The Development of Research and Practice on Smart Libraries in China: Postprint

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Abstract

[目的/意义] By integrating theoretical research and practical construction of smart libraries in China, this study analyzes the current status and development trends of smart library research and construction in China. [方法/过程] Using CNKI, Wanfang Data Knowledge Service Platform, VIP Chinese Science and Technology Journals, and other databases, this paper retrieved CSSCI journal research papers on smart libraries in China from 2010 to 2019, summarized and analyzed their main research themes, and investigated the practical construction status of smart libraries in China through online sources. [结果/结论] The study found that: Chinese scholars' research themes on smart libraries mainly focus on the concept and characteristics of smart libraries, development of smart library system platforms, smart management of smart libraries, and smart services of smart libraries; various types of libraries in China are actively exploring the application practices of smart spaces, smart management, and smart services in smart libraries, but the smart practice construction of public libraries lags relatively behind that of university libraries; currently, attention to smart library research and application practices in China is gradually increasing, research themes are gradually enriching, and application practice construction is gradually unfolding, but basic research on smart libraries is insufficient, research on the application of new technologies in smart libraries is not in-depth, and the application of theoretical research findings in smart library practice is not comprehensive.

Full Text

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Research and Practice of Smart Libraries in China

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Abstract:
[Purpose/Significance] This study analyzes the current status and development trends of smart library research and construction in China by integrating theoretical research with practical development. [Method/Process] Using CNKI, Wanfang Data Knowledge Service Platform, and VIP Chinese Science and Technology Journals, we retrieved CSSCI journal articles on smart libraries published between 2010 and 2019, summarized the main research themes, and investigated the practical construction status of smart libraries in China through online research. [Result/Conclusion] The findings reveal that Chinese scholars' research on smart libraries primarily focuses on the concept and characteristics of smart libraries, development of smart library system platforms, smart management, and smart services. Various types of libraries in China are actively exploring the application of smart spaces, smart management, and smart services in smart library practice, though public libraries lag behind university libraries in smart construction. Currently, research and application of smart libraries in China are receiving increasing attention, research themes are gradually diversifying, and practical construction is unfolding step by step. However, there remain deficiencies in basic research on smart libraries, in-depth studies on the application of new technologies in smart libraries, and comprehensive application of theoretical research findings in smart library practice.

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Since the concept of the smart library was introduced in 2003 [1] and the concept of the smart planet in 2008 [2], smart libraries, as an important component of the smart planet, have focused on the "smartification" of library management and services. With emphasis on both theoretical research and practical application, smart libraries have experienced rapid development. On December 13, 2019, we conducted a search for Chinese scholars' research on smart libraries using CNKI, Wanfang Data Knowledge Service Platform, and VIP Chinese Science and Technology Journals as data sources, with CSSCI journals as the source category, and "smart library" as the subject term under search fields including "topic," "title," and "keywords." After screening by thematic relevance and citation frequency, we obtained 378 relevant CSSCI journal articles. The literature review shows that research on smart libraries in China began in 2010. Over the past decade, research output has grown year by year (see Figure 1 [Figure 1: see original paper]). Scholars' main research findings can be summarized into several aspects: concept and characteristics of smart libraries, development of smart library system platforms, smart management of smart libraries, and smart services of smart libraries. During different development stages, scholars' research emphases have varied. Between 2010 and 2015, most scholars primarily explored fundamental questions such as what smart libraries should look like, what characteristics they should possess, how they differ from digital libraries, and how to evolve from digital libraries to smart libraries. From 2016 to 2019, more scholars began focusing on practical construction aspects, including smart

services of smart libraries, applicability of modern information technologies in smart libraries, and development of smart library system platforms.

In addition to reviewing papers, we also examined projects related to smart libraries in the National Social Science Fund project database. However, there were few projects, and no project outcomes were available yet. We also reviewed research on smart libraries by major database providers in China, who mainly focus on smart library system platforms rather than physical venue construction. Therefore, the selected objects for thematic analysis in this paper are primarily CSSCI journal articles.

