

DIGITAL HORIZONS IN HERITAGE MUSEUMS: A COMPARATIVE ANALYSIS OF DISPLAY EVOLUTION AND RESEARCH TRENDS

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ABSTRACT

The construction and development of museums have gained increasing attention as a prominent research topic in recent years. Digital technology has enhanced the presentation of artefacts across various museums. However, adequate visualisation software for analysis in heritage museum research remains lacking in China or even around the world. Consequently, this study conducts a statistical analysis of literature on heritage museum displays that was sourced from Web of Science and CNKI (China's National Knowledge Infrastructure) for 2002–2023, examining publication frequency, principal authors, research institutions, and keywords to identify research hotspots and trends. The results show that although there is a lack of study on historical museum exhibits both in China and abroad, the amount of research is trending significantly. Strengthening collaboration between core authors and institutions is necessary as it's currently limited. Internationally, AI research commenced earlier, with a focus on integrating augmented and virtual reality, among others. In China, the emphasis is on heritage museum conservation and architectural space research. Research trends indicate a deeper integration of heritage museums and AI technology, with its application on tangible and intangible cultural heritage proving significant for improved display, conservation, and legacy. This research provides insights for expanding heritage museum research in the areas of technological innovation and cultural heritage protection. It also outlines the current condition of heritage museum research and lays out fresh pathways for its future growth.

Keywords: Heritage museum, Display, Comparative study, CiteSpace, Digital Technology

INTRODUCTION

Relics are an important part of cultural legacy, offering a limited and invaluable geographic resource for understanding human origins, history, and culture (S. Macdonald, 2007). The heritage museum serves as a portal to ancient culture and a conduit for dialogue across time, enabling modern society to learn from the past, contemplate the present, and move forward the future (Huang, 2014). The heritage museum not only interprets and showcases the significance of sites within their environmental contexts but also fulfils roles in science popularisation, education, and recreation, amongst others. It offers a space for the public to gain knowledge, broaden their understanding, and immerse in the depth of human culture (Wang, et. al., 2019). In 2005, the State Administration of Cultural Heritage of China, in conjunction with the Ministry of Finance, established a dedicated fund for the conservation of major sites, allocated for their upkeep, management, and the implementation of model conservation projects. Subsequently, China's heritage museums have grown rapidly, reflected by the expansion in the number of museums and parks, enhanced exhibition quality, and a marked rise in social impact. Recently, the role of heritage museums has evolved, extending beyond conventional bounds, with exhibition forms and spaces embracing a broader remit than mere 'coverage' protection, thus diversifying the modes of display (Cao, 2018).

Concurrently, research into heritage museums has become more profound. Since 2005, the Longmen Grottoes Research Institute, among others, has effectively utilised three-dimensional digital technology for conservation and exhibition, accomplishing projects such as the Longmen Grottoes 3D film, virtual displays of the Fengxian Temple and Binyang Cave, and the creation of a three-dimensional digital virtual museum (Geng, 2018). In November 2011, the "Summit Forum on the Protection of Great Sites" convened in Jingzhou, resulting in the Jingzhou Declaration, which advocated for a renewed approach to site protection and exhibition, and the integration of these principles into the national agenda for cultural fortification. In 2017, the State Administration of Cultural Heritage's 13th Five-Year Plan for National Cultural Relics emphasised the "Network + Chinese Civilization" initiative. This involves leveraging digital technology's attributes—convertibility, restorability, reproducibility, and shareability—to reconstruct and exhibit site scenes and information (NCHA, 2017).

Consequently, this research analyses the literature from databases on both international and Chinese heritage museum displays, comparing publication volumes, key authors, collaborative institutions, and research focal points to delve into current trends and future directions in this domain. To clarify the present research landscape and address prevailing ambiguities, this study employs bibliometrics and visual analysis to assess museum display research, using CiteSpace for visual knowledge mapping. It synthesises the Chinese and English literature, distilling the essential concepts and findings.

Consequently, this study focuses on analyzing the database literature concerning the display aspects of international and Chinese heritage museums. It delves into the comparative analysis of publication frequencies, pivotal authors, collaborative networks, and research focal points to unearth current hotspots and predict future trajectories within this domain. To gain a comprehensive understanding of the present academic landscape and its complexities, this research incorporates bibliometric and visual analysis methodologies. Utilizing the CiteSpace Visual Knowledge Mapping software, it illuminates the foundational status and progressive trends in heritage museum research.

