grounded in original and traditional approaches, while respecting culturally significant values and evolving authenticity, is imperative. These viewpoints regarding cultural property conservation policy and practice are comprehensively outlined in the Venice Charter [7], the Burra Charter [8], and the Nara Document on Authenticity [9]. The principles of conservation are centered around safeguarding the cultural significance of a building, and guidelines are established to ensure the preservation and maintenance of the structural integrity of a building [10].

Preventive maintenance is a necessary set of routine tasks that extend the longevity and optimize the performance of historic structures, creating a sustainable legacy for future generations. These regular maintenance measures are crucial for preserving built heritage. Restoration techniques aim to efficiently restore the functional and cultural value of architectural heritage to its original state as closely as possible. For instance, when dealing with wooden architectural heritage, it is crucial to develop a restoration plan that preserves cultural heritage's utmost originality. This may involve repairing or replacing certain wooden elements damaged by environmental factors and establishing an efficient process that minimizes resource, time, and cost usage; however, the issue arises that managing the as-built information necessary for performing maintenance and restoration activities, along with the accumulated repair information, is challenging to integrate [11].

Building information modeling is the process of creating and utilizing building data throughout the lifecycle of a construction project. The functional model of a typical BIM system encompasses the efficient digital documentation of a building's physical and functional features within an integrated environment and the operational management of various facilities. The full-scale implementation of BIM in the architectural heritage sector is hindered by the complex geometry of heritage buildings and the non-standardization as well as diversity of part types, despite its potential benefits and uses. Unlike traditional construction projects, where BIM information is generated throughout the planning and construction processes, architectural heritage structures are already built and necessitate a precise post-modeling phase. Specifically, historical, environmental, and archaeological data must be collected independently and digitized to facilitate the operation and upkeep of the building. Therefore, it is essential to establish a framework for creating a precise 3D digital model along with merged maintenance data, encompassing damage, repair, and refurbishment.

Figure 1 presents an overview of the existing and overlapping literature concerning BIM, heritage buildings, and facilities' management as well as preservation. The circles depict research topics, and the bullet points within the rectangular boxes illustrate the research focus or overlap of each topic. Building information models utilize the

OpenBIM standard to store a wide range of building properties as an information model, encompassing geometric data, non-shape attributes, project planning, and lifecycle management [12][13]. This method aligns with the fundamental concepts of object-oriented programming and modeling. In the context of heritage architecture, the HBIM concept has been used to model, document, and conserve historical structures. Several studies have investigated the implementation process and techniques of HBIM [14][15][16][17][18]. They have also examined its benefits and drawbacks in improving maintenance and operational efficiency. Furthermore, studies have investigated the incorporation of cutting-edge technologies and equipment, such as laser scanners, photogrammetry, and visual programming, into HBIM [19][20][21][22]. In the realm of the facility management of heritage buildings, there have been studies on data utilization methods to support decision making for building maintenance. These include structural [23][24] and condition analyses [25][26] of heritage buildings by integrating lifecycle data into HBIM. Methods to ensure data sharing and mutual compatibility for planning maintenance and restoration actions based on the integrated information of historic buildings for BIM have also been researched [27][28]. Furthermore, diverse web platforms were developed to promote cooperation and collaboration among the different stakeholders involved in the restoration and maintenance activities of built and cultural heritage sites, by integrating historical and geometric information and heritage documentation databases [29][30][31]. These HBIM case studies address issues related to modeling complex architecture, accurately documenting historic buildings, and creating data structures suitable for modern HBIM for an online platform. Although various technologies and applications have been explored in numerous studies, there is still a research gap in the application of BIM to preserve and manage heritage buildings. Most studies related to HBIM maintenance involve different technologies and application cases, but few focus on creating an organized BIM-based maintenance database, transferring non-shape data, or establishing maintenance procedures through attribute information, all of which are advantages of BIM. Furthermore, the discussion on the use of BIM for the preventive and repair maintenance of heritage buildings is limited.

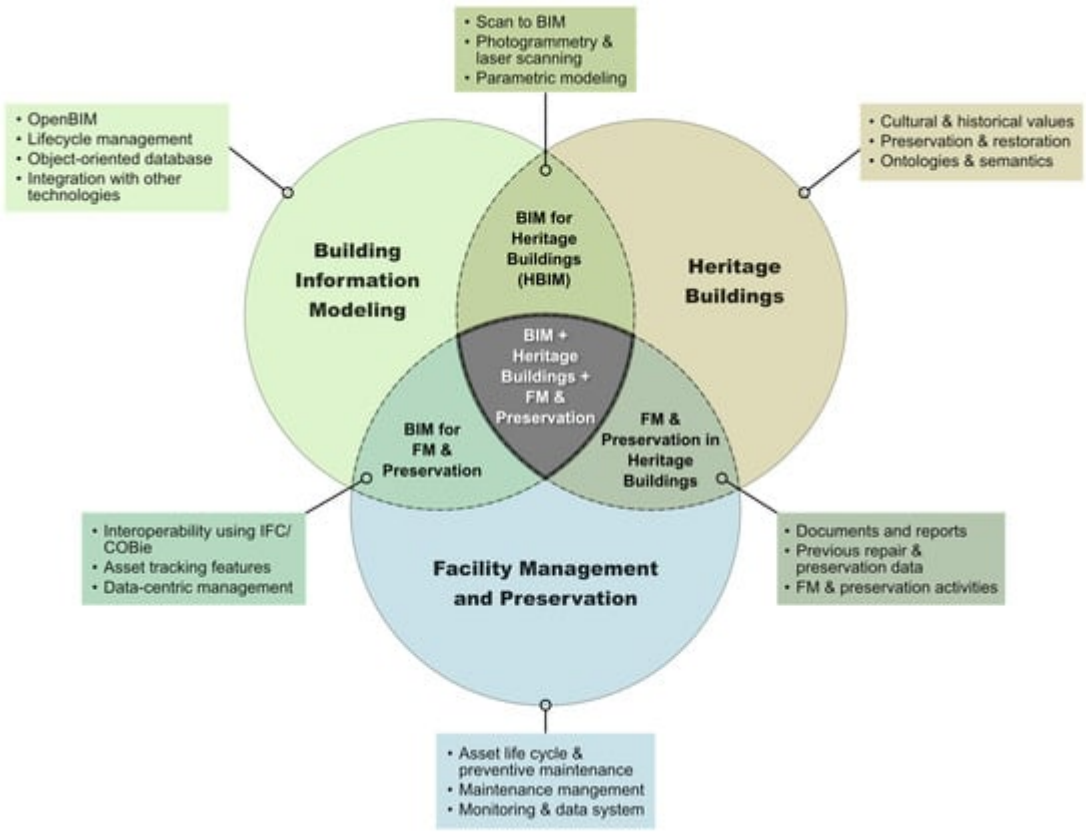

Figure 1. Literature analysis Venn diagram.

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