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The Role of Artificial Intelligence in Optimizing Library Access and Services for Science and Technology in the Digital Age

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Abstract: Artificial intelligence (AI) has become an important element in the transformation of science and technology libraries in the digital age. This study aims to investigate the role played by AI in optimizing library access and services in this field. Using a Systematic Literature Review approach, this study systematically reviewed the available literature from 2013 to 2024 through indexing sources such as Scopus, DOAJ, and Google Scholar. The aim was to fill the gap of previous research results and gain a deeper understanding of AI integration in the context of science and technology libraries. The results show that AI has made a significant impact in improving the accessibility, efficiency, and relevance of library services. The use of AI-based intelligent search algorithms and natural language processing (NLP) has enabled libraries to provide more efficient and relevant search services to their users. Technologies such as BERT language models have also been shown to enhance automated search and classification capabilities, providing users with easier access to digital collections in research activities. This study provides important insights into how AI integration has changed the landscape of library services, by strengthening operational efficiency and improving information accessibility. The practical implication of the findings is that science and technology libraries should continue to adapt to advances in AI technology to meet user needs and optimize the services they provide.

Kata Kunci:
Kecerdasan Buatan, Akses Perpustakaan, Pelayanan Perpustakaan.

Abstrak: Kecerdasan buatan (AI) telah menjadi elemen penting dalam transformasi perpustakaan sains dan teknologi di era digital. Penelitian ini bertujuan untuk menyelidiki peran yang dimainkan oleh AI dalam mengoptimalkan akses dan pelayanan perpustakaan di bidang ini. Dengan menggunakan pendekatan Systematic Literature Review, studi ini secara sistematis meninjau literatur yang tersedia dari tahun 2013 hingga 2024 melalui sumber pengindeksan seperti Scopus, DOAJ, dan Google Scholar. Tujuannya adalah untuk mengisi kesenjangan hasil penelitian sebelumnya dan memperoleh pemahaman yang lebih mendalam tentang integrasi AI dalam konteks perpustakaan sains dan teknologi. Hasil penelitian menunjukkan bahwa AI telah memberikan dampak yang signifikan dalam meningkatkan kemudahan akses, efisiensi, dan relevansi layanan perpustakaan. Penggunaan algoritma pencarian cerdas yang berbasis AI dan pemrosesan bahasa alami (NLP) telah memungkinkan perpustakaan untuk menyajikan layanan pencarian yang lebih efisien dan relevan kepada pengguna mereka. Teknologi seperti model bahasa BERT juga telah terbukti meningkatkan kemampuan pencarian dan klasifikasi otomatis, menyediakan akses yang lebih mudah bagi pengguna untuk mengakses koleksi digital dalam kegiatan penelitian. Studi ini memberikan wawasan penting tentang bagaimana integrasi AI telah mengubah lanskap pelayanan perpustakaan, dengan memperkuat efisiensi operasional dan meningkatkan aksesibilitas informasi. Implikasi praktis dari temuan ini adalah bahwa perpustakaan sains dan teknologi harus terus beradaptasi dengan kemajuan teknologi AI untuk memenuhi kebutuhan pengguna dan mengoptimalkan layanan yang mereka berikan.

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A. INTRODUCTION

The library plays a crucial role in supporting knowledge and innovation in the fields of science and technology (Nashihuddin & Trianggoro, 2018). In the face of advancing information technology, the transformation of libraries from physical to digital formats has become imperative (Diana, 2016). This change not only enables broader access to information sources but also accelerates the dissemination and exchange of knowledge among academics and practitioners. Aligning the library's role with the increasingly digital and interconnected needs of society is essential to maintain its relevance as a knowledge hub. Libraries must proactively develop digital collections, provide adequate online services, and integrate technology into information management processes to meet the ever-changing demands of the times. Thus, libraries will remain key partners in supporting exploration, research, and innovation in the world of science and technology.

In the digital era, libraries face challenges in providing optimal access to scientific and technical information (Sokil et al., 2023). The role of libraries is crucial in facilitating the use of digital collections for research and development purposes (Shalygina, 2022). The effectiveness of global Internet search systems compared to specialized systems such as the Scientific and Technical Information System of Belarus is considered to enhance information retrieval (Polak, 2023). Additionally, research also explores historical aspects of communication issues in the field of science and international scientific cooperation, highlighting barriers in scientific contacts and information dissemination (Zianchuk & Saltanova, 2022). There are also efforts to present theoretical generalizations about libraries and information research, providing a model for assessing the development level of each library based on tasks and human resources, which can aid in personnel training and the formation of new organizational structures in research institutions (Lavrik & Kalyuzhnaya, 2022).

