Reader-Centered Smart Library Research Post-print

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Abstract

[Purpose/Significance] The smart library represents a novel library model driven by intelligent technologies. Theoretical research on smart libraries has currently entered an in-depth stage. Therefore, it is necessary to summarize past research on smart libraries and contemplate future research directions. [Method/Process] This study summarizes the thematic content of smart library research from the past five years, both domestically and internationally, including fundamental issues, technology applications, practical cases, smart services, and smart librarians. [Result/Conclusion] It is concluded that smart libraries are supported by technologies such as big data and artificial intelligence, and that the construction focus should start from the three elements of librarians, resources, and readers, establishing a multi-dimensional interaction model among library collections, librarians, and readers to provide smart services. Future construction of smart libraries should begin with the precise identification of reader needs, emphasize reader experience, and build more reader-centered libraries.

Full Text

Reader-Centered Smart Library Research

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Abstract

[Purpose/Significance] The smart library represents a new library model driven by intelligent technologies. Current theoretical research on smart libraries has entered a deep stage, making it necessary to summarize past research and consider future research directions. **[Method/Process]** This study summarizes the thematic content of smart library research from the past five years, including fundamental issues, technology applications, practice cases, smart services, and

smart librarians. [**Result/Conclusion**] Smart libraries are supported by big data, artificial intelligence, and other technologies. Construction should focus on three key elements—librarians, resources, and readers—to establish a multi-dimensional interactive model among library collections, librarians, and readers, thereby providing smart services for readers. Future smart library construction should begin with the accurate identification of reader needs, emphasize reader experience, and build a more reader-centered library.

Keywords: big data; smart library; smart service

1. Introduction

The development of new technologies has accelerated library transformation and reform. In recent years, with the advancement of big data and artificial intelligence technologies, public attention to smart libraries has grown daily. Following digital libraries, big data technology has become a new driving force for library development and transformation [1]. The emergence and development of smart libraries reflect the influence and drive of a new round of technological revolution, demonstrating to a considerable extent that libraries are in an important period of transformation and profound change [2]. Smart libraries will inevitably affect library business structures, operational mechanisms, management methods, and service capabilities. The transformation from digital libraries to smart libraries represents an adaptation to changing user needs [3]. Since 2003, when M. Aittola, T. Ryhänen, and T. Ojala from the University of Oulu Library in Finland first proposed the concept of "smart library" in their paper *Smart Library: Location-Aware Mobile Library Services* [4] at the International Symposium on Human-Computer Interaction with Mobile Devices, smart libraries have sparked a global wave of theoretical research and practical exploration. Currently, theoretical research on smart libraries has entered a deep stage, making it necessary to summarize past studies and consider future research directions. Based on this, this research summarizes the thematic content of smart library research from the past five years and discusses how to construct a reader-demand-centered smart library.

2. Literature Review

This study retrieved research articles on smart libraries from SSCI and CSSCI (limited to the period from January 2014 to September 2018). The search yielded 29 relevant studies from SSCI and 82 from CSSCI, totaling 111 articles. Overall, research on smart libraries mainly includes five themes: basic issues, technology applications, practice cases, smart services, and smart librarian development.

2.1 Basic Issues of Smart Libraries Basic issues include conceptual definitions, characteristic connotations, comparative analyses, development evolution,

and future directions.

(1) Conceptual Definition. Scholars interpret the definition of smart libraries from various perspectives: technology application, library services, intelligent buildings, and the smart connotation of smart libraries [5]. Chu Jingli et al. propose that smart libraries result from the interaction and integration of intelligent technologies, smart librarians, and library operations and management [6]. R. A. Baryshev et al. consider academic smart libraries as a set of library service systems supporting scientific research activities [7].

(2) Characteristic Connotation. Scholars have explored the characteristic connotations of smart libraries, such as the five elements [8], four cores [9], and three characteristics [10].

(3) Comparative Research. Scholars have compared smart libraries with traditional libraries, digital libraries, intelligent libraries, hybrid libraries, and blended libraries [2, 11].

(4) Development Evolution. Scholars interpret the evolution and future development trends of smart libraries from different perspectives. Some propose the paradigm evolution from traditional to digital to smart libraries [12-13]; others present new theoretical frameworks from philosophical perspectives of unity of Dao and Qi and symbiosis of wisdom and virtue [14]; and some propose logical frameworks for top-level design [15].

