Research and Reflections on Library Spatial Functions and Service Innovation in the Intelligent Era: Postprint

Authors: Li Jiao, Sun Tan, Guojian Xian, Huang Yongwen, Luo Tingting, Chen Boli

Date: 2023-04-01T15:51:22+00:00

Abstract

[Purpose/Significance] This study investigates the transformation of library spatial functions, resources, and innovative service trends in the intelligent era, aiming to provide references for the development planning of future library spatial services. [Method/Process] The research examines the transformation of library user roles under new circumstances, the repositioning of library functions, and the integrated development of technological innovation, and analyzes the development trends of future library spatial function services and the important supporting technologies involved based on the three elements of space, resources, and services. [Results/Conclusion] Libraries have undergone a transformation and upgrading from traditional resource-oriented entities to knowledge centers characterized by learning and communication, evolving into composite functional spaces and inclusive cultural facilities that support diversified service models. High-density automated storage book warehouses, reconstruction of innovative service spaces, multi-modal resource association and integration, and immersive reading will become the key foci of transformation in library spatial function innovation.

Full Text

Research and Reflection on Library Space Functions and Service Innovation in the Intelligent Era

Li Jiao[1], **Sun Tan**[2,3], **Xian Guojian**[1,3], **Huang Yongwen**[1], **Luo Tingting**[1], **Chen Boli**[1]

[1]Agricultural Information Institute, Chinese Academy of Agricultural Sciences, Beijing 100081
[2]Chinese Academy of Agricultural Sciences, Beijing 100081

[3]Key Laboratory of Agricultural Big Data, Ministry of Agriculture and Rural Affairs, Beijing 100081

Abstract: *[Purpose/Significance]* This study explores the transformation of library space functions, resources, and innovative service trends in the intelligent era, aiming to provide references for future library space service development planning. *[Method/Process]* The research examines the transformation of user roles, functional repositioning of libraries, and integrated technological innovation under new circumstances, analyzing future development trends and key supporting technologies based on three elements: space, resources, and services. *[Result/Conclusion]* Libraries have undergone a transformation from traditional resource-centered institutions to knowledge centers characterized by learning and exchange, evolving into complex functional spaces and inclusive cultural facilities that support diversified service models. High-density automated storage libraries, innovative service space reconstruction, multi-modal resource association and integration, and immersive reading will become key focal points for library space function innovation.

Keywords: intelligent era; space reconstruction; resource construction; service model

---

As fundamental infrastructure for human social and cultural activities, libraries bear the responsibility and mission of knowledge inheritance and dissemination. Their service mechanism, based on knowledge aggregation and knowledge-intensive work, faces enormous challenges brought by transformations in knowledge creation, dissemination, and utilization environments [1]. Against the backdrop of the intelligent era spawned by big data and artificial intelligence, where innovation has become the norm, the superposition of multiple trends—including changes in research paradigms and academic communication, influences from social and industrial environments, development of information technology and services, and shifts in community needs and service diversity—continuously drives the transformation and reform of libraries. The 84th IFLA World Library and Information Congress in 2018, themed "Transform Libraries, Transform Societies," explored global library transformation trends from perspectives such as urban infrastructure, information communication technology, and information literacy programs [2]. The Global Vision Report identified the transformation of roles in the digital age as a major opportunity for contemporary library development, emphasizing the need to view readers as innovators, support innovation, better understand community needs, and design new service models while keeping pace with technological change [3].

2. Opportunities and Challenges for Libraries in the Intelligent Era

2.1 Transformation of Library User Roles

Traditionally, libraries were viewed as quiet places for independent research. However, with the development of participatory culture, this perspective has gradually been replaced by an emphasis on collaborative and experimental environments. The growth of user-generated videos, maker communities, and crowdfunding projects demonstrates that creativity is increasingly becoming a means of active, interactive, and practical learning. Beyond quiet reading environments, people expect libraries to provide spaces for interpersonal communication and knowledge creation. This fundamental change in user expectations has triggered a theoretical revolution in library service systems, shifting from "library-centered" to "user-centered" approaches. This trend breaks the barriers of traditional service paradigms, freeing library service capabilities and boundaries from the constraints of limited space and resources [4]. Consequently, users have evolved from service recipients to decision-makers, from fixed-space readers to users of ubiquitous multi-functional spaces, and from resource consumers to creators and providers, becoming "third librarians" beyond professional librarians and volunteers [5].

