From Digital Libraries to Smart Libraries: Post-prints

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Abstract

This paper explores new directions for digital library development in the era of artificial intelligence, advancing the construction and development of smart libraries in China. It analyzes the connections and distinctions between digital libraries and smart libraries, proposing development requirements for smart library construction: squarely confronting the opportunities and challenges brought by intelligent technologies to ensure continuously evolving technical support; grasping the construction objectives of smart libraries to steadily advance their development; and continuously enhancing service capabilities to strengthen libraries' knowledge services and smart services. Smart library construction should consistently center on the fundamental principle of "demand-driven, technology-driven, service-oriented, capability-tested" to accelerate the transformation and upgrading of libraries toward smart libraries.

Full Text

Preamble

From Digital Libraries to Smart Libraries

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Abstract

This paper explores the new direction of digital library development in the era of artificial intelligence and promotes the advancement of smart library construction in China. It analyzes the connections and distinctions between digital libraries and smart libraries, and proposes development requirements for smart

library construction. These include confronting the opportunities and challenges presented by intelligent technologies while ensuring continuously evolving technical support; grasping the construction goals of smart libraries to steadily advance their development; and continuously improving service capabilities while strengthening knowledge services and smart services. Smart library construction should adhere to the fundamental principle of "demand-driven, technology-enabled, service-led, and capability-tested" to accelerate the transformation and upgrading of libraries toward smart libraries.

Keywords: Digital Library; Smart Library; Smart Service; Knowledge Service; Classification Number: G250

Introduction

In 2019, the International Federation of Library Associations and Institutions (IFLA) stated in both its *IFLA Strategy 2019-2024* and *IFLA Trend Report 2019 Update* that libraries must "adapt to a changing world, keep pace with technological innovation, and meet user needs" [1], and that "libraries need wisdom, must develop new skills, enhance library leadership, and achieve a grander vision built on technological development" [2]. In recent years, with the continuous evolution of information technology and the vigorous rise of artificial intelligence, concepts such as "Smart Earth," "Smart City," "Smart Community," and "Smart Campus" have emerged, bringing both new challenges and new vitality to library development. Libraries must seize the opportunities brought by technological transformation, accelerate their transition from digital libraries to smart libraries, and shift their strategic focus from digital library construction to smart library construction.

Smart libraries represent a new form of library that emerges in a new era and environment to meet new user needs, constituting a new goal for library development and a fusion of intelligent technology and human wisdom. We must recognize that society and the public do not need libraries to disappear, but rather need libraries to evolve into new forms and fulfill new functions. The strategic goal of future library development is not digital libraries, nor intelligent libraries, but smart libraries. Some experts have proposed that although smart libraries represent the highest stage of development for today' s libraries, they will not be the ultimate stage [3]. In the foreseeable future, smart library construction will be the top priority for library development. The *Outline of the 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives Through 2035 of the People' s Republic of China* specifically mentions "smart libraries" in its section on "providing smart and convenient public services" [4].

Naturally, the development direction and model of libraries depend on practical needs and social demands. Based on this understanding, this paper conducts a comparative analysis of digital libraries and smart libraries to clarify the construction priorities of smart libraries and promote accelerated transformation

from digital libraries to smart libraries in both theoretical and practical research.

2.1 Digital Libraries

The concept of digital libraries was first introduced to China in 1994 [5], when an article translated from the American magazine *Information* rendered it as "fiber-optic library." Within less than a year, scholars such as Li Jinsuan [6], Lu Xiangyu [7], Liu Xiwen [8], and Zhu Qiang [9] introduced the development of digital libraries in the United States, formally establishing the concept of "digital library" in Chinese academia.

Digital libraries are distributed information systems based on the Internet that process and store various library information resources in encoded form to facilitate user retrieval and utilization [10]. Digital libraries—and all mobile libraries derived from digital and network technologies—represent the first transformation of traditional libraries, integrating digital resources and networked services into a new service model and marking a transition from emphasizing resources and technology to emphasizing service functions [11]. Although digital libraries recognize the important role of librarians, they are not smart libraries [12]. Due to the absence of human "wisdom" and limitations in digital technology development, digital libraries are increasingly unable to meet users' deep-level, diversified, and complex information needs. The rapid development of emerging technologies, particularly artificial intelligence, provides both the external environment and technological momentum for the transition from digital libraries to smart libraries.