Meanwhile, we investigated the practical construction of smart libraries in China. Due to the pandemic, we adopted online research instead of field surveys to obtain the current status of smart library construction. The investigation reveals that some key university libraries and public libraries at various levels are utilizing information technologies such as the Internet of Things and artificial intelligence to construct smart libraries, launching corresponding application practices based on scholars' research themes related to smart libraries.

2 Main Research Themes of Smart Libraries

Based on understanding of the connotation of smart libraries, researchers have conducted a series of studies on various aspects of smart libraries. In terms of research themes (see Figure 2 [Figure 2: see original paper]), these mainly concentrate on the concept and characteristics of smart libraries, development of smart library system platforms, smart management of smart libraries, and smart services of smart libraries.

2.1 Concept and Characteristics of Smart Libraries

2.1.1 Concept of Smart Libraries Chinese researchers hold different views on the concept of smart libraries, which can be summarized into three types: smart library as a model, smart library as intelligent information service, and smart library as a smart form. Confronted with the current intelligent development trend of libraries and combining previous experience, researchers have conceptualized smart libraries as a new generation library model that integrates technology, resources, services, librarians, and users to achieve intelligent services and management. For instance, Yan Dong [3] proposed that a smart library is a library model that uses new information technologies to change the way users and library system information resources interact, thereby achieving intelligent services and management. Some researchers suggest that the connotation of smart libraries is mainly reflected in their smart services, utilizing information technologies such as the Internet of Things and big data to optimize and innovate information services based on libraries' massive information resources, thereby achieving the intelligentization of library services. For example, Gao Ying [4] defined smart libraries as libraries that collect, store, and

diversely manage various types of data using new-generation information technologies to provide users with information services unrestricted by time and space. Other researchers believe that smart libraries represent a new form of library under the conditions of new-generation information technologies such as the Internet of Things and artificial intelligence. Chu Jingli et al. [5] proposed that smart libraries are an advanced form of library that realizes knowledge services and represent the top form of library development.

2.1.2 Characteristics of Smart Libraries Wang Shiwei [6] believes that smart libraries have three major characteristics: interconnection, efficiency, and convenience. Interconnection is the foundation of smart libraries, efficiency is the core, and convenience is the purpose—the foothold of interconnection and efficiency characteristics and the essence of the people-oriented philosophy of smart library scientific development. Liu Libin [7] proposed that comprehensive perception, interconnectivity, green development, and smart service and management are the four main characteristics of smart libraries. Comprehensive perception and interconnectivity are the technical foundations of smart library services and management, green development is the sustainable development strategy of smart libraries, and smart service and management are the ultimate foothold and most significant characteristics of smart libraries. Yu Dan [8] argued that smart libraries have four features: comprehensive perception, efficient interconnectivity, green development, and smart convenience. In summary, the distinctive features that differentiate smart libraries from digital libraries are comprehensive perception, efficient convenience, and interconnectivity.

2.2 Development of Smart Library System Platforms

2.2.1 Construction of Smart Library System Platforms How to construct and develop smart libraries in practice is a concern for many scholars. Shen Kuilin et al. [9], taking Nanjing University Library as an example, proposed that the construction of smart library system platforms should start from users' actual information needs, utilize information and communication technologies to build convenient service facilities, aggregate various information resources, and provide users with convenient physical library services and digital library platform services unrestricted by time and space, truly achieving interconnectivity, convenience, and efficiency. Gong Chunjian [10] studied the construction of smart library system platforms from both hardware/software and services aspects, specifically including artificial intelligence, big data, Internet of Things, cloud computing, databases, as well as training, salons, maker spaces, and smart seminar rooms. Wei Lai et al. [11] explored the construction of smart library system platforms from a data management perspective, dividing smart library data into three categories—resource data, user data, and environmental data—and accordingly classified smart library functions to construct a data management-based functional framework for smart libraries.

