Digital Built Heritage Representation and Documentation: A Systematic Mapping of Platforms and Hybrid Models

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Abstract – **The growing interest in art history, architecture, and urban history, combined with international initiatives promoting cultural heritage digitization, has underscored the importance of digital platforms for documenting and managing built heritage. This paper presents a systematic literature mapping of recent scientific production on digital tools applied to architectural heritage. Through a review of methodological approaches, the study highlights key trends such as metadata-based modeling, semantic data integration, and real-time systems. Results reveal the application of advanced technologies, like laser scanning, computer vision, drones, and BIM/CIM integration, for multi-scale documentation, from individual buildings to urban contexts. Terms like hybrid and integrated describe workflows linking representation, simulation, and generative design. The concept of virtualization, particularly in digital twins, is prominent for proposing comparative analyses and unified data management systems. This research contributes to understanding the interplay between traditional preservation practices and innovative technologies, offering pathways for interdisciplinary heritage interpretation and documentation.**
Keywords: Cultural heritage, digital platforms, architectural documentation, Digital Documentation of Built Heritage.

I. INTRODUCTION

The increasing engagement with art history, architecture and urban history, together with the digitization of cultural heritage promoted by international initiatives, as well as by collaborative international projects focused on heritage digitization such as those by the United Nations Educational, Scientific and Cultural Organization (UNESCO), has led to the development of inventories, cataloguing systems and specialized digital tools for documenting, managing and investigating cultural heritage. Digital platforms have, thus, taken on a strategic role in mediating the production, organization and dissemination of information by offering expanded access to integrated databases and digital repositories.

Cultural heritage management, particularly regarding material assets, is faced with the challenge of dealing with significant volumes of heterogeneous and fragmented information, which requires structured approaches to research, documentation and organization. The construction of digital models of cultural assets requires the definition of specific metadata descriptors, which are essential for interpreting, making interoperable and disseminating digital content. In this sense, metadata gives digital models an identity and links them to other sources of information, enabling their reuse and the development of comparative and interdisciplinary analyses.

The intersection of theoretical foundations, documentation methodologies and technological applications has led to more comprehensive results in the documentation, analysis and interpretation of built heritage. Innovative technologies such as 3D modelling, laser scanning, large-scale data capture systems and machine learning algorithms have proven indispensable for reconstructing design processes, analyzing the form and spatial characteristics of buildings, and simulating morphological features at multiple scales. Methods for acquiring and processing digital data and developing

metadata schemes are important for meeting the requirements for representing, managing and valuing the tangible and intangible aspects of architectural heritage.

Against this backdrop, this article presents the results of a systematic literature mapping aimed at identifying, categorizing and analyzing the key themes, methodological approaches and emerging trends in recent scientific output concerning the use of digital platforms in the context of built architectural heritage. The research also seeks to understand how the challenges and potential associated with the digitization of built heritage have been addressed in research, paying special attention to the creation of repositories and integrated management systems.

II. RESEARCH METHODS

This research reviews, systematizes and classifies scientific papers on the topic of digital platforms and hybrid models for built heritage documentation and representation published between 2011 and 2024. Documents were retrieved using Scopus database.
Focusing on the production and management of these digital platforms, the analysis considered criteria such as hybrid and integrated methodologies, including 3D modeling, point cloud capture and processing, simulations, and the use of emerging technologies such as machine learning and digital twins. The search string included the following key terms: "architectural heritage," "digital representation platform," and "hybrid model," as well as concepts related to "data acquisition", photogrammetry, "digital documentation", and "point clouds". The aim was to review methodological advances in the area, with an emphasis on platforms that integrate massive data and offer solutions for the management and representation of built heritage. This research included documents that were open access covering areas such as engineering, humanities, environmental, computer, and social sciences. VOSviewer software, version 1.6.20, was used to conduct a bibliometric analysis to identify important authors, organizations and references in the field; common topics and key-words. The content of the documents were reviewed to systematize the platforms, tools, applications, workflows and methods they used aiming at subsidizing their application to research and practice.

III. RESULTS

The final sample of 34 documents highlights technological and methodological advances in digital documentation, with applications in fields such as civil infrastructure; transportation infrastructure; building analysis and material specifications; digital twins; archival, and documentary and iconographic collections; urban history, and virtual technologies for museums and collections. Furthermore, the sample discussed web platforms, augmented reality, automation, neural networks, and machine learning, as well as classification

systems and metadata standardization for 3D models.

The documents also characterized specific processes in the field, such as point cloud segmentation, translation and conversion of file extensions in BIM and CIM platforms, and the use of computer vision technologies, sensors, laser scanners, and drones. These methods were analyzed in relation to their applicability at different scales, from individual buildings to the urban level, considering the processing of massive data and the integration of semantic information. Classifications based on the terms "hybrid" and "integrated" explored processes that connect representation and reconstruction, including simulations, verifications, and generative design. The concept of virtualization emerged in studies of digital twins, pointing to the proposition of parameters, comparative analyses, and unified systems for real-time data capture and management.