2.2 Smart Libraries

A search of the CNKI database for articles on the theme of "smart libraries" reveals that the concept was first mentioned in Chinese research in 1999 [13]. Subsequent studies featuring this concept were published by scholars including Lin Wenrui, Shen Qiaomei [14], Li Nianzu [15], Yang Peichao [16], Jin Lihong [17], Zhang Rui [18], and Yin Yuehua [19]. However, prior to July 2010, scholars' research focused only on digital libraries or information services provided by libraries to users, not on "smart libraries" in the true sense that incorporate librarian and human wisdom. After IBM formally proposed the concept of "Smart Earth" in 2008 [20], the genuine "smart library" was formally introduced in 2010 [21-22], followed by contributions from scholars such as Shao Bo [23-24], Chu Jingli [10,25], Cheng Huanwen [3], and Wu Jianzhong [12].

This study defines smart libraries as an advanced form of library development dedicated to achieving knowledge services through human-computer interaction coupling. They represent the core connotation of third-generation libraries and new-type libraries, the advanced form and dominant model of future libraries, and the new positioning, new image, and new capability of libraries in the new era. If the first major transformation in library development was the shift from paper-based physical libraries to digital and networked digital libraries, then

the second major transformation is the shift from digital libraries to intelligent and smart libraries [6][25].

It can be argued that the mission of digital libraries has been essentially completed, while smart library construction has become the core content and construction goal of library strategic planning, serving as the main driving force for library transformation and development. Smart libraries integrate the intelligence of things and the wisdom of humans, characterized by "AI (Artificial Intelligence), Big Data, Cloud Service, and IoT (Internet of Things)." Smart library construction must adhere to the basic principle of "demand-driven, technology-enabled, service-led, and capability-tested." However, it must be clarified that smart libraries are not an extension of digital libraries, nor are they equivalent. While digital libraries are characterized by digitization and networking, smart libraries are characterized by intelligent systems and human wisdom, with greater emphasis on the wisdom of people (librarians and users), making librarians' wisdom particularly important.

3 The Evolutionary Process of Library Forms

Since their inception, libraries have undergone two major transformations alongside technological and environmental changes. The first was from traditional first-generation paper-based, physical libraries to second-generation digital, mobile libraries, and the current transformation is toward third-generation intelligent, smart libraries, as shown in Figure 1 [Figure 1: see original paper].

Figure 1 The Evolutionary Process of Library Forms

First-generation paper-based, physical libraries centered on physical library buildings, primarily relying on library space and document resources to function, with the core mission of providing in-person document services to on-site readers. With the emergence and rapid development of Internet technology, second-generation digital, mobile libraries began using networks to provide networked information services to users. Currently, with the rapid application of IoT technology and intelligent agent technology, and the emergence of disruptive innovative technologies such as big data and artificial intelligence, library services are being rapidly upgraded and transformed. Intelligent and smart libraries (still in embryonic form) have begun to emerge, and libraries have started providing intelligent, smart knowledge services to help users quickly obtain desired knowledge in a world filled with fragmented information. The transformation from digital libraries to smart libraries is imperative.

Although libraries have undergone two major transformations, library services have always been demand-driven for many years, continuously upgrading service content and models. Services have evolved from initially providing only in-person document services to coming to users' sides, using networks to provide information services across time and space, and beginning to transition toward providing intelligent and smart knowledge services. However, it must be clarified that the development process of libraries is not one of replacement; original

library functions still exist, and in-person document services still have their significance. It is just that with the development of networks and technology, original functions may be relatively weakened, and libraries are deriving new attributes and functions with greater contemporary significance.

4.1 Differences Between Digital Libraries and Smart Libraries

Smart libraries are the goal and advanced form of digital library development. The two have certain differences in functional attributes, construction goals, mechanisms of action, and construction content:

First, functional attributes differ. Digital libraries correspond to physical libraries and represent a service information system developed from physical library document and information resources combined with information technology. Their function is to facilitate users' retrieval and utilization of collection information resources. Smart libraries correspond to digital libraries and have evolved from digital libraries. Smart libraries achieve intelligent application of multiple information technologies in libraries and combine librarian wisdom to provide smart services to users. Digital library development is network service-oriented, with the basic function of guaranteeing literature and information resources. Technological innovation, changing application scenarios, and actual technological application effectiveness directly influence digital libraries' functional positioning and service products. Smart libraries are smart service-oriented, with the basic function of knowledge utilization. Their driving force comes from the internal development needs of library transformation and innovation in the new era, and they represent the inevitable requirement for libraries to reshape core capabilities and strengthen knowledge services.

