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Harnessing AI for Enhanced Searching in Digital Libraries: Transforming Research Practices

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Abstract - **The application of Artificial Intelligence (AI) technologies in digital libraries is changing the paradigm in which users search and interact with digital content. This article is focused on how the use of AI technologies improves the search in digital libraries, demonstrating the benefits of such technologies in overcoming the challenges associated with formulation of query, information retrieval, and end user usage. Most search engine systems face the problems of user queries, which are inherent in online searches. Many user queries are vague, imprecise or ambiguous with regards to the context and as a result lead to less than satisfactory search results. AI technologies such as Natural Language Processing (NLP) and Machine Learning (ML) solve this challenge effectively as they enhance comprehension of queries, contextual understanding, and relevance of the results returned. With the capabilities of NLP incorporated in search engines, search queries which are in the form of natural language can be understood and executed which leads to efficiency in targeting the information needed. Comprehensive restructuring of standard information systems is used by computer learning algorithms for searches by inference and instills usage in users. This study also examines the place of AI in query formulation and the different ways it can be employed; fully automated, semi-automated and/or manually so that the users are less faced with the challenges that are usually present during the query formulation process. Such increases in the level of difficulty and scope of information retrieval suggest that search AI improved the scenario.**

Keywords: **AI, Digital Libraries, Natural Language Processing (NLP), Machine Learning (ML)**

I. INTRODUCTION

Among the many services provided by a digital library (Sumithra et al., 2024) the service of searching information through a query formulated by a user plays a crucial role. It's the very first step taken by a user who wishes to extract information from the wealth of knowledge gathered in a digital library. Ensuring fast and efficient searching leads to a satisfying experience on the part of a digital library user. However, effective searching is not a trivial job. It is challenging for users because an information need has to be expressed in an appropriate query to get satisfactory search results that are relevant to the need (Jaillant & Caputo, 2022). Moreover, a query formulated by a user should be able to uncover a piece of relevant information from a whole collection. Searching is also a challenge for many digital library service providers. Understanding the query posed by a user and interpreting it properly to extract the required information from a collection is a hard and nontrivial task. Information extraction is not straightforward due to the vagueness, ambiguity, imprecision, and complexity of a query.

Artificial intelligence is a multidisciplinary subject that encompasses the processes and techniques employed by machines and other artificial systems to perform highly sophisticated human-like tasks like reasoning, learning (Ronald et al., 2024; Mohamed et al., 2024) understanding natural language (Tohma & Kutlu, 2020) speech recognition, etc. Many of the technologies and techniques of AI have great potential to tackle some of the key issues and challenges faced by digital libraries in different areas, including searching. Recent advancements in several areas of AI have made it possible to use the technologies to enhance searching in digital libraries and transform the searching practice of users, which is yet to be harnessed at a significant level. AI might be applied at various levels, including fully automated and semiautomated modes, to assist users in posing queries. AI-based automated techniques can alleviate the difficulties experienced by users when recognized and handled properly (Colavizza et al., 2021).

Background of Digital Libraries

Digital libraries evolved in response to the need to manage the vast quantities of electronic information that we produce, collect, and consume in figure 1. In a predominantly print-based world, deeply entrenched information seeking and use habits developed, especially in academic environments. The increased focus on electronic resources and the resulting unmeasured growth in their numbers have altered information environments and created new problems (Gangadharan et al., 2024). Such problems have been felt and expressed, particularly by the librarians who are responsible for managing the resources and those who mediate access to and locate resources for the users. System architects, facing these new problems, have designed new digital libraries. At first, these were designed independently to afford services to specific communities, but as electronic collections became distributed, different communities with different views and interests drifted onto the network. There are now many such systems and they have become commonplace. Digital library systems that store and mediate access to information have become commonplace and are scattered all over the Internet (Bi et al., 2022). Consequently, information retrieval also has to contend with distributed/networked systems. These systems may differ in architecture and characteristics (e.g. user community, document collection and genres, types of metadata and indexing style, query languages and styles, management policies, operating environment, system performance, etc.). If these systems are interoperable and the contents of some of them are accessible to user community k, then group Gk is said to be supported by a digital library. Standard indexing and interoperability practices and methods have, therefore, been developed in libraries and information agencies (Fox et al., 2005). But with networked information systems, automatic indexing becomes more demanding, not only because of the quality of the documents being processed but also because undesired inclusion of irrelevant materials can deteriorate performance and overload users with too many results. Information filtering can be used to advise users to pursue queries in alternative information sources or to set aside some queries and the corresponding results (Xiao, 2022).