(5) Future Directions. Many scholars have envisioned the future of smart libraries. Wang Shiwei proposes that the advanced stage of future smart libraries will be blended libraries with five characteristics: integration, interaction, visualization, ubiquity, and intelligence [16]. P. S. Aithal believes that as resources become increasingly digital, smart libraries will break through physical limitations to develop into networked universal resource centers [17]. B. Matthew suggests that future library buildings will be smart buildings [18]. Some scholars argue that the development from smart libraries to intelligent libraries will be inevitable in the AI era [19]. Luo Li et al. propose that future smart libraries should build literature metadata asset management systems, establish precise and accurate service mechanisms, and support construction with new technologies [1]. Liu Qian suggests that future smart libraries should deepen smart services to meet the needs of different reader groups [20].

2.2 Technology Applications in Smart Libraries Since 2012, many countries have introduced big data and AI strategies and policies, with research output growing rapidly [21]. Scholars have applied big data, AI, and other technologies to smart library construction. RFID technology has been applied to smart libraries for a relatively long time with abundant research results. In the past five years, scholars have explored remote identification systems integrating Zigbee and RFID technologies [22]; smart library management systems based on RFID technology [23-24]; and design and implementation of book inventory robots based on high-frequency RFID technology [25]. Some scholars

have identified problems in library RFID applications and proposed strategies such as multi-party cooperation, establishing technology alliances, clarifying tag and reader selection, building universal technology exchange mechanisms, and exploring new applications [26].

Beyond RFID, new technologies such as virtual reality, augmented reality, robotics, and wearable devices have become hot topics. Applications include: using geographic information and geospatial technologies to collect reader behavior trajectory data [27]; using wearable devices as remote controllers for smart library operations and comprehensive data collection terminals [28]; using smart home sensor equipment for data collection [29]; applying machine learning principles and TensorFlow to explore semi-automation of newspaper index classification processes [30]; using strong association rule mining for massive library data [31]; applying automatic book spine recognition to inventory management [32] and supervised deep text reading for book shelving [33]; using decentralized concepts to build mobile visual search resource management systems [34]; applying VR and AR to virtual book finding, visual information retrieval, 3D resource display, library navigation, and intelligent consultation [35]; using linked data technology to establish big data smart library systems from different sources [36]; integrating different resources, equipment, and systems to build highly integrated intelligent interaction systems [37]; and IoT identification technology-based construction strategies [38].

2.3 Practice Cases of Smart Libraries Many libraries have applied big data and AI technologies to smart library construction. Scholars have summarized these practices. For example, Chongqing University Library created a smart library system with three characteristics: integrated metadata management for print and digital resources, consistent service portals for PC and mobile, and an Internet-thinking library service alliance [39], and designed a smart library APP [40]. Taiwan Public Information Library applied wearable smart devices and RFID smart shelves [41]. Shenzhen Library comprehensively promoted RFID applications [42]. Nanjing University Library designed a UHF RFID-based intelligent library inventory robot [43]. Additionally, Shanghai University Library and Denmark Technical University Library have conducted related explorations [44-45].

2.4 Smart Services Research on smart services has become an important content in recent years. Scholars have explored various ubiquitous smart services from a technical perspective, with context-aware services being a current hotspot. Using context-aware technology, scholars have explored context-aware library smart service models [46], context-aware micro-learning system frameworks [47], and context-aware micro-service hierarchical frameworks [48]. Using QR codes and low-energy Bluetooth to identify readers, books, and seats enables context-aware service experiences based on reader location [49]. Scholars have also used various technologies to build knowledge services for readers to enhance experience, such as hybrid BLE and WiFi positioning systems for creating

reader knowledge exchange groups [50], embedded knowledge services [51], and smart disciplinary services [52]. Ningbo University Smart Library optimized traditional borrowing processes using "Internet+" concepts to achieve online-offline service integration [53].