Artificial Intelligence (AI) plays a significant role in enhancing accessibility to digital library collections (Asif & Singh 2020). By leveraging AI-based tools, libraries can offer personalized recommendations Wang & Huang (2020) and intelligent search capabilities Coleman (2020), thereby enhancing service quality. AI technologies, such as limited Boltzmann machines and collaborative filtering algorithms, can address challenges in effectively managing and providing access to information resources (Lee, 2020). Furthermore, AI can help identify and correct biases in data, ensuring more inclusive and diverse collections (Pomputius, 2020). Libraries can advocate for digital accessibility by integrating AI tools that enhance access to online information, aligning with the library's ethos to serve all customers equitably.

The applications of Artificial Intelligence (AI) in libraries are diverse, encompassing back-end processes, service enhancement, community development, data literacy, and user management (Cox & Mazumdar, 2022). Studies emphasize the increasing importance of AI, focusing on automation and AI technology in library services (Adi, 2022). The rapid growth of AI and its potential to replace human capabilities are highlighted, especially in education and various sectors (Pandit, 2022). The integration of AI in education has revolutionized the learning experience, offering adaptive systems and virtual tutors (Kramer, 2022). Particularly, AI's role in libraries extends to optimizing collection management, enhancing reference services, and promoting inclusivity (Rabeya et al., 2022). Future opportunities lie in developing advanced AI systems for personalized recommendations and addressing biases in library collections through innovative AI techniques, demonstrating the untapped potential of AI in enhancing library performance.

Literature reviews indicate several gaps in the application of Artificial Intelligence (AI) in the context of optimizing access and services for science and technology libraries in the digital era. While there have been studies highlighting AI's potential to improve search efficiency and access to information, as well as addressing biases in library collections, broader integration of these findings into library practices is still needed. Additionally, few studies specifically explore the impact of AI integration on the inclusivity and diversity of library collections. There is also a gap in understanding how AI can be used to strengthen library communities and enhance data literacy among users, with a lack of understanding of effective implementation strategies in the context of science and technology libraries in the digital era. The primary objective of this research is to address these gaps through a systematic review of existing literature, focusing on broader AI integration and a deeper understanding of its impact on efficiency, inclusivity, and community development in library contexts. It is hoped that this research will provide more concrete guidance for library practitioners in adopting and optimizing the use of AI in relevant contexts.

B. METHOD

This study employs a qualitative research method utilizing a Systematic Literature Review approach to address the research gaps concerning the role of artificial intelligence (AI) in optimizing access and services in science and technology libraries in the digital era. The inclusion criteria encompass studies exploring the use of AI in library contexts focusing on science and technology, research addressing implementation, benefits, and challenges in optimizing access and services using AI technology, analysis of the effectiveness of AI systems in improving efficiency in searching for and accessing scientific and technical information in science and technology libraries, as well as research discussing the use of AI to enhance relevance, personalization, and inclusivity of library services, and its contribution to scientific and technological advancement. Meanwhile, exclusion criteria include studies indirectly related to the use of AI in science and technology library contexts, research only covering general aspects of AI without specific focus on AI's role in enhancing library access and services, research lacking direct relevance to the development of library practices or policies to improve access and services in the digital era, and publications not available in a language understandable by researchers or not meeting relevant academic standards. Data will be searched through the Scopus, DOAJ, and Google Scholar databases using keywords such as "Artificial Intelligence," "Library Access," "Library Services," and "Science and Technology" with a publication year interval between 2013 and 2024.

The research stages begin with identifying the inclusion and exclusion criteria to select literature relevant to the research objectives. These criteria are carefully crafted to ensure that studies relevant to the research topic are included, while irrelevant ones are avoided. Once the criteria are established, the next step is to conduct literature searches using the predetermined databases. Subsequently, the identified literature will be selected based on the established inclusion and exclusion criteria. Literature selection is done meticulously to ensure that only relevant and high-quality studies are included in the analysis. After the literature is selected, the data analysis stage ensues. This involves thorough reading and understanding of each selected study, as well as identifying key findings and emerging patterns from the literature. Finally, the results of the literature analysis will be compiled into a literature review report. This report will include summaries of each analyzed study, discussions on key findings, identified research gaps, and practical implications as well as recommendations for further research. Thus, these research stages will provide a solid foundation for understanding the role of artificial intelligence in

optimizing access and services in science and technology libraries in the digital era, as shown in Figure 1.