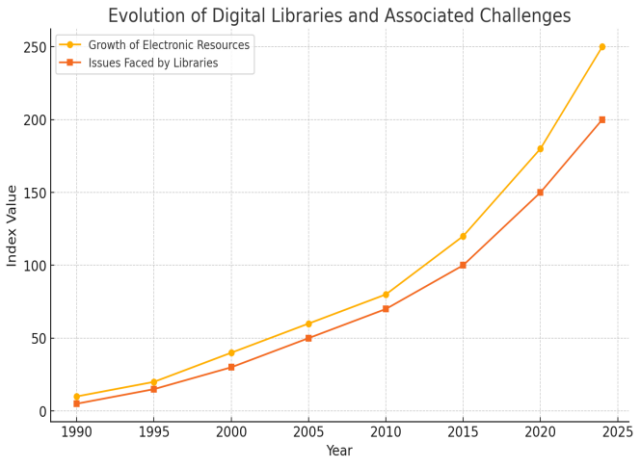

Fig. 1 Evolution of Digital Libraries and Associated Challenges

Importance of Efficient Searching in Research

A thorough literature review is generally regarded as the initial stage of any investigation or research project. This process is essential for examining preexisting studies, assists in shaping new research questions, and provides additional insight into the practical application of theory (Kuzi, 2021). Nevertheless, the increasing number of research articles published and shared in digital formats has made it increasingly challenging to access and retrieve articles relevant to particular research fields. Articles related to similar keywords can be both beneficial and problematic. They can include irrelevant publications with similar terminology from other scientific fields or can belong to the same subject matter but from different digital libraries, presentations, or documents. This challenge goes beyond mere retrieval, actively necessitating knowledge development and elaboration of new approaches to facilitate efficient and effective access to information relevant to researchers' needs.

Ideally, researchers search for specific information in publications. However, searching for information in a particular document is relatively efficient compared to searches across publications. Current systems are text-based retrieval systems that assist researchers in retrieving literature relevant to particular keywords. Hence, there is a need for advanced searching methodologies that can better meet users' demands when searching in digital libraries (Hersh, 2024). This paper concentrates on digital libraries and their information system, focusing on technologies that use Artificial Intelligence (AI) to enhance current searching capabilities.

II. AI Technologies for Enhanced Searching

Artificial Intelligence has been widely adopted in diverse domains, benefiting numerous global communities (Asemi & Asemi, 2018). There is an increasing demand for Information and Library Science professionals to enhance and enrich information retrieval in online library services by considering the transformation of information seeking behavior and the emergence of digital libraries. To improve the process of searching and information retrieval as well as to facilitate the research process, creative solutions based on advanced technologies can be utilized. Recent advancements in various AI technologies such as machine learning, natural language processing, and knowledge representation, can be harnessed for enhanced searching in digital libraries. These AI technologies empower improved search capabilities by utilizing advanced content processing, search query understanding, and result analysis technologies. The functionalities and impact of these AI technologies contributing to enhanced searching are elaborated upon (Saeidnia et al., 2024).

Leveraging AI technologies, a new paradigm for an enhanced design and provision of digital libraries, as well as the underlying enriching searching technologies, is presented in Figure 2. They rely on the core AI components that comprise

advanced semantic content processing, AI-enhanced query understanding, and improved result analysis and presentation. In such a paradigm, novel approaches for the design and provision of digital libraries, as well as the underlying enriching searching technologies, are discussed. This opens a new venue for the collaborative design, construction, and branding of digital libraries as well as their search gateways, e.g., a digital library of digital libraries or an enhanced Infomediary digital library, whose search service can extract the added value from the queried information needs of a wider community of users.

