The "Technological Yardstick" of Library Development: A Comparative Study of Library Technology Evolution Based on Library-Related Patents (Postprint)

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Abstract

[Purpose/Significance] Technology patents in the library domain serve as a crucial indicator of library technology development. Employing them as a unit of measurement can constitute one of the important dimensions for observing the overall development and transformation of libraries. By systematically reviewing the evolution of patents in the library domain, we can better explore and grasp the developmental patterns of libraries. [Method/Process] This study analyzes the temporal distribution, patent holders, thematic distribution, and changing patterns of patents in the library domain, and conducts a comparative analysis with multiple dimensions such as library development policies and library research literature. [Results/Conclusion] Based on the analysis of library-related patents, it is found that the relevant technologies primarily focus on "physical books" and "facilitating daily applications for librarians," with increasing attention to "user" scenarios in recent years, particularly regarding artificial intelligence technologies that have experienced rapid growth. In the multi-dimensional comparison of library development, the themes in the relevant domain exhibit asynchrony across the technological, research, and policy levels.

Full Text

The "Technical Scale" of Library Development: A Comparative Study on the Evolution of Library Technology Based on Library-Related Patents

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Abstract: [Purpose/Significance] Technical patents in the library field serve as an important representation of library technology development. As a unit of measurement, they form one of the key dimensions for observing the overall transformation of libraries. By examining the evolution of library-related patents, we can better explore and grasp the developmental patterns of libraries. [Method/Process] This paper analyzes the temporal distribution, patent holders, thematic distribution, and changing patterns of library-related patents, and compares them with multiple dimensions such as library development policies and library research literature. [Result/Conclusion] Based on the analysis of library-related patents, it is found that relevant technologies primarily focus on "physical books" and "facilitating librarians' daily applications," with increasing attention to "user" scenarios in recent years, particularly the rapid growth of artificial intelligence-related technologies. In the multi-dimensional comparison of library development, themes in related fields exhibit asynchrony across the technical, research, and policy levels.

Keywords: technology evolution; patent analysis; bibliometrics; library development
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1. Introduction

1.1 Quantifying the "Technology-Institution-Concept" Dimensions in Library Development The transformation path of libraries has long been a focal point in both library science theory and practice. Library development itself results from the comprehensive interaction and mutual driving forces of "technological change," "institutional innovation," and "conceptual evolution" [2]. These three dimensions form distinct "scales" for measuring and observing library development progress.

Through in-depth research, our team further argues that each dimension—technology, institution, and concept—has now developed quantifiable, measurable, and cross-analyzable key indicators. Based on this, we propose a multi-dimensional observation framework as shown in Figure 1 [Figure 1: see original paper].

The significance of this framework lies in three aspects: First, it identifies the three key drivers of library development. Institutions are more fundamental than technology in determining organizational development and growth [3], while concepts are the critical force influencing institutional formation and evolution [4], playing an important role in institutional change. Second, it points to quantifiable analytical objects for each dimension: policy represents institutional output [5-6]; academic papers embody professional thinking and occupational concepts of a given period [2]; and patents are important carriers of technological development [7]. Using established measurement methods from library

and information science, we can more precisely and clearly depict these three elements of library development and effectively reflect their evolution. Third, it provides possible pathways for analyzing the interactions among technology, institutions, and concepts, such as whether specific library themes first emerged in academic research, policy statements, or technological R&D applications, and how they diffused across different sectors, thereby facilitating examination of the leading activity and inter-dimensional traction among the three dimensions.

Regarding the third point, the following operational steps can be adopted [8]: First, complete quantification processing for the three sectors of institutions, concepts, and technology in the library field by identifying measurable indicators. Policy texts, academic literature, and technical patents can serve as outputs of institutional, conceptual, and technological activities respectively for textometric analysis. Second, identify cross-sector, cross-dimensional textual element associations, such as citations of policy texts in academic literature and adoption of research findings in policy documents. This can draw on citation analysis methods from academic literature, extending to content-level analysis of co-occurrence and differential expression of library themes across the three domains. Finally, by introducing temporal variables, conduct diachronic analysis of citation and co-occurrence metrics among the three dimensions to examine the generation, diffusion, and adoption mechanisms of these elements during library development.