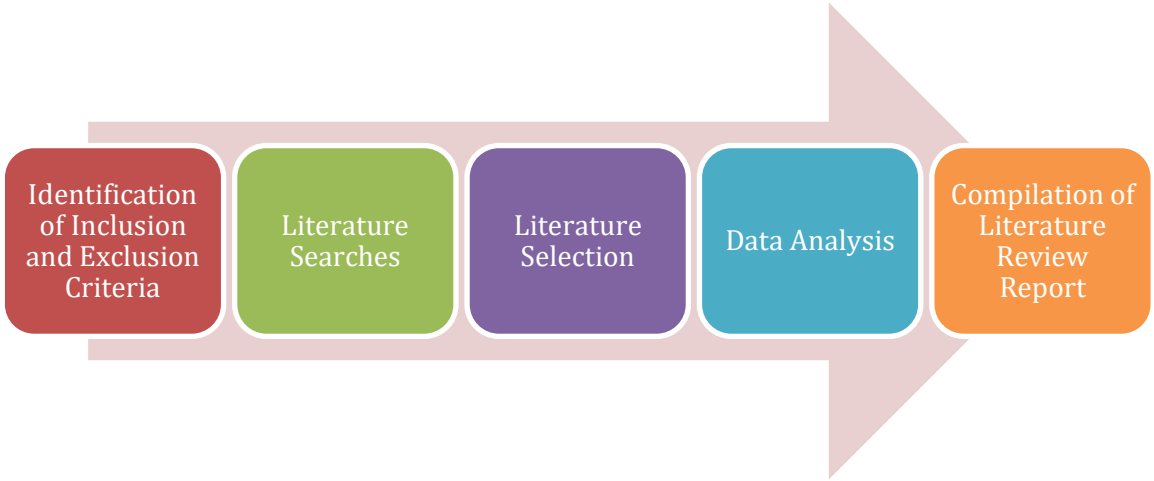

Figure 1. Research implementation steps

C. RESULTS AND DISCUSSION

The application of artificial intelligence (AI) in the library context has become an increasingly important topic in efforts to enhance accessibility, efficiency, and the quality of information services. This summary encapsulates the results of analyses from various studies highlighting the role of AI in various operational aspects of modern libraries. From improving accessibility through intelligent search algorithms to developing personalized recommendation systems, each study provides valuable insights into how AI technology can be integrated to enhance user experiences and information resource management. By synthesizing the various research focuses, we can gain a more comprehensive understanding of how AI is transforming the landscape of modern libraries, along with the associated challenges and opportunities. The summary is depicted in Table 1.

Table 1. The focus and results of the research are in accordance with the established standards

No	Focus	Authors	Insights or Research Variables Discussed
1	Improving Library Accessibility and Efficiency through Smart Search Algorithms and AI Technology	Haffenden et al. (2023); Rakhmatullaev et al. (2023)	AI and NLP-based intelligent search algorithms enable libraries to efficiently recommend relevant literature. AI technologies such as BERT language models enhance search capabilities, automatic classification, and OCR cohesion, making access to digital collections easier.
2	Improved Management and Utilization of Digital Resources in Libraries through AI Integration	Ridley & Pawlick-Potts(2021); Aliwijaya & Suyono (2023)	The integration of AI in library systems, including recommendation systems and intelligent storage platforms, can improve the management and utilization of digital resources.
3	Development of a Personalized Recommendation System in Libraries	H K et al. (2023); Özkara & Turan (2023); Zhang & Shen	The use of techniques such as Content Based Filtering (CBF) and Collaborative Filtering (CF), along with the use of knowledge graphs and Entity Interaction

		(2023); Hu et al. (2023)	Knowledge Graphs (EIKG), can improve recommendation accuracy by considering user behavior and interaction data.
4	The Role of AI in Summarizing Scientific Information in Libraries	Inceoglu et al. (2022); Ang et al. (2023); Modiba (2023); Abd-Elsalam & Abdel-Momen (2023)	AI-based tools like ChatGPT can help simplify complex scientific information, speed up the publishing process, and generate different types of scientific papers and statistics, although concerns about the integrity and role of human researchers still exist.
5	Improving User Experience through Integration Chatbot in Library Services	Khamis (2023); Maranchak (2023); Lappalainen & Narayanan (2023); Donkor & Ampadu (2023); Pival (2023)	The integration of chatbots in library reference services enhances the user experience by providing instant and personalized support in answering questions about scientific and technical literature, as well as improving search functions and automating routine tasks.
6	AI Research and Development in Improving Library Functions and Services	Adi (2022); Berendt (2023); Xu (2023); Kapterev (2023); Nugroho et al. (2023); Haffenden et al. (2023)	AI technologies such as OCR, data mining and machine learning play an important role in improving library functions and services, while the use of Natural Language Processing technologies, such as BERT language models, enhances automated search and classification capabilities.

