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A Review of Digital Library Research in the Big Data Era: Postprint

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Abstract

[Purpose/Significance] Systematically reviewing domestic and international research literature on digital libraries in the big data era, aiming to provide reference and guidance for further research in this field domestically.

[Method/Process] Employing comprehensive, inductive, and comparative methods, this study conducts a review from four dimensions: research on the connotation of big data and its impact on digital libraries, research on big data technology applications in digital libraries, research on digital library construction in the big data era, and service models of digital libraries in the big data era.

[Results/Conclusion] The findings indicate that while considerable achievements have been made in related research areas, certain issues remain. The study proposes the following research priorities for the field: clarifying the service objectives of libraries in the big data era; through analysis of domestic and international successful cases, deeply investigating various factors influencing library information services to identify the core elements through which big data promotes and optimizes these services; promoting interdisciplinary collaborative research; and seeking breakthroughs and innovations in research methodologies.

Full Text

Preamble

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A Review of Research on Digital Libraries in the Era of Big Data

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Abstract

[**Purpose/Significance**] This article systematically reviews domestic and international research literature on digital libraries in the era of big data, aiming to provide reference and guidance for further research in this field in China. [**Method/Process**] Using synthesis, induction, and comparison methods, this review examines four aspects: the connotation of big data and its impact on digital libraries, the application of big data technology in digital libraries, the construction of digital libraries in the big data era, and service models for digital libraries in this context. [**Result/Conclusion**] The findings indicate that while considerable achievements have been made in related areas, several problems remain. The article proposes key research priorities for this field: (1) clarifying the service objectives of libraries in the big data era; (2) combining analysis of successful domestic and international cases to deeply explore various factors affecting library information services and identify the core elements through which big data can optimize these services; (3) conducting interdisciplinary collaborative research; and (4) seeking breakthroughs and innovations in research methodologies.

Keywords: big data, digital library, information service, challenges, opportunities
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Introduction

Big data has emerged as a new term widely discussed in online media following Web 2.0 and cloud computing. It represents not only massive datasets but also high-volume, high-velocity, and high-variety information assets that enable rapid information retrieval from diverse data types, permeating every sector of society. In the big data era, libraries face significant threats but must seize this opportunity to comprehensively re-examine their service concepts, technologies, resource development, and service methods. By transforming outdated service models and concepts, libraries can restructure digital libraries and turn challenges into opportunities for renewed growth. Therefore, revealing research progress on digital libraries in the big data era holds both theoretical and practical significance for enhancing library information service quality and improving user satisfaction.

Big data has attracted close attention from academia and industry. Top international journals *Nature* and *Science* published special issues on big data in 2008 and 2011, respectively, exploring its theories, technologies, and applications. In May 2011, the renowned management consulting firm McKinsey & Company reported in "Big Data: The Next Frontier for Innovation, Competition, and Productivity" that big data had penetrated every industry and business function, gradually becoming a crucial production factor. Big data encompasses complex and profound concepts that have infiltrated various research fields. T.K. Huwe

from the University of California, Berkeley [1] argued that big data and libraries are a natural fit, particularly for librarians conducting user research projects. R. Lauren and J.W. Rachel [2] suggested that as libraries continue to provide more data services, librarians have the opportunity to become experts and authorities in the big data era. While numerous foreign studies on big data exist, few focus on library and information science. A title search in Web of Science using keywords "Big Data" AND "Library" up to March 27, 2018, yielded 19 documents, but after manual screening and deduplication, only two were directly relevant to digital libraries in the big data era.

In China, big data has attracted multifaceted attention from government, enterprises, and libraries, being hailed as a force capable of catalyzing social transformation. Exploring big data applications and value across industries will undoubtedly become a major trend in academic research across disciplines. Using "big data" and "library" as keywords in CNKI title searches up to March 27, 2018, retrieved 1,557 papers. The earliest research paper on digital libraries based on big data appeared in 2012 with only four documents, but research output grew rapidly thereafter. The annual distribution of papers is shown in [Figure 1: see original paper], peaking in 2016 with 441 papers.

2. Big Data Attracts Attention from Library Research

2.1 Foreign Literature Retrieval

The advent of the big data era has garnered widespread attention across various fields. However, literature concentrated in library and information science remains limited. As mentioned above, a Web of Science search yielded only two directly relevant documents.

