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AI-Driven Knowledge Mapping in Complex Information Environments Using Hybrid NLP and Graph-Based Techniques

1. Srinivas Sambari
Librarian
Government Degree College, Thorrur.
Email: Sri.wgl@gmail.com

2. Chandra Chary Sreeramoj
Librarian
Koneru Lakshmaiah Education Foundation (KLHGBS), Hyderabad.
Email: Chandrachary81@gmail.com

Abstract:

The exponential growth of unstructured digital information has intensified challenges related to knowledge extraction, organization, retrieval, and decision support in knowledge-intensive environments. Traditional manual and rule-based knowledge management approaches often suffer from inefficiencies, low retrieval accuracy, and limited semantic understanding, particularly when processing large volumes of complex textual data such as research articles, technical reports, and organizational documents. In response to these limitations, this paper proposes an AI-driven knowledge mapping framework that integrates advances in natural language processing (NLP), large language models (LLMs), knowledge graphs, epistemic AI, and neurosymbolic AI to transform unstructured text into structured, actionable knowledge representations.The proposed framework systematically combines lexical, syntactic, and semantic NLP techniques—including keyword extraction, named entity recognition, relationship extraction, and semantic similarity analysis—to enable accurate knowledge identification and representation. Network-based analysis and graph querying mechanisms are employed to enhance knowledge integration, visualization, and retrieval within complex and interconnected information environments. By addressing inefficiencies observed in conventional hyperlink-based and keyword-driven retrieval systems, the framework aims to improve both retrieval speed and precision.Recognizing the need for trustworthy and ethically grounded AI systems, the study adopts a hybrid knowledge management perspective that balances AI automation with human contextual validation. This approach enhances knowledge accuracy, reduces bias, and supports high-quality decision-making while maintaining transparency and human oversight. The framework further facilitates the organization of both explicit and tacit knowledge, enabling the discovery of hidden insights within large textual corpora.This study contributes to the literature by synthesizing concepts from NLP, knowledge graph construction, complex network theory, and hybrid AI paradigms into a unified conceptual model for intelligent knowledge mapping. The proposed framework is applicable across diverse domains, including libraries, engineering, biomedical research, and organizational learning systems. Overall, the paper advances the development of scalable, efficient, and ethical AI-enabled knowledge mapping systems that support improved information retrieval, informed decision-making, and continuous learning in dynamic digital ecosystems.

Keywords:AI-Driven Knowledge Mapping, Natural Language Processing, Knowledge Graphs, Hybrid Knowledge Management, Information Retrieval, Complex Information Environments.

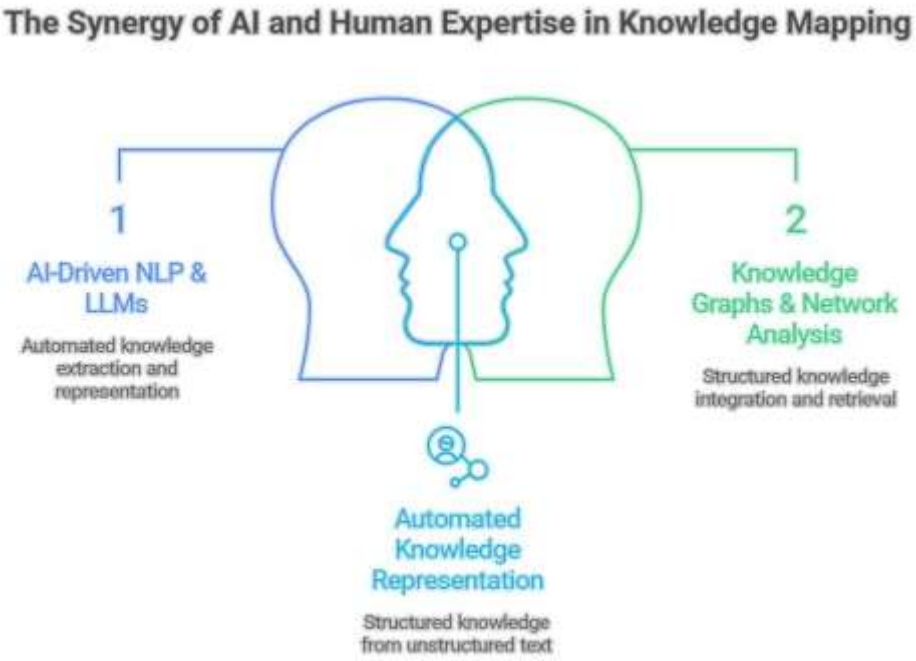
Introduction:

The rapid growth of digital information has transformed the way knowledge is created, stored, and disseminated across academic, organizational, and professional environments. Vast volumes of information are now generated in unstructured and semi-structured formats, such as PDF documents, reports, research articles, emails, and domain-specific textual repositories. While these resources contain valuable insights, their unstructured nature poses significant challenges for effective knowledge extraction, organization, retrieval, and reuse. Traditional manual and rule-based knowledge management approaches struggle to cope with the scale, complexity, and heterogeneity of such data, often resulting in inefficiencies, fragmented understanding, and suboptimal decision-making. In recent years, artificial intelligence (AI)—particularly advances in natural language processing (NLP), large language models (LLMs), and knowledge graph technologies—has emerged as a promising solution to these challenges. NLP techniques enable machines to analyze human language at lexical, syntactic, and semantic levels, allowing for automated extraction of key concepts, entities, relationships, and contextual meaning from complex texts. When combined with network-based analysis and knowledge graph representations, these techniques facilitate the transformation of unstructured textual content into structured, machine-readable knowledge maps that enhance interpretability, integration, and discovery.Despite these advancements, existing knowledge extraction and retrieval systems continue to face notable limitations. Many conventional retrieval mechanisms, including hyperlink-based and keyword-driven systems, suffer from low accuracy, slow response times, and limited semantic understanding—particularly in complex and highly interconnected information environments. Furthermore, fully automated AI systems raise concerns related to trustworthiness, bias, and contextual misinterpretation, highlighting the need for hybrid knowledge management (KM) models that integrate AI capabilities with human expertise and validation.Against this backdrop, there is a growing research imperative to develop intelligent, ethical, and scalable knowledge mapping frameworks that can effectively bridge the gap between unstructured information sources and structured, actionable knowledge. Emerging paradigms such as epistemic AI and neurosymbolic AI offer new possibilities by combining data-driven learning with symbolic reasoning, thereby improving contextual awareness, accuracy, and explainability in knowledge representation and retrieval.This paper responds to these challenges by proposing an AI-driven knowledge mapping framework that leverages LLMs, advanced NLP techniques, semantic similarity measures, and graph-based querying to enhance knowledge extraction, organization, and retrieval. By synthesizing insights from NLP, knowledge graphs, complex network theory, and hybrid KM systems, the study aims to provide a unified conceptual approach that supports both explicit and tacit knowledge management. The proposed framework is particularly relevant for knowledge-intensive domains such as libraries, engineering, biomedical research, and organizational learning, where effective knowledge discovery and decision support are critical.Ultimately, this research seeks to contribute to the evolving body of literature on intelligent knowledge systems by advancing the design of AI-enabled knowledge mapping solutions that promote accuracy, efficiency, transparency, and continuous learning in complex and dynamic information ecosystems.

Purpose of the Paper:

The purpose of this paper is to conceptualize and propose an AI-driven knowledge mapping framework that addresses long-standing challenges in knowledge extraction, organization, retrieval, and decision support across complex and document-intensive environments. Drawing on prior research in natural language processing (NLP), knowledge graphs, epistemic and neurosymbolic AI, and hybrid knowledge management (KM) systems, this study seeks to bridge critical gaps between unstructured information sources and structured, actionable knowledge representations. Existing manual and rule-based approaches to document analysis and knowledge review are prone to inefficiencies, missed inconsistencies, low retrieval accuracy, and slow processing speeds—especially when handling large volumes of unstructured content such as PDFs, biomedical texts, and organizational documents. This paper seeks to overcome these limitations by leveraging large language models (LLMs), advanced NLP techniques, and network-based analysis to enable scalable, accurate, and cost-effective knowledge extraction. Building on research in lexical, syntactic, and semantic analysis, the study aims to demonstrate how NLP techniques—such as keyword extraction, named entity recognition, relationship extraction, and semantic similarity computation—can be systematically combined to convert complex textual content into structured knowledge maps and knowledge graphs. These representations are intended to improve data integration, interpretability, and cross-domain comprehension. Motivated by studies highlighting inefficiencies in hyperlink-based and conventional retrieval systems, the paper seeks to design an AI-based retrieval approach that improves both speed and precision. By incorporating semantic similarity measures, network analysis, and graph-based querying, the proposed framework aims to support more effective knowledge discovery within intricate and interconnected

