Smart Library Construction: Misconceptions and Strategies (Postprint)

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Abstract

[Purpose/Significance] This study investigates the primary strategies for constructing smart libraries, addressing fundamental questions regarding the definition and model of smart libraries, resolving ambiguous theoretical and practical issues in their development, and broadening perspectives in the field. [Methodology/Process] Employing a combined approach of literature review and field investigation, this research systematically examines the developmental trajectory of libraries, identifies prevalent misconceptions in smart library construction, and proposes corresponding strategic frameworks. [Results/Conclusion] The study puts forward five major strategies for smart library construction: comprehensive goal analysis and design; transitioning from data to big data; integration of multi-source data; coordinated cooperation and phased implementation; and creation of an innovative environment.

Full Text

Preamble

Smart Library Construction Misunderstandings and Strategies

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Abstract

[Purpose/Significance] This paper explores the primary strategies for constructing smart libraries, addressing fundamental questions about what smart libraries are, what they should look like, and how they should be built. It aims to resolve ambiguous theoretical and practical issues in smart library development and broaden perspectives in the field. **[Method/Process]** Through a

combination of literature review and field research, this study traces the evolution of libraries, identifies common misconceptions in smart library construction, and proposes corresponding strategies. **[Result/Conclusion]** The paper presents five key strategies for smart library construction: (1) comprehensive goal analysis and design; (2) transitioning from data to big data; (3) integration of multivariate data; (4) coordinated cooperation and phased implementation; and (5) cultivation of an innovation environment.

Keywords: big data, artificial intelligence, smart library, Internet of Things
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1 Background and Problem Statement

1.1 Background

In January 2009, U.S. President Obama proposed the "Smart Earth" vision at a roundtable meeting with business leaders, recommending government investment in new-generation smart infrastructure that leverages emerging information technologies—particularly the Internet of Things—to transform interactions among government, corporations, and individuals [1]. In November 2009, Oriental Press published *Smart Earth: IBM Business Value Research* by the IBM Institute for Business Value [2], introducing IBM's research and design concepts for smart earth. By 2010, domestic monographs and literature on this theme began to emerge, prompting in-depth and systematic discussions. The concept of "Industry 4.0," related to smart earth, originated from the German government's "High-Tech Strategy 2020" formulated in 2000, and the term was officially adopted in 2011—seven years ago. Industry 4.0 represents the progression from the steam engine era (1.0) to the electrical age (2.0), the computer age (3.0), and today's interconnected, everything-connected era (4.0). At the end of 2014, China proposed "Made in China 2025," which was officially issued by the State Council in May 2015. In July 2017, the State Council released the *New Generation Artificial Intelligence Development Plan*, which states that by 2020, AI technology applications should become a pathway to improving people's livelihoods. The plan specifically tasks relevant parties with building a safe and convenient intelligent society, developing efficient intelligent services, and enhancing social governance intelligence levels [3]. Library functions fall within the scope of "smart society" and "developing efficient intelligent services."

Current smart city initiatives have already demonstrated preliminary convenience in daily life. For instance, smart parking systems help users locate, store, and remember their vehicles, while smart payment "apps" can remind users about utility bills (requiring prior association or binding), push billing information on schedule, redirect to payment systems, and instantly resolve payment issues. The emergence of bike-sharing and unmanned supermarkets exemplifies data sharing and universal connectivity. In contrast, libraries appear to remain at the digital library stage, still focusing primarily on digital

resources and network services. Examining library evolution reveals a necessary progression from physical libraries to digital libraries, hybrid libraries, and gradually toward smart (intelligent) libraries. Internationally, libraries are perceived to have evolved from Library 1.0 to Library 4.0 [4], continuously advancing alongside technological changes. However, domestic research and practice on smart libraries still harbor certain misconceptions, and practical problems urgently require resolution and standardization to establish effective construction strategies.