METHODS AND TOOLS

This section explains the following aspects:

(1) selection of the research tools; (2) research data collection; (3) Parameter setting and analysis;

2.1 Selection of The Research Tools

This research used the CiteSpace 6.2.R4. Chen Chaomei, a professor of computer and information technology at Drexel University, developed the CiteSpace program in 2004 (Chen, 2016). CiteSpace is a knowledge visualization tool, designed for bibliometric analysis, that processes and visualises vast quantities of scientific literature data (Chen, 2016). This software facilitates visual citation analysis. Its visualization capability allows for the depiction of structures, patterns, and knowledge distribution within scientific texts, effectively creating a 'scientific knowledge map' (Chen, 2006). It enables same-citation, co-occurrence, cluster, and keyword burst analyses for scientific inquiry (Chen, 2006). The study utilizes CiteSpace to assess and visualise literature from the Web of Science and CNKI databases. It examines publication volumes, key authors, collaborative institutions, and keyword co-occurrence in heritage museum display research, aiding in comprehensively understanding the field's development and research focal points.

2.2 Research Data Collection

The data analysed was sourced by thorough searches of professional academic platforms, specifically the CNKI and Web of Science core databases. The search was comprehensive, starting from January 1, 2002, the year CNKI first indexed a document on heritage museums.

The CNKI database, being among China's most crucial and authoritative academic databases, was selected as the Chinese data source for this study. To enhance data analysis validity, a consistent search timeframe from January 1, 2002, to November 1, 2023, was adopted. This study takes the combination form of "site museum + display", and "site museum + exhibition" as the theme and searches for related literature in the CNKI database, and a total of 163 publications were retrieved with the following search formula: (主题%='遗址博物馆' or 主题%='遗址类博物馆') and (主题%='展示' or 主题%='陈列' or 题名%='展览' or 题名%='展陈') and (年 Between ('2002','2023')). In addition, to enhance the quality of the selected literature, this study refined search results by omitting conference proceedings, reports, and unrelated works, while also eliminating duplicates. Subsequently, 150 pertinent journal articles were identified for detailed analysis.

Within the WoS core collection, to guarantee document quality, three sub-databases: SCI, SSCI, and AHCI were specifically targeted. The advanced search employed the following syntax: (TS = (cultural heritage museum) OR TS = (heritage museum) AND (TS=(display) OR TS=(exhibition) OR TS=(exhibit) OR TS=(installation)). Searches were constrained to English language documents, specifically articles and reviews. The search, followed by manual refinement, yielded 789 pertinent documents.

2.3 Parameter Setting and Analysis

Prior to data processing, initial configuration in CiteSpace is required: (1) Determine the node type corresponding to the targeted analysis; (2) Time slicing was set from 2002 to 2023; (3) Each time slice was configured to a duration of 1 year; (4) Selection criteria were established for the top 25 entries, with other parameters left at default settings.

Next, after setting up the parameters, the three main paths were analyzed using CiteSpace software to address the research questions. The initial analytical pathway was publication quantity, comparing the volume of papers from CNKI and WoS to discern research trends over time. The second pathway entailed co-network analysis, facilitating a comprehensive understanding of the research landscape, including author and institutional collaborations. The third pathway involved keyword-based co-occurrence analysis, yielding a co-occurrence map that can highlight research hotspots in China and globally across various periods. The fourth pathway, keyword burst analysis, indicates rapid changes or dramatic increases in keyword occurrences, underscoring abrupt shifts in focus. It serves to identify the most dynamic research areas within a timeframe and to analyse current and trending topics.

COMPARATIVE ANALYSIS OF DESCRIPTIVE STATISTICS

This section provides a bibliometric analysis of the heritage museum research literature in terms of annual distribution of publications, core authors, and collaborating institutions, to present a basic picture of the development of heritage museum research from 2002 to 2023.

This section consists of a two-part discussion: (1) an analysis of the publication count across various timeframes, intended to offer an in-depth view of the research distribution dynamics over the past two decades and to evaluate the quality of the articles published; (2) an analysis of the co-operation between the core authors and the research organizations, which identifies prominent academics and institutions, as well as the character of their collaborative relationships.

3.1 Publishing Volume Analysis

The number of literature publications based on temporal distribution can offer a macroscopic perspective of the research field's developmental status (Dou, 2023). Figure 1 reflects the publication counts for heritage museum display research from WoS and CNKI databases between 2002 and 2023. Overall, the number of WoS publications has shown a significant growth trend over the past two decades, particularly since 2009, with the most growth occurring between 2019 and 2020. Judging from the publications in the CNKI, before 2013, research output on heritage museums in China was minimal, with annual publications generally in single digits, indicating a stable trend. From 2014 onwards, the number of publications began to grow significantly, and the number of publications fluctuated greatly from year to year.

In summary, the comparative analysis shows that China's research in the field of display of heritage museums started late; the number of fluctuations is high, but the overall trend is growing, of which the number of literatures published in 2021 is the largest. It reflects that in this research field, the academic attention to the study of heritage museums is low, and there is still a lot of potential for development in the future.