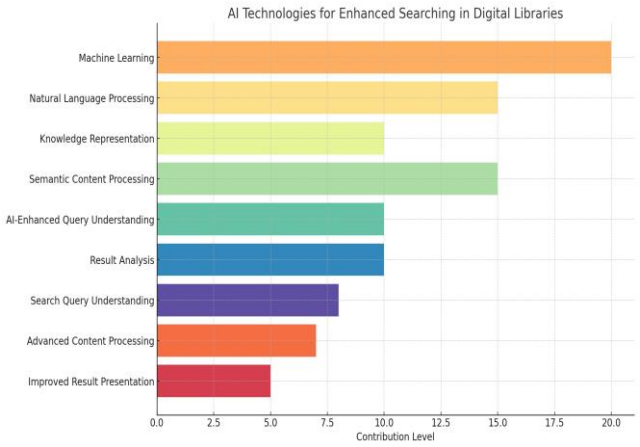

Fig. 2 AI Technologies for Enhanced Searching in Digital Libraries

Natural Language Processing

Natural Language Processing (NLP) is an essential artificial intelligence technology that can understand and process human language. Using NLP, machines can listen, speak, read, and write. NLP enables computers to make sense of unstructured textual data, a new capability for searching. A machine can analyze the relationship between words on a numeric level through stem analysis and context weighting. In this way, the importance of each word can be assessed, enabling the fuzzy searching capability or broader searching capability of text strings. Fuzzy searching means an imprecise query matches possibly relevant documents. For example, the document containing the text "artificial intelligence" can be retrieved even if the query is "AI" (Shaik et al., 2022). Through a comparison of the concepts of textual query and indexed description, a wider semantic searching is achievable, where terms with similar meanings even from different languages can be matched.

The information retrieval function can be redefined to incorporate NLP development. Initially, systems indexed documents with a few keywords chosen carefully by librarians using standardized lists. Then new indexing techniques and a better index presentation to the user were developed, which allowed other terms to be used in the searching task. After that, probabilistic or Bayesian models were introduced, making use of statistical data. Currently, some systems using NLP can understand a query or documents synchronized with its language analysis and has been successfully experimented with in some areas like legal and patent retrieval (Liddy, 1998).

Machine Learning Algorithms

Among the various AI techniques, machine learning (ML) algorithms play a pivotal role in enhancing the search accuracy and relevance of search engines being used in digital libraries (DLs). DLs are vast repositories of academic knowledge represented in textual and audio-visual forms. They have become reliable sources for researchers seeking prior works on their chosen topics. However, performing searches on DLs is not as straightforward as performing regular web searches. The underlying databases of DLs consist of thousands of articles with appended keywords generated by the authors, who may not fully address the complete understanding of the original idea. Annotating article representations with keywords is a challenging task and may produce unexpected results, consequently leading to irrelevant search outcomes. Though attempts have been made to improve the relevance of search results, they employ techniques that do not cater to hierarchical classes of topics. In the case of novel ideas, it is possible that there are no prior works on the same or similar work being performed (Dilorom et al., 2024). Consequently, none of the results generated appear relevant. Moreover, the dynamic nature of research undertaken in the simulated domain keeps adding extra dimensions to the datasets in table I.