2.2 Domestic Literature Retrieval

In China, big data has attracted attention from multiple stakeholders including government, enterprises, and libraries, being described as a force for social transformation. Research on big data applications and value across industries represents a major academic trend. The journal *Library and Information* published a special series on big data in its 2012 Issue 6, exploring applications in intelligence research, library services, traffic management, and other fields. In terms of project funding, among 131 projects funded by the National Social Science Fund in library, information, and archival science in 2014, 18 contained "big data" in their titles, surpassing any other topic [3]. With a typical research cycle of 3-5 years, these projects generated numerous papers, contributing to the 2016 peak in big data research output. In 2015, Wuhan University, together with the iSchools alliance and the Association for Library and Information Science Education (ALISE), hosted the "4th Sino-American International Symposium on Library and Information Science Education in the Digital Age" with the theme "Strategies for Library and Information Science Theory and Education Development in the Big Data Era," discussing eight major issues in global LIS

research and education [4]. This demonstrates that the big data era has attracted significant scholarly attention, with researchers continuously exploring integration points between big data and library and information science.

2.3 Analysis of Funded Domestic Papers

Analysis of retrieved papers reveals that 71 received funding at various levels. Funding statistics for projects with three or more papers are shown in , with 27 supported by the National Social Science Fund and 11 by the National Natural Science Foundation, indicating substantial national support for this research area.

Table 1. Papers Funded by Various Programs
(Only programs with 3+ papers are listed)

Funding Program	Number of Papers
National Social Science Fund	27
National Natural Science Foundation	11
Jiangsu Provincial Department of Education Humanities and Social Sciences Project	
Henan Provincial Soft Science Research Program	
Chongqing Municipal Education Commission Research Fund	
Hunan Provincial Education Commission Research Fund	

3. Research Approaches to Digital Libraries in the Big Data Era

Scholars have conducted numerous studies on big data concepts, technologies, and applications in digital libraries, though review papers remain scarce. Some reviews analyze literature [5], while others examine developmental progress chronologically [6]. This article employs content analysis to review research on digital libraries in the big data era, comparing and commenting on existing achievements. To observe big data's impact on library research, a visual analysis of 144 retrieved documents was conducted, with the keyword co-occurrence network shown in [Figure 2: see original paper].

Figure 1. Annual Distribution of Big Data-Related Library Papers

While the number of retrieved papers confirms that big data-related library issues have become a hot topic in library and information science, some focus on traditional rather than digital libraries. Others mention "big data era" in

their titles but devote little attention to the characteristics and services of digital libraries in this context. Conversely, some papers address digital libraries in the big data era without explicitly stating so in their titles. After manual reading, screening, and deduplication, 144 closely related papers were identified. Since foreign literature is significantly less abundant than domestic, this review focuses primarily on these 144 core domestic papers, citing foreign literature only when referencing specific concepts or research topics.

Figure 2. Keyword Co-occurrence Network

Big data emphasizes not merely large volumes but also conceals more complex and profound concepts. Different disciplines are paying attention to big data's profound impact on their research and practice at various levels, and digital library research is no exception. Intelligence researchers have successfully introduced big data concepts and methods into the field. The keyword co-occurrence network in [Figure 2: see original paper] reveals complex relationships among concepts related to digital libraries in the big data era. Based on analysis of keyword frequency and co-occurrence relationships for terms like "library" and "big data era," this review begins with big data concept research, examines characteristics of the big data environment, uses big data technologies such as cloud computing, data mining, and data analysis as entry points, and then investigates personalized services, knowledge services, service innovation, and service models in digital libraries. The review is organized into four sections: big data connotation and its impact on digital libraries, big data technology applications in digital libraries, digital library construction in the big data era, and digital library service models.

4. Content Review

4.1 Research on Big Data Connotation and Its Impact on Digital Libraries

4.1.1 The Connotation of Big Data Big data does not refer to any specific technology but rather an abstract concept, much like emerging IT concepts such as "cloud computing" and "Internet of Things." Currently, no accurate and unified definition exists in the industry. Wikipedia defines big data as datasets whose capture, management, and processing time using common software tools exceeds tolerable limits. This aligns closely with McKinsey & Company's May 2011 definition: data collections that traditional software tools cannot search, manage, or process within a short timeframe [7]. The authoritative IT research and advisory firm Gartner defines big data as "extreme information management and processing issues that exceed traditional IT capabilities in one or more dimensions." IBM identifies four V-characteristics: Volume, Velocity, Variety, and Veracity. Gartner's reports also describe big data as high-volume, high-velocity, and high-variety information assets requiring new processing methods to enhance decision-making, insight, and process optimization. These definitions differ in description but all recognize big data's characteristic of massive

scale. Traditional large-scale data differs considerably from big data in terms of volume, structural complexity, and production speed. Only through specialized processing can raw data be transformed into valuable knowledge and information. Precisely because of these characteristics, big data has profoundly impacted library development, raising user expectations for information service quality and revealing latent demands for knowledge mining and data analysis value-added services. Libraries must explore integration points with big data.