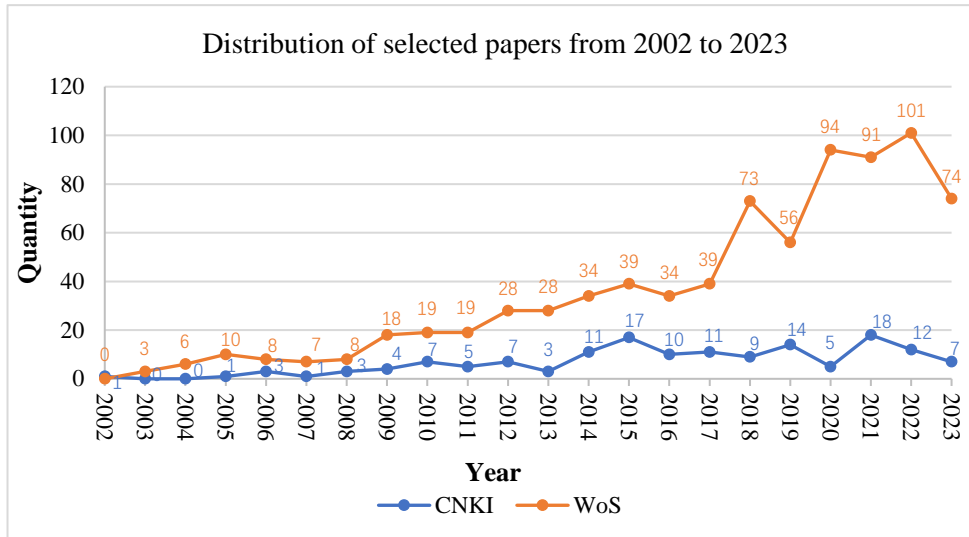


Figure 1. Distribution of selected papers from 2002 to 2023

3.2 Author Cooperation Network Map

An author cooperation network map was created using CiteSpace to help researchers understand the contributions and effects of authors in the field of heritage museum display research. This map serves to ascertain the publication frequency and collaboration intensity of the authors. In CiteSpace, the "Authors" node was selected, covering the period from January 2003 to November 2023, and the length of per time slice was "1". Enhanced visualization of author activity produced a co-occurrence map, facilitating analysis of author collaborations within the field. On the map, each node signifies an author; node size correlates with the author's publication frequency, and lines between nodes indicate collaborative relationships. Node size is indicative of the frequency of associated data occurrence; larger nodes denote higher frequencies (Chen, 2016). A link between two nodes signifies co-authorship on a publication, while a thicker line reflects a stronger collaborative bond (Chen, 2016). The author collaboration network map, characterized by thin and dispersed lines, suggests that most authors undertake research independently, with limited collaboration.

According to Price's law, half of the papers are authored by a subset of distinguished scholars who are numerically approximately equal to the square root of the total number of authors. The calculation formula is as follows:

$$M \approx 0.749 * (N \max)^{1/2}$$

Where N max represents the maximum number of papers authored by a single researcher within this field, the N max for heritage museum display research in WoS is determined to be $m=1.982$. Accordingly, authors with two or more publications are considered core contributors. The publication frequency of authors was recorded, identifying a total of eight authors with two or more publications. Due to space constraints, only those with a publication frequency greater than three are included in the text; refer to Table 1 for details.

Table 1. List of core authors in WoS

Ranking	Count	Name	First Year
1	7	Ilies, Dorina Camelia	2021
2	7	Ilies, Alexandru	2021
3	7	Caciora, Tudor	2021
4	5	Hodor, Nicolaie	2021
5	4	Baker, Sarah	2013
6	4	Grama, Vasile	2022
7	3	Ashley, Susan L T	2011
8	3	Antoniou, Angeliki	2018
9	2	Owley, Jessica N	2023
10	2	Guzel, Emine Torgan	2023

CiteSpace was used to quantify the authors in this field within the CNKI database and produce a mapping of their collaborative network, as shown in Fig. 2. The occurrence frequency of authors was calculated, revealing a maximum of four appearances (N max) within the CNKI. Applying Price's law yielded an M value of approximately 1.498, identifying authors with two or more publications as central to this field. Table 2 presents a list of ten authors who have published two or more papers. Figure 2 depicts thin and scattered lines, indicating that most authors predominantly engage in independent research with limited collaboration. However, small clusters of collaboration exist. Notably, Wang Xinwen has formed multiple research partnerships with Liu Kecheng, Du Le, and Wang Xiaomin. Under the direction of Wang Xinwen, this group has predominantly researched the functionality and design of site museum buildings, as well as the conservation and exhibition of cultural relics.