TABLE I MACHINE LEARNING ALGORITHMS: ASPECTS AND DESCRIPTIONS

Aspect	Description
Role of ML Algorithms	ML algorithms enhance search accuracy and relevance in DLs by learning from data, allowing search engines to generate more relevant results.
Characteristics of Digital Libraries	DLs are repositories of academic knowledge, containing textual and audio-visual content that serve as reliable sources for researchers.
Challenges in DL Searches	Searching in DLs is complex due to large, diverse databases with articles tagged by keywords that may not fully represent the original ideas.
Keyword Annotation Issues	Articles in DLs are often annotated with keywords by authors, which can be incomplete or misleading, leading to irrelevant search outcomes.
Relevance Improvement Attempts	Existing techniques often fail to cater to hierarchical topic structures, making searches for novel ideas or niche topics particularly challenging.
Dynamic Research Domain	The evolving nature of research continuously adds new dimensions to datasets, complicating search relevance and completeness.
Comparison with Rule-Based Searches	Rule-based search engines rely on predetermined indexes and search terms, whereas ML-based engines learn from input data to find relevant matches.
Learning and Adaptation	ML search engines are fed with intended results and corresponding content, allowing them to learn and understand semantic relationships in data.
Enhanced Search Capabilities	ML algorithms improve search accuracy by adapting to unindexed content and considering potential matches based on semantic similarities.
Benefits of ML Search Engines	They include relevant results not initially specified, handle complex content relationships, and cater to the nuanced needs of researchers.
Limitations	Challenges include handling novel ideas with no prior data, addressing the evolving nature of research, and the dependency on high-quality training data.

Search engines employing ML algorithms tend to adapt and learn from data in order to generate better search results. Unlike rule-based search engines that rely on predetermined indexes and individual search terms to find matching content, ML search engines are fed with intended results together with the corresponding content. This enables the search engines to learn and replicate the semantic aspects of matching content that were not originally specified. As a result, potential matches on different terms may also be included in the search results. This greatly improves search accuracy while generating results that were not indexed but are germane to the subject of the original illustration (MacFarlane et al., 2020).

III. Applications of AI in Digital Libraries

This section explores the application of artificial intelligence (AI) within digital libraries. More specifically, it focuses on recommendation systems, which aid users in discovering new resources, and semantic search, which enhances digital libraries by facilitating a deeper contextual analysis of search queries shows in table II.

TABLE II APPLICATIONS OF AI IN DIGITAL LIBRARIES: APPLICATIONS, BENEFITS, CHALLENGES

Application	Description	Techniques Used	Benefits	Challenges
Recommendation Systems	AI-driven systems that suggest relevant resources to users based on their previous interactions and preferences.	Deep Learning (CNNs, Autoencoders), Collaborative Filtering, Hybrid Techniques.	Enhances resource discoverability, personalizes user experience, increases library usage.	High computational cost, requires accurate user data.
Semantic Search	Enhances search capabilities by understanding the context and meaning of search queries, beyond exact keyword matching.	Natural Language Processing (NLP), Machine Learning Algorithms, Contextual Analysis.	Provides more relevant search results, reduces irrelevant outputs, improves user satisfaction.	Complexity in interpreting nuanced user intent, data dependency.
Techniques for Recommendation Systems	Techniques like deep learning extract features and model user preferences; collaborative filtering suggests items based on user similarity.	Content-Based Filtering, Clustering Methods, Hybrid Approaches.	Combines strengths of different algorithms for improved accuracy and scalability.	Balancing recommendation diversity and relevance, potential for echo chamber effects.
Examples of Digital Libraries	Digital libraries using these techniques include ACM Digital Library, IEEE Xplore, Research Gate, ArXiv, Google Scholar.	AI-powered algorithms, classical recommendation strategies.	Facilitates easy discovery of vast numbers of academic items (articles, papers, patents).	Managing the growth of content, ensuring up-to-date recommendations
Hybrid Techniques	Combining multiple approaches, such as collaborative filtering with content-based methods, to enhance system performance.	Content-Based + Collaborative Filtering, Clustering Techniques.	Improves recommendation accuracy by leveraging diverse data sources.	Complexity in integrating multiple approaches effectively.

Recommendation is one of the prominent applications of AI in digital libraries. Based on users' previous interactions, recommendation systems provide personal recommendations for discovering other resources (Asemi & Asemi, 2018). Digital libraries can employ a wide variety of techniques for developing recommendation systems. Popular approaches employ deep learning techniques, such as convolutional Neural Networks (CNN) or autoencoders, for extracting features from items and for modeling users' preferences. These features are then used with classical collaborative filtering algorithms to provide recommendations. Recommendation systems could greatly facilitate the usage of academic digital libraries (Saeidnia et al., 2024). In recent years, many academic digital libraries, such as ACM Digital Library, IEEE Xplore, Research Gate, ArXiv, or Google Scholar, have been developed, which gather a huge number of academic items, such as articles, conference papers, or patents. With the rapid growth of the number of items in academic digital libraries, it has become difficult for users to find the items which are relevant to their interests. Recommendation systems can assist users in discovering suitable items and increase the usage of digital libraries. To improve the performance of the recommendation systems, hybrid techniques, which combine different approaches, have also been proposed. For example, it is possible to combine content-based items with collaborative filtering techniques using clustering methods. In addition, to enhance the accuracy of recommendations, there are different algorithms to match the target user with similar users or relevant items. Digital libraries can leverage both AI and classical algorithms for developing efficient and scalable recommendation systems.