Second, construction goals differ. Digital libraries aim to achieve digitization of internal business processes to meet library operation and development needs and improve operational efficiency. Digital libraries aim to use technological means to solve fundamental contradictions in library development, namely the contradiction between users' literature needs and insufficient library resource guarantees. Smart libraries aim to provide users with intelligent analysis capabilities to meet high-level, increasingly deep service needs, solving the contradiction between users' demand for new library services and insufficient library service capabilities. The technological means used in smart library construction emphasize providing intelligent and smart solutions to users through intelligent technology to help users discover knowledge in large collections. In this scenario, libraries are not only places for information query and retrieval but also service mechanisms for knowledge utilization and knowledge services.

Third, mechanisms of action differ. The basic requirement of digital libraries is to "do things right," following system instructions and settings to respond to each user request and instruction mechanically. Smart libraries, however, emphasize "doing the right things," using system intelligence to assist human wisdom, enabling library operations to correct deviations in real time and pro-

vide more personalized services. "Do things right" and "do the right things" represent two distinct ways of thinking and acting. The former focuses on the present and emphasizes the correctness of "methods," while the latter focuses on the long term and emphasizes the correctness of "direction." It is precisely because of these different conceptual orientations that differences arise in the mechanisms of action between digital and smart libraries. Therefore, "doing the right things is more important than doing things right" [26].

Finally, construction content differs. Digital library construction primarily focuses on library portals to meet users' literature needs, with emphasis on network information collection, digital resource organization and discovery, cross-database retrieval functionality, information portal construction, digital reference services, and MyLibrary, Personal Library, and hybrid library construction. These have characteristics of being collection-focused, literature-centric, intermediary, transactional, and skill-based. Smart library construction focuses on how to provide smart services to meet users' knowledge needs, directly facing user needs and processes. Based on the "intelligence" of "things" such as library physical space, smart space, and smart business, it provides big data analysis and decision support for library operations, achieves intelligent business processing and analysis and smart user services, and then organically combines with the "wisdom" of "people" such as expert librarians and smart librarians to provide knowledge-based, creative, and value-added smart services, striving to make libraries deep partners in users' research and learning.

In summary, the technological core of digital libraries is the digitization of collection literature and information resources, while the technological core of smart libraries is the datafication of knowledge needed by users. The goal core of digital libraries is to use technology to solve libraries' development needs in the information age, while the goal core of smart libraries is to combine librarian wisdom with technological means to provide smart solutions to users. The demand core of digital libraries is to solve internal library development needs, while the demand core of smart libraries is to meet users' knowledge needs. The service core of digital libraries is to meet users' needs for resource retrieval and utilization, while the service core of smart libraries is to discover and meet users' high-level, deep knowledge needs.

4.2.1 Digital Libraries as the Foundation of Smart Libraries

Without digital libraries, there would be no intelligent libraries, let alone smart libraries. The core of smart libraries is "human wisdom" + "intelligence of things." Their "wisdom" is manifested through humans' subjective initiative and creative problem-solving abilities. Intelligent libraries represent the organic unity of "intelligent technology organically combined with digital libraries" and "library physical environment." Their "intelligence" is manifested through systems or platforms replacing human labor. Digital libraries are distributed information service systems built based on physical library resources and Internet technology, characterized by digitization and networking, providing the most

basic application scenarios for various intelligent technologies.

Digital libraries are the foundation of smart libraries, and smart libraries are the development goal of digital libraries. As the main platform for library construction, organization, and provision of literature and information resources, digital libraries are essentially still an extension of the traditional library model. Digital library services rely on traditional literature and information products rather than information content [27]. Digital libraries are technology-led, focusing on the production and provision of digital products. Smart libraries, however, are smart service-led, achieving exchange and interaction between librarian wisdom and user wisdom to meet users' knowledge needs, representing the top form of library development.

4.2.2 Smart Libraries as the Development Goal of Digital Libraries

Digital libraries need to become intelligent and even more so, smart. As an information service system, digital libraries help certain user groups utilize certain information content according to certain application purposes [20]. The service model of digital libraries must transform from providing retrieval and access to literature resources to providing deep-level, diversified knowledge services, which cannot be achieved without the assistance of various intelligent technologies. It is evident that digital libraries represent the digitization, virtualization, and informatization of library information resources, representing partial changes to libraries. On the basis of digital libraries, smart libraries combine new technologies such as artificial intelligence, machine learning, and IoT to achieve a comprehensive upgrade of libraries from digitization to intelligence to smartification, representing a global upgrade of libraries. Digital library construction needs to step out of its original comfort zone, abandon the resource-centered "geocentric theory" and develop toward a user-centered "heliocentric theory," transform from a "retrieval view" centered on literature search and delivery to a "utilization view" centered on supporting users' various utilization needs for information [20], actively and skillfully discover new technologies to develop new services and create new value, and achieve development toward intelligent libraries and ultimately smart libraries.