Libraries have begun to provide spaces and resources that support innovation and creation, accommodating maker spaces equipped with 3D printers, scanners, and computer-aided design (CAD) software, enabling readers to participate in hands-on practice and interdisciplinary learning for discovering new knowledge, interests, and research [6]. For instance, Kent State University at Tuscarawas' Library Makerspace helps readers transform ideas into commercial investments and marketable products, while Ryerson University's Isaac Olowolafe Digital Media Experience (DME) Lab provides Oculus VR headsets and other technologies. New York University offers data, software, and training services in the form of art studios. Undoubtedly, the library's function as a creation center represents a natural extension of its traditional role, providing a connective space for knowledge creators and users. Accordingly, an increasing number of libraries have launched corresponding programs, actively seeking collaboration with universities and other organizations to promote active learning and innovation. For example, the University of Virginia Library's Scholars' Lab develops digital projects centered on humanities or specific software tools through co-design with librarians and readers [7], while UCLA's Simul8 project funds application development to increase the convenience of shared library collections [8].

2.2 Re-examining and Repositioning Libraries

If reading is defined as an activity spanning the entire process from data to information, knowledge, wisdom, and solutions [9], libraries' primary function is to help users organize knowledge infrastructure, connect various knowledge environments, transform digital and knowledge-based processes, utilize and cre-

ate knowledge, and support multi-level reading needs for rapid summarization, exploratory analysis, and knowledge construction [1], thereby comprehensively serving research, education, and innovation. The era when "libraries were the sole pillar of knowledge dissemination" ended with the advent of the internet. Today, information is everywhere, and with the development of knowledge datafication and computationalization, users increasingly rely on more productive Knowledge-as-a-Service (KaaS) platforms. For example, a 2015 EBSCO survey on university students' research habits showed that approximately 70% of respondents began their research using Google and Wikipedia, although library resources also played important roles [10]. As experts and professional institutions in knowledge discovery, organization, preservation, and dissemination, libraries face tremendous challenges in their service capabilities, methods, and objectives, requiring expansion and even redefinition to innovatively adapt to knowledge service under new circumstances.

The American Library Association's 2016 State of America's Libraries Report indicated that libraries in the digital age need to transform from "quiet places for research, literature search, and reading" to "community centers that help people learn, create, and share through librarians and resources," thereby enhancing public awareness of libraries' value, impact, and services [11]. MIT's 2017 "Future of Libraries" Task Force Report envisioned future libraries developing toward open digital platforms, becoming knowledge and data repositories accessible and analyzable by humans, machines, and algorithms, combining traditional resource advantages with various innovative activities to provide experimental and innovative solutions to major challenges in research and academic communication [12]. The Association of College and Research Libraries (ACRL) 2015 Environmental Scan Report predicted future trends for academic libraries, including collaborative collection development, scientific data services, knowledge discovery services, and library infrastructure, noting that libraries as innovation spaces primarily provide academic support services, with remaining space used for book storage [13]. The 2021 report proposed development directions including Expanding Literacy, integration and access services, research services and support, and immersive technology [14]. Systematically, contemporary libraries focus on a trinity service system based on space (reading + discussion + experimental innovation + cultural communication), platform (ubiquitous, precise, and intelligent knowledge discovery), and people (wisdom + data + tools).

2.3 New Technologies Supporting Library Transformation

With the development of academic communication and information technology, the knowledge environment has undergone profound transformation. We stand at the intersection of the big data and large-scale computing eras, with fully digitalized information resources and knowledge content becoming rich-media, linked, intelligent, and openly shared. New technologies centered on intelligent technology, including artificial intelligence, big data, cloud computing, information visualization, semantic web, and linked data, continuously facili-

tate knowledge representation, computation, and discovery. The Internet of Things enables intelligent library services and management, catalyzing highly knowledge-based and flexible smart services. The *NMC Horizon Report: 2017 Library Edition* identified six technology/practice trends that would enter academic and research libraries within five years (2017-2021): big data, digital scholarship technologies, library service platforms, online identity, artificial intelligence, and the Internet of Things (see Figure 1 [Figure 1: see original paper]). These trends, technological developments, or challenges evolve over time, continuously emerging with new perspectives and dimensions.