4.1.2 Opportunities and Challenges Big Data Brings to Libraries Big data has become a research hotspot in library and information science, with scholars recognizing the opportunities and challenges it presents. In 2012, Han Cuifeng [8] analyzed big data's connotation and revealed that libraries would face enormous challenges and tests in data storage, mining, and analysis. In 2013, Liu Wei et al. [9] explored the development prospects of big data and linked data in library and information science. In 2014, Chen Chuanfu et al. [10] conducted needs analysis for digital library construction under big data, summarizing challenges and proposing recommendations for promoting digital library development and big data management practices in China. In 2015, Su Xinning [11] published a monograph titled "Opportunities and Challenges Facing Digital Libraries in the Big Data Era," emphasizing that libraries must seize this opportunity. Regarding resource development, libraries need big data thinking, break through traditional frameworks, establish comprehensive service concepts, fully utilize big data technology, and expand service methods. Everything about traditional libraries must change to better adapt to big data. Su Xinning's ideas, frequently cited, have guided research on resource development and information services in digital libraries. In 2016, S. Mutula [12] emphasized that librarians must understand big data's importance for fundamental research, using examples from several prestigious American universities like the University of Pittsburgh to explore its significance for library and information science and analyze benefits of big data analytics in academia. In 2017, A. Waqur and A. Kanwal [13] analyzed papers in the ISI Web of Knowledge database to examine trends in big data research in library and information management, concluding that library information services will remain a research hotspot and that big data will trigger a major transformation. By embracing big data concepts and technologies and breaking away from traditional frameworks, libraries can promote their development in the big data era, which will provide a completely new research perspective for existing library information services.

4.2 Research on Big Data Technology Applications in Digital Libraries

4.2.1 Big Data Analytics in Digital Libraries Intelligence science and intelligence analysis have existed since the 1950s, whereas big data and big data analytics are recent concepts. Intelligence analysis cannot simply apply big data concepts; researchers must clarify the tasks, priorities, and challenges of big data analytics and technology to effectively support digital library development. In 2013, Wu Hequan [14] analyzed massive data across socio-economic dimensions,

proposing that big data's task is to eliminate redundancy, classify data, and extract valuable knowledge and information—transforming big data into small data through specific analytical methods, which is precisely the key issue facing digital libraries. Digital libraries must expand resource scope while strengthening big data analysis to explore interconnections among various resources and integrate them organically.

4.2.2 Big Data Processing Technologies in Digital Libraries With the rapid development of academic resource providers, digital library resources grow exponentially annually. Larger scale increases processing difficulty but also potential value, explaining big data's appeal to libraries. In 2013, Liu Wei et al. [9] discussed the relationship between linked data and big data, noting that increasingly many big data applications are introducing semantic technologies to make data description more standardized and machine-understandable. Rich semantic links offer better openness and interoperability, enabling big data analysis to penetrate to the knowledge level. In 2014, Cheng Xueqi et al. [16] concluded that big data processing challenges lie not in volume alone—since system scaling can address this to some extent—but rather in data type diversity, timeliness requirements, and data uncertainty. Regarding uncertainty, data authenticity poses the greatest challenge. Current data center technologies struggle to meet big data needs, with storage capacity growth far lagging behind data growth. Li Guojie and Cheng Xueqi [17] emphasized several critical issues: (1) big data redundancy reduction techniques; (2) new representation methods; (3) efficient, low-cost storage; (4) effective data fusion; (5) efficient processing of unstructured and semi-structured data; (6) big data mining tools and development environments; and (7) new technologies to reduce energy consumption in data processing, storage, and communication. Traditional relational database technologies cannot handle these challenges; specialized big data processing systems are essential.