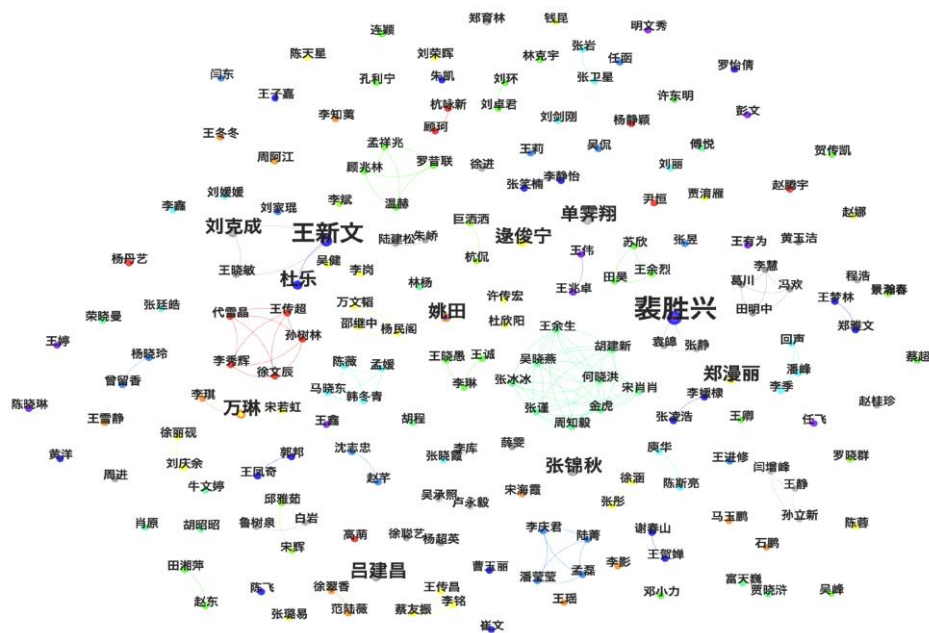


Figure 2. Author collaboration network map from 2022 to 2023 in CNKI

Table 2. List of core authors in CNKI

Ranking	Published Quantity	Name	First Year
1	4	Pei Shengxing	2011
2	3	Wang Xinwen	2012
3	2	Wu Xiaocong	2006
4	2	Shan Jixiang	2009
5	2	Lv Jianchang	2008
6	2	Du Le	2015
7	2	Yao Tian	2014
8	2	Zhang Jinqiu	2010
9	2	Liu Kecheng	2010
10	2	Wan Lin	2021

3.3 Institutional Cooperation Network Map

The network map illustrates the geographical spread of research influence within the field, with the publication count serving as an indicator of an organization's research capabilities (Hou et al., 2022). CiteSpace's collaborative network analysis tool provides heritage museum scholars with insights into the inter-institutional connections within the discipline. Analysing the output of heritage museum research entities facilitates an understanding of the field's institutional landscape and fosters scholarly collaboration and exchange.

In CiteSpace 6.2.R4, choose the "institution" node. Web links can represent institutional collaborations and provide a basis for the scientific evaluation of academic institutions. Figure 3 shows a network diagram depicting the distribution of research institutions in heritage museums, generated post-analysis. The node size corresponds to the research institution's publication output, while the link strength indicates the collaboration intensity between institutions. In the graph, nodes symbolise the origin institutions of site museum research literature; larger nodes and fonts indicate a higher publication volume from that institution. A connecting line between nodes signifies joint authorship by two institutions in a publication, denoting their collaborative partnership. Network density reflects the interconnectivity strength within a social network, influenced by the members' interaction frequency and proximity (Fu et al., 2009).

The literature from WoS was analysed while keeping other parameters static to produce a knowledge graph for heritage museum research institutions. Figure 3 depicts the resultant institutional cooperation mapping. The sample consists of 374 nodes and 247 connections, and the network density is 0.0035. Statistics on CNKI site museums and their collaborative networks within China are detailed in Table 3, which includes domestic institutions appearing two or more times. In China, 142 institutions have engaged in this research area, establishing 39 collaborative links, corresponding to a network density of 0.0039. Table 1 enumerates the fifteen leading research institutions by publication count, including museums and universities like Chengdu Jinsha Ruins Museum and Qinshihuang Imperial Mausoleum Museum. Specifically, Chengdu Jinsha Site Museum and Qinshihuang Imperial Mausoleum Museum top the list with the most publications, collectively amounting to nine articles.

After comparing, we discovered that there are a great deal of organizations and academic institutions studying heritage museums both in China and abroad, and that universities are the

primary research institutions in the field of heritage museum studies today. In China, while a select number of museums stand out for their literature contributions, universities are the principal document publishers in this domain. Furthermore, the field is quite fragmented with limited collaboration and interaction among research institutions. There is a need to bolster international and interdisciplinary collaborations, as well as academic exchanges, to enhance the global research landscape.

