The Theoretical Logic, Practical Challenges, and Path Forward for Artificial Intelligence Applications in Libraries: Postprint

Authors: Yang Jiulong, Yang Yukun, Xu Bihan

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Abstract

[Purpose/Significance] The application of artificial intelligence technology in libraries represents not only an outcome of evolving information technology applications, but also a requisite for the intelligentization, diversification, and specialization of library services. However, library technology and library services do not naturally converge; bridging this gap necessitates contemplation from a humanistic perspective. [Method/Process] Grounded in a literature review, this study elucidates the theoretical logic underlying AI technology application in libraries, examines current practical dilemmas, and envisions prospective development pathways. [Results/Conclusion] Innovation in artificial intelligence and its supporting technologies constitutes the fundamental prerequisite for the application of artificial intelligence technology in the library domain. Building upon technological innovation, conceptual and institutional innovations that ultimately achieve qualitative enhancement of library services represent the basic condition and goal orientation for the application of artificial intelligence technology in libraries. Concurrently, current AI applications continue to face challenges of experiential discontinuity, ethical predicaments, and data leakage risks. Finally, three major recommendations are proposed: cultural mission and ethical embedding, technological iteration and intelligent extension, and institutional optimization with human-machine coexistence.

Full Text

Preamble

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The Theoretical Logic, Practical Difficulties, and Path Prospects of Artificial Intelligence in Library Applications

Yang Jiulong, Yang Yukun, Xu Bihan
School of Public Administration, Northwest University, Xi'an 710127

Abstract

[**Purpose/Significance**] The application of artificial intelligence technology in libraries is not only a product of the development of information technology but also a response to the demand for more intelligent, diversified, and specialized library services. However, library technology and library services are not naturally integrated, and bridging this gap requires reflection from a humanistic perspective. [**Method/Process**] Based on a literature review, this paper clarifies the theoretical logic of AI application in libraries, examines practical difficulties, and prospects future development paths. [**Result/Conclusion**] The innovation of AI technology and its supporting technologies constitutes the fundamental prerequisite for AI application in the library field. On this basis, conceptual and institutional innovation to ultimately achieve high-quality enhancement of library services represents the essential condition and ultimate goal of AI application in libraries. Currently, AI applications still face issues of experiential discontinuity, ethical dilemmas, and data leakage risks. Finally, three major recommendations are proposed: cultural mission and moral embedding, technological iteration and intelligent extension, and institutional optimization and human-machine coexistence.

Classification Number: G250.7
Keywords: artificial intelligence; library; application logic; practical difficulties; development path

Introduction

Since J. McCarthy proposed the concept of artificial intelligence (AI) in 1956, AI has undergone more than 60 years of development. As an active pioneer in applying information technology, libraries have demonstrated high sensitivity to technological developments and have naturally devoted considerable attention to the application of this emerging technology in the library field. Internationally, the *2017 NMC Horizon Report: Library Edition* identified AI as one of the key technologies to watch within 4-5 years [1], while Gartner ranked it first among its "Top Ten Strategic Technologies" [2]. Domestically, AI is also considered one of the major issues influencing library development [3] and a "disruptive technology for libraries in the next decade" [4].

Current academic research on AI and libraries shows a homogenized trend, with most studies limited to explorations of technological applications. The majority of scholars discuss the possibilities of AI technology in smart library construction and library services from a macro perspective, such as intelligent library spaces, intelligent resource systems, and intelligent users [5]; the reshaping of fundamental library elements [6]; applications in traditional library operations like reference consultation, cataloging, classification, and indexing [7]; improve-

ments and updates to library knowledge services [8]; necessary transformations in information resource construction, services, librarians, and library management [9]; the expansion of library academic and knowledge services [10]; and the shared purpose between AI and libraries in information tasks [11]. Some scholars have also analyzed AI applications in specific operational areas, such as semantic web services in academic libraries [12], chatbot services [13-14], rapid call number location [15], frameworks and design of information recommendation services [16], and analysis of information resource ordering strategies [17]. Among these, intelligent retrieval and intelligent reference consultation technologies have become hot topics in recent years. AI technology can optimize search engines and improve retrieval success rates by processing and analyzing user history and popular search predictions [18]; however, this service requires substantial foundational data support and cannot provide accurate retrieval services when data is insufficient.