4.2.3 Big Data Systems in Digital Libraries To address big data difficulties and challenges, internet companies like Google, Facebook, LinkedIn, and Microsoft have launched various big data processing systems. Typical systems include Google's GFS (2003), MapReduce (2004), and Bigtable (2006); Hadoop (2008); Dremel (2010); Twitter's Storm; Facebook's Scribe; and LinkedIn's Samza. Extracting value from big data requires content analysis and computation, with key technologies including: (1) deep learning; (2) knowledge computing; and (3) visualization. Deep learning and knowledge computing form the foundation of big data analytics, while visualization is crucial for both analysis and presenting results. These technologies work synergistically to support decision-making. Literature review reveals limited domestic achievements in digital library big data processing systems.

4.2.4 Big Data Thinking in Digital Libraries In the big data era, research thinking has gradually shifted, with scholars embracing big data thinking when

studying digital libraries. In 2015, J. Renaud from UC Irvine and S. Britton from MIT et al. [18] used big data technology to deeply mine digital library user behavior and help universities analyze student reading patterns and related information. Also in 2015, Su Xinning [11] conceptually proposed that big data thinking in digital libraries means considering all library issues from a big data perspective, fully integrating digital libraries into the big data ecosystem, expanding digital products, improving service levels, and solving library problems using big data technology. Digital library big data technologies include data collection, information processing, organizational structures, knowledge mining, analysis and prediction, result presentation, and service technologies—specifically: (1) semantic technology; (2) data clustering; (3) information analysis; and (4) retrieval technology. Su Xinning not only proposed this thinking but also concisely summarized big data technologies from a digital library technology system perspective, providing valuable reference for future construction.

4.3 Research on Digital Library Construction in the Big Data Era

Scholars have identified new functional changes for digital libraries in the big data era: libraries will shift from traditional information retrieval and push services to analyzing and mining potentially valuable information and knowledge from massive datasets. Digital libraries already exhibit big data characteristics, with ever-growing, diverse information resources. Big data construction research must be prioritized.

4.3.1 Key Issues in Digital Library Construction In 2013, Wen Haoyu and Li Jingjing [19] addressed heterogeneous data integration in big data-era digital libraries, proposing a NoSQL middleware model to facilitate knowledge mining from massive heterogeneous data and support decision-making. In 2014, Chen Chuanfu et al. [10] analyzed current digital library construction, noting that libraries' data processing scope, methods, objects, and purposes will change dramatically. Traditional operations will shift toward data analysis and mining, with analyzing large datasets becoming a primary business function. The more patterns discovered and potential value identified from massive data, the faster service levels will improve. In 2016, T. Sandra, R. Stephen, and D. Loukia [5] introduced the "Big Data History of Music" project, a collaboration between University College London and the British Library, highlighting challenges posed by music big data heterogeneity and methods for using various structured catalog data. These examples demonstrate how scholars and scientists produce big data through large-scale analysis and database construction—key issues worthy of reference for China's digital library construction practice.

4.3.2 Considerations in Digital Library Construction Foreign scholars have identified several issues requiring attention: (1) R. Kara Gust and S. Breezy [20] (2015) noted that librarians need to understand why big data matters and its importance for sustainable open resources; (2) C.D. Grand and R.C. Scott [21] (2016) argued that libraries must re-examine core values amid big data

and social media development; and (3) P. Sarah and L. Amber [22] (2017) emphasized that user data privacy protection represents a prominent challenge for libraries in the big data era.

4.4 Research on Digital Library Service Models in the Big Data Era

As the big data era evolves, scholars increasingly recognize that digital libraries must break through traditional thinking, requiring big data thinking in both service concepts and working methods.

4.4.1 Research on Innovative Library Information Service Models In 2012, Li Guangjian and Yang Lin [23] analyzed intelligence analysis from a big data perspective, noting that big data characteristics would bottleneck traditional information service models, with computer-based intelligent analysis replacing manual analysis. In 2013, Han Cuifeng [24] explained that improving library service quality requires big data support, which will become digital libraries' core asset. As big data analytics mature, they will become increasingly valuable, with reader borrowing records and service consumption traces enabling predictive innovation analysis for digital library development and service models. Wang Tianni [25] identified knowledge consulting as a new model for future library services, noting that data resources and talent development are two key drivers, and further analyzed big data technology applications in reading promotion, exploring a "3A5-step" methodology [26]. In 2017, Wang Junguang et al. [27] analyzed common problems in domestic library information services and proposed innovative models for university library information services based on big data.