Recommendation Systems

Recommendation systems, also known as recommender systems or recommendation engines, are a branch of artificial intelligence (AI) that focus on filtering and predicting the interests of a user within a specific domain. Online systems, such as e-commerce sites and internet service providers, collect information about users when they visit their web pages. This information is stored and processed, allowing new users to receive recommendations based on knowledge gained from existing users. These recommendation systems are of great significance to users, business owners, and site managers, helping provide more personalized services and increasing user satisfaction and loyalty (Surayyo et al., 2024).

A recommendation is a suggestion about items that should be of interest to the user, based on their past behavior, as well as the behavior of other similar users. Users have either positively or negatively rated or purchased an item in their history. The first approach, collaborative filtering, originated in the mid-1980s and attempts to solve the recommendations problem by analyzing the past ratings and purchases of a

community of users to predict new ratings or purchases. The second approach, similarity indexing, is used by companies such as Amazon.com and involves searching for an item that is similar to one previously rated or purchased in order to recommend it to the user. The search for similar items is often based on predefined similarity measures applied to the items' characteristics. (Montebello & Mallia Milanes, 2018).

Semantic Search

Semantic search, enabled by using AI, allows for more robust comprehension of search queries by determining the contextual meaning of terms and phrases (Sloan, 2017). Where traditional keyword searching sheds light on the presence or absence of terms or phrases generally within a searched document, semantic searching augments this by narrowing to the deep understanding of the intent and contextual meaning of words. For example, in response to a search for hybrid vehicles, keyword searching returns documents containing "hybrid" and "vehicle", while semantic searching draws attention to the association of the words "hybrid" and "vehicle" in the context of "cars that use both gasoline and electricity", as opposed to "plants" or "trains". Such a search can return results that contain terms such as "gas-electric cars" and "hybrid electric vehicles". Thus, where there is a mismatch in a keyword search with regards to searching terms and differing terms used within the corpus being searched or other limitations or expansions around the meaning of those terms, a semantic search would result in an enriched search. Semantic searching ultimately takes the job of enhancing the search process away from the researcher (Hou & Tao, 2019).

IV. Challenges and Limitations of AI in Searching

Despite the potential benefits of AI, several challenges and limitations are associated with its integration into searching in digital libraries. Bias and fairness issues remain a concern, as AI systems may inadvertently perpetuate existing biases present in digital library collections or exhibit biases in the underlying algorithms and model training (Bubinger & Dinneen, 2021). Another challenge lies in data privacy, which has become an increasingly important issue for many organizations. The adoption of AI to enhance searching may call for even more data incompatibility and questions about who owns the data (Jaillant & Caputo, 2022). Likewise, understanding the unique context in which searching happens and how AI may influence and transform this context also contains challenges and limitations. Globally, literacy levels of searching information are still far below what is required of future citizens, which, prior to AI-enhanced searching, has led to research on how searching information could be transmitted successfully to everyone.

Bias and Fairness Issues

AI-driven search algorithms have the potential to unintentionally reinforce societal biases present in training data. Textual data drawn from the web, books, or other contexts may inadvertently encode biases about attributes such as race, gender, religion, and nationality. These biases could lead to skewed or unfair search results that reproduce harmful stereotypes or favor the perspectives of certain groups over others. This concern has emerged in other domains as algorithms have been found to amplify odious language from social media or associate certain occupations with specific ethnicities (Bubinger & Dinneen, 2021). Digital libraries must implement a design process that comprehensively considers what constitutes fair or unbiased performance and attempt to proactively mitigate those biases.