Figure 1. NMC Report > 2017 Library Edition - Technology Trends Supporting Library Transformation

(1) Continuous Development of Library Systems. The 2020 *Library Systems Report* published by *American Libraries* magazine noted that libraries continue migrating from Integrated Library Systems (ILS) to cloud-based Library Services Platforms (LSP), concentrating all resources on unified platforms for full lifecycle management and providing corresponding discovery services [16], enabling readers to access them ubiquitously through multiple devices. Ex Libris Alma, OCLC's WorldShare Management Services (WMS), and the open-source FOLIO have made significant progress, with almost all large academic and research libraries or library consortia selecting Alma systems [17]. LSPs offer clear advantages in time and cost efficiency and functionality over traditional systems. Libraries that have migrated to LSPs can more ethically use their databases to enhance analytical functions, assist learning, teaching, and research, and improve workflows by leveraging shared community LMS tools to create new functionalities that meet user needs. For example, the University of Wales Trinity Saint David's migration to Ex Libris Alma and Primo platforms enables multi-terminal access to library management systems and discovery services for all faculty and students [18], while Saddleback College Library adopted WMS LSP to improve physical collection quality and enhance visibility and scalability through applications [19]. Essentially, LSPs enable libraries to consciously handle complex tasks or workflows, advancing their integration with user communities.

(2) Intelligent Library Management and Services. Smart library management and services have long been a priority for library development. The increasing maturity of intelligent library environments and robotics has brought unprecedented opportunities for building intelligence, management intelligence, and service intelligence. Library robots are widely applied in intelligent three-dimensional book stacks, inventory, automated storage and retrieval, intelligent consultation, remote reading, and services for special populations, fundamentally improving the quality and efficiency of library management and services [21]. As early as the late 20th century, the rise of Automated Storage and Retrieval System (ASRS) technology led to widespread adoption in international libraries, such as California State University, Northridge's Oviatt Library and the British Library [22]. With robotics development, applications have emerged in-

cluding the University of Nebraska-Lincoln's chatbot [23], book transport robots at Berlin University Library, and remote book access robotic systems at Johns Hopkins University [24], with domestic representatives including Tsinghua University's chatbot "Xiaotu" and Nanjing University's inventory robot. Currently, library robots remain a high-cost investment, with deployment and application involving complex factors including space planning, automation systems, and human resources. Service effectiveness depends on high-quality corpus construction, requiring libraries to plan long-term and rationally introduce robots to embed and excel in more real service scenarios.

(3) Knowledge Computing Enhancing Knowledge Service Levels. We are in a data environment where open science has become a global consensus. Machine learning algorithms, text mining, and data visualization tools accelerate knowledge accumulation and reuse, with various accessible technologies enabling data integration and mining. The connotation of information literacy continues to expand, no longer limited to literature retrieval and utilization skills, but encompassing multi-literacies including data and computation, intelligent organization, and knowledge-based experimentation and discovery [1]. The data-intensive research paradigm increasingly demands data, knowledge, and knowledge tools, ushering knowledge services into a post-knowledge service era based on the "data (D)-wisdom (W)" chain and centered on smart services [5], transforming from literature guarantee to ubiquitous discovery, acquisition, and knowledge mining analysis. The development opportunity of knowledge computing technology undoubtedly provides powerful support for knowledge services oriented toward scientific discovery and technological innovation [25]. Following Google's launch of Knowledge Graph and semantic search that liberated people from "George Boole's binary search prison," association exploration, computational mining, precise recommendation, and intelligent Q&A based on knowledge graph mechanisms have rapidly become the new normal for knowledge services. Organizing computable content resources, providing intelligent reading and discovery services, in-depth analysis services, and intelligent decision-making support for various needs have become essential capabilities for libraries and information service institutions to enhance core competitiveness [1]. In terms of key technologies and product development capabilities for digital knowledge representation and organization, Springer Nature launched SciGraph, which organically integrates various information in the research community and establishes associations with external datasets [26]; the Open Academic Graph (OAG) published by the Open Academic Organization integrates hundreds of millions of papers from Microsoft's heterogeneous academic graph MAG and AMiner, generating over 60 million link (matching) relationships for research use [27]; GoPubMed, jointly developed by Transinsight and Dresden University of Technology, achieves semantic networks, biomedical information retrieval, and visualization analysis of biomedical hotspots based on semantic lexicons and ontologies [28]. In academic search and discovery, Entrez from the U.S. National Library of Medicine's National Center for Biotechnology Information, Semantic Scholar from the Allen Institute for AI [29], and BASE-Search

developed by Bielefeld University Library [30] enable semantic knowledge association exploration and deductive reasoning. In professional knowledge service platforms [33], Indiana University's Chem2Bio2RDF Dashboard system provides integrated association services in chemistry, biology, and drug domains [31], while Clarivate's Derwent Innovation platform offers patent data and scientific literature retrieval and analysis functions [32]. Domestic practices include Shanghai Library's genealogy service platform based on genealogy, celebrity, and manuscript resource systems, providing ancient literature evidence-based services [34]; the Institute of Automation, Chinese Academy of Sciences' released cross-modal general AI platform "Zidong Taichu," demonstrating mutual conversion and generation between different modal resources, covering video description, intelligent Q&A, image retrieval, Chinese text continuation, and other functions. Meanwhile, intelligent knowledge services such as causal inference-based revelation of scientific innovation chain evolution, technology foresight, and development trend prediction are becoming research hotspots.