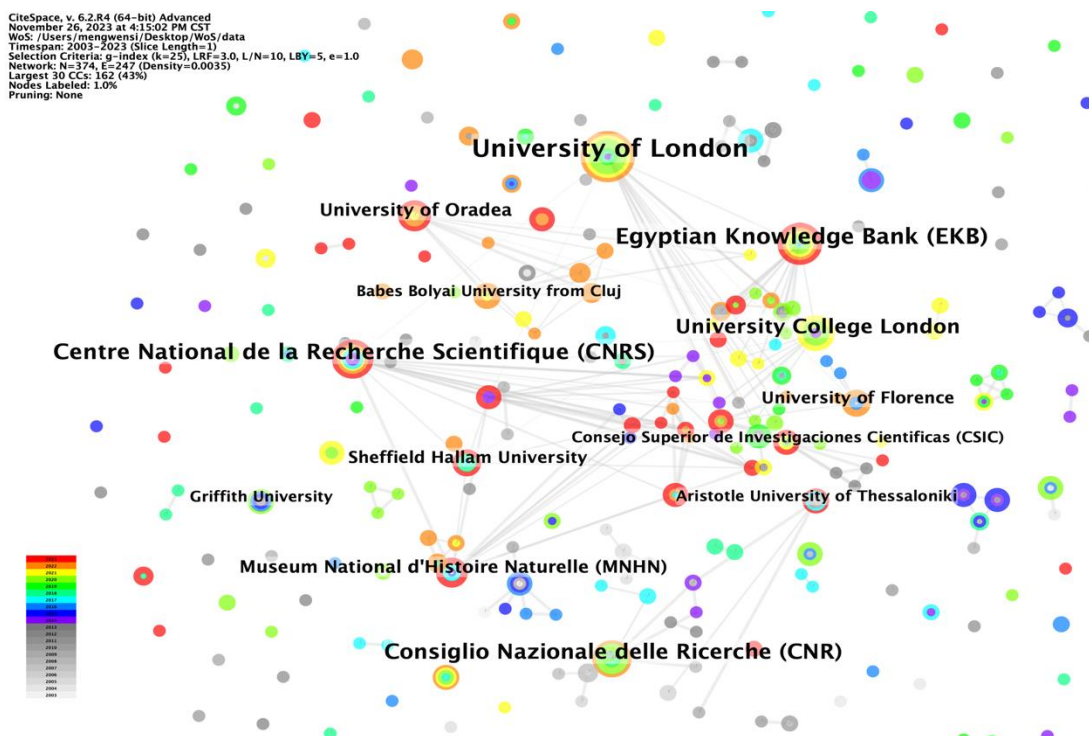


Figure 3. Institution cooperation network map from 2003 to 2020 in WoS

Table 3. The ten most productive research institutions in WoS

Rank	Institution	Records	Year Began
1	University of London	20	2010
2	Egyptian Knowledge Bank (EKB)	14	2010
3	Centre National de la Recherche Scientifique(CNRS)	13	2004
4	Consiglio Nazionale delle Ricerche(CNR)	12	2008
5	University College London	10	2010
6	University of Oradea	7	2021
7	Museum National d’Histoire Naturelle	7	2004
8	Sheffield Hallam University (MNHN)	6	2017
9	University of Florence	6	2007
10	Babes Bolyai University from Cluj	5	2021

Table 4. The ten most productive research institutions in CNKI

Ranking	Institution	Records	Year Began
1	Chengdu Jinsha Site Museum	9	2009
2	Emperor Qinshihuangs Mausoleum Site Park	9	2013
3	Xi'an University of Architecture and Technology	6	2010
4	Fujian Tanshi Mountain Site Museum	5	2014
5	Chongqing Hongyan Revolutionary History Museum	5	2017
6	Tongji University	4	2009
7	Department of Cultural Heritage and Museology at Fudan University	3	2012
8	China Architecture Design & Research Group	3	2009
9	Southeast University	2	2017
10	School of Art and Design, Harbin University	2	2014
11	Jiangnan University	2	2015
12	Shanghai University	2	2008
13	South China University of Technology	2	2014
14	Panlongcheng Site Museum	2	2021
15	University of Science and Technology Beijing	2	2022

Upon comparison, we find that there is an abundance of organizations and institutions studying heritage museums both in China as well as worldwide. universities act as the primary research institutes in the field of heritage museum studies today, and in China, in addition to a few representatives, typical museum research institutions producing more literature, universities are also the main source of articles published in this area. Furthermore, there is currently limited collaboration and interaction among research institutions in this particular field of study, and these institutions are scattered across various locations. It is crucial to strengthen international collaboration across nations, as well as promote cross-disciplinary and global academic contacts.

ANALYSIS OF HOTPOTS AND TRENDS IN RESEARCH ON HERITAGE MUSEUMS

As Professor Chen C. has pointed out, keyword analysis is an appropriate method for identifying popular research domains as well as the evolution of relevant research hotspots and frontiers (Chen, 2006). Through keyword knowledge maps, co-occurrence data, and cluster analysis of keywords to understand the distribution of hotspots and research trends of research topics in heritage museums. Subsequent analyses employed CiteSpace for keyword evaluation, yielding two distinct maps — keyword co-occurrence and bursting keywords — to unveil the research hotspots and the forefront of topic developments.