The 34 documents were analyzed using VOSviewer. Figure 1 represents a map of co-occurrring terms in the sample, created using textual data from titles and abstracts, retrieved from the OpenAlex API. Only terms co-occurring a minimum of three times were included in the analysis; the final sample was manually cleaned to removed further irrelevant terms. The figure illustrates a shift in focus in the from Building Information Modeling and BIM to Digital Twins after 2022. Management, virtual environments and terrestrial laser scanning have also gained traction after 2023, possibly related to the budding interest in digital twins.

A. Emerging Themes Over Time

Text map using title and abstracts from OpenAlex API, binary counting, co-occurring a minimum of 4 times in the sample (24 out of 1142). Final terms were manually selected based on their relevance (14 out of 68). Terms are weighted by number of co-occurrences. The color overlay represents the average publication date.
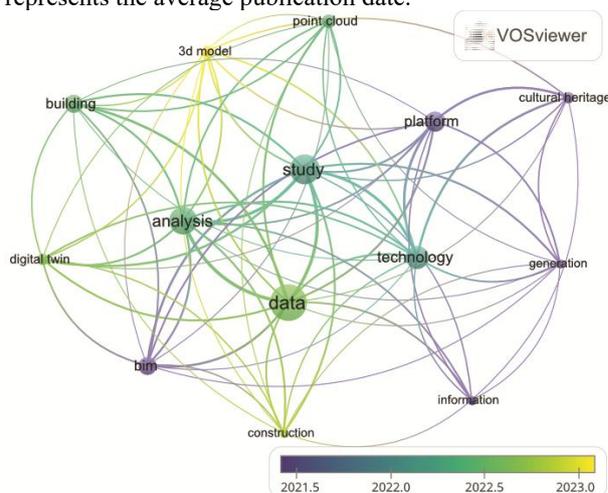

Fig. 1. Synthetic visualization representing the semantic structure of key research topics in digital

documentation of built heritage. The arrangement illustrates the conceptual proximity between terms, weighted by co-occurrence frequency, with color coding denoting average publication dates to reveal thematic evolution over time

B. Conceptual Linkages and Emerging Themes in Digital Heritage Documentation

The analysis of the co-occurrence of concepts used by the authors as key-words, shown in Figure 2 illustrates the nascent interest in the use of artificial intelligence (AI) in relation to photogrammetry, point clouds, geometry and visualization, due the need for more efficient segmentation and geometry generation procedures, that can be improved with AI. However, the questions of reliability and precision remain challenging. Civil and architectural engineering key words are strongly related to BIM and interoperability, with terms such as political science, world wide web and data science illustrating a new interest in using these tools for urban management and public participation. Cultural heritage and archeology are strongly related to augmented reality, showing and interest in visualization techniques.
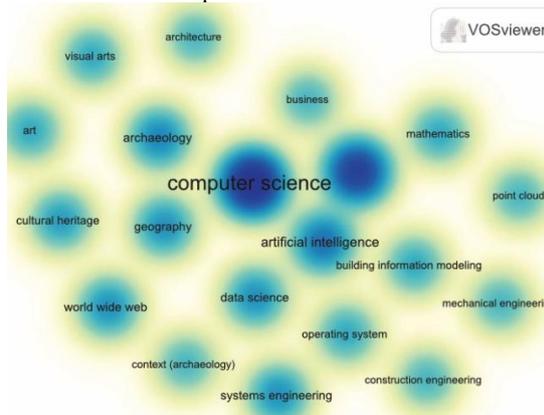

Fig. 2. Co-occurrence of concepts OpenAlex API data, with a minimum of 5 occurrences in the sample (20 key words from 214).

C. Bibliographic Coupling by Authors

Bibliographic coupling by authors illustrates a limited level of coupling, illustrating a heterogeneity and a low level of collaboration between research groups, as well as reduced research continuity in the sample (Figure 3).

D. Bibliographic Coupling by Countries

This collaboration and reference use are limited to Spain and Italy, which appear prominently in the sample, with contributions from Brazil and Portugal (Figure 4 and 5).
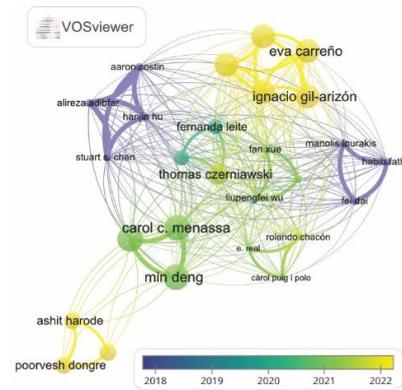

