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Transformation of Libraries with AI –powered Knowledge Graphs

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ABSTRACT

Libraries cannot be exclusively associated with physical books or printed materials anymore due to the emergence of the digital era. Libraries have, therefore, shifted to carrying enormous volumes of digital materials such as e-books and research articles. Considering further that the amount of data is increasing even faster and traditional search engines are becoming ineffective, new systems of information organization must be delivered. Knowledge graphs present such systems and assist in how information is categorized and searched. Since different databases are closely linked and related concepts are interlinked, knowledge graphs improve search results and offer access to relevant information more efficiently. The purpose of this present study is to demonstrate the transformation that takes place in librarians' worldviews thanks to knowledge graphs. It does so by reviewing their design, advantages, and possible use. Issues of knowledge extraction, knowledge representation, and subsystem development in mass information systems are considered, as well as perspectives on their evolution.

Introduction

As we have entered into the digital age, libraries have evolved from being mere containers of books. They now consist of plenty of digital information, such as online libraries, e-books, and research papers, which rendered the conventional ways of searching for details obsolete. Paradigms shift as the quantity of information increases; in this case, libraries have to contend with ensuring the user blazes through the sea of information and manages to collect precise and pertinent data. Knowledge graphs help address this problem by changing how information is structured and how it is accessed. These graphs connect related concepts to provide more relevant search results and make it easier for users to

find their required information. In this chapter, the impact of knowledge graphs on information retrieval in the context of libraries facilitates more enriching and efficient user-centered search experiences. With the increasing amount of information being captured and arranged in libraries, knowledge graphs emerge as practical tools for enhancing the retrieval of information. The knowledge graph is a collection of structured information that connects various data points in ways to improve the quality and relevance of search results. This chapter describes how knowledge graphs are changing the design of information retrieval systems in libraries, making them less effortful and more efficient. It also highlights the advancement of knowledge extraction, representation, fusion, and reasoning, along with their

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applications. The paper finally discusses the future challenges and the applications of knowledge graphs.

Evolution of Information Retrieval and Knowledge Graph in Libraries

“Web 1.0” is characterized by document interconnection, “Web 2.0” for data interconnection, and “Web 3.0” for knowledge interconnection. Due to the connection on the World Wide Web, multiple heterogeneities, loose organizational structures, and knowledge in a large data environment become significant challenges. Based on the principles of knowledge organization in the context (Wang, Mao, Wang & Guo, 2017), new perspectives are being explored—compatibility with changes in web-based information resources and adaptation to user awareness. The “knowledge network” vision became possible. Knowledge mapping is not an entirely new concept as early as 2006—the literature (Berners-Lee, Hendler, & Lassila, 2001). There has been a wave of semantics, and the technology of knowledge mapping is in place. It was initially intended to enhance the search engine’s capabilities and improve user searches.

At present, with intelligent information services, knowledge mapping has been widely applied to intelligent search, intelligent questions and answers, and personalized recommendations. The user’s search request is no longer limited to simple keyword matching. Searches will be reasoned according to the context and intent of the user query and will be realized through conceptual retrieval. At the same time, the results of the user search will have a hierarchy. For example, if a user searches for keywords for Melvil Dewey, the engine will give details on Dewey in the form of a knowledge graph. More intelligent feedback to users by understanding human language communication patterns is required to answer (Cao & Zhao, 2015). Through knowledge mapping, web information, data, and links are brought together into knowledge to make information resources more straightforward to calculate, understand, and evaluate, as well as a set of Web Semantic Knowledge Bank. The first part of this paper analyzes the definition

and structure of knowledge mapping. The second part describes the key technologies in knowledge mapping, such as knowledge acquisition, knowledge expression, knowledge integration, and exploration.

The third part presents various challenges faced by knowledge graph mapping. The way we find information in libraries has changed over time. In the past, people used card catalogs to search for books and materials. These catalogs organized information by author, title, or subject, but finding specific details could be slow and challenging. With the rise of computers, digital catalogs replaced the traditional card system. They allowed users to search for information faster by typing keywords into a database. It became easier to find relevant books, journals, and other resources. As technology continued to develop, libraries started storing not just books but also digital content such as e-books, research articles, and multimedia. Traditionally, the library was just a storehouse of books and other information; however, with the advent of information technology, we can now define it as including much digital information such as online libraries, e-books, and research papers, which made the traditional methodology of searching for details completely irrelevant. The paradigms are shifting, and the amount of information is growing day by day. The libraries are making sure the user is not overwhelmed by the amount of information out there and is able to gather relevant and pertinent information. Knowledge graphs, therefore, solve this problem by altering the way information is made and the way it is retrieved. These graphs relate related concepts and hence give more relevant searches, which is quite helpful to the users. Using the knowledge graph approach in information retrieval by libraries and institutions enables the provision of a more rewarding user-centric search. As the amount of information continues to be captured and stored in libraries, knowledge graphs have become helpful in improving the search for information. The same applies to a knowledge graph, which is also known as a knowledge base and is recognized as a set of structures that help enhance the relation between data items that actually require better search quality and relevance. In this article, the author emphasizes how knowledge graphs are altering the framework of information access systems in libraries and making them less exerting and more efficient.