Table 1 outlines various studies that highlight the application of artificial intelligence (AI) in the library context. These studies encompass several key focuses. Firstly, there are research efforts exploring how AI-based intelligent search algorithms and AI technologies such as BERT language models can enhance accessibility and efficiency in accessing digital library collections. Furthermore, research discusses the integration of AI into library systems to improve the management and utilization of digital resources, including recommendation systems and smart storage platforms. The development of personalized recommendation systems in libraries is also a focus, employing techniques such as Content-Based Filtering (CBF) and Collaborative Filtering (CF), as well as technologies like Entity Interaction Knowledge Graphs (EIKG). Additionally, studies highlight the role of AI, such as ChatGPT, in simplifying scientific information, expediting the publishing process, and generating various types of scholarly works and statistics, though concerns persist regarding integrity and the role of human researchers. The integration of chatbots into library services is also discussed to enhance user experiences with instant and personalized support in answering questions about scientific and technical literature. Finally, research explores the development and utilization of AI in enhancing library functions and services, including the use of technologies such as OCR, data mining, machine learning, and Natural Language Processing (NLP). Overall, this body of research underscores the vital role of AI in supporting the transformation of libraries towards more efficient, personalized, and inclusive services. A detailed discussion of these aspects will be addressed in the following section.

1. Artificial Intelligence Implementation Improves Library Access in the Digital Age

Smart search algorithms, based on Artificial Intelligence (AI) and Natural Language Processing (NLP) technologies, play a crucial role in enhancing access to digital collections in libraries. By analyzing user information needs, preferences, and behaviors, these algorithms can efficiently recommend relevant literature (Haffenden et al., 2023). Moreover, AI technologies like BERT language models can enhance search capabilities, automate classification, and improve

Optical Character Recognition (OCR) cohesion in academic libraries, making digital collections more accessible for research purposes (Rakhmatullaev et al., 2023). Additionally, the integration of AI into library systems, including recommendation systems and smart storage platforms, can significantly enhance the management and utilization of digital resources, providing users with convenient and effective services (Ridley & Pawlick-Potts, 2021) (Aliwijaya & Suyono, 2023). Overall, the implementation of smart search algorithms in libraries not only accelerates information retrieval but also ensures users can easily navigate and access related information within digital collections.

Personalized recommendation systems play a crucial role in enhancing user experiences by suggesting content based on preferences and reading behavior patterns. These systems utilize techniques such as Content-Based Filtering (CBF) and Collaborative Filtering (CF) to recommend items similar to user interests (H K et al., 2023). Combining users' historical behavior and topic preferences, along with knowledge graphs, can significantly improve recommendation accuracy (Özkara & Turan, 2023). Furthermore, the use of Entity Interaction Knowledge Graphs (EIKG) can enhance recommendation methods by considering user behavioral similarity and interaction data (Zhang & Shen, 2023). By designing interpretable recommendation systems that optimize the accuracy of click behavior predictions through weighted sum interaction ranking and matrix factorization, substantial improvements in personalized recommendations can be achieved (Hu et al., 2023). These advancements collectively contribute to refining the search experience and facilitating information discovery for users.

The implementation of artificial intelligence in smart search algorithms enables libraries to provide more efficient and relevant services to users. By automatically analyzing user preferences and behavior, these algorithms can generate more accurate literature recommendations tailored to individual needs. AI technologies like BERT language models also open up new opportunities in text processing and recognition, allowing libraries to enhance the quality of their services and accessibility to digital collections. Although the implementation of artificial intelligence in smart search algorithms has brought many benefits in improving library access in the digital era, there are still some challenges to overcome. One of these is the need for accuracy and validity in the information recommended by these algorithms. Additionally, it's important to note that not all users have the same preferences or behaviors, thus additional efforts are needed to ensure that the recommendations provided align with individual needs.