(4) Immersive Technologies Supporting New Reading Modes. Extended Reality (XR) technologies, representing immersive technologies, fuse physical and virtual environments to provide fully immersive virtual experiences. As immersive technologies evolve from simple setups like Google Cardboard to more complex head-mounted displays and external sensors, their combination with artificial intelligence and machine learning becomes more frequent. In recent years, numerous initiatives have integrated Augmented Reality (AR), Virtual Reality (VR), and other immersive technologies into library collaborative spaces, content management, and services [35]. For example, Miami University Library's team pioneered ShelvAR in 2011, using machine-readable spine labels to drive virtual reality bookshelf reading systems [36]; AR/VR platforms supporting digital scholarship education such as Aurasma [37], EONreality [38], and Layar [39] enable users to interact with library digital resources in entirely new ways; immersive digital animations recreating demolished buildings based on library archival photos and drawings [40], etc. Several Chinese information institutions have also launched related initiatives, such as the National Library of China's new reading space, which utilizes 5G technology and panoramic video VR to create "panoramic exhibition halls" and "reading books" immersive exhibits, supporting readers' scene-based, experiential reading distinct from traditional modes. It is foreseeable that immersive technology will serve as an important supplement to existing library technologies [41], providing opportunities for libraries to collect and display resources through three-dimensional visual collections, potentially developing into a mainstream model that enhances digital media accessibility and improves readers' digital literacy, collaboration, creative thinking, and problem-solving skills [42], catering to both general readers' "non-utilitarian" extensive reading needs and student and researcher users' "utilitarian" systematic knowledge acquisition needs, benefiting cross-professional, cross-cultural, and all-age readers.

3. Development Trends of Library Space Innovation Services

Facing challenges from the knowledge explosion era, big data intelligence technologies, and multi-agent knowledge dissemination, libraries are undergoing disruptive innovation and transformation. MIT's "Future of Libraries" proposed transformation directions including data resource management, storage, and usage technologies, collection browsing patterns, library space allocation, and availability of tangible and digital media [12]. Singapore's "Future Smart Libraries: Disruption and Innovation" conference proposed library transformation elements including space renovation, all-age service upgrades, and digital infrastructure construction [43]. Academic research has also addressed this theme, analyzing library transformation concepts and paths from dimensions of space, resources, services, and management, such as theoretical foundations for library space innovation in the data era [44], supply-side structural reform of knowledge services in the post-library era [1], transformation from library "geocentrism" to "heliocentrism" [4], and library transformation elements [5]. Based on this, our study examines changes in internal and external environments, focusing on sustainable library space reconstruction, multi-modal resource organization and construction, and diversified service models in the intelligent era, proposing visions for future library space functions and services.

3.1 Library Space Reconstruction

Library space is an important spatial form supporting academic communities [12], and space innovation forms the foundation for changes in library service and management methods. The evolution of library space elements has transformed from physical buildings to complex spaces interweaving physical and virtual dimensions. The integrated development of intelligent technologies further deepens digital and hybrid libraries, shifting the library definition from "institution" to "place" [5], as described in *Living Libraries—The House of the Community Around the World*, which calls libraries "third places" that promote growth, connection, and exchange [45]. Library architecture has transformed from designing for book storage and related physical facilities to focusing more on people, communities, and their communication and innovation [46], representing an upgrade from traditional resource-centered to learning- and exchange-oriented knowledge centers [47], achieving infinite space and ubiquitous services [5]. IFLA includes flexibility, sustainability, and learning spaces as evaluation criteria for library awards [48], demonstrating that flexible space design is crucial for supporting value realization and addressing future development possibilities.

(1) Physical Collection Spaces. In the fully digital era, collection structures have changed significantly, with digital information's share growing rapidly. Many libraries have gradually shifted from print-dominant to digital-dominant collections. For example, Stony Brook University Libraries increased electronic collections from 2008 to nearly 100% by 2020, while Yale University Library and UC Berkeley Library allocated 60% of their collection budgets to digital re-

sources in 2019 [49]. However, this does not mean future libraries will abandon print for data. Physical collections, as important indicators of library competitiveness, require parallel and deep integration with digital resources (virtual collections). The 86th IFLA World Library and Information Congress 2021 focused on "Power of Transformation: Open Access and Library Collections" [50], making core resources and collection capacity building focal points again under open science. Digital resource development (multi-modal, multimedia) accompanies changes in human reading characteristics. Regarding space reconstruction for physical collections, we argue that large-scale intelligent high-density automated storage libraries will become the main trend. This type of automated storage system is not new, with nearly 70 high-density storage facilities initially built in North America a decade ago [51], while domestic practice started relatively later, such as Suzhou's second library recently building a large intelligent book stack with 7 million volume capacity. Collection warehousing can both inherit paper-based reading cultural heritage containing human knowledge records [52] and release more space for diverse reader activities.