1.2 Previous Research Foundation Under this framework, our research team has conducted a series of preliminary studies measuring different "scales":

(1) In policy measurement representing institutional evolution, previous research [8] collected public cultural service policy texts, used machine-automated extraction combined with manual standardization for thematic indexing, constructed a policy category framework, and analyzed core content themes in public cultural service policies.

(2) In academic literature measurement representing conceptual evolution, previous research [2] systematically examined "thinking" expressions in library science literature, developed quantifiable thinking expression indexes, and employed bibliometric and content analysis methods to analyze temporal distribution, scenario distribution, expression intensity, and changing patterns, finding that thinking expressions in library science research have grown rapidly in the past decade, primarily applied in library services, resource development, and leadership management, with current expressions showing continuous deconstruction and reconstruction alongside increasing localization and professionalization.

(3) In cross-dimensional comparative analysis, previous research [8] identified divergence, asynchrony, and displacement between academic research and policy statements in the library field, particularly in public cultural service supply and governance systems where policy statements were richer and

more forward-looking than academic research. Academic research mostly reflects explorations of what *is*, while policy formulation reflects efforts to change practice, often being normative or prescriptive [9]. Future research needs to examine whether the relationship between the two is "reinforcing" or "corrective" [9], and whether the leading relationship is "theory serving policy" or "policy conforming to theory." Although traditional views hold that theoretical research guides decision-making, reality often shows that newly emerging policy themes lead research and concepts, even creating "strategic surprises" [10].

1.3 Research Questions Thus far, previous research has left the measurement of technological change unaddressed, as well as comparative analysis linking the technological dimension with other dimensions. This study aims to fill this gap and explore this direction.

From a technological perspective, over the 40 years since China's reform and opening up, Chinese libraries have made substantial technological progress. In 1978, Nanjing University developed China's first computerized library application system [11]. From MARC to integrated library management systems, from CD-ROM to digital resources, from barcodes to RFID, and from library automation to digital libraries and then smart libraries, libraries have experienced the developmental stages of "automation-digitalization-intelligentization," revealing previously overlooked patterns in library development [12].

Following the aforementioned research perspective and steps, this study uses technical patents as a quantifiable representation to depict the "technical scale" of library development and transformation. It analyzes the evolutionary trends of library technologies horizontally while vertically comparing the interactive relationships among technology, institutions, and concepts in the library field.

2. Literature Review on Library Patent Analysis

This study treats patents as a quantifiable representation of library technology, forming two major research themes: "patents" and "libraries." Searching the CNKI full-text database with "library" + "patent" in titles yielded 72 papers published in CSSCI core journals since 1998. Thematic analysis reveals that most literature discusses patents as part of library services, analyzing demand [13], service models [14], organizational aspects [15], target users [16], and service innovation [17] of patent information services.

A minority of studies directly address library-related patent technologies themselves. Zhang Lei [18] examined the status of library-related patents, 梳理了图书馆领域专利的基本态势、技术领域及相关特征，分析了专利技术演化对图书馆事业发展的影响. Shao Simi [19] analyzed and compared patents applied for by Chinese and overseas libraries as patentees, finding that Chinese applications concentrate in the digital library domain, often in collaboration with enterprises, a trend also observed in overseas libraries.

Previous studies provide a patent-based perspective for observing library development but have limitations. Most analyze only cases where libraries are patentees, reflecting libraries' technological originality but offering a narrow perspective by using patent quantity and content as the sole indicator of library development level. In reality, besides libraries, other entities and even users may be patentees of library-related technologies. Moreover, beyond patentees, factors like technology users (including librarians and users) and application scenarios have not received adequate attention in previous research.

