Evolution and Trends of Research Focuses on Smart Libraries in China

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Abstract

With the rapid development of the digital economy, the development of smart libraries has become a priority and a key direction for the library sector. This study employs bibliometric analysis, utilizing tools such as ItgInsight and CiteSpace to conduct a visual analysis of the literature on smart libraries from the CNKI database. The aim is to identify the core research institutions, leading authors, research foci, and evolutionary trends within this field. The findings reveal that research on smart libraries has formed a collaborative network primarily led by university libraries and schools of management. The research foci have evolved sequentially from an initial emphasis on technology introduction, to service innovation, and then to the exploration and integrated application of cutting-edge technologies. Future research is expected to place greater emphasis on the convergence and innovative application of technologies, the enhancement of intelligent services and personalized user experiences, as well as on fostering cross-disciplinary collaboration and building a robust academic community.

CCS Concepts

• **Applied computing** → Education; Digital libraries and archives.

Keywords

smart libraries, bibliometric analysis, visualization analysis

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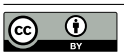

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1 INTRODUCTION

Driven by the rapid advancement of new-generation information technologies and the escalating societal demand for knowledge services, the smart library has garnered significant attention as a pivotal form for the library sector to adapt to the information society. The concept of the "smart library" was first introduced by Aittola et al. from the University of Oulu Library in 2003, who defined it as a mobile library service system, unconstrained by physical space and capable of being perceived, which can respond to user needs in real-time via wireless networks [1]. Currently, although academic research has yielded substantial findings in key sub-fields such as theoretical studies [2], service models [3], and technology with practical applications of smart libraries [4], a consensus on a precise definition remains elusive. This paper conceptualizes a smart library as an intelligent ecosystem resulting from the integration of smart technologies into library infrastructure. It represents a synthesis of an intelligently perceptive environment and the intellectualization of digital library services.

Visualization studies in the field of smart libraries have primarily been conducted using bibliometric analysis [5] and text mining [6]. However, existing research has not incorporated data from the last two years, which limits a comprehensive understanding of the various developmental stages of smart libraries in China and a deeper insight into their overarching trends. As a forefront of information development, the smart library domain is characterized by rapidly shifting research foci and a swift growth in academic output. This dynamic nature creates a pressing need for new research to provide timely updates and deeper analysis. This study employs a bibliometric approach, utilizing the visualization tools ItgInsight and CiteSpace to analyze relevant literature on smart libraries indexed in the CNKI database. The objective is to delineate the major contributing forces, identify critical turning points, and trace the evolutionary trajectory within this field. The findings aim

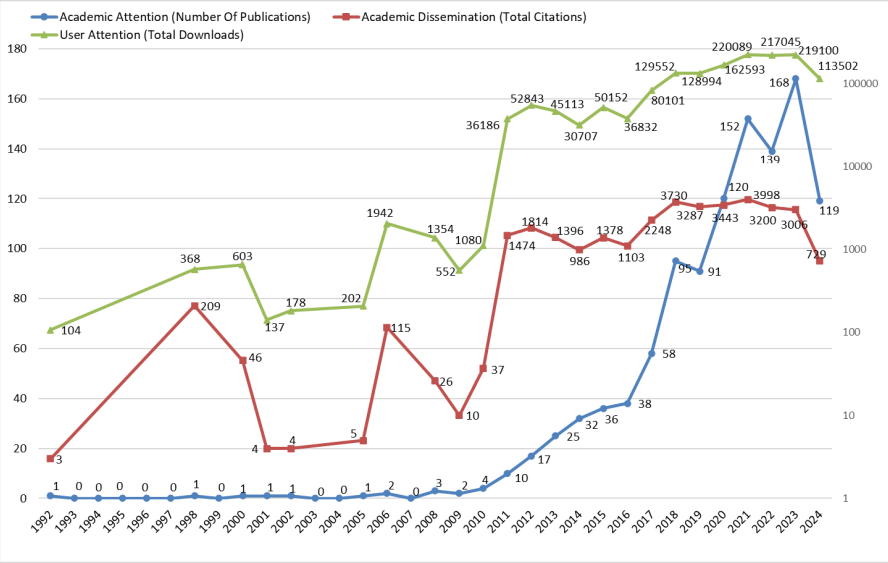

Figure 1: Research Trends in Smart Libraries in China.

to provide a theoretical foundation for sustaining and innovating future research on smart libraries in China.