Fig. 3. Bibliographic coupling by authors using OpenAlex API data, with authors with a minimum of 20 citations in the sample (33) limited to the largest connected set. Weighted by normalized citations. The color overlay represents the average publication date.
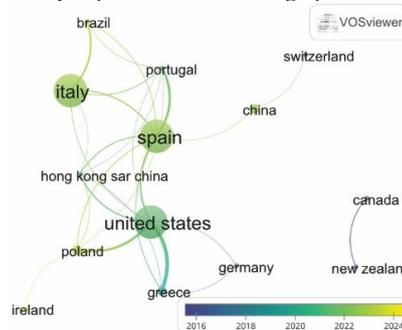

Fig. 4. Bibliographic coupling by countries with OpenAlex API Data, using all countries in the sample. Weighted by normalized citations, color overlay by average publication date.

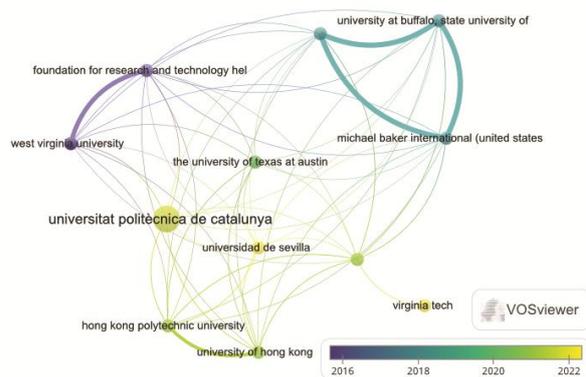### E. Bibliographic Coupling by Organizations

Fig. 5. Bibliographic coupling by organizations with a minimum of 20 citations using OpenAlex API data, limited to the largest connected set organizations. Weighted by normalized citations, color overlay by average publication date.

F. Bibliographic Coupling by Co-Citation Analysis

Figures 6 demonstrates the limited co-citation of authors in the sample, further illustrating a lack of continuity to previous research and seminal works. The most co-cited research papers in the sample are "Toward automated generation of parametric BIMs based on hybrid video and laser scanning data" by Ioannis Brilakis et al., 2010 and "Building Information Modeling (BIM) for existing buildings — Literature review and future needs" by Rebekka Volk, Julian Stengel, Frank Schultmann from 2014.
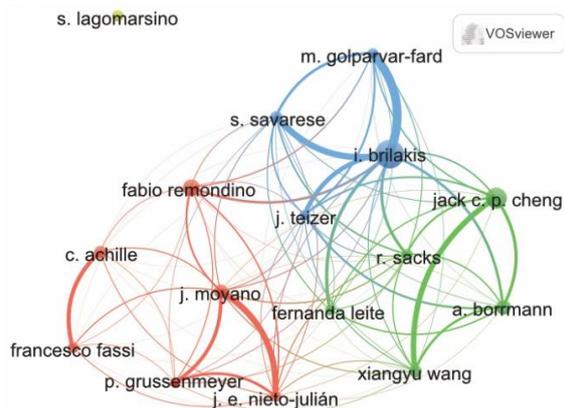

Fig. 6. Co-citation of authors analysis using Semantic Scholar API data, limited to authors cited at least 10 times in the sample (16 out of 4690 cited references).

IV. CONCLUSIONS

This study was based on the Systematic Literature Mapping (SLM) methodology and aimed to identify and analyze the main methodological advances, technological applications, and emerging trends in the digital documentation of architectural heritage between 2015 and 2024. The analysis of 34 relevant studies revealed significant growth in scientific output during this period, particularly in recent years. This growth has been driven by international demand for the digitization and preservation of cultural heritage, influenced by initiatives promoted by UNESCO and other international and national agencies, as well as through international cooperation projects for heritage digitization.

When applied in a hybrid and integrated way, digital platforms have proved to be tools for addressing the challenges related to the representation and management of built heritage. Technologies such as 3D modelling, photogrammetry, point clouds, artificial intelligence, BIM/CIM and digital twins have been employed to collect, simulate and interpret data at various scales, ranging from individual buildings to urban complexes.

The use of metadata and semantic schemes is crucial for ensuring interoperability and interconnection with other sources, as well as the reuse of digital models in different contexts. Classifying and segmenting point clouds, and translating formats for BIM and CIM environments, are important technical advances, particularly with regard to

creating integrated systems and repositories that are accessible to multiple audiences.

In conclusion, the intersection of theoretical approaches, documentation methodologies and technological applications has increased the capacity to represent, analyze and preserve built heritage. Additionally, there is a growing trend towards virtualization and the adoption of dynamic computer models that can simulate the physical and historical conditions of cultural assets in real time. Against this backdrop, the development of integrated, semantically enriched digital platforms is emerging as a promising strategy for the intelligent, interdisciplinary management of architectural heritage. This approach opens new avenues for research, heritage education, and the development of public policies.

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