Fig 1: Evolution of Information Retrieval (Asadnia et al., 2023).

Figure 1 illustrates the evolution of information retrieval. It shows the progression from traditional search methods to advanced retrieval techniques, including the use of knowledge graphs. The figure highlights key developments that have improved search accuracy and efficiency over time.

Concept of Knowledge Graph

A knowledge graph is a database that depicts and organizes information in a graph. It consists of nodes, which are entities or concepts, and edges, which show the association of these entities. There are two ordinary parts: nodes, edges, and labels. Nodes are the persons, places, and objects. Edges are the things like relationships that connect two nodes. Attribute labels are the constraints or characteristics that expose how and what relationships—if any—exist between or among the nodes. Knowledge graphs (Ammar, Groeneveld, Bhagavatula & Power, 2020) enable users to reach the target by propagating connective, semantic, and comprehension-rich information storage systems accurately and effectively. The order of expansion of the knowledge graph is as follows:

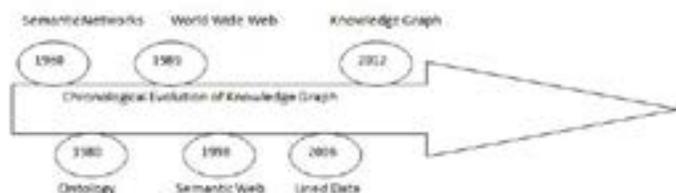


Fig 2: Evolution of Knowledge Graph

Figure 2 illustrates the evolution of knowledge graphs. It shows how knowledge graphs have developed over time, from simple data structures to complex interconnected systems. The figure highlights key advancements, including improvements in knowledge representation, extraction, and integration.

Related Work

Libraries are changing with new technology. Knowledge graphs help find and organize information. Many studies show how they support digital libraries. Rahmanova (2025) explains that digital catalogs and search tools improve how users find information. Knowledge graphs help in organizing data better. Linxen et al. (2024) discuss how knowledge bases improve searching in academic libraries. Knowledge graphs make it easier to access and manage information. Mohamed et al. (2025) state that knowledge graphs help connect and organize complex data. They improve searching, recommendations, and resource management in libraries. Muslim (2024) talks about AI systems in knowledge management. AI makes searching faster and more accurate but needs good planning and support. Patil (2024) highlights how ICT has improved library services. Knowledge graphs help by making information easier to access and use. Din and Ali (2024) discuss AI in libraries for learning and cataloging. Knowledge graphs can help organize and link information effectively. Ahmad Tarmizi et al. (2024) mention how NLP helps in managing knowledge. NLP improves how information is classified and found, working well with knowledge graphs. These studies show that knowledge graphs help digital libraries. They improve searching, organizing, and managing information, making libraries more useful for users.

Knowledge Graph Software

There are many software tools for constructing knowledge graphs. Some important software founders, salient features, date of first release, and areas of study are listed in the following table:

Software	Founder	Features	Date of Release	Motto	Areas of Study
Apache Jena	HP Labs (now Apache Software Foundation)	Framework for building Semantic Web applications, RDE, SPARQL, OWL support, ontology management	2000	Information Management	Knowledge management, information retrieval, semantic search
Protege	Stanford University	Ontology editor, RDF/OWL support, visualization tools, plugin architecture	1999	The Ontology Editor”	Ontology development, knowledge representation, semantic web
InfoRapid	Stefan H. Kinsella	management software, visual knowledge mapping, semantic search	2000	Information and Knowledge Management	Knowledge management, information retrieval, semantic search
Ontotext GraphDB	Atanas Kiryakov	RDF triplestore, SPARQL engine, semantic reasoning, scalable	2000	Empowering Meaningful Knowledge	Media, finance, life sciences, semantic web