Fairness in information retrieval, concerns about bias in algorithms related to search and recommendation systems, and a digital library's commitment to creating an unbiased corpus are areas of scholarly inquiry relevant to libraries and librarians. Because a library's collection is often shaped by acquisition practices that reflect a digitization and collection policy, it is imperative to understand how those policies impact inclusion or exclusion in the data set. This body of literature assists developers in identifying decision points, data sources, and procedures that require scrutiny to ensure fairness. Additionally, AI tools learned from user interactions such as clicks, rates, and interactions embed the digital traces of those users into models deeply connected to the design of technologies that shape everyday online experiences (Ferrer et al., 2020).

Data Privacy Concerns

Digital libraries are becoming increasingly common for multilingual search requirements, allowing researchers to automatically translate queries, extract relevant information, and summarize literature (Radanliev et al., 2024). However, there are cohortes of researchers who do not yet take advantage of these sophisticated technologies and remain dependent on keyword-based searches of unfamiliar databases. Consequently, they miss pertinent information, impairing research quality and slowing down knowledge dissemination (Sousa et al., 2021). There is a need for technologies that make it easy for these researchers to automatically send concise, literature-based queries in English while protecting sensitive information (e.g., proprietary aspect, details regarding non-public experiences) incorporated in such queries. Such solutions would directly benefit researchers from all over the world and would positively impact companies and institutions that conduct scientific research or surveying globally.

The growing concern for upholding a just, peaceful, inclusive, and healthy society for current and future generations and the rise of data-driven translation, extraction, and summarization technologies constitute a unique opportunity for the democratization of science. However, there is a significant risk that these emerging technologies are deployed without properly understanding societal needs and potential concerns, leading to the aggravation of existing inequalities in the access, pace, and quality of science worldwide. In this context, it is crucial to also contemplate the data privacy violation and the possible use of artificial intelligence-enhanced search technologies, to benefit

researchers, institutions, or even governments, to conduct unintended scientific surveillance.

V. Future Directions and Opportunities

The future outlook of AI-powered searching holds great promise, providing potential directions and opportunities to shape the future. One exciting avenue is the integration of multi-modal data sources such as images, graphs, videos, and text as complex formats. Different multi-modal materials require distinct pre-processing methods, indexing techniques, and searching algorithms. Only when AI-enabled technologies can conduct multi-modal search with ease will a true shift towards enhanced searching be facilitated. It is envisioned that users can simply import a picture, video, or any other preferred searching format to seamlessly obtain relevant results across complex materials, which has the potential to greatly improve searching experiences (Khashimova et al., 2021; Urinboevna et al., 2019).

In addition, the collected massive data of research materials have realized a shift from the L0 or L1-norm space into a continuous space for more efficient storage and representation. The concept of a learned index is to employ machine learning techniques to build a model representing the index structure of an application. When the model becomes sufficiently accurate, it can use its output to effectively replace conventional index structures. In the new three-dimensional index structure, the unstructured text materials and complex propagation can be stored in a pre-trained translation model that converts them into millions of 768-dimensional text representation (Odilov et al., 2024). Such a shift holds special promise for both data sponsors and investigators, as it allows full release of sensitive conditioned data while effectively mitigating privacy exposures. The inactive AI-enabled search technologies provide good prospects for an enhanced user experience, opening a door for innovative research projects as well.

Integration of Multi-modal Data Sources

Online search engines facilitate location-based queries with textual content. This method lacks consideration of relevant multimedia data formats (e.g. imagery, dockets, and audio). Rich textual content associated with such data typically exists on social media platforms. Combining textual with different multimedia data formats can enhance the experience of online searching. An AI-assisted deliberation has been proposed where combining diverse data formats for novel searching can enrich overall search experience (Fowler et al., 2016). Considering the digital library as a domain, while conducting searches on certain exploration topics, relevant visual, textual, and auditory data formats could be considered. Previous searches in academic digital libraries (e.g. IEEE, ScienceDirect, etc.) exclusively focus on only textual data formats (e.g. article titles, abstracts, keywords), framing queries according to such a textual perspective.