Compared with the excessive affirmation of AI technology in domestic research, different voices have emerged abroad regarding the relationship between libraries and AI. B. A. Wood et al., through empirical surveys, found that academic librarians' enthusiasm for AI differs not only from that in law, medicine, and other industries but also from libraries' attitudes toward previous new technology adoptions [22]. S. Pinfield et al. expressed concern over survey results showing that academic librarians are aware of AI but do not truly understand the technology [23]. A. Asemi used exploratory factor analysis to study AI development in Iran's library and information science field, finding that recommendation systems and natural language processing represent the most and least developed areas, respectively [24]. A. Oyelude tracked emerging technology trends in online public discourse in 2017, discovering a shift in library technology hotspots from AI to information literacy [25]. V. Guliciuc et al. conducted reverse thinking, proposing the importance of libraries in the AI era and demonstrating new goals for libraries with "minds and souls" to serve humanity [26].

In terms of applications, D. Gede et al. analyzed expert systems in libraries and found that readers could better query, download, and read collection resources [27]. J. Jin et al. proposed using intelligent keyword extraction to improve digital library retrieval functions [28]. R. Parikh and A. R. Vasant proposed a machine learning-based document content recognition method [29]. M. Ottelio introduced BLIIPS, a project using AI to improve public library intelligence in the Netherlands [30]. Z. Joseph introduced MetriDoc, a library decision support intelligent system used at the University of Pennsylvania [31]. J. Muralikumar et al. designed a semantic relationship identification model between documents in digital libraries [32]. A. Comsa et al. introduced intelligent book control using AI in libraries [33]. Meanwhile, most commercial library automation systems, such as ExLibris and Alma, also employ AI to improve library automation systems and enhance user experience.

However, library technology and library services are not naturally integrated. Library services represent an organic combination of technology, concepts, and

institutions [34]. What users ultimately perceive is library service rather than individual technologies. Technological progress brings "instrumental rationality" that cannot be directly converted into "value rationality." As a product of humanistic thought, libraries must simultaneously consider the importance of humanistic-related concepts and management in library services. This also applies to AI technology. Therefore, clarifying the logic between AI technology and library services, understanding their practical difficulties, and prospecting their development paths become essential for bridging the gap from technology to service.

2. From Technological Innovation to Service Optimization: The Application Logic of AI

AI, as a frontier technology, will inevitably change libraries' approaches to knowledge management and information services from scientific research to practical application, profoundly transforming knowledge service structures and the behaviors of subjects and objects in knowledge and cultural services. Currently, AI technology is widely applied across various fields. Based on technological innovation, AI applications need to evolve from "weak application" to "deep application."

2.1 Technological Innovation as the Prerequisite for AI Application

Technological innovation of AI is the fundamental prerequisite for its application in the library field. AI technologies centered on expert systems, pattern recognition, natural language processing, robotics, machine learning, and deep learning neural networks have broad application prospects in library information resource retrieval, cataloging and classification, book selection and procurement, subscription and circulation, reference consultation, and library automation and intelligent services [35]. However, AI as an extension of human wisdom requires the joint action of many supportive, auxiliary, and foundational technologies alongside AI itself. On the one hand, the "datafied scholarship" triggered by related technological innovations provides the broad context for AI to play an intelligent service role in libraries. In recent years, with the rapid development of cloud computing, big data, and other information technologies and the digital transformation of traditional industries, global data volume has grown exponentially. The geometric growth of computer data volume and the rapid improvement of computing speed have provided sufficient technical and data foundations for AI technology based on big data and cloud computing. Meanwhile, machine learning, data mining technology, and expert systems based on information technology are gradually moving from theory to practice. This transformation is also profoundly changing academic research paradigms, making "data-driven" research a trend in academic inquiry. Without the innovation of related information technologies, without a datafied library environment, and without massive data interaction between libraries and their related elements, AI would lack the data environment necessary for survival and development

and could not truly be applied in libraries. On the other hand, AI's own technological innovation, deepening connotation, and expanding extension are also important prerequisites for AI technology application in libraries. The utilization of AI technology requires AI technology itself to develop with the times. In reality, library applications of AI have evolved from early automation operations to robots and then to expert systems, representing deeper levels and broader scopes of evolution. This is an inevitable choice for AI technology to move from theory to practice, from research and development to application. Continuous innovation of AI technology in practice enriches and improves the types and effectiveness of its functions. The combination of technological functions with corresponding concepts and institutions forms various library services, all of which result from the deepening of AI technology itself. This also continuously enhances the awareness and importance of AI technology, forming a virtuous cycle from technological innovation to service application.