1.2 Problem Statement

Zhou Chengcong and Liu Yueqiang analyzed and summarized papers on "smart libraries" from 1999-2015, revealing the current state of research and understanding. Their findings indicate that smart library research remains in its infancy, covering six major areas, with ten high-frequency terms providing perspective: digital library, library services, Internet of Things, information services, information technology, mobile library, cloud computing, smart city, smart services, and smart library. They recommend that libraries should prioritize smart library research [5]. Tracing the research trajectories of digital and smart libraries shows that digital library research began around 1995, while smart library research started around 2010. These two time nodes correspond respectively to the period when computers gradually became popularized and applied in libraries, and the period following the proposal of "Smart Earth" when smart devices gradually found application. Sun Lifang defines smart libraries as those featuring digitized books, intelligent services, global scope, networked resources, and massive storage, utilizing advanced technological equipment with smart librarians, users, discovery, and management as core elements. Their essence lies in broad, fast, precise, and accurate ubiquitous services unrestricted by age, race, gender, religion, nationality, language, space, or social status, enabling information seekers to obtain required resources anytime, anywhere [6]. Chu Jingli and Duan Meizhen identify the components of smart libraries as intelligent technology, smart librarians, and library business and management systems—three main elements that integrate and develop together to form a smart system [7]. Wang Shiwei notes three characteristics of smart libraries: "interconnection, efficiency, and convenience" [8], and has published multiple articles discussing their features and functions. Zhang Yanxian and Wang Mei analyze three connotations of library smart services: intelligent services represent technical wisdom; knowledge-based services represent scholarly wisdom; and conceptual services represent humanistic wisdom [9]. Xu Chunman and Chen Lianfang further analyze the construction of smart librarian teams under the smart service model in university libraries, defining library smart services as those relying on professional librarians and high-quality, diverse information resources to provide proactive, flexible, ubiquitous, and varied services that effectively support user knowledge application and innovation under the drive of interconnected, intelligent technologies [10]. Xu Yibin identifies smart services as the highest stage of current library services and proposes measures to realize them by leveraging

libraries' intellectual and resource advantages to achieve their primary role in developing wisdom, cultivating character, and enlightening minds [11]. Li Yiping et al. propose a comprehensive service model for libraries as open smart service centers, where such centers are based on comfortable physical and virtual network spaces, featuring open resource sharing and virtual-physical integration, experience-first and intelligent-assisted technologies, and diverse participation and collaborative learning in services, ultimately aiming to enhance user experience and promote collaborative innovation [12].

The concept of smart libraries continues to evolve and reshape alongside smart technology development. Current research remains insufficiently deep, and practice is still in its preliminary exploratory stage. Smart libraries represent not only a transformation of library models and capabilities but also an inevitable requirement of user needs and social development. Strengthening understanding of smart libraries and grasping their essence is essential for actively and effectively advancing their construction.

2 Basic Understanding of Smart Libraries

2.1 Digital Libraries

Smart libraries are closely related to digital libraries. Without the digitalization process and the foundational construction of digital libraries, "smartness" would be impossible to achieve. China's digital library construction can be divided into several stages: content construction, platform construction, and library consortium construction. Content construction primarily refers to the digitization of literature, which includes commercial and self-built models. The commercial model involves publishers or digital companies specializing in producing and integrating digital documents—domestic examples include Wanfang, CNKI, and Superstar, while international examples include Elsevier and Springer. The self-built model involves user units digitizing their own special literature or collaborating within an industry to digitize and share collection resources, such as the water resources digital library jointly built by multiple units in Zhejiang Province. Platform construction involves placing various types of databases on a unified platform for one-stop service to solve data integration and resource retrieval problems. Platforms have continuously improved alongside search engine technology, and with the deepening of mining technology, current platforms have entered the "discovery" stage. Library consortium construction involves organizational restructuring to address the limitations of individual library collections and build a mechanism for co-construction and sharing of digital resources and services. Some scholars have proposed the concept of "conceptual library" [13], emphasizing integration, systematic input-output, and innovative activities relative to traditional models, concluding that a library's value should be reflected in reader success, with strategic cooperation and management capabilities.

From a technical perspective, digital libraries focus more on data structure, orga-

nization and storage, processing and retrieval, ensuring data accuracy, long-term preservation, and co-construction and sharing. For example, domestic metadata research typically combines Dublin Core experimental research and standards with local conditions to formulate a series of norms and standards. Platform architecture research specifically involves platform heterogeneity, integration and unification, mining and discovery, with openness, security, compatibility, and sharing as principles. However, these remain at the digital library level. With the application of mobile internet, online-to-offline (O2O), ubiquitous libraries, RFID technology combined with the Internet of Things, and robotics development, libraries with "smart" functions have gradually entered people's vision. Readers can access materials anytime and anywhere, quickly locate books, enable automatic book return, conduct automatic inventory circulation, and have robots answer simple inquiries. Digital libraries are beginning to evolve toward smart libraries.

Digital library construction and research have laid a solid foundation for smart library development and accelerated its progress. Digital libraries serve as a bridge to smart library construction—without this bridge, smart libraries cannot be realized. Crossing this bridge clarifies the form of smart libraries.