2.2.2 Architecture of Smart Library System Platforms Scholars' research on the architecture of smart library system platforms can be divided into hierarchical theory and dimensional theory. Regarding hierarchical theory, Wang Dongbo [12] divided the architecture of smart library system platforms into six layers: presentation layer, application layer, service layer, perception layer, data layer, and support layer. Xu Xinlong et al. [13] designed the information system of smart library platforms with five layers: perception layer, transmission layer, data layer, application layer, and presentation layer. Chen Chen [14] believed that the system structure of smart libraries mainly consists of four parts: data perception layer, data transmission layer, data analysis layer, and smart service layer. Chen Songmin et al. [15] simply divided the overall architecture of smart libraries into three layers: application layer, platform layer, and technology layer. Regarding dimensional theory, Wang Lan [16] proposed constructing the main architecture of smart libraries from three aspects: resource environment, technology, and intellectual support. Xie Fang [17] divided the construction of smart libraries into material, technical, and service dimensions. Whether analyzing the architecture of smart libraries from hierarchical or dimensional perspectives, they all aim toward smart environment, smart management, and smart services.

2.2.3 Supporting Technologies for Smart Library System Platforms In today's highly informationized era, the development of any industry is inseparable from the application of information technology, which is particularly crucial for the construction and development of smart libraries. Many scholars have expressed their opinions on what information technologies can be applied to smart library construction and have conducted in-depth research. Among these, scholars unanimously agree on the application of RFID technology in library self-service, book inventory, and other aspects. Additionally, Liu Wei et al. [18] studied the application of 5G technology in ten scenarios in libraries: unperceived borrowing, navigation and guidance, ultra-high-definition video, smart study rooms, smart venues, cloud classrooms, precise push, robot services, smart security, and regional services. They also pointed out that 5G technology brings challenges to smart libraries in multimedia resource construction and services, business models of libraries as knowledge intermediaries, modern management service platforms, and application security. Chen Xiaoping [19] believed that the characteristics of blockchain technology—decentralization, consensus mechanism, temporal stability, and reliable data relationships—are well-suited to the practical problems faced by smart services in libraries, such as huge data volumes, complex interaction types, and fast transmission speeds. Using blockchain technology as the underlying support and blockchain concepts as a breakthrough for smart service dilemmas can help transform library smart services in management systems, institutional repository construction, and knowledge transaction service models, meeting readers' needs for smart services in equipment space usage and online learning exchange platforms. Wang Shiwei [20] found that diverse autonomous devices, facial recognition machines, robot

librarians, unmanned book delivery vehicles, and smart touch screens applying artificial intelligence technology have become assistants to librarians. Wang Wentao et al. [21] studied the application of future virtual reality technology in constructing virtual reality libraries, three-dimensionally displaying collection resources, building new database resources, developing virtual teaching, developing smart libraries, and optimizing information and user services. They also pointed out potential problems in applying virtual reality technology in libraries, such as high costs, information literacy issues of users and library staff regarding virtual reality information resources, and users possibly experiencing stereo vertigo. Liu Xiqiu et al. [22] expanded the application of wearable technology in libraries to multifunctional navigation, personalized services, and helping disadvantaged groups use library resources. Qin Hong et al. [23] proposed that facial recognition technology can be applied to library access control, staff attendance, and identity verification.

2.3 Smart Management of Smart Libraries

Research on smart library management mainly focuses on three areas: smart management of information resources, smart management of library spaces and equipment, and smart management of library security.

2.3.1 Smart Management of Information Resources Library information resources mainly include traditional books and materials and digital information resources, which form the foundation for libraries' existence and various services. For the smart management of library resources, particularly traditional books and materials, most scholars believe that RFID technology, supplemented by the Internet and artificial intelligence, can achieve smart resource management. For example, Ni Cheng [24] proposed an intelligent book inventory robot using RFID as the core technology to replace traditional manual inventory work, thereby breaking through the single mode of library services and promoting the transformation and diversification of library service methods. Jia Shuangshuang et al. [25] emphasized that RFID represents an innovation in library automated management models and can play an important role in self-service borrowing and returning, automatic shelving, smart inventory, and security.