2.5 Smart Librarian Development The transformation from digital to smart libraries presents new requirements for librarians. Many scholars have discussed what kind of librarians smart libraries need. Wang Shiwei proposed the "smart craftsman spirit" for smart librarians [54]. Chu Jiewang and Li An suggested that librarian training needs to reform recruitment models and advocate for "specialized-lifelong" learning [9]. Zheng Zhi emphasized the importance of spiritual and humanistic concepts, diversified knowledge structures, and innovative service capabilities [55]. Zheng Yixin and Bao Ping designed and empirically studied a core competency index system for smart librarians [56]. Some scholars believe that with robotics advancement, library robots may develop into smart librarians [43]. Tsinghua University Library designed a robot as a virtual librarian for smart libraries and put it into practice [57].

Additionally, scholars have addressed smart library standard system construction [58], personal data protection [59], and privacy issues [60].

Analysis of smart library research themes over the past five years shows that research has moved from conceptual description with insufficient business exploration [61] to a deeper stage combining specific applications and practices. Current research is mostly technology-driven, starting from big data, AI, and other advanced technologies to improve certain management or services. However, localized smartness only makes libraries somewhat smart but not truly smart libraries. Although smart libraries are driven by intelligent technologies, their core should be human-centered—meeting reader needs. As W. Guo et al. propose, smart libraries should promote sustainable human development as their core characteristic and aim to meet readers' growing information needs [62]. Technology gives libraries the ability to understand and respond to reader needs and preferences. Therefore, the focus of smart libraries is not what technologies are introduced but how advanced technologies are used to understand, mine, and predict reader needs and provide smart knowledge and services. Smart libraries should start from reader needs, with librarians using big data and AI to mine and analyze reader needs, then provide smart knowledge services and products. Better meeting reader needs is the core concept of smart libraries, while big data, AI, and other technologies are the guarantee for construction.

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3. Reader-Demand-Centered Smart Library Construction

To better meet reader needs, smart library construction should focus on reader demands, use big data and AI technologies, and through multi-dimensional interaction among librarians, resources, and readers, accurately identify user needs

to provide smart recommendations, retrieval, analysis, and interaction services for readers and smart decision support for librarians. Based on this, this study proposes that smart library construction should start with three key elements: librarians, resources, and readers. First, librarians need to master big data and AI technologies and possess innovation capabilities. Second, librarians should use these technologies and capabilities to conduct smart knowledge organization of collection data resources, including collection, organization, analysis, and integration, to form new smart knowledge value-added products and applications. Third, librarians should use big data and AI technologies to collect reader data, build reader profiles, analyze smart needs, and match these needs with smart knowledge value-added products and applications to better satisfy user needs.

3.1 Training Smart Librarians As Ian Johnson profoundly described in "Smart Cities, Smart Libraries, and Smart Librarians": "No one but a smart librarian can create a smart library" [63]. With robotics advancement, robots may undertake most mechanical work such as routine Q&A, borrowing procedures, book storage and inventory, and data collection and processing. However, robots can never replace work requiring creativity, thinking, and aesthetic ability. Librarians must move away from mechanical work to become smart librarians with these capabilities. Libraries can train smart librarians through three approaches: First, create an innovative environment and learning atmosphere, promoting awareness of the importance of learning new technologies and developing innovation capabilities. Second, build a core competency index system including technical and innovation abilities, and improve overall librarian smartness through recruitment or training. Third, actively introduce advanced technologies to free librarians from repetitive mechanical labor, enabling them to engage in creative, reader-demand-oriented work such as assisting readers in knowledge organization, mining, and reprocessing of collections, ultimately providing knowledge value-added products and services, making librarians a "think tank" for readers.

3.2 Smart Knowledge Organization of Collection Resources From the essence of library knowledge services, smart libraries as a new form need to adhere to long-term development concepts [5], focusing on how to provide knowledge services according to user needs to satisfy higher-level needs such as knowledge application and innovation. With comprehensive digitalization of information resources, rich media content, linked data, and intelligence, library collections have become knowledge collections [64]. The increasing volume and variety of resources require libraries to use big data and AI technologies to process large, complex information resources. Smart knowledge organization and mining of collections are valuable for readers' knowledge discovery, application, and innovation. For academic and research libraries especially, interdisciplinary, cross-regional, and complex strategic research requires librarians to conduct smart knowledge organization to provide knowledge value-added products. Big data and AI technologies enable libraries to move from coarse-grained to fine-grained

knowledge organization. Libraries can use big data storage technologies to build smart collection systems, then apply smart data, linking, ontology, and knowledge graph technologies to parse massive collection resources into fine-grained units, describe multiple features, build knowledge element models, and reveal associations and semantic relationships, thereby assisting readers' knowledge discovery and innovation. For example, in digital humanities research involving humanities, natural sciences, and social sciences, libraries can use smart data, linking, and visualization technologies to help readers discover possible intersection points among disciplines, promoting further knowledge discovery and innovation.