2.2 Management Innovation as the Condition for AI Application

Whether library services are technology-based or human-based, they all depend on scientific management. Similarly, on the basis of technological innovation, achieving deep application of AI technology in libraries requires management concept and system innovation as basic conditions. The arrival of the AI era has a significant reshaping effect on society and industry development, bringing new opportunities for library information resource construction, service content and method transformation, library space distribution and architectural environment reform, and library management innovation. Concepts and institutions constitute the epistemology and methodology of management. They require profound management concepts to guide library AI application actions and reasonable management systems to avoid risks in AI application, enabling library management to better leverage the role of emerging technologies and better meet people's cultural and information service needs in the knowledge economy era. First, library management innovation constitutes the soil for AI technology's specific practice in libraries. Only by improving the compatibility between library management systems and AI technology can we better leverage the advantages and roles of AI technology in enhancing library service quality. Second, library management innovation is the key node for AI to move from application to perfection. Through specific application practices of AI technology in libraries, we can continuously identify problems, analyze them, and solve them, thereby promoting further technological development. In the history of library technology applications, the development history of RFID and other technologies with management can also provide similar experiences and lessons. Finally, library management innovation is also the critical springboard for AI technology to move from applied technology to quality service realization. Management is not rigid control but an art. Only through profound changes in library management concepts and methods, increasing the flexibility and adaptability of AI application in libraries, can AI better play its role in library application fields and produce better technological performance.

2.3 Service Optimization as the Ultimate Goal of AI Application

Achieving the expansion of library service content and innovation in service methods is the ultimate goal of AI technology application in the library field. Currently, AI technology development has entered the stage of machine intelligence. By connecting machines to the Internet to obtain various network resources and information and using a series of advanced algorithms to learn from experience, libraries can greatly expand their service content and space. Using AI technology to achieve more diversified and professional information and knowledge services can meet people's increasingly diversified, multi-level, and multi-type knowledge and cultural service needs. In addition, AI application also provides tremendous opportunities for transforming library service methods. AI's unique advantages in machine learning and demand discovery enable libraries to provide point-to-point precise services for readers, explore readers' preferences and habits in using library information resources, and better meet readers' library service needs. Through AI's machine learning and human-computer interaction, using big data and user information storage, AI can provide more targeted, precise, and habit-compliant information services for each customer. At the same time, AI technology application also provides possibilities for innovating library service concepts. With AI technology application, especially in mining user preferences and habits, libraries can transform from previous passive services to active information provision and transmission. By effectively combining user data with the Internet and IoT for knowledge delivery, providing readers with precise, efficient, and convenient knowledge, culture, and information services has become an inevitable choice to meet people's information needs in the context of rapid information growth and knowledge iteration.

3. From Experiential Deficiency to Ethical Dilemma: Practical Difficulties in AI Application in Libraries

AI technology application in libraries is still in its infancy, which means there remains a distance from AI technology to library AI technology services. Currently, AI technology application in libraries still faces practical difficulties that urgently need to be solved due to defects in technology, concepts, and institutions.

3.1 Insufficient Technological Development: Experiential Discontinuity in Human-Computer Interaction

The AI people usually refer to mainly means a symbolic logic system that is a self-aware machine with cognitive complexity similar to the human brain, namely "general AI" or "strong AI" mentioned in academia. However, the AI field is still limping forward and has not truly understood the uniqueness of the human brain [36]. Current AI remains dominated by "weak AI." Therefore, the limitations of AI's own technological innovation inevitably cause limitations in

libraries' AI applications. In the medical field, where AI application discussions are fervent, many experts have raised the issue of AI lacking "human touch" [37]. Libraries are also a field that requires extensive communication and interaction with humans. How to ensure users' service experience does not become discontinuous after using AI technology in libraries is also a question worth considering. Regarding the original information ecosystem of libraries, libraries have substantial interactions between people and resources, and between people themselves, both in physical and virtual fields. On the one hand, library staff need to understand information resources and communicate and interact their physical or mental work results with library users through their own understanding and work, ultimately providing users with information acquisition services to meet their information needs. After AI replaces some service functions, problems may arise in these two interaction links due to current technological development limitations. On the one hand, how machines understand information resources, whether they can fully understand information resources, and how to detect whether machines have understood information resources deserve more exploration. More importantly, previous person-to-person interactions will become person-to-machine interactions. However, taking robots as an example, current AI technology applications still face issues such as immature related technologies, insufficient library-specific corpora, and overly complex library environments [38]. Currently, machines do not yet have the complete ability to understand humans, and user needs may not be understood by robots. Under the current technological bottleneck, the human-computer interaction experience may degrade, lacking both the friendliness of person-to-person interaction and, sometimes, the sense of security and trust in person-to-person communication. Whether intelligent consultation robots in virtual space or service robots walking in physical library spaces with interactive functions, all need to provide warm services more like librarians.