2.3.2 Smart Management of Library Spaces and Equipment People usually refer to library spaces with smart functions as "smart venues." Regarding smart venues, scholars emphasize using wireless sensor technologies to real-time detect and automatically adjust library environments, creating suitable environments for personnel and resource equipment to meet the requirements of cost reduction, energy saving, and environmental protection for smart buildings. Li Libin [26] proposed that embedding sensor devices in library equipment to monitor environmental conditions in real-time can construct an intelligent building integrating fault analysis, energy consumption management, equipment monitoring, and property management, providing suitable environments for personnel and equipment operation to achieve cost reduction and energy-saving re-

quirements for smart venues. Chen Songmin et al. [27] believed that RFID and wireless sensor technologies can be used for intelligent monitoring and perception of library equipment environments to automatically adjust environmental conditions. Huang Hui [28] studied how real-time data from smart switches and smart sensors can automatically control various equipment in libraries to effectively reduce energy consumption.

2.3.3 Smart Management of Library Security As large public spaces housing numerous valuable information resources, personnel, and equipment, security is an important guarantee for library management and services. Research on smart library security mainly focuses on fire safety and theft prevention. Zhou Shuanlong et al. [29] proposed that smart security systems include smart fire protection systems with smoke sensors and video surveillance systems, anti-theft systems, and intelligent monitoring systems integrating monitoring, control, inspection, and management. Liu Wei et al. [18] supplemented that smart security should include multi-camera networking, emergency automatic response, crowd monitoring, risk warning, network alarm, and linkage control functions.

2.4 Smart Services of Smart Libraries

The core of smart libraries lies in the various smart services they provide, including the smartification of traditional library services and innovative smart services. Analysis reveals that scholars' research on smart services mainly concentrates on mobile services, self-services, intelligent consulting services, personalized recommendation services, knowledge services, and intelligent navigation and guidance services, with particular attention to personalized recommendation services.

2.4.1 Mobile Services Research on smart library mobile services mainly includes two aspects: designing smart library mobile apps using mobile devices and the Internet, and implementing mobile services through mobile social media such as WeChat and Weibo. Chen Hongmei [30] proposed that smart library app service models can achieve library service smartification in 4G network environments. Wei Qunyi et al. [31] studied and designed the system structure of smart library mobile apps. Wang Dongbo [12] emphasized the need to correctly understand mobile apps, not only using them to provide services but also enhancing their service capabilities and effectiveness. Dou Hongqing et al. [32], taking Ningbo University's smart library app as an example, elaborated on services that smart library apps can provide, including micro-book guidance and book transfer. Zhou Shuanlong et al. [29] proposed that libraries can use WeChat, Weibo, and other platforms to provide push, consultation, and reservation services.

2.4.2 Self-Services Self-service is an important smart service in smart libraries, including self-service borrowing and returning of books, self-service

printing and copying, and self-service seat reservation. Rao Zengyang [33] proposed that besides conventional services, smart libraries should provide self-services where readers can independently complete printing, copying, and other operations using self-service systems, with smart libraries accepting various payment methods such as bank cards, Alipay, and WeChat. Wang Weiqiu et al. [34] proposed that using facial recognition systems for borrowing and returning books can solve problems such as readers forgetting their library cards.

2.4.3 Intelligent Consulting Services With the development of Internet technology, library consulting services have transformed from traditional on-site consultation, message consultation, SMS consultation, telephone consultation, and email consultation to digital reference consultation, including online consultation and mobile consultation through WeChat and Weibo. With the application of artificial intelligence technology in libraries, people have begun to pay attention to a new type of consulting service: intelligent robot consultation. Liu Baisong et al. [35] regarded robots as the "tentacles" for interaction between the "library brain" and users, proposing that robots can provide user consultation, borrowing and returning guidance, code scanning for book location, user guidance, and daily communication with users and staff, promoting intelligent interaction between libraries and users. Kang Cunhui et al. [36] proposed that intelligent robots can provide on-site consultation or guidance services.