4.1 Keyword co-occurrence analysis

Since keywords serve as a high-level synopsis of the author's research article and their frequency of occurrence is strongly correlated with hotness, the direction and hotness of this

research issue can be partially revealed by analyzing high-frequency keywords. (Adabre et al., 2021). In CiteSpace, choose "Keyword" as the node type while maintaining default settings for the rest. Figure 4 and 5 presents a keyword co-occurrence map for this research field spanning 2002 to 2023. Herein, each node symbolises a keyword; a larger node denotes a higher frequency of occurrence. A connecting line signifies the simultaneous appearance of two keywords in a single publication.

Cultural heritage is the most frequently occurring keyword in the WoS, followed by 'heritage', 'augmented reality', 'art', 'virtual reality', and 'digital heritage'. In CNKI's knowledge map concerning heritage museum literature, aside from the theme term 'museum', 'conservation' surfaces as the most frequent keyword. This indicates a significant focus within Chinese research on the preservation of archaeological sites and their artefacts, a central theme in site museum studies. Other consolidated high-frequency keywords include 'exhibition design', 'cultural heritage', 'architectural design', and 'virtual reality', reflecting a research emphasis in China on the spatial display and utilisation of cultural relics within heritage museums, with a strong orientation towards practical application. Comparative analysis reveals that international researchers tend to focus on applying AI technologies like AR and VR within heritage museums, whereas Chinese scholars are more invested in the conservation of architectural spaces and artefacts.