2.2 Smart Libraries

The key to smart library construction lies in "smartness." Wisdom originally refers to an advanced comprehensive ability based on neural organs (the material foundation) in living organisms, including perception, knowledge, memory, understanding, association, emotion, logic, discrimination, computation, analysis, judgment, and decision-making. Wisdom enables profound understanding of people, events, objects, society, the universe, current situations, and the future, granting the ability to think, analyze, and seek truth. Unlike intelligence, wisdom represents the ultimate function of intellectual organs, enabling decisions that lead to success. Wise individuals are called sages [14]. Robin Li of Baidu notes that from the steam revolution, electrical revolution, to the information technology revolution, the first three technological revolutions involved humans learning and innovating the world by themselves. However, the artificial intelligence revolution, because of deep learning, involves humans and machines learning and innovating the world together. The AI era is one where machines actively learn and adapt to humans [15].

What is a smart library? The concept closely resembles the foreign notion of Library 4.0, which corresponds to Industry 4.0 and focuses on semantic analysis and modern technology research [16]. Industry 4.0 includes not only software but also the development of a technological ecosystem, such as manufacturing, sensing technology, digital content, big data, cloud computing, and augmented reality. In the smart library construction environment, human roles are particularly emphasized, not just intelligent technology. The emphasis is on humans and machines learning together, with technology that can think from the library's perspective and needs—a library that can "think," "breathe," and

engage in "learning exchanges" with readers, providing more effective and efficient answers, suggestions, consultations, and deliveries than expert librarians. Library robots representing smart library application capabilities are evolving from simple question-answering functions to advanced consulting capabilities.

2.3 Misunderstandings in Smart Library Construction

The transition from digital libraries to smart libraries involves many issues. While smart libraries can bring more efficient and effective service management quality compared to digital libraries, they face more complex technical environments and application scenarios. Current domestic research and practice in smart library construction show that understanding remains insufficient, and practical promotion has just begun. Analyzing and addressing smart library construction and development in China requires first clarifying several misconceptions.

2.3.1 Misunderstanding 1: Sloganeering Sloganeering involves following trends and fashionable rhetoric, creating superficial work that does not contribute to smart library construction. Smart libraries represent the future direction and trend of library development. We must fully recognize their significance and impact, strengthen in-depth learning and research on smart libraries, and intensify experimental exploration of smart library applications.

2.3.2 Misunderstanding 2: Buying Equipment Smart devices (systems) are essential for smart library construction and can be purchased, but wisdom itself cannot be bought. We cannot substitute equipment and system procurement for smart library construction, nor simplify smart library building as merely buying various smart devices or systems, or "contracting out" smart library construction to technology vendors. Technology vendors can only provide general, universal scenarios and applications, not customized solutions for library or user-specific problems. Without top-level design and personalized needs analysis, libraries cannot develop smart libraries that meet actual requirements.

2.3.3 Misunderstanding 3: Environment Decoration Introducing smart devices (such as intelligent book delivery systems, interlibrary loan unmanned vehicles, consultation robots, etc.) will change the library's external environment and user research and learning environments. In smart library application scenarios, intelligent technology will not only transform the overall library environment but also intrinsically change library attributes and functions. To some extent, libraries will shift from tangible to intangible, from perceivable to experiential, from external influence to internal drive. The relationship between libraries and users will become closer, eventually integrating into one. Smart library functions and capabilities will bring changes and impacts to users in research, learning, teaching, and management, reflecting the essential value of smart libraries.

2.3.4 Misunderstanding 4: Resource Pushing Resources are the foundation of library services, and promoting resource utilization is an important goal of library services. Traditional libraries follow the principle of "finding the right person for the book," while digital libraries push resources of interest to users' mailboxes through customization or "alerts." Smart libraries emphasize resource-reader interaction but have surpassed the "push" level. By leveraging big data, artificial intelligence, the Internet of Things, and other intelligent technologies, they conduct intelligent data analysis to anticipate and even exceed user needs, providing timely and intelligent problem-solving solutions for users.

Using a library seat reservation management system as an example can illustrate a smart library service scenario. Current library seat management systems primarily address seat occupancy issues, offering only basic functions like reservation, check-in, and departure. From a smart library perspective, the envisioned scenario would be: a reader can make reservations anytime, anywhere via mobile terminals or local PCs; the reservation system automatically reminds the user upon successful booking and a few minutes before the scheduled time; after check-in, the mobile terminal can direct the user to the reserved seat (directional guidance); upon reaching the seat, the desk lamp automatically turns on (when lighting is insufficient); after about an hour of study, the system issues a health reminder; when taking a break or leaving, the user can inform the system, which simultaneously requires the user to establish a credit rating. The system also provides a library service request channel, maintaining connections with other systems to enable data exchange and sharing. The system possesses bidirectional, interactive, voice, and visualization functions, even creating a scenario service with certain entertainment and relaxation effects. This involves not only software but also sensing devices, spatial layout, and robots. Additionally, it should include virtual sessions with authors, experts, or classmates, as well as VR/AR experimental simulation scenarios. Smart library scenarios require implementation based on simulated reader psychology and behavior, demanding rich imagination and continuously updated creativity.