3.2 Lagging Service Concepts: Service Anomie and Ethical Dilemmas Under Deficiency

Libraries are products of human social progress and homes of human spiritual civilization, shining with the light of humanistic spirit. However, due to the disruption and impact of information technology on libraries, a phenomenon of technology research dominating library science has emerged, severely impacting the value orientation of library science and causing a phenomenon where actual library services contradict their concepts and missions. The scientific connotation of library humanistic spirit manifests as "revering library institutions, safeguarding library rights, providing knowledge care for vulnerable groups, and adhering to library professional spirit" [39]. As a product of humanistic thought, libraries should be powerful promoters of social fairness. However, in current reality, due to imperfect management concepts, AI may amplify or enhance existing inequality systems, generating racial, religious, and gender discrimination issues, thereby causing library service "anomie." Tesla CEO E. Musk mentioned at the National Governors Association Summer Meeting that building AI with

general intelligence equals "summoning demons." In the actual operation of AI, ethical and moral issues have also emerged due to management negligence. In recent years, the chatbot Tay developed by Microsoft was launched on Twitter but was urgently shut down after 24 hours. Tay was a virtual robot supported by AI algorithms designed to imitate human communication methods on social network platforms. However, due to lax regulation, the robot drew information from the worst racist and sexist corners, not only insulting users but also making racist comments and inflammatory political declarations. While current AI is in and can be expected to remain in the weak AI stage for a long time, how to ensure AI possesses human values, library service values, and upholds social justice and ethical fairness so as not to oppose social mainstream and social fairness and justice? Using AI technology to replace librarians' work can indeed improve work efficiency, but without corresponding management concepts, it is highly likely to trigger control crises, causing fierce ethical issues in library-society interactions and generating greater contradictions.

3.3 Absence of Management Systems: Machine Learning and Information Leakage

Library AI inevitably requires massive user data for machine learning. While providing convenient and precise services for users, it also brings enormous risks to user information security and privacy protection. In this process, if reasonable management systems are absent, data leakage and illegal data transactions can take advantage. On the one hand, libraries can use user data for machine learning of user reading and borrowing habits, thereby providing better borrowing recommendations, which is conducive to the full utilization of information resources and effective improvement of user experience. On the other hand, users' personal privacy may also be leaked, triggering community public relations crises. In this data revolution, Europe's attitude is notably cautious. This year, the EU's General Data Protection Regulation (GDPR) officially took effect, which will effectively curb government and corporate use of user privacy data. It grants more rights to individual users while restricting technology companies from profiting from big data [40]. It goes without saying that reasonable systems are the criterion for regulating the proper application of library AI technology and also the means to curb illegal data utilization. Therefore, the boundary between user information and user privacy is difficult to determine, especially under the background of imperfect user information management systems, which brings great hidden dangers to library users' privacy and data security. In future society, as AI-based intelligent machines increase, AI will have more and more opportunities to access personal privacy, posing new challenges for personal privacy protection.

4. From Cultural Return to Human-Oriented Management: The Path Forward for AI Application in Libraries

Libraries are both technology-sensitive public departments and places shouldering the mission of knowledge dissemination and cultural inheritance. Therefore, achieving library service quality enhancement requires not only emphasizing the role of AI technology in improving service capabilities but also focusing on the humanization of library management, returning to libraries' cultural attributes, and achieving institutional optimization and human-machine coexistence under AI application through moral embedding and technological iterative innovation.