2.4.4 Personalized Recommendation Services Personalized recommendation services have always been a key focus area, reflecting the core concept of library services. Research on smart library personalized recommendation services mainly includes personalized recommendation based on reader personal data, personalized recommendation based on reader location, personalized recommendation based on user context, and embedded information recommendation based on user stratification. Liu Wei et al. [18] studied the application of big data analysis in precise push of readers' reading and activity behaviors in smart libraries. Huang Yueshen et al. [37] proposed that libraries can use Beacon technology to real-time perceive readers' locations and push refined resource information to readers' usage contexts. Zeng Ziming et al. [38] believed that context-aware smart library recommendation models should meet readers' real-time access needs, automatically perceive readers' contextual information, and provide personalized services and resources under various contextual factors. Ma Bo [39] focused on the smartification of personalized recommendation services in university libraries, proposing that personalized and refined services can be provided according to users' disciplinary learning stages or research directions.

2.4.5 Knowledge Services Knowledge services are also a focus area for researchers. Intelligence services, think tank services, and disciplinary services provided by libraries are all included in the category of knowledge services, as the essence of these services is to provide different users with different content

or forms of knowledge through analysis and processing of user needs and information resources. Lei Nianping [40] proposed that intelligence services refer to libraries collecting, processing, and sorting out materials to meet users' specific needs and providing highly customized knowledge service products. Shang Shan et al. [41] expanded the scope of think tank services from providing literature information for government legislation and decision-making to providing public opinion supervision and emergency measures for the country. Liu Lu [42] believed that disciplinary services are a new professional library service model for professional learning and research personnel. Hu Haiyan et al. [43] proposed that customized information services in smart libraries mainly include customized services for databases and journals, course literature, thematic literature, innovative research, and lecture training.

2.4.6 Intelligent Navigation and Guidance Services Currently, the rapid development of various types of libraries is reflected not only in resource quantities and hardware equipment but also in spatial scale. Users unfamiliar with library layouts can easily waste time searching for different functional areas, especially in libraries with large building areas and novel spatial layouts. Therefore, scholars have focused on how to use GPS, virtual reality technology, and other technologies to implement intelligent navigation and guidance services in libraries. Ma Jie et al. [44] proposed that university smart libraries should use modern technologies such as WiFi, mobile networks, and GPS to provide users with intelligent indoor navigation services through in-house equipment or mobile apps. Cao Yi [45] proposed that wearable devices can help smart library readers understand the entire library layout and access any corner they want to reach. Huang Yueshen et al. [40] proposed that libraries can learn from Beacon application models in museums to provide navigation services. Wang Shiwei [20] suggested that in super-large libraries, robots can provide positioning services for the last 100 meters to solve problems caused by oversized library spaces.

3 Application Practice of Smart Library Construction

Chinese scholars also pay close attention to the application practice of smart library construction. Fan Huili et al. [46] took the innovative practice of book inventory using intelligent robots at Nanjing University Library as an example, conducting empirical analysis and reflection on the advantages, limitations, and future development of intelligent robot book inventory. They concluded that intelligent robot book inventory has advantages over traditional manual inventory in terms of cost, inventory efficiency and accuracy, regularization of inventory work, and innovative services, but still faces challenges in interactive collaboration with librarians and adaptation to complex dynamic library environments. Kang Xiaodan [47] analyzed and introduced Shanghai University Library's implementation of smart library systems from three technical levels—perception, computing, and interaction—and explained its practices and future vision in the field of smart library technology implementation. Cao Tian [48] analyzed

and introduced Nanjing Xiaozhuang College Library's approach to tracking and researching reader behavior big data in the early stage, forming two methods for discovering user interests—common search term sequential lists and fragment clustering—by extracting user search terms and TF-IDF information of books, as well as the development path and construction experience of self-built robot librarians [49].