2. Artificial Intelligence in Library Services in the Context of Science and Technology

AI technology, such as ChatGPT, plays a crucial role in simplifying complex scientific information for users (Inceoglu et al., 2022) (Ang et al., 2023). These AI-based tools assist in organizing thoughts, generating drafts, and enhancing the quality of scholarly works, ultimately expediting the publishing process and enabling researchers to focus on their core work (Modiba, 2023). Additionally, AI tools like ChatGPT can aid in summarizing literature, composing essays, and producing statistical studies, thus transforming scientific communication (Abd-Elsalam & Abdel-Momen, 2023). Despite the benefits of AI in accelerating innovation and diversifying scientific perspectives, concerns about the integrity and role of human researchers persist (Khan et al., 2023). It is crucial for the scientific community to engage in discussions regarding the implications of AI technology in research and learning to ensure transparency, reliability, and ethical usage.

The integration of chatbots or AI-based virtual assistants in library reference services can significantly enhance user experiences by providing instant and personalized support in

answering questions about scientific and technical literature. This technology offers benefits such as real-time interaction, personalized recommendations, and efficient query handling (Khamis, 2023) (Maranchak, 2023) (Lappalainen & Narayanan, 2023). Research has shown that chatbots can effectively handle user queries outside regular operating hours, improving accessibility to library services (Donkor & Ampadu, 2023). Furthermore, AI technologies like chatbots can assist in analyzing user behavior, enhancing search functions, and automating routine tasks in libraries (Pival, 2023). By leveraging AI in reference services, libraries can offer more efficient and tailored support to users, ultimately enhancing their overall experience and satisfaction.

The integration of artificial intelligence (AI) technology, such as chatbots or virtual assistants, into library reference services has brought significant positive impacts. Chatbots provide interactive real-time services, personalized recommendations, and efficient query handling, enhancing the overall user experience. Additionally, AI aids in analyzing user behavior patterns, improving search quality, and automating routine tasks in libraries. The utilization of AI technology in library reference services provides more efficient and tailored support to users, improving their accessibility and satisfaction. While AI technology offers many benefits in enhancing library services, concerns regarding the integrity and role of human researchers persist. The use of AI technology in the context of research and library services raises questions about transparency, reliability, and ethics that require serious consideration.

3. Artificial Intelligence's Contribution to Scientific and Technological Advancement through Libraries

The analysis of AI on library collections aids in identifying research directions and trending topics in science and technology. Studies reveal the evolving applications of AI in libraries, focusing on machine learning, deep learning, and high-level language processing (Ecem Gürsen et al., 2023) (Borgohain et al., 2024). AI technologies such as OCR, data mining, and natural language processing significantly impact library functions, leading to the identification of key technologies for practical applications (Nugroho et al., 2023). The correlation between AI and libraries has intensified, especially during the pandemic, with a surge in scholarly production related to AI and digital libraries (Xu, 2023). Automation and AI technologies increasingly replace manual tasks in libraries, emphasizing the need for research to explore the development and utilization of AI in library services (Adi, 2022). This collective data underscores the pivotal role of AI in shaping the future of libraries and information management.

AI techniques are increasingly employed in libraries to address biases and enhance inclusivity in collections, promoting diverse scientific and technical perspectives. Libraries have long recognized the risks of bias in AI applications and have developed preventive measures to mitigate these issues (Berendt, 2023). Key AI technologies such as OCR, data mining, and machine learning play a crucial role in enhancing library functions and services, aiding in bias detection and correction within collections (Xu, 2023) (Kapterev, 2023). Furthermore, the integration of Natural Language Processing (NLP) technologies, such as BERT language models, in national libraries has facilitated the development of tools for automatic classification and improved search capabilities, contributing to a more inclusive representation of diverse perspectives within library collections (Haffenden et al., 2023).

These studies depict the evolution of AI's role in transforming the library landscape. With a focus on machine learning, NLP, and data mining, libraries can efficiently manage, analyze, and integrate information within their collections. The use of AI technology also assists libraries in addressing challenges such as bias in collections and enhancing accessibility through more

inclusive representations of various perspectives. Additionally, the research highlights the importance of continuously exploring and developing AI applications in library services to enhance efficiency and relevance. The overall contribution of AI to libraries is positive. The use of AI technology such as machine learning and NLP enables libraries to be more efficient and effective in information management, trend recognition, and identification of trending research topics. Moreover, AI integration helps address biases in collections and expands representation of diverse perspectives, enhancing inclusivity in information access. However, it is crucial to continually monitor and evaluate AI usage to ensure no negative impacts such as increased information access disparities or academic freedom restrictions.