RDFLib	Soren Auer (initial development)	Python library for RDF, SPARQL query support, serialization formats	2006	RDFLib: A Python library for RDF	Semantic web, linked data, knowledge representation
Neo4j	Emil Eifrem	Native graph database, Cypher query language, scalable, built-in visualization	2007	The Leader in Graph Databases	Data science, AI, fraud detection, knowledge management
SPARQL	W3C (World Wide Web Consortium)	A query language for RDF supports querying and manipulation of RDF data	2008	SPARQL: Query Language for RDF	Semantic web, data integration, linked data
Stardog	Kendall Clark	SPARQL support, reasoning engine, data unification	2015	Unify Enterprise Data	Enterprise data, semantic data, AI
Amazon Neptune	Amazon Web Services	RDF & property graph support, SPARQL, Gremlin, fault-tolerant	2017	Fully Managed Graph Database Service	Cloud computing, recommendation systems
OpenKE	Fudan University	Knowledge graph embedding, open-source, support for various embedding models	2019	Open Knowledge Embedding Toolkit	Knowledge graph embedding, machine learning, AI

Table 1: Details of Knowledge Graph Software

Construction of Knowledge Graph

The methodology for constructing a knowledge graph from articles published in LIS journals involves a series of systematic steps, each designed to ensure the accurate extraction, representation, and analysis of knowledge within the field. It comprises five key stages: data collection, data preprocessing, knowledge graph construction, designing a unified user interface, and testing the cases used.

I. Data Collection - It is essential to collect detailed and relevant data from reliable sources to create a knowledge graph that maps scholarly communication in Library and Information Science journals. This process includes two steps:

a. Selection of Journal Sources: To find and nominate the first-tier LIS journals and repositories like Scopus, Web of Science, and other websites. Select articles from these journals using academic databases such as Scopus, Web of Science, and Google Scholar to capture articles that may represent the field's scholarly output in the past twenty years.

b. Data Acquisition: Retrieve the articles and related metadata such as titles, abstracts, keywords, and authors' affiliations from the databases in batch mode using APIs if provided; otherwise, use web crawlers. Semi-structure the collected articles and their metadata and store them systematically in MS Excel and a data warehouse for further processing.

II. Data Preprocessing – This is important when constructing knowledge graphs in knowledge mapping. In this context,

one has to select, transform, and load data from the domain of Library and Information Science journals. This step means that it is possible to have clean data that is well structured to help in creating knowledge when mapping scholarly communication. This process includes two steps:

a. Text Cleaning and Normalization: This process removes content such as advertisements, authors' introductions, acknowledgments, and other scholarly sections by stripping HTML tags, memorable characters, and formatting.

b. Data Structuring: Usually, the data is structured by arranging its cleaned textual form into an acceptable format such as JSON or XML. Each document is given a structured object form that contains metadata.

III. Knowledge construction is significant when it comes to the construction of knowledge graphs needed in semantic mapping. It integrates the extracted entities and relations from LIS journals and indexes them under one system. It becomes a valuable and systematic process through which raw data is converted to represent scholarly communication, revealing the flow of ideas and the interconnectivity of various concepts. This process includes two steps:

1 Graph Schema Design: Design a schema for the knowledge graph, defining the types of entities (e.g., authors, institutions, concepts) and relationships (e.g., citation, authorship, thematic similarity) that will be represented. Create a hierarchical or ontology-based structure, where entities are linked according to the identified relationships, and concepts are categorized into broader thematic areas within the Library and Information Science domain.



Fig 3: Data Sets of LIS Journals

Figure 3 presents the datasets of LIS journals. It shows various journal sources, their volume of data, and how they contribute to research in the field. The figure highlights key datasets used for analysis in LIS studies.

2 Graph Population: The entities and relations identified

are then incorporated into the knowledge graph. Store and manage the knowledge graph with Neo4j and/or an RDF system like Apache Jena. Adopt strategies for dealing with duplicates, such as identifying each entry uniquely and linking it to those associated with it.