Expanding "patents" to the broader concept of "technology" and combining it with the multi-dimensional framework in Section 1 reveals further limitations in previous research on the technological dimension of library development: (1) Research themes are relatively isolated and static, often focusing on specific technologies or application cases without examining relationships among technological elements or their evolution over time. (2) The vague and broad connotation of "technology" as a noun includes both specific technical objects and the concept of technology itself [20]. Previous studies focused on the former concrete objects, causing the concept of technology to become "generalized" and lacking targeted, specific extraction and excavation.

Identifying these limitations helps optimize this study's design. Unlike previous research, this study first examines technology from a multi-dimensional comparative perspective, and second, adopts a retrieval strategy based on patent themes rather than patentee identity when collecting library-related patents, introducing a temporal dimension to examine changes over time.

3. Data Sources and Research Process

Data for this study were sourced from the AIpatent platform, a patent intelligence retrieval system developed by Nanjing Shenside Information Technology Co., Ltd., offering machine translation, patent dictionaries, concept retrieval, cross-national patent databases, and frontier patent topics to facilitate independent patent information retrieval [21-22].

This study focuses on domestic library-related patents, using AIpatent's retrieval function to select the "China Patent Database," which contains patent information published by the China National Intellectual Property Administration. Search limitations included patent types (invention applications, authorized inventions, utility models, and design patents). Since patents undergo a lengthy processing period from application to final publication, this study uses the final time node in the approval process—the "publication date"—as the reference point, limiting the timeframe to the past decade (2011-2021) with a retrieval cutoff date of September 30, 2021.

AIpatent provides multiple search approaches including text search, classification number search, company/individual search, date search, and address search. This study selected text search by invention title, using "library" as the search term to collect patents involving libraries in their titles as the defining

condition for "library-related patents."

Under these conditions, a total of 3,166 data entries were obtained. Since the retrieval date ended on September 30, 2021, data for 2021 are incomplete. Given the large number of patents, manual statistics were impractical; therefore, this study used a self-developed Python crawler program to traverse the search results and extract six data fields for each patent: invention title, applicant, application number, application date, publication date, and abstract. Each patent served as a statistical unit, with extracted data classified and visualized to examine temporal distribution, thematic distribution, and subject distribution.

4. Findings and Discussion

4.1 Temporal Distribution of Library-Related Patents Statistics of domestic library-related patents by publication date are shown in Figure 2 [Figure 2: see original paper]. Except for a slight decrease in 2014, patent volume increased year by year. Annual statistics for three applicant types—enterprises, universities, and individuals—are shown in Figure 3 [Figure 3: see original paper]. University-applied patents grew most significantly. Combined with Figure 2, universities contributed most to the overall growth in library-related patents. Additionally, most provinces launched mixed-ownership reforms for 职务科技成果 between 2016-2017. Taking Sichuan Province as an example [23], since initiating reforms in 2016, the number of disclosed university 职务发明专利 has increased rapidly. This overall surge in university patents made 2016 a watershed year, after which growth accelerated substantially.

4.2 Distribution of Patentee Types Statistics on patentee identities for library-related patents over the past decade reveal three basic types: universities, enterprises, and individuals. As shown in Figure 4 [Figure 4: see original paper], universities are the primary patentees, holding 58.8% of all granted and published library-related patents. Figure 5 [Figure 5: see original paper] shows annual proportions of different patentee types, revealing that in 2011, the three types had similar shares, but over the decade, university patentees showed an upward trend. This likely reflects that among different library types, university libraries possess the strongest technological capabilities and increasingly contribute to library-related technologies, demonstrating that libraries' technological originality is improving across different patentee types.

4.3 Analysis of Typical Application Scenarios In *The Disappearance of Distance: How Electronic Media Affect Social Behavior*, scenarios are defined as specific people engaging in specific activities at specific places and times [24]. In the era of contextual computing, libraries as "specific places" exhibit increasingly distinct technological application scenarios. The "specific people" in library technology scenarios can be divided into library staff and library users.