5.1 Facing Opportunities and Challenges of Intelligent Technology and Ensuring Continuously Evolving Technical Support

Libraries should face up to the opportunities brought by intelligent technology. Shao Bo [24] believes that the core of the smart library concept is AI technology. At present, with the rise of technologies such as artificial intelligence, machine learning, augmented reality, virtual reality, speech recognition, data analysis, text mining, data visualization, and IoT, various industries are actively exploring innovation with new technologies, and libraries are no exception. For example, Nanjing University launched China' s first library intelligent robot— "Tubao" —which integrates chatbot, consultation robot, and inventory robot functions. Based on the "security magnetic strip + barcode" technol-

ogy for book management, it integrates Internet, IoT, and artificial intelligence technologies. Through Tubao' s scanning and recording of book information, real-time updated book location information can help readers quickly find the exact location of books, with positioning accuracy reaching 97% [28]. After its launch, Tubao quickly attracted attention from industry peers, and the Chinese University of Hong Kong (Shenzhen) Library immediately signed a letter of intent for cooperation with it. Tubao' s technology can be used not only for book scanning but also for shelf scanning, which technically broadens the boundaries of libraries. Meanwhile, driven by intelligent technology, libraries have also begun to use intelligent access control systems, intelligent monitoring systems, and self-service card issuance systems, creating library-specific self-service borrowing and returning systems, smart bookshelves, intelligent shelving systems, intelligent Q&A systems, intelligent recommendation systems, intelligent management systems, and knowledge discovery systems. They have also launched 24-hour self-service libraries, with many such libraries currently being put into use nationwide.

Libraries should also face up to the challenges brought by intelligent technology. While new technologies bring new vitality to libraries, they inevitably also bring challenges. If libraries do not timely replenish the "energy" brought by new technologies, and if librarians do not promptly master new technologies, they will be unable to provide users with equally efficient and high-quality services as other transformed libraries in a short time, potentially reducing or even losing users' demand for libraries. However, adopting new technology does not guarantee being needed by users; intelligent technology is a necessary but not sufficient condition for libraries' transformation to smart libraries. Library services should always center on user needs. With the assistance of intelligent technology, libraries should focus on knowledge-based services such as subject services, intelligence services, and think tank services, using intelligent technology to help users quickly obtain needed information from massive amounts of information, ensuring continuously evolving technical support for library development and construction, and continuously enhancing user stickiness.

5.2 Grasping the Construction Goals of Smart Libraries and Steadily Promoting Their Development

First, shift the construction focus from digital libraries to smart libraries. Digital libraries have achieved digitization of library business and management, providing application scenarios for intelligent technologies and basic conditions for library smartification. If the current digital library model is still a simple extension of the traditional library model [29], then the smart library model should be even less a simple extension of the digital library model. Smart libraries represent the strengthening of library functions and values and the full excavation of librarians' wisdom capabilities. Smart libraries are the more advanced form and dominant model of future libraries and the core connotation of digital libraries, third-generation libraries, and new-type library construction.

Driven by the wave of digital development, China' s digital library construction mission has been basically completed. For the "14th Five-Year Plan" period and future library construction, smart libraries should be the construction focus, accelerating the transformation and upgrading from digital library construction to smart library construction.

Second, shift the construction focus from intelligent libraries to enhancing smart services. Intelligent libraries are an upgrade of digital libraries, emphasizing machine intelligence more. However, the essence of machine intelligence is machine-aided intelligence, which cannot completely replace humans. Since intelligent technology relies more on computer intelligence than human wisdom, it inevitably brings development limitations to intelligent libraries. For example, procedural steps make it difficult for end users to customize their own needs and meet personalized requirements; high system development and maintenance costs may increase financial pressure on libraries; the inherent complexity of intelligent system development places higher professional requirements on librarians'capabilities; natural language capabilities are still limited and require human intervention and correction; and intelligent systems cannot handle problems beyond their limits due to technological constraints [30]. As a transition from digital libraries to smart libraries, intelligent libraries represent library intelligentization but still have a considerable gap from library smartification. The essence of intelligent libraries is machines replacing humans, while the essence of smart libraries is humans utilizing machine intelligence. Smart libraries require not only intelligent technology but also the combination of librarian wisdom to transform "intelligence" into "wisdom," providing deep-level, diversified smart services.