4.4.2 Research on Cross-Boundary and Interdisciplinary Information Service Models When exploring new service models, scholars have attempted cross-boundary, interdisciplinary collaboration between big data technology and libraries. In 2012, IBM collaborated with the University of Wrocław Library in Poland [28] to use big data technology to preserve and digitize 800,000 pages of European manuscripts, books, and maps, creating the largest digital archive of medieval manuscripts and ancient atlases—a successful cross-boundary application of big data technology in library information service models. Beyond such collaboration, scholars argue that libraries must break through inherent thinking and engage in interdisciplinary cooperation with society. In 2017, J. Vanessa [29] managed a geophysical data database and workflow project for an Australian company, where librarians collaborated with geophysicists, data analysts, and IT experts. The results showed that through interdisciplinary cooperation, librarians provided better metadata capture, data management, optimized search functions, and clearer project objectives. Practice demonstrates that only by transforming thinking and making bold attempts can libraries better serve users and society. Chinese research on cross-boundary and interdisciplinary library information service models requires further expansion.

4.4.3 Research on Information Service Models Embedded in Research Processes As researchers' information needs and scientific research models undergo significant changes, scholars have particularly noted transformations in academic information service models. In 2014, Deng Zhonghua et al. [30] analyzed embedded information service models from the perspective of embedded service concepts, considering changes in users' research environments. These models center on information services, focus on research users, take data resources as the core, orient toward user needs, and rely on embedded information service teams. Scholars believe that libraries' information service and analysis models will change, and that building integrated platforms with strong resource integration capabilities, massive information analysis capabilities, big data mining capabilities, and multi-dimensional information visualization capabilities represents the future trend.

5. Summary and Future Research

5.1 Summary of Current Research

Beginning with big data's connotation, this article systematically organized, integrated, and analyzed related research, revealing several issues despite existing achievements:

(1) **Fragmented and unsystematic research.** Domestic studies focus on bottlenecks and obstacles libraries encounter, service concepts, and service model predictions, but rarely examine service effectiveness, influencing factors, or conduct comparative studies with pre-big data contexts. Empirical case analysis and data comparison studies are particularly scarce.

(2) **Insufficient integration of big data and digital library research.** Most big data research analyzes its connotation, characteristics, and technical applications across fields, while library research still emphasizes traditional service content and models. Few studies combine the two, and applications of big data technology in library resource development and service optimization require further exploration.

(3) **Unclear library service objectives.** Since their inception, libraries have had to adapt their service concepts to changing social environments. In the information age, librarians often struggled to clarify functions and service objectives. Big data is new, and questions about how library service objectives differ between the network and big data eras, how resource development should evolve, and how librarians should improve themselves require serious consideration.

(4) **Uninnovative research methods.** Existing research predominantly uses literature analysis; methodologies need optimization, and research methods specific to digital libraries in the big data era require deeper exploration.

5.2 Future Research Directions

Future research should focus on:

(1) **Clarifying library service objectives in the big data era** by comparing traditional and new service content and models, and proposing targeted optimization strategies.

(2) **Combining analysis of successful domestic and international cases** to deeply explore factors affecting library information services and identify core elements through which big data can optimize these services.

(3) **Conducting interdisciplinary collaborative research.** Since big data applies to multiple fields beyond intelligence science, interdisciplinary cooperation can 借鉴 other fields' achievements for application in library research across resource development, technology application, and service models.

(4) **Seeking methodological breakthroughs and innovations.** Researchers can learn from foreign scholars' methods and tools. For example, in 2017, K. Young-Seok and C. Louise [31] pioneered the use of Chernoff face image methods for library big data analysis, comparing library operations between London and Seoul to evaluate service quality, providing a novel assessment technique worthy of emulation.

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Book Announcement

Title: *Network Users and Network Information Services*
ISBN: 9787502798994
Publisher: Ocean Press
Editor-in-Chief: Chu Jingli
Price: ¥52.00

Network Users and Network Information Services, edited by Professor Chu Jingli and published by Ocean Press in March 2018, focuses on the evolving information environment. The book systematically addresses major issues that library and information services must resolve in the digital and network environment. With comprehensive content and rich materials, it combines theory and practice to promote adaptation to new demands of network users and enhance the capabilities of library and information professionals. Centered on network users' needs and behavioral characteristics, the book examines current conditions and trends in library and information science from the perspective of network information services. It summarizes research findings and application progress in network information services both domestically and internationally, providing an important reference for researchers and practitioners in the field. The book can serve as a graduate-level textbook for library and information science programs.

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

Source: ChinaXiv — Machine translation. Verify with original.