(2) Knowledge Service Spaces. Diversified digital information, evolving teaching forms, and changing research paradigms force library work to shift from resource collection to providing knowledge services using resources to meet reader needs [53], requiring necessary space configuration or reconstruction of existing spaces. Compared to first-generation libraries centered on collections with one-way reading, and second-generation libraries integrating collection and reading with two-way interaction, we have entered the third-generation library stage characterized by "complementary collection and reading, people-oriented" approaches. Knowledge service spaces emphasize human needs, accessibility, and openness, requiring functions that promote knowledge circulation, innovative exchange environments, multi-literacy, and community vitality [54]. As a community for human and organizational exchange, libraries have seen emerging space forms such as Idea Stores, maker spaces, shared spaces, and intelligent spaces. Future development will inevitably trend toward complex functional spaces and inclusive cultural facilities supporting human-human interaction, human-machine interaction, and immersive reading, especially ubiquitous knowledge-aggregating and intelligent spatial forms. The integration of spatial functions and technological innovation and the balance with user cognitive experiences are crucial for practical effectiveness.

3.2 Multi-Modal Resource Association and Integration

Under digital environments, library information resource construction is an important driver of service transformation. The University of Illinois Library's "2019-2023 Strategic Plan" establishes "integrating and managing knowledge, promoting learning and innovation" as development goals [55]. Libraries' vast collections essentially constitute a massive knowledge set that is increasingly datafied and computable with the development of digital library business [1]. The organic combination of physical and digital collections and the association

and integration between resources/data have become keys to continuous value-added resource development, thereby improving scientific "information velocity" and promoting scientific productivity. Previously, the digitization of physical resources became an unavoidable trend. In the digital era driven by open science, digital research, and networking, libraries acquire high-quality open academic resources, scientific data, important public website information, and courseware through multiple collection methods beyond purchased books and literature, covering multimedia forms including text, images, audio, and video, and comprising data types such as values, charts, texts, formulas, and tools. Various resources have strong or weak content crossovers and semantic associations [56]. Cross-media multi-modal data, especially dynamic resources like sound, animation, and video, can form new data objects and knowledge content through semantic correlation analysis, mining, and deep integration to supplement and expand traditional text-based knowledge systems, while supporting intelligent knowledge services such as relationship discovery and cross-modal retrieval, and immersive reading experiences, improving resource discoverability and accessibility. Through integrated applications of intelligent technologies such as natural language processing, machine learning, semantic web, and knowledge graphs, all library resource silos will ultimately be organized, connected, and integrated into an interactive organism that promotes local storage, long-term preservation, collaborative sharing, and information value-added. Research on multi-modal resource association and discovery services in library and information science remains in its infancy, with pioneering cases such as the British Museum (https://www.britishmuseum.org/) using semantic technology to semantically annotate, organize, and associate various static digital resources including texts and images, providing diversified knowledge service forms.

3.3 Diversified Service Models

Innovative services relying on library space and resources have been continuously developing. Artificial intelligence and IoT connect people, devices, content, services, and transactions into an ever-expanding network [33], greatly extending library service utility and coverage, providing readers with personalized and professional library experiences that more effectively connect them with resources aligned with their goals. Meanwhile, as we enter the third media era characterized by immersive reading [44], it is crucial for libraries to incorporate new media and immersive technologies in strategic planning, keeping pace with evolving formats for storing and publishing data, scholarly records, and publications such as video, visualization, and virtual reality, to match broader social consumption trends and serve users' immersive engagement in knowledge production and intelligent activities, transforming reading into an active, exploratory, and constructive process. As previously discussed, future library space function innovation will support diversified service models including human-human interaction, human-machine interaction, and immersive reading to achieve interconnectivity among people, objects, and knowledge. Human-human interaction relies on academic exchange centers, discussion spaces, and maker spaces;