2 DATA SOURCES AND RESEARCH METHODS

2.1 Data Sources

This study utilized the Chinese National Knowledge Infrastructure (CNKI) journal database as its primary data source. A comprehensive search was conducted using the terms " smart library " and " intelligent library " in the title, abstract, and keywords fields with a logical "OR" operator. The publication date range was set for all records up to December 31, 2024. Furthermore, the search was limited to journals categorized as A Guide to the Core Journal of China, Chinese Social Sciences Citation Index (CSSCI), and Chinese Science Citation Database (CSCD). This search strategy initially identified a total of 1117 relevant bibliographic records.

2.2 Research Methods

This study employs a bibliometric analysis, leveraging the complementary strengths of two visualization tools, ITGInsight and CiteSpace, to conduct a multi-dimensional and cross-validated examination of the literature within the smart library research domain. ITGInsight, a specialized tool for mining and visualizing scientific literature, excels at performing multi-dimensional analyses—such as examining co-authorship, co-occurrence, and coupling relationships—on scholarly publications and patents. It integrates features for evolutionary analysis, cluster analysis, and generates various technical charts, thereby enhancing the capacity to process and interpret large-scale datasets [7]. By combining the capabilities of ITGInsight with CiteSpace's strength in detecting keyword bursts for research front analysis, this methodology aims to systematically and objectively uncover the research hotspots and developmental trends in the field.

3 ANALYSIS RESULTS AND FINDINGS

3.1 Analysis of Research Trends

The research heat and attention within an academic field are generally measured by three key metrics: the number of publications, citation counts, and download counts. Specifically, the publication volume reflects academic attention, citation counts indicate scholarly influence and dissemination, while download counts represent user interest [8]. Together, these three indicators provide a comprehensive picture of the research trends and impact in a given field. Consequently, a statistical analysis was performed on the retrieved literature data based on these three metrics, with the results presented in Figure 1. In the figure, the horizontal axis represents the publication year. The left vertical axis, using a linear scale, corresponds to the annual publication volume. The right vertical axis, employing a logarithmic scale, corresponds to the total citation counts and total download counts. This dual-axis approach with different scales effectively integrates data of varying magnitudes and growth characteristics, thereby optimizing the visual presentation.

Academic attention, measured by the annual publication volume of scholarly papers related to smart libraries, is represented by the blue trend line in Figure 1. This line reveals that research in this field has evolved through three distinct phases: From 1992 to 2010, the field was in a nascent stage, with annual publications consistently numbering fewer than five. Between 2011 and 2019, it entered a phase of sustained growth, where the annual output broke into double digits and peaked at 93 publications. From 2020 to 2024, despite some annual fluctuations, the field maintained an overall upward trajectory, reaching a historical peak of 163 publications.

Scholarly dissemination is measured by the cumulative total of citation counts for the relevant publications over the years. It is important to note that due to the inherent time lag in citation accrual, the data for 2023 and 2024 should be considered as preliminary. The

Table 1: Centrality Metrics in the Collaboration Network of the Top 10 Core Institutions by Publication Volume.

No	Institution	Publication Volume	Proportion	Degree	Closeness Centrality	Betweenness Centrality
1	School of Information Management,Nanjing University	67	6.00%	58	0.273	4.836
2	School of Information Management,Wuhan University	41	3.67%	62	0.273	5.769
3	Nanjing University Library	32	2.86%	18	0.272	0.555
4	Chongqing University Library	25	2.24%	22	0.197	0.038
5	Shanghai Library	22	1.97%	40	0.273	4.708
6	Shanghai Academy of Social Sciences Information Institute	19	1.70%	0	0.000	0.000
7	School Of Information Management,Central China Normal University	18	1.61%	18	0.273	1.504
8	National Library of China	18	1.61%	8	0.272	0.560
9	Nanjing Xiaozhuang University Library	15	1.34%	16	0.198	0.012
10	School of Public Administration of Xiangtan University	14	1.25%	14	0.273	2.901

red trend line in Figure 1, representing this dissemination, shows a rapid increase in academic influence within the smart library field from 2009 to 2012. Following 2011, the annual citation counts exhibited a fluctuating yet overall upward trend, indicating that research in China's smart library domain is in a highly active and rapidly evolving state. The year 2013 marked a period where smart libraries gained significant traction in both practical application and theoretical research, leading to scholarly dissemination being maintained at a high level.

User attention, which is directly correlated with download frequency, serves as a key indicator. A high number of downloads for a research topic typically signifies substantial research interest and practical value within both academic and public spheres. To obtain a robust measure of overall impact, the cumulative download counts across all years were calculated and are represented by the green trend line in Figure 1, denoting user attention. The trends for user attention and scholarly dissemination demonstrate a notable congruence. Both exhibited a rapid increase from 2009 to 2012, followed by a pattern of fluctuating yet sustained growth after 2011.