3 Smart Library Construction Strategies

Through theoretical 梳理 and rational reflection, and from the perspective of user needs and libraries themselves, this paper argues that smart library construction should be based on five strategies: overall goal analysis and design; from data to big data; multivariate data integration; coordinated cooperation and phased implementation; and innovation environment cultivation.

3.1 Strategy 1: Overall Goal Analysis and Design

Smart library construction must first undergo systematic design in a holistic sense. A smart library is essentially a system—more accurately, it should be called smart library service scenario design. It is a neural network system based on the Internet of Things, big data, and cloud computing, comprehensively covering and extending library functions while organically integrating smart

technologies with construction goals. Smart library construction goals can be divided into long-term, medium-term, and short-term objectives. Long-term goals represent relatively long-range planning with overall direction and accurate positioning; medium-term and short-term goals address what should be done and how to do it within 3-5 years and currently. The prototype of smart libraries has already emerged, including self-service borrowing and returning, self-service printing, seat reservation, RFID technology applications, and robots.

A key issue requiring research in smart library construction is the interactive relationship between readers and libraries—the scenarios triggered by mutual interaction. Different types of readers have different needs and generate different behavior patterns. In-depth research and analysis are needed for different needs, scenarios, and patterns to establish models. Based on this, smart library goals and functions can be designed holistically. In their book, Robert Scoble and Shel Israel mention five technological forces that construct scenarios: big data, mobile devices, social media, sensors, and positioning systems (see Figure 1 [Figure 1: see original paper]) [17], providing some pathways and methods for smart library construction.

3.2 Strategy 2: From Data to Big Data

The key to smart library construction is possessing an intelligent support system and service environment that fully 演绎 smart applications. The accumulation of wisdom is achieved and enriched through continuous learning. The process of data accumulation forms the foundation and source of wisdom. Currently, the amount of data we have accumulated is very small. Although bibliographic metadata seems abundant, with tens of millions or even hundreds of millions of records, this amount is insignificant in the big data environment. More problems exist in data structure, as most of these data are unstructured, making them difficult to integrate, associate, mine, and utilize. For example, the reader data libraries possess is very limited, with only a few basic dimensions—far insufficient for deep learning and effective data utilization.

Big data is the foundational data for smart libraries. According to Thomas Davenport, big data consists of large amounts of unstructured data from extremely broad sources, possibly including online conversations, continuous camera footage, or hospital patients' DNA analyses. Such data volumes are enormous, potentially reaching petabyte (PB) levels. For instance, Google processes 24 PB of internet data daily, and AT&T converts 30 PB of voice and communication data every day [18].

AlphaGo became a Go master surpassing humans because it mastered all data about its opponents and established its own behavior patterns. It is said that as data volume continues to grow, humans are no longer match for AlphaGo, which can only play against itself. This illustrates the importance of data—AlphaGo's wisdom is generated from data. Wang Tianyi proposed the concept of generative adversarial networks and discussed reinforcement learning models, including

five aspects: environmental states, agent actions, state transitions, transition rewards, and agent observations [19]. Whether "adversarial" or "reinforcement learning," both rely on big data accumulation and require sufficiently massive data volumes. Therefore, a critical issue in smart library construction is the aggregation of large amounts of data, requiring much solid foundational work.

Transitioning from data to big data is an important strategy. Data is concrete and continuously enriched and expanded in practice. Big data constantly dissolves the original boundaries of data, adding multilateral associations to data sets, including text data, video data, audio data, image data, picture data, map data, as well as two-dimensional, three-dimensional, and four-dimensional data. It also includes spatial data, location data, popularity data, activity data, competitive data, experimental data, learning data, social practice data, problem data, personality data, preference data, social data, and interactive data. A current concept called "360-degree worldview" [20] provides an angle from which to scan the data needed for smart library services, representing our target data.