3.1 Application Practice of Smart Library Space Construction

People usually refer to library spaces with smart functions as "smart venues." Regarding smart venues, scholars emphasize using wireless sensor technologies to real-time detect and automatically adjust library environments, creating suitable environments for personnel and resource equipment to meet the requirements of cost reduction, energy saving, and environmental protection for smart buildings. According to our research findings, seven libraries—including Shanghai Jiao Tong University Library, Minzu University of China Library, Nanjing University Library (machine room), Nankai University Library (special collection room), Wuhan University Library (ancient books room), Shandong University Library (ancient books room), and Shenzhen Bao'an District Library—have introduced relevant implementations of smart venue construction, accounting for 9.09% of the 77 libraries surveyed. Other libraries have not yet introduced smart venue construction. Therefore, smart venue construction of various types and levels of public libraries in China is still in its initial stage.

3.2 Application Practice of Smart Management

Our online survey found that 23 of the surveyed libraries have implemented smart management to varying degrees, accounting for 30% of the total. These libraries widely use technologies such as intelligent robots, wireless Bluetooth, facial recognition, and intelligent security inspection to achieve smart management of information resources (including intelligent sorting, inventory, transportation, and shelving of books) and smart security management of library space environments, as shown in Table 1 .

Table 1 Current Status of Smart Management Application Practice in Smart Libraries

Smart Management Practice	Applied Equipment	Libraries Implementing	Ratio
Smart management of information resources	Inventory guns with inventory carts, unmanned inventory robots, wireless Bluetooth book return carts, intelligent universal return carts, etc.	Nanjing University Library, Wuhan University Library, Southeast University Library, Tsinghua University Library, Shenzhen Bao'an District Library, Tianjin Binhai New Area Library	16.88%
Smart management of library spaces and equipment	Intelligent sorting, transportation, inventory, and shelving; access control recognition, remote fire monitoring and early warning, intelligent anti-theft, video surveillance, intelligent dual-frequency book monitors, etc.	Nanjing University Library, Southeast University Library, Shanghai Jiao Tong University Library, Zhengzhou University Library, Harbin Institute of Technology Library, University of Electronic Science and Technology Library, Huazhong University of Science and Technology Library, Northwestern Polytechnical University Library, Tianjin University Library, Beijing Institute of Technology Library, Sun Yat-sen University Library, National Library of China, Hubei Provincial Library	30%

Smart Management Practice	Applied Equipment	Libraries Implementing	Ratio
Smart management of library security	Intelligent sensors, smart monitors, etc.	Shanghai Jiao Tong University Library, Central Minzu University Library, Nanjing University Library (machine room), Nankai University Library (special collection room), Wuhan University Library (ancient books room), Shandong University Library (ancient books room), Shenzhen Bao'an District Library	9.09%

As shown in Table 1, some information technologies that can support smart library construction and research findings related to smart library management have been applied in a small number of libraries. Various types and levels of libraries have begun to pay attention to the application of emerging information technologies in smart libraries and smart library management.

3.3 Application Practice of Smart Services

The current status of smart service application practice in smart libraries in China is shown in Table 2 .

Table 2 Current Status of Smart Service Application Practice in Smart Libraries

Smart Service Type	Practice Content	Libraries Implementing	Ratio
Mobile services	Mobile apps, WeChat, Weibo, etc.	All surveyed libraries	100%

Smart Service Type	Practice Content	Libraries Implementing	Ratio
Self-services	Self-service borrowing/returning, self-service printing/copying (excluding self-service seat reservation)	All surveyed libraries	100%
Intelligent consulting services	Robots, virtual reference consultation	Tsinghua University Library, Nanjing University Library, Wuhan University Library, Southeast University Library, Sichuan University Library, Sun Yat-sen University Library, Shanghai Library, National Library of China, Tianjin Binhai New Area Library, Liaoning Provincial Library, Peking University Library, Zhengzhou University Library, Northwestern Polytechnical University Library, Northwest A&F University Library, Tongji University Library, Nankai University Library, Yunnan University Library	22.08%