Based on this definition, this study categorized application scenarios of domestic library-related patents over the past decade through a combination of automatic

extraction from patent titles and manual interpretation to cluster similar scenarios. As shown in Figure 6 [Figure 6: see original paper], patents involving book collection scenarios are most numerous, followed by library backend management systems, artificial intelligence, and reader services.

Scenario 1: Book Collection
Book collection accounts for 31.9% of all library-related patents. Since libraries' inception, book preservation has been their most fundamental business, and caring for books has been the profession's earliest mission [25]. Typical patents in this area fall into three categories: (1) book storage devices, mainly various bookshelf designs; (2) book protection devices, widely applied for moisture-proofing, insect-proofing, and tear-proofing; and (3) transportation devices such as "transport carts," "lifting equipment," and "hand trucks." The original intention behind these inventions reflects that collection work, as libraries' most basic business, directly affects librarians' workload and intensity, with many technologies designed to facilitate librarians' work.

Scenario 2: Management Systems
These systems integrate multiple subsystems including acquisition, cataloging, retrieval, circulation, and reproduction tailored to library business scopes and characteristics. Since the 1990s, China has successively introduced advanced foreign library automation management software such as Millennium, Unicom, Horizon, and Aleph500. Current library automation management systems have formed compatible, stable integrated systems. Against this backdrop, patents over the past decade rarely address overall library automation system architecture, instead focusing on specific functional subsystems or internal functions, such as cataloging systems, query systems, and automated book return/retrieval systems.

Scenario 3: Artificial Intelligence
The ultimate goal of AI technology in libraries is to expand service content and innovate service methods [26]. Before 2013, AI-related patents were rare in the library field, but from 2014 onward, patent titles began featuring terms like "intelligent," "smart," and "robot." Notably, AI themes appeared in library patents approximately three years earlier than in library academic journals, suggesting that library practice responded to and explored AI technology more rapidly and deeply than academic research, demonstrating a practice-driven research trend. Comparing this with the timing of AI's concentrated appearance in Chinese policy statements reveals that policy and research emerged roughly simultaneously. The diffusion of AI across technology, policy, and research dimensions warrants further investigation. Overall, the AI scenario in library technology once again confirms the library community's enthusiasm for technological innovation and adoption.

Scenario 4: Reader Services
Technological development and social progress have quietly transformed reading methods. New reading forms based on electronic devices like mobile phones have transitioned from emerging disruptions to mainstream norms, gradually

weakening traditional paper-based reading and posing significant challenges to libraries' long-standing reading services, spaces, and equipment design. For libraries, enabling book utilization is the starting point and destination of their work, and improving reading environments effectively promotes reading. In the digital reading ecosystem, users expect libraries to provide immersive spaces for reading, learning, and contemplation [27]. Patents in the reader services scenario confirm this demand, mostly involving "reading," "seats," "study rooms," and "noise reduction," reflecting readers' concerns for comfort, immersion, and experience in library reading spaces.

The direction of library technology is demonstrating several trends: (1) from acting on "inorganic bodies" (devices) to "organic bodies" (living beings); (2) from focusing on collection to emphasizing service extension; (3) from automation to intelligentization; and (4) from "librarian-centered" and "facilitating librarians' work" to "user-centered" and "facilitating users' needs." These shifts become more pronounced through diachronic analysis with temporal variables.

4.4 Thematic Distribution Patterns and Expression Intensity From the typical application scenarios identified above (book collection, management systems, AI, reader services), library-related patents naturally align with the classic Chinese library science framework of "books, methods, and people," with AI as an emerging technological element simultaneously empowering all three classic elements.