3.3 Strategy 3: Multivariate Data Integration

Smart library construction requires and depends on multidimensional, multilevel data sources. Big data consists of large amounts of unstructured data, and the key lies in fusing, discovering, extracting, and transforming this data—a complex data processing engineering task. Fusion involves bonding all data together, especially cross-boundary data, requiring the establishment of new data collection models. AR applications in the publishing industry exemplify excellent fusion. Big data emphasizes establishing associative relationships between previously unrelated data, building intrinsic correlations between different attribute data, and finding "dark matches." Today's innovation is often based on "disruption" and "flipping," seeking breakthroughs and generating new ideas.

The digitization of resources, ontology construction of subjects, data traces of user behavior, scenario construction by modern equipment systems, and ecological rationality of systems are all objective elements of smart library construction. How to integrate them, how to function, and how to maximize effectiveness represent another level of innovation. This specifically involves whole-domain data control, from collection to organization, analysis to mining, discovery to association, as well as reasonable data structure and ecology. Machine equipment system architecture also requires integration from low-end to high-end, from local to whole, from space to scenario environment. Innovation processes must be 梳理 to solve various obstacles and create a relaxed innovation environment.

3.4 Strategy 4: Coordinated Cooperation and Phased Implementation

Current AI research, including speech recognition, image recognition, semantic analysis, and location positioning, encompasses critical technologies with significant application value. Given individual libraries' scale, human resources, and funding, it is unrealistic for each library to independently build a smart li-

brary. Except for a very few libraries with certain R&D capabilities (even these are weak), most libraries lack the conditions and capacity for comprehensive smart library construction. Therefore, this paper proposes industry collaboration (such as data sharing) and cross-industry cooperation (such as robotics), leveraging libraries' existing consortium advantages to conduct cooperative research and construction according to local conditions. Problem-oriented and driven by reader needs, libraries should divide labor and cooperate, with implementation 落户 in individual libraries. The reality is that domestic libraries have not yet formed internal and external collaborative mechanisms, with serious fragmentation and independent operation.

3.5 Strategy 5: Innovation Environment Cultivation

American scholars have proposed nine survival principles for future society: emergence over authority, pull over push, compass over maps, risk over safety, disobedience over compliance, practice over theory, diversity over ability, resilience over strength, and systems over individuals [21]. Their greatest contribution lies in adjusting innovators' thinking patterns, clarifying how to handle nine major relationships, determining priorities, and establishing orientation on the thinking scale. Such a thinking pattern represents not only a change in understanding but, more importantly, application, experience, summarization, and accumulation in practice.

Building smart libraries must first cultivate an innovation environment. From the subject perspective, we must emphasize each librarian's role—smart librarians are key traits for successful smart library construction [22]. Only when every librarian begins to think can the entire library start to move. Ranganathan believed that a library is a growing organism, so not only librarians but also readers (users) must actively participate in smart library construction. Libraries should establish several data observation points, with technical departments serving as business departments that automatically harvest these observation points. Current library initiatives such as subject services, tracking evaluation, and knowledge 推送 can generate much cross-boundary data beyond original scopes, requiring attention and timely collection. Libraries must also collect practical problems from industries and broad disciplinary fields to open more data channels. Observing search engine data companies like Baidu and Google reveals that positions have evolved from CTO and CIO to CDO (D=Data) or CAO (A=AI), strengthening big data trend description, analysis, and prediction. Big data must be organized and managed as a resource for full utilization. Libraries should also establish dedicated data analysis positions to transform traditional resource and information organization methods.

The first Digital China Construction Summit has just concluded. From a macro-environmental analysis, China will achieve leapfrog development in core technologies. The widespread application of digital construction environments and smart technologies will 催生 increasing new demands. Consequently, demand-oriented smart library construction will usher in new development opportunities.

Therefore, smart library construction is not an illusory "dream." We must seize opportunities, down-to-earth accumulate data, track and absorb technology applications, coordinate cooperation, and collaboratively promote smart library construction and development.

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Author Contributions

Chang Qing: Responsible for paper conception, content writing, structural design, and revision.
Yang Wujian: Responsible for literature collection and theoretical-methodological framework design.
Gong Jingxing: Provided paper revision suggestions.

Abstract: [Purpose/significance] This paper aims to explore the main strategy of building smart library, and answer what is the smart library, what is the style of it, and the strategy of building smart library, solving some obscure theoretical and practical problems in the construction of smart library, so as to broaden our horizons. [Method/process] The literature survey and field research are combined to comb and analyze the development course of library, point out the misunderstandings in the construction of smart library, and put forward the construction strategies. [Result/conclusion] It gives five strategies of intelligent library construction: overall objective analysis and design; from data to big data; multivariate data integration; coordination and step-by-step landing; innovation environment construction.

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