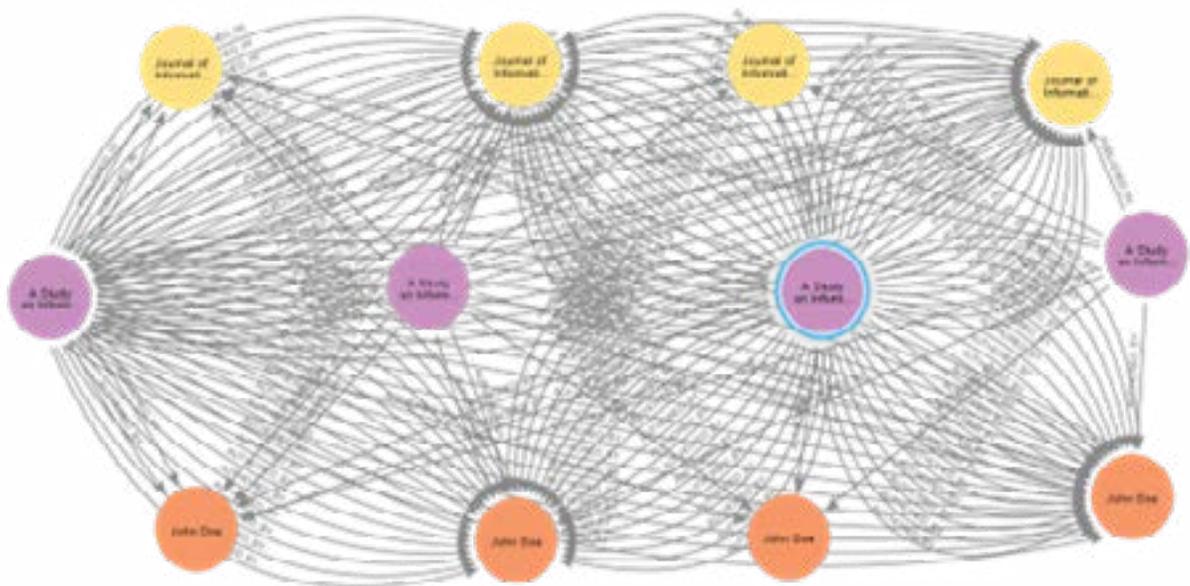


Fig. 4 Knowledge Graph of LIS Journals (Source: Neo4j)

Figure 4 presents the knowledge graph of LIS journals. It visually represents the relationships between different journals, authors, and research topics in the field of Library

and Information Science. The figure highlights how knowledge graphs structure and connect information for better search and analysis.

Use Cases in Libraries

Knowledge graphs also have the capability of transforming the way libraries manage, search for, and display information to users. While placing the given information in relevant interconnected systems of relationships, such knowledge graphs allow for efficient analysis of diverse information. Finally, in the context of libraries, these features are especially significant for both increasing utility and work efficiency and making the search and finding of resources more efficient and accurate. They (knowledge graphs) can be used in a number of ways, ranging from an academic establishment, where they will prove helpful in research, to even public libraries, where they are going to enhance the integration of special collections as well as create a personalized environment for learning. The following sub-sections focus on the most important application scenarios of knowledge graphs in libraries and their contribution to facilitating information acquisition and the overall research process.

1 **Subject-Specific Knowledge Graphs:** A kind of knowledge graph that can be created in libraries is discipline-specific, with a focus on history, medicine, computer science, and more. These kinds of graphs can enrich information search as they give subject-matter specialists and researchers more relevant and significant information.

2 **Supporting Discovery in Special Collections:** Special libraries that possess special collections, including rare books or manuscripts, can equally benefit from a knowledge graph when these items are linked to other extended academic content.

3 **Enhancing Digital Libraries:** Modern digital libraries that face challenges with the interpretation and analysis of unstructured data can leverage knowledge graphs to replace data with a more structured map of interconnected nodes. It facilitates navigation and retrieval and allows users to browse more conveniently (Cimiano, Hotho, & Staab, 2020).

Benefits of Knowledge Graphs in Information Retrieval

With a vast amount of data created and accumulated daily, the conventional technique of information retrieval (IR) loses its effectiveness in the search and identification of pertinent and exact information. Libraries are mainly required to deal with large amounts of data that can be related to diverse fields and disciplines and in diverse formats. Addressing such challenges requires a new level of data organization. In this regard, knowledge graphs (KGs) present an improved way of addressing these challenges by organizing data in entities and relations. Knowledge graphs are superior to simple keyword searches because they offer a deeper analysis of the user's queries and, therefore, improve the precision, relevance, and

contextual information of the results. This article focuses on the significant advantages of applying knowledge graphs in information retrieval, as well as provides an example of how knowledge graphs are revolutionizing the way libraries disseminate and organize information.

1 **Contextual Search:** It is always advantageous to understand which knowledge graph assists users with context-aware results. Rather than reporting results based on individual key terms, KGs possess information that describes the connections between two entities. For example, if one types the search term 'climate change on agriculture,' it would return results that address the relationship between agriculture, climate conditions, and certain areas of the world.

2 **Disambiguation of Terms:** It is common practice to find that a query is ambiguous, and one of the significant problems in information retrieval is how to handle these ambiguities. For instance, the search term 'Java' can be associated with the programming language, the Indonesian island, or coffee. Knowledge graphs help to resolve such terms based on the context in which the search query is provided to the search engine (Singhal, 2012).