4.1 Cultural Return and Moral Embedding

AI is an open human technology-ethics experiment, and its value reflection and ethical questioning are incomplete [41]. The pursuit of machine ethics is a necessary preventive measure. When introducing and managing AI technology, correct values and epistemology must be established. The introduction of library technology, including AI, is not simply for pursuing work efficiency, task speed, or technological advancement but must be combined with libraries' own development strategies, construction missions, and grand visions, achieving cultural return and moral integration. First, adhere to the people-oriented principle. For AI technology, we must adhere to the concept of active development, for human use, and integration with library spirit. In practical application, consider all relevant stakeholders, such as library users, library managers, and library technicians, and their needs and actual situations. When applying and introducing technology, organically integrate library humanistic culture into the management of departmental personnel and technology. Second, adhere to the principle of balanced development. Libraries must not neglect any party, ensuring both formal and substantive rationality in development forms. Weber distinguished between formal rationality and substantive rationality. The former implies calculability, efficiency, and impersonality—that is, formal, instrumental aspects—while substantive rationality means action is not only based on rational calculation but also includes human ethical, political, and other needs [42]. Utilizing library AI technology must not cause an imbalance between these two types of rationality; otherwise, it is prone to cause technological crises. Finally, adhere to the principle of seeking truth from facts. We must fully understand the relative consistency and internal differences of library user groups. Measures should be adapted to local conditions, and according to different types of libraries' service goals and scopes, different technical implementation means should be adopted for different groups to meet different groups' usage preferences and information content.

4.2 Technological Iteration and Intelligent Extension

Technological innovation, as the prerequisite for library AI technology, requires the library community to pay more attention to achieving intelligent application of AI technology in library management and services with the help of mobile

Internet, IoT, big data, cloud computing, and other technologies, driving the overall leap of library services. Emphasizing technological innovation not only means the evolution of technology's own functions but also requires designing technology-based services according to the characteristics of technology itself and library users' needs, synchronizing service and technological iteration. At the same time, efforts should be made to transform from "weak AI" to "strong AI." The process of AI technology development must be controlled, and so-called extended intelligence should be developed—that is, how to embed human values into AI. Achieving extended intelligence requires multi-faceted approaches. For example, the source of AI must be controlled, and the behavior of AI scientists should be regulated, with behavioral norms and moral control implemented when technology is created. We must ensure AI technology follows the "Three Laws of Robotics": not harming humans, protecting humans, and obeying humans on this basis, while also focusing on self-protection. Professor J. H. Moor of the Philosophy Department at Dartmouth College distinguishes machines that operate internally according to certain ethical rules, based on their ethical judgment and action capabilities from low to high, into implicit ethical agents, explicit ethical agents, and full ethical agents [43]. Among them, explicit ethical agent-type AI technology is what libraries should try to adopt or vigorously develop. When applying AI technology, libraries must accurately identify its moral agent attributes and utilize or transform it accordingly.

4.3 Institutional Optimization and Human-Machine Coexistence

Leveraging respective strengths for library services while improving technological digestion capabilities. The issue of the relationship between humanities and technology is essentially how to digest technological capabilities [44]. AI benefiting libraries importantly lies in how to find people who can reasonably use library AI. Reasonable utilization concepts need to be established for AI managers and technicians, using AI under the premise of ethical compliance without using its machine functions for evil. At the same time, government regulatory departments need to control libraries' use of AI technology to ensure public interests are not harmed and no single group benefits exclusively. Finally, ideological education should also be conducted for the public and other users potentially involved in library AI technology, popularizing relevant knowledge. The public should be made to maintain reverence and vigilance toward rationality, always noting that while scientific research is endless, technology application has forbidden zones. In addition, relevant laws and regulations are indispensable, and mandatory provisions and regulations can also effectively avoid technological risks arising from AI application in libraries. Maintaining and inheriting libraries' humanistic traditions will enable users to obtain warmer and more humane intelligent services.

Conclusion

The application of AI technology in the library field reflects, on the one hand, the technological development requirement of AI moving from research and development to application, from application to perfection, and from perfection to popularization. On the other hand, it also reflects the inevitable requirement of better fulfilling libraries' knowledge popularization and information dissemination roles and meeting readers' information needs against the background of information explosion and accelerated knowledge iteration. Currently, achieving AI application in libraries still faces many issues, including insufficient technological development, lagging management concepts, and absent information protection. Future better application of AI technology in libraries requires the positive interaction of science, technology, and humanistic spirit. Only by more accurately grasping libraries' cultural attributes, accelerating technological progress and intelligent enhancement, and promoting the innovation and progress of management concepts can we better achieve AI application and perfection in the library field.

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Author Contributions

Yang Jiulong: Proposed the topic, determined the paper framework, wrote and revised the paper.
Yang Yukun: Collected and organized materials, wrote the initial draft.
Xu Bihan: Collected and organized materials, wrote the initial draft.

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