3.3 Reader Profiling Applications for Smart Services User needs are fundamental to libraries and will determine library development and even survival [5]. Therefore, smart library construction should focus on analyzing real needs and mining potential needs. In business, user profiles (user profile or persona) are widely used to interpret consumer needs for precise marketing. User profiles are virtual representations of real users based on real data (marketing data, usability data). Libraries can adapt this approach to build reader profiles, which help: understand reader needs through full-sample data, changing previous rough survey methods; conduct association mining by combining past and future profile data; optimize reader experience online and offline; achieve precise marketing by visually displaying preferences and attributes for point-to-point matching; support management decisions; and improve smart service levels through precise matching.

3.3.1 Reader Profiling Process **(1) Data Collection.** Collect all reader-related data, including static data (registration information, family, occupation) and dynamic data (borrowing records, activity trajectories, event participation, website usage, APP usage) (see Figure 1 [Figure 1: see original paper]). Libraries can capture reader data using indoor positioning, self-service sensors, WiFi positioning, traffic capture, smart monitoring, facial recognition, AI, and SoLoMo technologies.

(2) Reader Tagging. Building reader profiles involves tagging readers. Tags are highly refined feature identifiers of reader information. More precise tags cover fewer people, enabling "thousands of faces with thousands of features." Tagging allows computers to programmatically process collected reader data.

(3) Establishing Tag Systems. After tagging, readers must be categorized with clear relationships to form group tag systems. Current user profile tag systems include structured, semi-structured, and unstructured systems. Structured systems have clear hierarchical divisions with strong explanatory power for demographics but poor flexibility. Unstructured systems are used for non-hierarchical, dispersed data—flexible, large, fine-grained, and fast-updating. Semi-structured systems emerge when structured systems cannot meet classification needs, offering strong flexibility while avoiding excessive chaos. Given

current reader data characteristics of fast updates, heterogeneity, and multiple sources, semi-structured systems with both standardization and flexibility are most suitable. Static data like demographics have structure, while dynamic data like trajectories and search records are flexible and constantly adding new types. An example semi-structured reader profile tag system is shown in Figure 2 [Figure 2: see original paper].

(4) Priority Ranking. With numerous tags of varying importance, priority ranking is needed. Libraries can assign different weights based on strategic goals, resources, and service priorities to initially complete user profiles.

(5) Profile Refinement. Reader profiles can never 100% accurately describe a person but can continuously approximate them. Profiles need constant refinement through: adding descriptive elements and scenarios for richness; concretizing abstract descriptions (e.g., changing "within 5 km" to "3 km"); and regularly collecting related data at fixed points over time to reveal patterns and improve profiles for better modeling.

3.3.2 Reader Modeling to Meet User Needs Based on reader profiles, libraries can conduct reader modeling to analyze real needs, mine potential needs, and even introduce time series, neural networks, and model trees to build demand models predicting future trends, including long-term, short-term, and real-time dynamic predictions. This guides librarians to adjust service strategies for smart services. Libraries can also build loyalty models to cultivate loyal readers and churn models to identify at-risk readers for targeted recommendations.

These models enable libraries to not only analyze real needs but also predict future and potential needs. With accurate demand understanding, librarians can provide needed smart knowledge products and services to specific readers, achieving the ultimate goal of smart library construction.

Technological innovation drives library transformation, but the ultimate goal remains meeting reader needs. Therefore, smart library construction should be more reader-centered, using advanced equipment and technologies to provide smart services for different reader types while optimizing experience based on technological innovation and accurate demand understanding. Future smart library construction should be reader-centered rather than technology-centered—both an inheritance of Ranganathan's Five Laws of Library Science and a reflection of libraries' function as important components of public cultural service systems meeting citizens' growing needs.

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