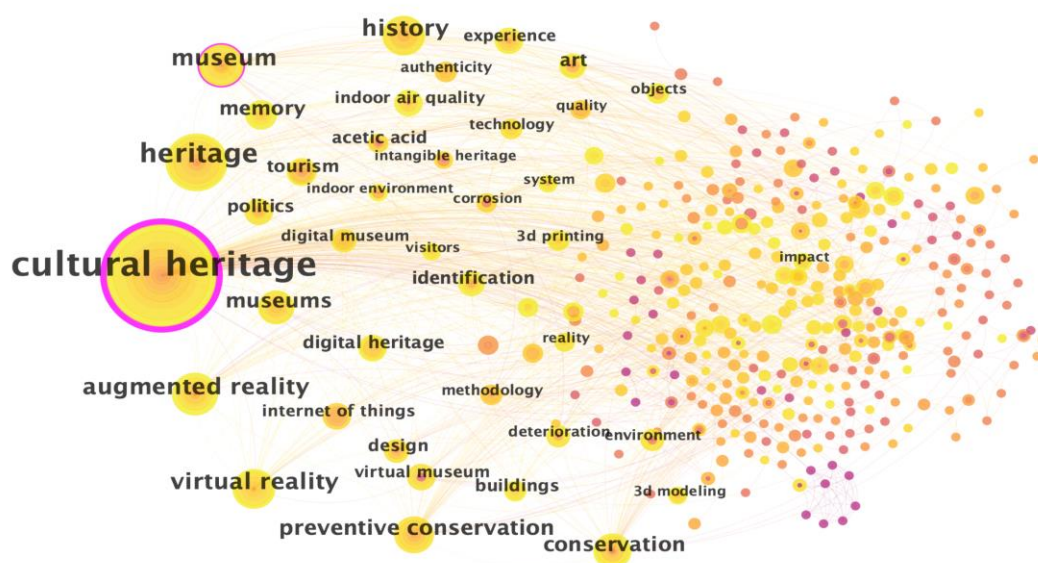


Figure 4. Co-occurrence knowledge map of keywords in WoS

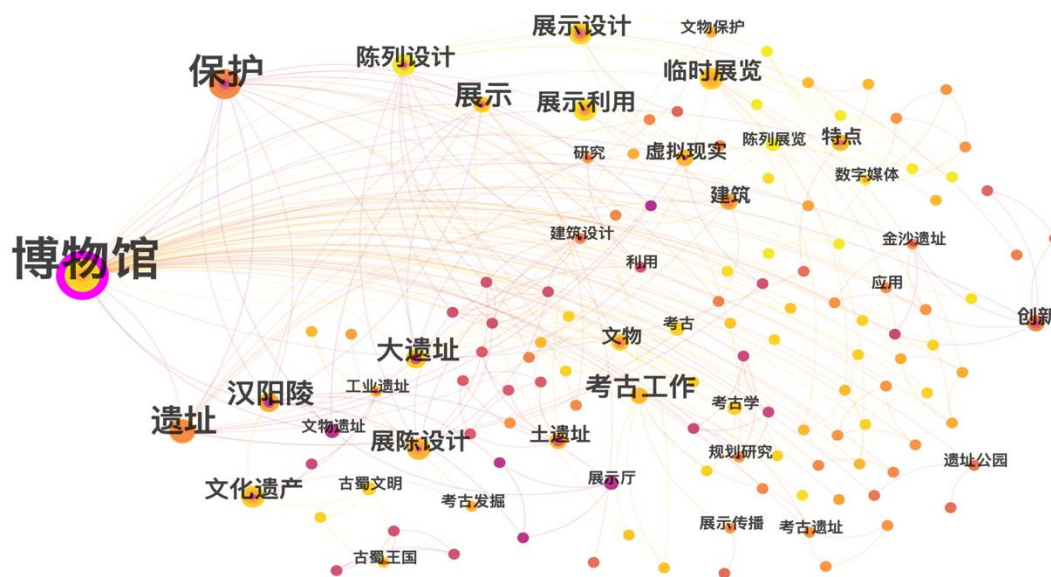


Figure 5. Co-occurrence knowledge map of keywords in CNKI

4.2 Cluster analysis

Cluster analysis facilitates the understanding of research hotspots and trends from a broader perspective. In CiteSpace, keyword clustering employs the LLR algorithm for data extraction, with clusters labelled by keywords. Thirteen valid clustering tags were identified in the CNKI literature, including 'Museum', 'Archaeological Work', and 'Great Sites', among others. Eleven clustering tags emerged from the WoS database, such as 'Cultural Heritage', 'Dark Tourism', and 'Virtual Reality'. If the modularity value is greater than 0.3, then it indicates a significant clustering structure. Moreover, if the average silhouette value is above 0.5, then the clusters are considered reasonable and scientifically valid. After that, the theme words were eliminated, and the remaining keywords were manually classified into four types of clusters: 'Archaeological Site Protection and Restoration', 'Case Study', 'Technology Research', and 'Display and Use'. In WoS, the categories summarised were: 'Protection and Restoration', 'Science, Technology, and Art', and 'Tourist Experience'.

Comparative analysis reveals that research in China on heritage museums concentrates on relic protection and digital media development. Internationally, the focus is on exploring virtual reality, digital museums, and visitor satisfaction, with a greater emphasis on museum experience studies.

4.3 Analysis of bursting keywords

Figure 6 and Figure 7 represent keywords with the strongest citation bursts, which can be used to forecast new trends in the area, and are defined as a keyword's rapid growth in frequency of use over time (Dang et al., 2021). A greater emergence degree signifies more intense research activity surrounding a trend, and examining these emergent words can pinpoint the field's pressing issues over time. The pattern of emergent words illustrates the intensity of keyword citations within the field and demarcates the peak citation years. Analyzing pivotal shifts and novel concepts introduced in specific years can reveal the field's evolving research trends, prominent issues, and emergent frontiers.

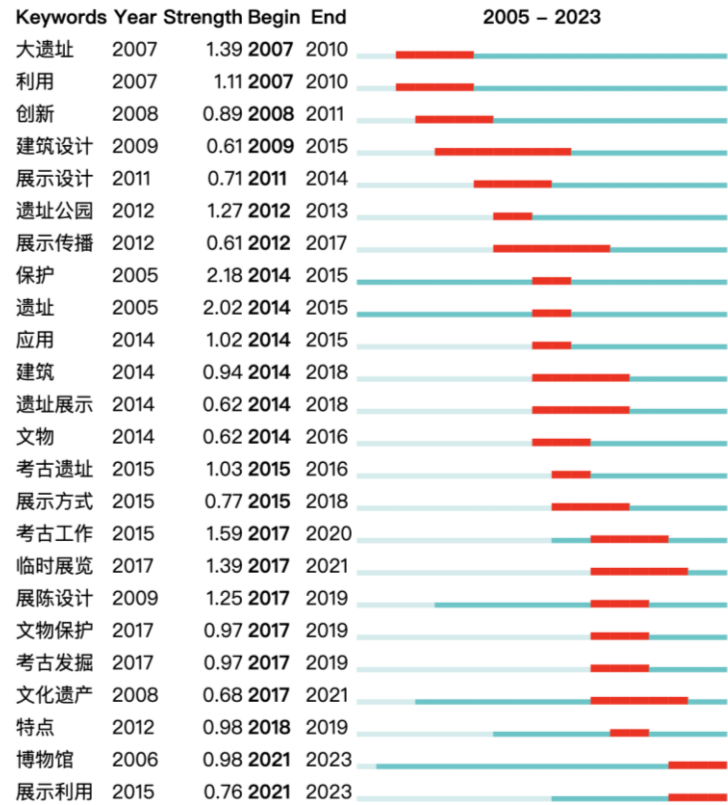


Figure 6. Top 24 Keywords with the Strongest Citation Bursts in CNKI.