Smart Service Type	Practice Content	Libraries Implementing	Ratio
Personalized recommendation services	Location-based personalized recommendation, subject librarians, big data-based personalized recommendation	Shanghai Library, Peking University Library, Renmin University of China Library, Tianjin Binhai New Area Library, China Agricultural University Library, Huazhong University of Science and Technology Library, Nanjing University Library, Northeastern University Library	10.39%
Intelligent navigation and guidance services	WiFi-based "in-house navigation," intelligent touch screen multimedia navigation, 3D navigation, VR virtual navigation, robot navigation, smart bookshelves, etc.	Peking University Library, Nanjing University Library, Nankai University Library, Huazhong University of Science and Technology Library, Xi'an Jiaotong University Library, Sichuan University Library, Harbin Institute of Technology Library, Wuhan University Library, Tianjin Binhai New Area Library, National Library of China	14.29%
Knowledge services	Intelligence services, think tank services, disciplinary services, etc.	All surveyed libraries	100%

Smart Service Type	Practice Content	Libraries Implementing	Ratio
Innovative experience services	VR virtual experience	Tianjin University Library, University of Electronic Science and Technology Library, Fudan University Library (Medical Library), National Library of China, Qinghai Provincial Library, Hunan Provincial Library, Shanghai Library, Nankai University Library	10.39%

As shown in Table 2, all 77 surveyed libraries have implemented partial smart services, with a high popularization rate of smart services, fully demonstrating that China places special emphasis on services in smart library construction. The survey also found that university libraries provide smart services earlier than public libraries, with relatively more service types. Besides earlier mobile services and self-services, only a very small number of public libraries have launched other types of smart services, indicating that public libraries' awareness and construction of smart services need further improvement.

4 Analysis of Characteristics and Weak Links in Current Smart Library Research and Application Practice in China

The survey results show that research and application practice of smart libraries in China over the past decade have achieved certain results, reflected in steady research progress and integration of theory and practice, but some weak links also exist.

4.1 Characteristics of Current Smart Library Research and Application Practice in China

4.1.1 Increasing Attention to Smart Libraries From the growth trend of research papers over the past decade, Chinese scholars are paying increasing attention to smart library research and construction, from only one relevant paper initially to nearly 100 research papers annually now. Research has evolved from initial interpretation of smart library concepts to specific solutions for smart library problems and application practice, with increasingly in-depth and specific studies and growing attention to smart libraries.

4.1.2 Gradually Diversifying Research Themes Smart libraries are a new phenomenon in form. The smartification of libraries based on hybrid libraries involves not only the smartification of existing service and management models but also the smartification of libraries themselves. The smart library research theme distribution cloud shows that research themes mainly concentrate on smart library services, such as self-service, intelligent navigation services, and mobile services, which represent the smartification upgrade and transformation of digital library information services. With the application of intelligent technologies, people have also begun to pay attention to smart library management issues, particularly smart management of information resources assisted by intelligent technologies. Research on smart library spaces is a new field, with scholars beginning to explore how to achieve the smartification of library buildings, internal spaces, and overall systems. Therefore, the scope of smart library research themes has further expanded.

4.1.3 Gradual Development of Smart Library Application Practice The online survey results show that some qualified libraries have begun smart library construction, including smart venue design, smart management of library resources, and development and application of smart services. In the construction of smart libraries, some research findings and intelligent technologies and theories have been widely applied in practice, such as RFID smart book stacks and robot inventory. The application of smart services in libraries is most closely connected with theory, with innovative smart services such as mobile services, self-services, intelligent consulting services, personalized recommendation services, intelligent navigation and guidance services, knowledge services, and innovative experience services being fully or partially launched in various types of libraries. Although the application practice construction of smart venues, smart management, and smart services has not fully synchronized with theoretical research, they are all gradually being implemented.

4.2 Analysis of Weak Links in Smart Library Research and Application Practice in China

4.2.1 Basic Research on Smart Libraries Needs Strengthening Smart libraries represent an inevitable trend in library development. The evolution from digital libraries to smart libraries will inevitably encounter many problems that need to be solved, particularly fundamental issues underlying smart library development. Currently, researchers mainly focus on the smartification of specific problems or specific business activities in library management and services, with few studies addressing fundamental issues of smart libraries. Smart libraries require proper top-level design, including their basic components, architecture, and platform structure, all of which require researchers' attention and investigation. Current research findings in this area need strengthening.