This study conducted word frequency statistics on all patent titles, generating the word cloud shown in Figure 7 [Figure 7: see original paper] to reflect thematic expression intensity and reveal overall distribution patterns over the past decade. Figure 7 shows: (1) Rich variety of library-related patents covering all library domains. High-frequency nouns totaled 168, involving book storage, reader borrowing, library security, digital libraries, smart libraries, and other areas. (2) Most patents involve physical facilities. The term "device" appears 676 times, consistent with the standardized format of patent documents. High-frequency terms like "bookshelf," "equipment," "robot," and "transport cart" indicate numerous patents involve physical tools. In contrast, digital and virtual technologies emphasized in library academic journals show weaker expression intensity in patents. (3) AI and related theme patents as emerging fields show significant growth.

Notably, library technology development can generally be summarized in three stages: automation, digitalization, and intelligentization. However, the word cloud and above analysis reveal that while "automation" and "intelligentization" stages are well-represented, the "digitalization" stage shows weak expression intensity, essentially being absent compared to the other stages. This phenomenon requires further investigation combining specific technological applications, characteristics, environments, and historical backgrounds of the digitalization stage.

4.5 Diachronic Analysis of Thematic Evolution To examine thematic evolution over time, this study used patent abstracts as text analysis objects with temporal dimensions, sorting high-frequency words annually to track changes, as shown in Figure 8 [Figure 8: see original paper]. Except for incomplete 2021 data, the technical themes "device" and "bookshelf" show annual increases consistent with total patent volume trends.

Keywords strongly related to computer technology—"data," "information," and "management system"—peaked in 2018-2019 then declined annually. This likely reflects that after three generations of evolution, computer-based integrated management systems have gradually stabilized, causing related technological inventions to decline after peaking. With the rise of next-generation smart libraries, traditional integrated system technologies will likely be replaced by various emerging smart/intelligent technologies in patent proportions.

The similar concepts "user" and "reader" also evolved over time. Before 2017, "reader" appeared more frequently than "user," but after 2017, "reader" plateaued and declined while "user" grew rapidly. This subtle shift reflects changes in library technology application scenarios and directions: "reader" emphasizes book readers, whereas "user" implies consumers of various library services both online and offline, whose behaviors extend beyond mere reading.

5. Three-Dimensional "Scale" Comparative Analysis: The AI Theme

Placing library-related patent analysis results within the framework shown in Figure 1 allows examination of the interactions among technology, concepts, and policy in library development and transformation. For instance, it enables analysis of the sequence between theoretical research and technological application, policy orientation reflected in technological application, and how theoretical research reflects, grasps, regulates, and organizes technological application.

This section uses the "artificial intelligence" theme for longitudinal comparative analysis with policy agendas and theoretical research literature related to library development.

5.1 Comparison of Policy Themes and Patent Technology Themes This study 梳理了过去 10 年间与图书馆所处技术环境关系密切的国家政策及其发布的关键时间节点, such as the "Twelfth Five-Year" and "Thirteenth Five-Year" Cultural Development Reform Plans [28-29], the *Outline for Promoting Big Data Development* (2015) [30], and the *New Generation Artificial Intelligence Development Plan* (2017) [31]. The "Thirteenth Five-Year Cultural Development Reform Plan" explicitly mentioned strengthening cultural technology support, proposing to "use cloud computing, artificial intelligence, IoT and other scientific and technological achievements to foster new cultural formats and improve the manufacturing level of core cultural technology equipment." The *Outline for Promoting Big Data Development* guided national top-level design and overall deployment for China's big data development, while the *New Generation*

Artificial Intelligence Development Plan systematically planned China's overall thinking, strategic goals, main tasks, and safeguard measures for AI development, charting a course for long-term development.

Examining changes in library-related patents around these policy release dates reveals that big data-related patents, driven by the 2015 *Outline for Promoting Big Data Development*, grew steadily from 2016 but already had some technological reserves before the policy release, particularly a small peak in 2012. In the AI domain, the State Council released the *New Generation Artificial Intelligence Development Plan* in 2017, but "intelligent," "smart," and "robot" themed library-related patents had already emerged three years earlier, with substantial synchronous growth in 2017 when the policy was released.