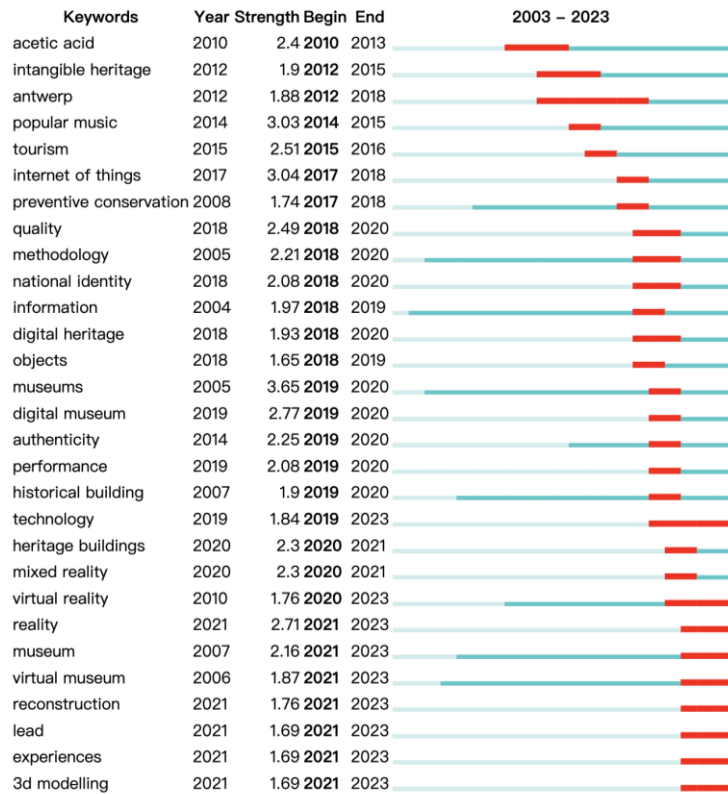


Figure 7. Top 29 Keywords with the Strongest Citation Bursts in WoS

The findings are displayed in Figs. 6 and 7, where the red color indicates the time period in which the burst word was burst. Employing CiteSpace's burstness function, we detected and chronologically sorted a list of burst words. Comparative analysis identified 24 terms have emerged from the CNKI. Because huge sites had received attention in the beginning, the state created a pertinent set of major site protection policies. Thereafter, China's research expanded to include technical and applied aspects of site protection and usage, along with emerging fields like industrial sites and national archaeological parks. The academic focus on "site display" (2014), "exhibition design" (2017), and "display utilisation" (2021) indicate that scholars have given new types of site display a lot of thought. The new site display has received great attention from the academic community and has become a research hotspot.

Augmented reality, as shown in Figure 7, will increasingly integrate with virtual and mixed realities. Simultaneously, the research emphasis is shifting from technology to user experience, with a trend towards more convenient and human-centred interaction. The prominence of the terms "information", "technology", and "experience" signifies a shift in augmented reality from mere "seeing" to immersive "experiencing". This shift heralds a move towards enhancing the "feeling" aspect of augmented reality, focusing on humanisation and interactivity.

DISCUSSIONS

CiteSpace 6.2.R4 was the visual analysis program utilized in this study for bibliometric analysis. evaluating 789 articles from the Web of Science (SSCI, SCI, AHCI) and 125 articles from CNKI pertinent to heritage site museum displays. Synthesising and contrasting findings from both Chinese and international domains yielded insights into publication volume, core authors, collaborating institutions, keyword clustering, and evolution, among other factors:

Firstly, in terms of publications, the publication trend from 2002 to 2023 is basically the same, although there are fluctuations, and the overall trend is increasing.

Secondly, in terms of core authors and research institutions, large universities hold a dominant position in this field's international arena in relation to core authors and research institutions, and universities fund the majority of research projects in this field. Numerous studies have been conducted in China not only by universities but also by several representative research institutions and museums. But there isn't much of a correlation between authors and institutions in this field, and there isn't yet a strong bond of cooperation, lacking robust cooperation. Therefore, fostering closer partnerships, interdisciplinary dialogue, and alliances with museums and cultural heritage bodies is essential to leverage resources for research.

Thirdly, from the viewpoint of research hotspots, each nation first concentrated on conserving and repairing historical and cultural sites. Globally, "Augmented Reality" was first appeared internationally in 2002. It developed prominence in 2016 and peaking in 2019. China's engagement with AR began in 2014, indicating a delayed start compared to the global community; however, the pace of technological advancement has accelerated recently.

Fourthly, in accordance with the general research trend, the global research direction includes a deep dive into technological applications within experiential, human-centric fields such as 3D modelling, and integrating tech with user experience. On the other hand, China pays greater

emphasis cultural heritage and its dissemination, progressively honing research domains into more nuanced sub-fields for thorough exploration.

CONCLUSION

This study presents a bibliometric review of displays for heritage museum researchers. The findings offer a comparative analysis of display evolution in heritage museums both in China and foreign historical museums. The study concludes that research hotspots in heritage museums are significantly influenced by digital technology, national policies, and public experiential demands. Chinese society and culture have a top-down socio-cultural framework, and government policy oversight and support are considered to be the most important factors driving its development. Undoubtedly, technology has propelled museum research forward, with the practical application of emerging technologies sparking academic debate. Furthermore, with the development of AI technology and the increased attention to heritage museums, AI technology elevates museum field research by innovating methods to engage the public and enhance visitor participation in museum activities. Moving forward, as AI technology advances and the focus on heritage museums intensifies, its application in displays will deepen, broadening research in this domain.

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