4.2.2 Research on Application of New Technologies in Smart Libraries Needs Deepening Currently, most research on the application of emerg-

ing technologies such as big data, cloud computing, artificial intelligence, and blockchain in libraries remains in the exploratory stage. Researchers mainly start from the technologies themselves, introducing basic principles and characteristics, discussing their feasibility for library application, or raising issues that need attention when applying them in libraries. Few studies involve actual application scenarios or examples, and in-depth research on applying emerging technologies to specific problems or types of problems has not yet begun, particularly regarding artificial intelligence and blockchain technologies. Since these technologies have not been around for long, they have attracted limited attention, with most research still at the stage of exploring application feasibility.

4.2.3 Application of Theoretical Research Findings in Smart Library Practice Needs Enhancement Scholars' research on smart libraries has expanded from initial concepts, characteristics, and development to technology, services, and other aspects. However, these research findings can only exert their maximum value when applied in the actual construction of smart libraries. Meanwhile, problems that may exist or emerge in the process of smart library construction in practice also require joint solutions from theoretical research. Close integration of theory and practice helps accelerate the development of smart libraries. The survey results show that smart library research has begun to move from theoretical research to the initial stage of combining theory with practice, which needs further strengthening.

Conclusion

Social progress and modern information technology development drive the innovative development of libraries. With the application of technologies such as the Internet of Things and artificial intelligence in the library field, smart libraries have become a theme of concern in library research and application practice. Through investigation of the development of smart library research and practice in China over the past decade, we found that Chinese scholars' research on smart libraries mainly focuses on the concept and characteristics of smart libraries, development of smart library system platforms, smart management, and smart services, with particular attention to system platform development and smart services. Through online surveys of smart library construction in important university libraries, provincial-level and above public libraries, and some well-constructed municipal and district-level libraries in China, we found that various types of libraries in China are actively exploring smart library practice and application. Some libraries, particularly university libraries, are using technologies such as the Internet of Things and artificial intelligence to achieve smart management of book sorting and inventory. Meanwhile, they are using robots, VR, and other technologies for intelligent consulting and navigation services, and using big data analysis technology for personalized information recommendation services, striving to achieve service smartification. However, the survey results also show that public library smart construction lags behind. Currently, smart library research and application practice in China

have three characteristics—increasing attention, gradually diversifying research themes, and gradually developing application practice—and three deficiencies—insufficient basic research, inadequate in-depth research on new technology applications, and incomplete application of theoretical research findings in practice. Future research will investigate and analyze international smart library-related research and practice, understand international progress in smart library construction, compare and analyze characteristics and trends of smart library research and construction between China and other countries, examine China's position and level in international smart library research and construction, and propose corresponding recommendations.

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Wu Zhiqiang: Proposed research ideas, revised the paper;
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A Preliminary Survey on Research and Practice of Smart Library in China

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Abstract: [Purpose/significance] Combining with the research and practice of

smart library in China to grasp the status quo and development trend of smart library's research and practice in China. [Method/process] This paper used China National Knowledge Infrastructure, Wanfang Data Knowledge Service Platform, Weipu Chinese Science and Technology Journals, etc. to search the CSSCI journal research papers on smart library in China from 2010 to 2019, summarized the main topics of these research papers, and investigated the practice of smart library in China by online research. [Result/conclusion] It was found that Chinese scholars' research on smart library mainly focuses on the understanding and features of smart library, development of the platform of smart library, smart management and smart services in smart library; and various libraries in China are actively exploring the practice of smart library, and that of public libraries is relatively lagging behind the development of university libraries; currently, the research interest of smart library is gradually increasing, and the research topics of smart library are gradually enriched, as well as the practice of smart library is gradually developing, however, the basic research of smart library needs to be strengthened, and the research on the application of new technologies in smart library needs more attention, and the practice of theoretical research on smart library needs to be enhanced.

Keywords: smart library; theoretical research; practice construction; China

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