These cases of big data and AI demonstrate that policy indeed promotes technological application and innovation in libraries, with the degree of promotion related to specific technological connotations and characteristics. Simultaneously, the germination, reserve, and development of related technologies precede policy recognition, consistent with innovation diffusion models in technology. For libraries, some technologically sophisticated libraries may become early innovators or adopters ahead of policy.

5.2 Comparison of Academic Research Themes and Patent Technology Themes This study selects thematic measurement results from library academic literature over the past decade [32] for comparison. Literature measurement shows that academic attention in the technology domain involves sentiment analysis, topic identification, LDA topic modeling, deep learning, etc.—themes rarely found in library technology patents, revealing a divide between research and practice. Additionally, the library academic community focuses on the close integration of library information technology and AI, emphasizing smart ontologies, smart perception, and smart service integration in research on smart recommendations, smart cataloging, smart restoration, smart Q&A, and smart visualization [33-34].

Comparing these with library technology patents on the same theme reveals that, besides AI patents appearing earlier than AI research, patents differ from research by not employing complex AI subdivisions. As previously noted, AI technologies in library patents often must combine with specific physical "devices" to be realized.

This multi-dimensional comparison helps better understand AI's positioning and role in library development—AI in libraries may not exist as an independent technology but functions by empowering, upgrading, and enhancing efficiency of existing library devices and facilities, needing to attach to and operate within specific devices, processes, or mechanisms.

6. Conclusion and Outlook

In the era of large-scale application of emerging technologies like AI in libraries, Mr. Wu Jianzhong noted that "whether libraries are people-oriented or technology-led is a question of values" [35]. This statement already implies the three elements of technology, concepts, and institutions. In the long term, these are not conflicting, competing, or substitutive relationships but rather mutually tractional, coordinated, and matched forces collectively driving library development—a viewpoint empirically supported by this and other studies in our series.

Following the overall analytical framework developed in previous research, this study uses quantitative methods to examine the institutional, conceptual, and technological elements in library development and transformation, focusing on the quantification of technological elements and exploring comparative analysis with policy and research outputs in the library field.

This study again demonstrates the need to break the one-dimensional linear logic of "technology triggers library change" [1], which has many limitations: it cannot explain why different libraries implementing the same technology show performance differences, nor why libraries in the same technological environment develop different management systems and models [36]. Our series of studies consistently aims to empirically verify that technological factors interact comprehensively with institutional, conceptual, and other factors. The technological dimension is an important "scale" for measuring library development but not the only one, and should not be examined in isolation.

Of course, as an exploratory study, this research has limitations: First, while using patents as a technological representation facilitates quantification and correlation with policy texts and research papers, patents are not the only technological representation. Not all technologies can or should be patented; a series of methodological applications, business processes, and tacit knowledge in library development possess attributes of technology in the broad sense. Therefore, future research should explore more dimensions and indicators reflecting library technology, such as engineering projects, procurement catalogs, and science and technology award records. However, as a technical literature carrier with novelty, timeliness, innovation, and practicality, patents remain uniquely significant for examining technology development and application, especially for emerging technologies like AI. Second, this study defined library-related patents through titles, which while ensuring specificity and library originality, excluded technologies migrated from other fields, requiring future attention for more comprehensive technological reflection. Third, this study raises questions needing further explanation, such as why the "digitalization" stage of library technology development is absent from relevant patents compared to "automation" and "intelligentization" stages. Finally, future research could examine more representative specific themes in the library field (e.g., big data), comparing their co-occurrence and differential expressions across technology, policy, and

academic literature to better understand these concepts' influence paths and mechanisms on library development.

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Wang Zheng: Responsible for research design, framework development, and paper revision and finalization;
Zhang Yile: Drafted the initial paper and conducted data collection and analysis;
Yang Jiaxin: Conducted literature review and paper revision.

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Keywords: technology evolution; patent analysis; bibliometrics; library development

Note: Figure translations are in progress. See original paper for figures.