Third, shift from technology-driven to demand- and service-driven. Whether from physical libraries to digital libraries or to intelligent libraries, the main driver has been technological development. To achieve the leap to smart libraries, user demand and knowledge services must become the drivers. Users' needs are essentially knowledge needs. Knowledge services and smart services can directly face user needs, integrating librarians' wisdom and knowledge work to provide embedded knowledge products and solutions, driving the upgrading of library services. Under the new-era library development concept of "service is king, demand is the foundation, resources are the basis, and technology is the wings," the amount of user demand determines the value of libraries' existence, and the level of library service capability determines the success of library transformation. User demand is the fundamental driving force for upgrading library services. Libraries need to flexibly use technological means, fully utilize librarian wisdom, continuously improve their knowledge service and smart service levels, and accelerate the smart library construction process.

Fourth, shift from process- and project-dominance to capability- and effect-dominance. If smart library construction is process- and project-dominant, it will focus more on external indicators such as resource increases/decreases, fund usage, talent recruitment, technology application, and building renovation, eas-

ily neglecting the internal improvement of library service capabilities and effects during the construction process. However, library service capability is the comprehensive embodiment of library strength, not excessive investment in one or several specific aspects. Libraries can provide not only traditional services such as teaching, research, and management but also knowledge services and smart services to meet users' diversified needs. Smart library construction and development should use libraries' own capabilities and actual effects as the test standard, focusing on the improvement of internal service capabilities and the economic and social benefits brought by smart services, demonstrating the importance and necessity of libraries' smart services to attract attention and support from higher authorities, and forming a virtuous cycle of smart library development and service effect testing.

5.3 Enhancing Service Capabilities and Strengthening Knowledge Services and Smart Services

Smart services are the core of smart library construction. Under the new-era library development concept of "service is king," service is the top priority of library work. As a new type of library with subject expertise, knowledge service capabilities, and integrated intelligent technology tools, smart libraries are libraries with wisdom driven by intelligent technology. Some experts believe that smart services are the ultimate goal of smart libraries [3]; without smart services, there would be no truly complete smart libraries. Smart library construction needs to take smart services as its core issue, leading smart library construction and development with smart services, and building a vibrant smart library.

Human wisdom is the service core of smart libraries. In smart library construction, we cannot rely solely on smart spaces and smart devices. Human wisdom (knowledge, experience, expertise, insight, capabilities, etc.) must play a leading and key role. We need to call for the emergence of smart librarians and organically combine intelligent technology with librarian wisdom to provide truly "smart" services to users.

As technology changes and the environment evolves, library services also need to continuously explore and innovate in the wave of the times, continuously improving their service capabilities. Libraries should realize that if they do not pay attention to or participate in smart library construction, they will be abandoned by the times. The size of a library' s capability does not lie in its scale but in its wisdom. In the new era, libraries need to continuously improve service capabilities under the drive of intelligent technology, transform from transactional to smart, from labor-intensive to knowledge-intensive, and continuously strengthen knowledge services and smart service levels. The ultimate goal of smart libraries is to achieve the "six-dimensional vision of smart libraries" [31]: ubiquitous service locations, virtual service spaces, intelligent service means, integrated service methods, knowledge-based service content, and satisfactory service experiences.

Smart libraries are the development trend, goal, and direction of libraries. Smart libraries should closely adhere to the basic principle of "demand-driven, technology-enabled, service-led, and capability-tested," always uphold a human-centered design concept, maintain a user-service-oriented technology-driven approach, integrate librarian wisdom, encourage librarian innovation, fully utilize various intelligent technologies, focus on the specific manifestation and capability transformation methods of knowledge services and smart services, ensure good connection between overall library development design and overall technical architecture, and strengthen the reconstruction of the overall library business system and reallocation of personnel and their capabilities. On the basis of clarifying the needs, goals, models, technologies, and paths for smart library development and construction, we should clarify its functional positioning and mechanism in "smart campuses," "smart cities," and "smart communities," promote collaborative work between libraries and academia and industry, and continuously promote the sustainable development of smart library construction.

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