human-machine interaction introduces intelligent devices like robots into library inventory, consultation, Q&A, and reading scenarios, combining rich knowledge bases and corpus resources to create intelligent human-machine interactive environments that improve knowledge service quality and efficiency through visual and intelligent interaction; immersive reading guides readers in thinking, analysis, and creation, representing a revolutionary service transformation. Initially applied to static text reading on web pages or reader terminals, such as Microsoft Office Lens's immersive reading mode and Amazon's Kindle Oasis, immersive reading offers advantages in knowledge absorption depth and systematicity compared to fragmented reading. With immersive technology development, it has gradually been applied to education and library reading spaces (physical and virtual), incorporating rich media information including video, audio, images, animation, and text to break barriers between virtual environments and knowledge entities, fully enhancing readers' sensory and cognitive experiences. For researchers, interdisciplinary integration and shortened innovation cycles make systematic knowledge absorption difficult amid busy research schedules, leading to more fragmented reading oriented toward Q&A or results. Immersive reading can provide concrete interpretations, associations, and experiences through multi-modal knowledge and its connections, helping them quickly understand concepts, relationships, and development contexts of specific topics, and even dynamically reorganizing articles and data for experimental reasoning. For general readers across ages and education levels outside academia, immersive reading in science, art, geography, history, and other popular science fields can fully engage their interest and motivation, providing humanistic care that meets spiritual needs. It is foreseeable that immersive reading will become the core service concept for libraries in the intelligent era to meet users' systematic knowledge needs, supporting the integration of physical and virtual library spaces and greatly improving the quality and efficiency of reader services.

Conclusion

The data-driven, computationally ubiquitous intelligent era has brought disruptive impacts to libraries. Deepening digitalization, intelligent technology development, and knowledge environment transformation are guiding libraries toward transformation and development, making it particularly urgent and challenging to reconsider and plan library space functions and service innovation. Libraries must maintain sensitivity to new technologies, but technology is both challenge and opportunity, a tool rather than a goal. Libraries must clarify the transformation of user roles and the resulting library functional repositioning and technology integration directions under new circumstances, while adhering to their core mission of civilization and knowledge inheritance, to realize their functional space value. Future-oriented libraries will place greater emphasis on open, innovative, personalized, and intelligent knowledge needs. Flexible space reconstruction can achieve infinite space and ubiquitous services [5], supporting diversified service models of human-human interaction, human-machine interaction, and immersive reading, while multi-modal knowledge association and

integration will become the main technology connecting physical and virtual library spaces and conducting online-offline integrated knowledge services.

References

[1] Zhang Xiaolin. Disruptive transformation and the post-library era: Promoting supply-side structural reform of knowledge services[J]. *Journal of Library Science in China*, 2018, 44(1): 4-16.

[2] IFLA. "Transform Libraries, Transform Societies" comes to Kuala Lumpur at the opening session[EB/OL]. [2021-08-07]. https://www.ifla.org/node/71282.

[3] IFLA. The global vision report summary[EB/OL]. [2021-08-07]. https://www.ifla.org/files/asset/gv-multimedia/publications/gv-report-summary_2.pdf.

[4] Chu Jingli, Qin Xiaoyan. From "geocentrism" to "heliocentrism": The transformation from library-centered to user-centered[J]. *Library and Information Service*, 2018, 62(13): 5-10.

[5] Ke Ping, Zou Jinhui. Library transformation in the post-knowledge service era[J]. *Journal of Library Science in China*, 2019, 45(1): 4-17.

[6] Maker movement[EB/OL]. [2021-08-01]. http://www.ala.org/transforminglibraries/future/trends/makers.

[7] PRISM[EB/OL]. [2021-08-01]. http://prism.scholarslab.org/pages/about.

[8] Chen H. UCLA student group Simul8 develops apps for UCLA Library[EB/OL]. [2021-08-21]. https://new.dailybruin.com/post/ucla-student-group-simul8-develops-apps-for-ucla-library.

[9] Zhang Xiaolin. Major trends disrupting digital libraries[J]. *Journal of Library Science in China*, 2011, 37(5): 4-12.

[10] Library Research Service. In EBSCO survey, nearly two-thirds of college students use library resources in their research[EB/OL]. [2021-08-01]. https://www.lrs.org/2016/02/24/in-ebsco-survey-nearly-two-thirds-of-college-students-use-library-resources-in-their-research/.

[11] American Library Association. The state of America's libraries 2016[EB/OL]. [2021-08-03]. https://www.ala.org/news/sites/ala.org.news/files/content/state-of-americas-libraries-2016-final.pdf.

[12] MIT. Institute-wide task force on the future of Libraries[EB/OL]. [2021-08-02]. https://future-of-libraries.mit.edu/sites/default/files/FutureLibraries-PrelimReport-Final.pdf.