To statistically validate observed trends, Mann-Kendall tests were applied to time-series data of the three key metrics. This non-parametric method is robust to non-normal distributions and missing values, making it ideal for identifying monotonic trends in scholarly activity data. Kendall's tau quantified trend direction and strength: a tau value greater than 0 indicates an upward trend, while the absolute value of tau reflects trend strength. Statistical significance at $p < 0.001$ confirmed the presence of true monotonic trends rather than random variation. Mann-Kendall results showed significant increasing trends for all indicators: annual publication volume (tau = 0.784, Z = 6.494, $p < 0.001$), annual total citations (tau = 0.634, Z = 5.234, $p < 0.001$), and annual total downloads (tau = 0.731, Z = 6.032, $p < 0.001$). These findings provide robust evidence that research attention, scholarly dissemination, and user engagement in China's smart library field experienced significant sustained growth during the study period.

Of the 1117 publications analyzed, 394 were collaborative works. As shown in Table 1, the top 10 most prolific institutions are primarily university libraries and management schools, with Nanjing University and Wuhan University's information management schools being the most productive. These two institutions exhibit significantly higher degree and betweenness centrality, serving as critical hubs and bridges in the collaboration network. Most core institutions show closeness centrality scores around 0.273, indicating their central positioning and efficient connectivity. In contrast, the Shanghai Academy of Social Sciences Information Institute demonstrates exceptional independent research capacity with no recorded collaborations.

3.2 Keyword Clustering Analysis

A keyword co-occurrence network for smart library research was constructed using the ITGInsight software. The top 40 core keywords were selected based on the Pcvalue metric. After clustering through the K-means algorithm, seven different clusters were determined, as shown in Figure 2. Within the resulting visualization, the size of each node corresponds to the frequency and influence of a keyword within the research field, while the connecting lines between nodes represent co-occurrence relationships.

The keyword clustering analysis reveals three constitutive dimensions of smart library research. The first, a technological dimension, anchors the field with "library" at its core, supported by keywords like "Information Technology" and "data," forming the intelligent infrastructure. The second, a user-service dimension, manifests through terms like "user profile" and "reader," signaling a paradigm shift towards personalized, experience-centric services. The third, a transformative dimension, is captured by "digitalization" and emerging technologies like "AI," pointing to a profound restructuring of library operations and service models. Notably, the co-occurrence of "society" and "culture" underscores that this technological evolution is concurrently a socio-cultural project, aiming to preserve and advance cultural value.

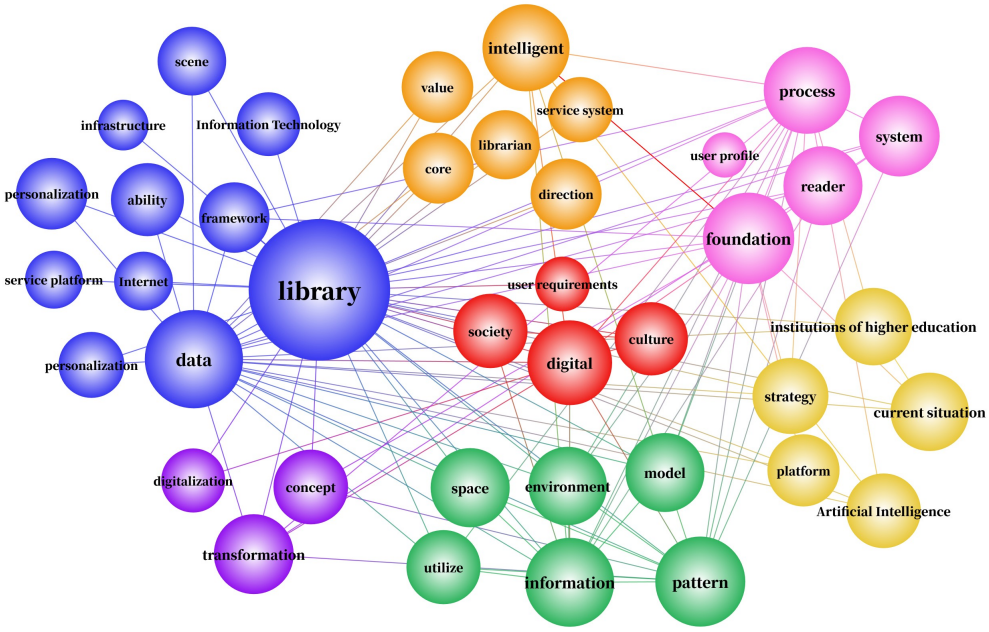

Figure 2: Keyword Clustering Map of Smart Library Research in China.