AI creates immense potential for seamless amalgamation of greater search topics, e.g. imagery, document text, and audio data. Novel search horizons are opened where combining visual contents (e.g. examining a gene in a biosystem), textual contents (e.g. text-based queries altogether can be processed), and audio contents (e.g. going through clarifications on YouTube) can address more comprehensive search outcomes. The audio-visual document contents can be emerged with the support of machine learning (ML) models (e.g. audio/speech-to-text or face detection) (MacFarlane et al., 2020). The appearance of textual data on social media platforms (e.g. tweets about a citizen aftermath event), hence, addressing multi-modal query contents gain greater attention over textual documents whilst neglecting visual documents.

Enhanced User Experience

The 21st century has seen growing interest in Artificial Intelligence (AI), driven by significant advances in computational power, analytical techniques and the speed of data collection. From a research supply stance, this landscape comes with considerable implications for digital libraries. Online collection platforms like Google Scholar and publishers' own aggregation tools have proliferated, potentially posing an existential threat to library collections. However, beyond traditional repository functions like cataloguing and preservation, opportunities also abound for digital libraries to fundamentally change how researchers think, navigate journals and search for information. With the intuitiveness and sophistication of new consumer-facing search tools typically targeting information overload in everyday life increasing, and with AI now being touted as playing a central role in this, researchers' expectations of digital libraries are also changing (Lu et al., 2024). Effectively harnessing AI to empower research supply comprises the second key component of the target vision. In addition to traditional means of detecting signals and sources of interest, new means based on AI would facilitate intuitive explorations of literature trends, discovery of potential files and instruments, and the ingestion and assimilation of a diverse array of documents with limited user effort (Asemi & Asemi, 2018). Harnessing AI for enhanced searching comprises the first key component of the vision. The rapid advance of AI technologies presents significant challenges in effectively and ethically adopting these in users' pursuit of knowledge. However, beyond simply searching for documents, new opportunities also abound to create beyond advanced optimization of traditional queries and document patterns whose relevance has been established based on implicit user feedback (Khashimova & Shamsitdinova, 2022)

VI. Conclusion

Information searching is a multi-stage activity involving a series of steps: selecting the information need, formulating a query to enter the system, interpreting the search results and interacting with them. With the emergence of the Information Age and the proliferation of digital libraries, it has become important to develop novel multimedia information retrieval systems to enhance information search performance for the complex information searching tasks in digital libraries. As an innovative technology, Artificial Intelligence (AI) is

rapidly making its way into several applications and industries across the world. AI is the simulation of human intelligence processes by machines, especially computer systems. In recent years, advances in AI technology have transformed the knowledge-seeking behavior and information search process (Colavizza et al., 2021). Most existing digital library searching systems focus on traditional phrase searching techniques, while recently emerging natural language processing and machine learning technologies have been increasingly adopted to provide more intelligent and user-friendly searching services. To facilitate better information accessing in a digital library, this chapter focused on understanding the current limitations and barriers in the searching behavior analysis, developed two innovative AI techniques to enhance searching in digital libraries, and encouraged further exploration of searching improvement in digital libraries (Jaillant & Caputo, 2022).

Easy and effective searching systems and services continue to be the backbone of the success of libraries, deepening their impact on knowledge dissemination and community development. While this searching task of either web search engines or library digital collections may appear to be trivial and effortless, the searching user modeling and searching system design and implementation are in fact very challenging. Searching in a digital library is a multi-stage and complex task and many factors would impact user effectiveness. However, exploring the used information search systems is still very limited. In addition, although modern digital libraries are transitioning from traditional keyword-based searching to more complex and user friendly searching systems, there has been a lack of investigation on user engagement in more advanced searching techniques such as contextual search and semantic search. In light of these challenges, this chapter mainly focuses on understanding the characteristics of user searching behavior in both keyword-based searching systems and more advanced semantic searching systems. By gaining insight into how patrons or users search documents, libraries can gain a better understanding of user needs is crucial in helping libraries improve searching strategies, searching systems and digital collections.

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