[13] ACRL Research Planning and Review Committee. ACRL environmental scan 2015[EB/OL]. [2021-08-01]. https://www.ala.org/acrl/files/publications/whitepapers/EnvironmentalScan

[14] ACRL Research Planning and Review Committee. ACRL environmental scan 2021[EB/OL]. [2021-08-01]. http://bit.ly/ACRL21Scan.

[15] Becker S A, Cummins M, Davis A, et al. NMC Horizon Report: 2017 Library Edition[M]. Austin, Texas: The New Media Consortium, 2017. https://cpb-us-e1.wpmucdn.com/blog.stcloudstate.edu/dist/d/10/files/2017/03/2017-nmc-horizon-report-library-EN-20ml00b.pdf.

[16] Marshall B. 2020 Library Systems Report[EB/OL]. [2021-08-21]. https://americanlibrariesmagazine.org/2020/05/01/2020-library-systems-report/.

[17] Xie Rong, Liu Wei, Zhu Wenjing. The third-generation library services platform: New demands and breakthroughs[J]. *Journal of Library Science in China*, 2019, 45(3): 25-37.

[18] Xiao Zheng. The innovation cycle: 2019 library systems market report[J]. *Library Tribune*, 2019, 39(8): 1-11.

[19] WHELF. From multiple legacy systems to a single LMS at UWTSD[EB/OL]. [2021-08-11]. https://whelf.ac.uk/from-multiple-legacy-systems-to-a-single-lms-at-uwtsd/.

[20] Jenny L. Create time for new initiatives[EB/OL]. [2021-08-12]. http://www.oclc.org/en/member-stories/saddleback.html.

[21] Fan Huili, Shao Bo. Research and application status of library robots at home and abroad[J]. *Library Journal*, 2017, 58(4): 88-94.

[22] Kountz J. Robots in the library: Automated storage and retrieval systems[J]. *Library Journal*, 1987, 112(20): 67-70.

[23] Allison D A. Chatbots in the library: Is it time?[J]. *Library Hi Tech*, 2012, 30(1): 95-107.

[24] Suthakorn J, Lee S, Zhou Y, et al. An enhanced robotic library system for an off-site shelving facility[M]//Springer Tracts in Advanced Robotics. Springer, 2006: 437-446.

[25] Sun Tan. The future of library intelligent knowledge services[J]. *Journal of Library Science in China*, 2021, 47(2): 15-18.

[26] Springer Nature. SN SciGraph: A linked open data platform for the scholarly domain[EB/OL]. [2021-08-15]. http://www.springernature.com/cn/researchers/scigraph.

[27] Open Academic Graph[EB/OL]. [2021-08-09]. https://www.microsoft.com/en-us/research/project/open-academic-graph/.

[28] Andreas D, Michael S. GoPubMed: Exploring PubMed with the Gene Ontology[J]. *Nucleic Acids Research*, 2005, 33(Web Server issue): W783-W786.

[29] Allen Institute for AI. Semantic Scholar[EB/OL]. [2021-08-15]. https://www.semanticscholar.org/.

[30] Bielefeld Academic Search Engine (BASE)[EB/OL]. [2021-08-15]. https://base-search.net/.

[31] Chen B, Ding Y, Wild D J. Improving integrative searching of systems chemical biology data using semantic annotation[J]. *Journal of Cheminformatics*, 2012, 4(1): 6-16.

[32] Clarivate. Derwent Innovation[EB/OL]. [2021-08-14]. https://clarivate.com/derwent/solutions/derwent-innovation/.

[33] Sun Tan, Huang Yongwen, Zhang Jianyong, et al. Research and prospect on national scientific and technical literature development strategy under open science environment[J]. *Library and Information Service*, 2020, 64(14): 3-12.

[34] Cui Juan, Liu Wei, Chen Tao, et al. Development practice of genealogy linked data service platform[J]. *Journal of Library Science in China*, 2016, 42(3): 27-38.

[35] Fujiu Chi K, Riggie J. Academic library collections in the age of extended reality (XR)[J]. *Collection Management*, 2019, 44(2/4): 296-303.

[36] Aaronson L. Video: Augmented reality app for librarians instantly shows which books are misfiled[EB/OL]. [2021-08-16]. https://www.popsci.com/technology/article/2011-04/augmented-reality-app-librarians-instantly-shows-which-books-are-misfiled/.

[37] Aurasma[EB/OL]. [2021-08-06]. https://www.auganix.org/hud/aurasma/.

[38] EON Reality. "Our Virtual 3D learning solution"[EB/OL]. Available at: www.eonreality.com/education/.

[39] Layar. Quick & easy self-service Augmented Reality[EB/OL]. [2021-08-12]. https://www.layar.com/features/.