3 **Personalized Search Experiences:** Since the knowledge graphs contain data, they can also filter the results according to user preferences and search history. This way, as KGs gain more insights from user experience, users can be suggested content, and the whole process of information searching becomes faster and less strenuous for them.

4 **Enhanced Data Integration:** Libraries contain information from different sources, such as books, articles, multimedia, and digital collections. This data can be nicely incorporated into knowledge graphs that allow users to access information from various formats and sources at the click of a button (Hogan et al., 2020).

5 **Improved Search Precision:** Thus, KGs can combine such data points through relationships and filter out unnecessary data, making the results more accurate. This is beneficial in academic libraries, where users are in search of a particular article or scholarly work within a given field of specialization.

Challenges in Implementing Knowledge Graphs

As will be described later, knowledge graphs are an effective solution for enhancing information search in libraries, although their application is not easy. The following sections describe the significant challenges that libraries could experience while implementing the knowledge graphs. From the above discussion on the importance of knowledge graphs, the following are some of the challenges of applying them in libraries. Another drawback is that the data used to create the knowledge graph must be curated for hours in order to make sure that the entities and their relations

that exist in the knowledge graph are accurate and recent. One major limitation of knowledge graphs is the problem of interfacing with other library systems, mainly because of some technical complexities, which may include the following: the integration of the knowledge graph with existing library systems might be highly technical and take a lot of time and resources (Nuzzolese, Gangemi, & Presutti, 2019). Challenges in knowledge graphs are as follows:

1 Data Quality and Curation – It is also important that the data that feeds the knowledge graph be sound, timely, and orderly. However, data curation is usually a tedious task that takes much time to complete and often involves data experts keying in data in order to make the data set presentable. Due to this, Paulheim (2017) argues that in library settings, the data source might come from many places and may have inconsistent quality, hence challenging the uniformity of the quality of the knowledge graph to be achieved. Ambiguous relations between the entities are incorrect relations, resulting in low-quality and less reliable knowledge graphs due to improper curation of data.

2 Integration with Legacy Systems – Libraries often use known systems to search, organize, and obtain information. It is even more challenging to incorporate knowledge graphs into such systems, which can pose significant technical changes. The conventional systems of libraries may not be scalable or structured to address the highly contextual, interlinked, and complex characteristics of knowledge graphs, as identified in sections 2 and 3; hence, original solutions need to be implemented, or the systems must be changed completely (Nuzzolese et al., 2019).

3 Semantic and Ontological Challenges – Ontologies are needed when building knowledge graphs; they are definitions of how relations are defined. Terminologies, along with semantic relations, are critical in attempting to define the nature and characteristics of the world for the valuable construction of ontologies. Nevertheless, the creation of a sound and unambiguous ontology that is applicable to all domains is still a problem, especially if the terms and their relationships in the multidisciplinary context may be somewhat different (Ehrlinger & Wöß, 2016). These semantic problems can result in incoherencies and misunderstandings in the knowledge graph.

4 Scalability Issues – With the increasing size of libraries in the knowledge graph, it is a challenge to expand or update the knowledge graph for new types of data. The knowledge graph contains a vast, massive volume of data, and storing and processing such a set of data is computationally expensive. It may also prove to be a significant task to handle the change management where new entities and relationships have to be incorporated into the system, and it will not affect the presence of data structures in the system (Hogan et al., 2020). Another issue is ensuring that the knowledge graph can be scalable and, at the same time, high-performing and reliable. . Concerns about privacy and security: as an information retrieval approach, knowledge graphs may entail user data in

the case of personalized information systems. It also raises a significant concern about privacy and security, more so when one is dealing with information like user search history or even involving a person's details. Therefore, privacy policies and legal regulations such as GDPR in European countries should be followed to protect user data and, at the same time, gain the benefits of the KGs' personalization for libraries (Choudhury, Aggarwal & Thirunarayan, 2021).

. Lack of Technical Expertise—Very often, there might be a scarcity of technical skills related to implementing a knowledge graph in a given library. The problem is that many libraries do not have the in-house talent to develop and sustain a knowledge graph, which is a drawback to creating such systems. It is also important not to underestimate the amount of time that it can take to hire or train new staff to handle such sophisticated systems.

Conclusion

Knowledge graphs are becoming the new paradigm of information retrieval in libraries. They are essential because most knowledge graphs are better personalized, contextually aware, and accurate than search graphs. Knowledge graphs are different from various databases as they provide relationships, patterns, and trends. Knowledge graphs offer substantial solutions to the problems of conventional information retrieval systems. In this context, knowledge graphs will become important for transforming libraries in the digital environment.

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