3.3 Evolution Analysis of Keywords

To decipher the intellectual structure and its dynamics within China's smart library domain, this study traces the evolution of the top 12 high-frequency keywords, which serve as proxies for core research themes and fronts. Their diachronic co-occurrence and evolutionary pathways from 2010 to 2024 are mapped in Figure 3. In this visualization, node size signifies keyword frequency, while the thickness of connecting lines denotes the strength of conceptual relationships, collectively illustrating the inheritance and derivation of knowledge across different periods.

The evolutionary path delineates a clear paradigm shift. The foundational phase (2010-2015) was dominated by infrastructural technologies (IoT, RFID, Cloud Computing), establishing the architectural bedrock for intelligentization. Around 2017, the emergence of AI marked a critical transition, catalyzing a shift from digital services to intelligent, scenario-specific applications such as personalized recommendations. More recently, the field has entered an exploratory frontier, characterized by the integration of disruptive technologies such as the metaverse and ChatGPT, alongside an emphasis on data governance. Throughout this evolution, the persistent focus on "service model" underscores a continuous scholarly effort to systematize these technological advances into coherent service paradigms.

3.4 Analysis of Research Hotspot Emergence

Keyword emergence in literature signals significant shifts in research focus, and changes in citation frequency are visualized through burst detection graphs. Burst strength measures both the rate of change in keyword frequency and its corresponding attention level. A higher burst value indicates more rapid change and greater attention, while a longer duration reflects sustained relevance of the research hotspot. Using CiteSpace for burst detection with parameters set to $\gamma[0,1]=0.6$ and Minimum Duration=2, this study identified 18 burst keywords from 2000 to 2024 (Figure 4). The top three keywords by burst strength were "IoT" (16.98), "metaverse" (12.76), and "big data" (5.44). When integrated with temporal trend analysis, these findings reveal three distinct phases of keyword emergence:

The first phase (2000-2010) marked the initial stage of introducing intelligent technologies for library infrastructure and foundational development in China. This phase is characterized by two burst keywords: "ubiquitous computing" and "IoT," signaling the nascent exploration of smart libraries in the country. Research during this period primarily focused on the application of radio-frequency technologies, the promotion of digital services such as e-books and online databases, and the introduction of intelligent equipment, all aimed at enhancing resource accessibility.

During its growth phase (2011-2019), smart library research underwent a paradigm shift toward service innovation. Key technologies such as AI and big data enabled a transition to intelligent, personalized services, while simultaneously redefining the librarian's role from traditional tasks to knowledge navigation and management.

The current phase (2020-2024) marks a strategic shift toward defining next-generation smart libraries through immersive and semantic technologies. The emergence of keywords including "digital twin," "metaverse," and "knowledge graph" reflects a dual focus: building trusted data infrastructure through governance

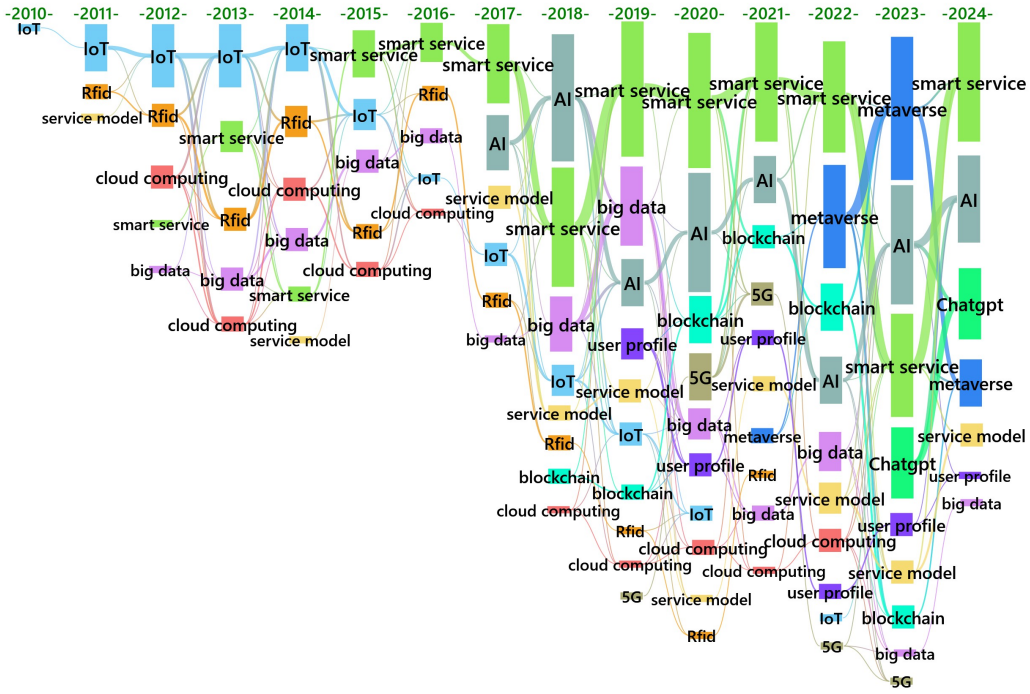

Figure 3: Evolution Path of Keywords in Smart Library Research in China.