[40] Frank Lloyd Wright Trust. Frank Lloyd Wright: The lost works[EB/OL]. [2021-08-16]. https://flwright.org/explore/the-lostworks.

[41] Massis B. Using virtual and augmented reality in the library[J]. *New Library World*, 2015, 116(11/12): 796-799.

[42] Papanastasiou G, Drigas A, Skianis C, et al. Virtual and augmented reality effects on K-12, higher and tertiary education students' 21st century skills[J]. *Virtual Reality*, 2019(23): 425-436.

[43] Library Association of Singapore. Smart libraries for tomorrow conference[EB/OL]. [2021-08-21]. https://www.las.org.sg/wp/lft/.

[44] Xu Hongyu. Theoretical basis and service practice strategies for library space innovation[J]. *Library*, 2021(4): 52-59.

[45] Slijkerman D, Vlimmeren T V. Living Libraries—The house of the community around the world[M]. de Bibliotheek Utrecht, 2021.

[46] Laerkes J, Manolis P. Building libraries for tomorrow: INELI cohort 1 collaborative project report[EB/OL]. [2021-08-18]. http://www.grlc.vic.gov.au/sites/default/files/pdfs/Board-Report-Attachment4-Sept-16-2013.pdf.

[47] Bennett S. History of paradigm change[J]. *Libraries and the Academy*, 2009, 9(2): 181-197.

[48] IFLA. Call for IFLA/Systematic public library of the year 2021 is open[EB/OL]. [2021-08-21]. https://www.ifla.org/news/call-for-ifla-systematic-public-library-of-the-year-2021-is-open/.

[49] Cai Ying, Cai Yingchun. Progress in collection organization in American university libraries[J]. *Library Tribune*, 2020, 40(6): 166-173.

[50] IFLA. WLIC 2021 virtual conference open programme by the acquisition and collection development section[EB/OL]. [2021-08-21]. https://www.ifla.org/node/93641.

[51] Payne L. Library storage facilities and the future of print collections in North America[EB/OL]. [2021-08-21]. http://www.oclc.org/programs/publications/reports/2007-01.pdf.

[52] Liu Ziheng. Ten major trends in future library development[N]. *China Publishing & Media Business Daily*, 2016-04-08(3).

[53] Jaguszewski J M, Williams K. New roles for new times: Transforming liaison roles in research libraries[EB/OL]. [2021-08-21]. https://www.arl.org/wp-content/uploads/2015/12/nrnt-liaison-roles-revised.pdf.

[54] Wu Jianzhong. Toward the third-generation library[J]. *Library Journal*, 2016, 35(6): 4-9.

[55] Illinois Library. Strategic framework 2019-2023[EB/OL]. [2021-08-21]. https://www.library.illinois.edu/geninfo/libraryinit/strategic-framework-2019/.

[56] Xiong Huixiang, Yang Zirong, Jiang Wuxuan. Research on semantic relevance of multi-modal data in cross-media knowledge graph construction[J]. *Information Studies: Theory & Application*, 2019, 42(2): 17-22, 28.

Author Contributions:
Li Jiao: Literature research and paper writing;
Sun Tan: Research concept, paper revision and finalization;
Xian Guojian: Literature research and paper revision;
Huang Yongwen: Literature research;
Luo Tingting: Literature research;
Chen Boli: Literature research.

Library Space Functions and Service Innovation in the Intelligent Era

Li Jiao[1], Sun Tan[2],[3], Xian Guojian[1],[3], Huang Yongwen[1], Luo Tingting[1], Chen Boli[1]

[1]Agricultural Information Institute, Chinese Academy of Agricultural Sciences, Beijing 100081

[2]Chinese Academy of Agricultural Sciences, Beijing 100081
[3]Key Laboratory of Agricultural Big Data, Ministry of Agriculture and Rural Affairs, Beijing 100081

Abstract: *[Purpose/Significance]* The advent of the intelligent era, spawned by big data and artificial intelligence, prompts serious re-examination of changes in library space functions, resources, and innovative service trends, aiming to provide references for future library space service development planning. *[Method/Process]* This paper researched the changes of library user roles, repositioning of library functions, and integration of technological innovation under the new situation, and analyzed the future development trends and important supporting technologies of library space function services based on the three elements of space, resources, and services. *[Result/Conclusion]* The library has undergone a transformation and upgrading from a traditional resource-based entity to a knowledge center characterized by learning and exchange, developing into complex functional spaces and inclusive cultural facilities supporting diversified service models. High-density automatic storage libraries, innovative service space reconstruction, multi-modal resource association and integration, and immersive reading will become the reform focus of library space function innovation.

Keywords: intelligent era; space reconstruction; resource construction; service model

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