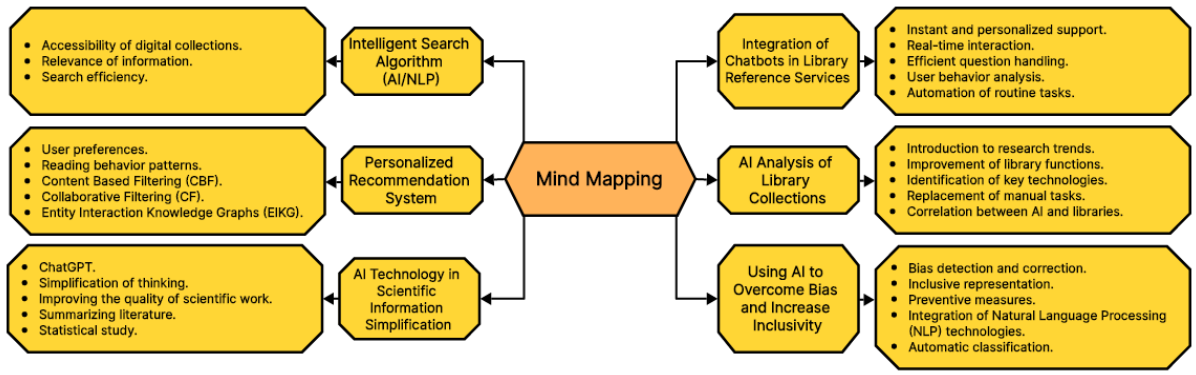

Figure 1. Research variables contained in this study

Figure 1 illustrates a framework encompassing various key elements in the implementation of artificial intelligence (AI) and natural language processing (NLP) in the context of library and scientific information management. Intelligent Search Algorithms (AI/NLP) serve as the primary foundation to ensure optimal accessibility to digital collections, focusing on enhancing information relevance and search efficiency. Personalized Recommendation Systems leverage user preferences and reading behavior patterns as the basis for presenting relevant recommendations, utilizing techniques such as Content Based Filtering (CBF), Collaborative Filtering (CF), and Entity Interaction Knowledge Graphs (EIKG) to enhance recommendation accuracy. AI technologies, such as ChatGPT, are utilized to simplify scientific information by summarizing literature, facilitating better understanding, and enhancing the quality of scholarly work. This also involves statistical studies for deeper analysis. Integration of Chatbots into Library Reference Services strengthens customer support aspects by providing instant and personalized services, catering to real-time interactions, and delivering efficient question handling while analyzing user behavior and automating routine tasks. AI Analysis of Library Collections aids in identifying research trends, enhancing library functions, and identifying key technologies supporting efficiency and accessibility. This may involve replacing manual tasks with AI-based approaches and clarifying the correlation between AI technology and libraries. The use of AI to Address Bias and Enhance Inclusivity emphasizes bias detection and correction, inclusive representation, and preventive measures to ensure inclusivity in information access, using NLP technology and automatic classification as key tools. Figure 1 visualizes the integration of these various elements to enhance information management and accessibility in the context of libraries and scientific knowledge.

D. CONCLUSIONS AND SUGGESTIONS

Based on the evaluation of the presented research, it can be concluded that the implementation of artificial intelligence (AI) in the context of libraries has had a significant impact on enhancing accessibility, efficiency, and relevance of services. The use of intelligent search algorithms based on AI and natural language processing (NLP) has enabled libraries to provide more efficient and relevant search services to their users. Technologies such as BERT language models have also improved search capabilities and automatic classification, making it easier for users to access digital collections for research purposes. Moreover, in the realm of scientific research, AI has played a crucial role in simplifying complex information, accelerating the research process, and transforming the way scientific communication is conducted.

However, it is important to acknowledge that challenges still exist, such as concerns about the integrity and role of human researchers, as well as risks associated with bias in the use of AI technology. Therefore, further research is needed to explore these aspects and ensure that the use of AI in libraries and scientific research continues sustainably, fairly, and inclusively. One pressing research topic is the development of methods to reduce and manage bias in the implementation of AI in libraries, as well as research on the ethical and social implications of using AI technology in the context of information and research. Thus, further research will help strengthen the role of AI in supporting scientific and technological advancements through libraries, while ensuring that fairness, integrity, and inclusivity remain preserved in information services and practices.

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