Top 18 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2000 - 2024
ubiquitous computing	2006	2.69	**2006**	2010	
IoT	2010	16.98	**2010**	2015	
cloud computing	2012	4.86	**2012**	2016	
context awareness	2015	3.22	**2015**	2019	
book inventory	2016	2.42	**2016**	2017	
robot	2012	2.16	**2016**	2017	
AI	2017	5.19	**2017**	2018	
big data	2012	5.44	**2018**	2019	
librarian	2018	2.5	**2018**	2020	
user profile	2019	2.06	**2019**	2020	
blockchain	2018	3	**2020**	2022	
data-driven	2020	2.43	**2020**	2021	
application scenarios	2020	2.24	**2020**	2024	
reading promotion	2020	1.99	**2020**	2021	
digital twin	2020	4.08	**2021**	2024	
metaverse	2021	12.76	**2022**	2024	
knowledge graph	2022	3.52	**2022**	2024	
virtual reality	2022	3.11	**2022**	2024	

Figure 4: Map of Bursting Keywords Indicating Research Fronts in the Smart Library Domain in China.

frameworks while advancing experiential services through virtual-physical integration. These technologies collectively enable a transition from transactional services to contextual, knowledge-centered environments—though still largely experimental, they establish a critical foundation for semantically rich and ethically grounded library ecosystems.

4 RESEARCH DIRECTIONS AND TRENDS

4.1 Technology Convergence and Innovative Applications

The advancement of smart libraries is fundamentally underpinned by new-generation information technologies. Current research in China's smart library domain primarily focuses on theoretical exploration and model construction, while studies on technology integration are still nascent yet rapidly evolving. To effectively incorporate the latest technological advancements into the development and operation of smart libraries, future research should prioritize application scenarios, alongside in-depth studies of cutting-edge technologies such as artificial intelligence and virtual reality.

4.2 Intelligent Services and Personalized Experience

Driven by users' increasingly diverse and personalized demands, the development of smart libraries must place greater emphasis on intelligent services and personalized experiences. Future research will increasingly focus on user-centric service innovation. By leveraging context-aware technologies and intelligent devices, smart libraries can enhance user satisfaction and engagement, providing highly efficient and customized information services. Concurrently, the training of smart librarians, user data security, mobile applications, and online services represent other critical research directions for intelligent services. Through data analytics and user behavior studies, more personalized recommendations can be delivered to users, thereby improving the targeting and effectiveness of services.

4.3 Cross-boundary Collaboration and Academic Community Building

Against the backdrop of the digital-intelligent era, research on smart libraries will no longer be confined to the traditional field of library science. Instead, it necessitates knowledge and expertise from humanities disciplines such as sociology and psychology, as well as from interdisciplinary fields like computer science, to fully grasp the opportunities presented by networking, digitization, and intelligentization. Establishing collaborative networks that transcend disciplinary and institutional boundaries, fostering knowledge sharing and academic innovation, and building a robust academic community are emerging as critical directions for smart library research. Advancements in these areas will further promote academic exchange and facilitate the dissemination of relevant knowledge.

5 CONCLUSION

Research on smart libraries in China has evolved through three distinct phases: an incipient stage (1992-2010), a growth stage (2011-2019), and a phase of rapid development (2020-2024), marked by a simultaneous increase in both academic and user attention. The core research capacity is concentrated primarily in schools of information management and university libraries, with relevant institutions at Nanjing University and Wuhan University serving as central hubs within the collaboration network. Thematic analysis has identified seven major clusters, encompassing areas such as technological infrastructure, user services, and digital transformation. Keyword evolution further illustrates a conceptual shift from establishing an enabling technological base, to reconceptualizing service models, and toward engaging with frontier technologies such as the metaverse and generative AI. Future efforts should prioritize deepening technology integration, focusing on personalized user experiences, and promoting the development of a cross-disciplinary academic community. These initiatives are essential to provide robust support for the theoretical refinement and practical implementation of smart libraries.

Acknowledgments

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