information environments. Recognizing the emerging need for trustworthy and ethically grounded AI systems, the paper emphasizes a hybrid KM perspective that combines AI automation with human contextual validation. The purpose is to ensure knowledge accuracy, reduce bias, and improve decision-making quality while maintaining human oversight, especially in organizational, academic, and library contexts. The paper aims to demonstrate how AI-powered NLP can help surface, classify, and organize both explicit and tacit knowledge, enabling better access to hidden insights within large text corpora. This is particularly relevant for knowledge-intensive domains such as libraries, engineering, biomedical research, and organizational learning systems. The paper aims to demonstrate how AI-powered NLP can help surface, classify, and organize both explicit and tacit knowledge, enabling better access to hidden insights within large text corpora. This is particularly relevant for knowledge-intensive domains such as libraries, engineering, biomedical research, and organizational learning systems. The paper seeks to contribute to the literature by synthesizing insights from epistemic AI, neurosymbolic AI, complex network theory, and knowledge graph construction into a unified framework. This framework is intended to guide future research and practical implementations of intelligent knowledge mapping systems that support continuous learning, innovation, and agile decision-making. The purpose of this paper is to advance the design of intelligent, AI-enabled knowledge mapping systems that transform unstructured textual data into meaningful, structured knowledge, thereby improving retrieval performance, decision support, and organizational learning in complex and dynamic information ecosystems.



Research Methodology: This study approvesaorganised literature review methodology to examine the concept, scope, and application of digital information literacy within university libraries. The methodology is designed to produce existing scholarly evidence, identify prevailing themes, and highlight research gaps related to digital and information literacy competencies among library professionals and academic stakeholders.

Research Design: The study follows a qualitative, descriptive, and analytical research design, relying on secondary data sources. A systematic approach was employed to ensure transparency, reliability, and replicability in reviewing and interpreting the literature relevant to digital information literacy in higher education and academic library contexts.

Data Sources: Relevant literature for this study was obtained from established academic databases and scholarly publishing platforms to ensure comprehensive and high-quality coverage. The sources included peer-reviewed journal articles, conference proceedings, and authoritative research reports. Major indexing and abstracting services—such as Scopus, Web of Science, Google Scholar, and ERIC—were systematically consulted, along with publications from leading academic publishers.The literature review focused on studies published between 2014 and 2025, enabling the inclusion of both foundational research and recent advancements in the field of digital information literacy and AI-enabled knowledge management. This time span ensured a balanced understanding of theoretical developments, methodological approaches, and emerging trends relevant to the objectives of the study.

Literature Review:

Rascanu(2024): The difficulty of converting structured engineering documentmostly PDF filesto knowledge g raphs, which is essential for appealing work processes and AI development, is the focus of this study.It empha sizes how crucial it is to boost productivity in engineering document analysis while lowering expenses and en hancing efficiency and decisionmaking skills.The suggested approach seeks to fill in the holes seen in convent ional review procedures, such as missed discrepancies and inefficiencies.The goal of the study is to use massi ve language models and sophisticated natural language processing techniques to convert complex document c ontent into organized knowledge visual representations that will improve data integration and comprehension.

Liu,B.(2019): The difficulties of low retrieval accuracy and sluggish retrieval speed in hyperlinkbased informa tion retrieval techniques are discussed in this work.It emphasizes how important it is to enhance these retrieval techniques, especially when dealing with intricate networks.A new strategy must be developed because the cu rrent approaches are ineffective and inefficient.The three primary steps of this research's artificial intelligence based key information retrieval approach include preprocessing file information, extracting keywords, and co mputing semantic similarity for information matching.The outcomes show gains in retrieval speed and accura cy, demonstrating the efficacy of the suggested approach.

Narang (2025): The article surveys the structure of AI-powered mix knowledge management (KM) systems and their control on smooth establishments. It highlights the importance of mixing AI technologies, mostly natural language processing and machine learning, with human workforce abilities to enhance knowledge management methods. The study finds a gap in accepting how hybrid systems can improve ethical truth, knowledge accuracy, and information flow in decision-making. The work sets out to propose a methodology for designing hybrid KM systems that combine AI automation with contextual human validation. It emphasizes the role of these systems in fostering organizational dynamism and innovation through continuous learning in agile environments.

Mar (2024): In order to allow technologies to understand and produce human language, the reading focuses on Natural Language Processing (NLP), a grave branch of artificial intelligence. It emphasizes the importance of both sophisticated technologies like word embedding and fundamental NLP tasks like lexical analysis, syntactic analysis, and semantic understanding. There is a detailed discussion of the difficulties in information extraction, specifically named entity recognition, connection extraction, and event extraction from complicated texts. The study highlights the significance of graph query in knowledge map applications and describes the entire process of knowledge map building, from data gathering to graph query. It offers an all-encompassing viewpoint on natural language processing (NLP), information extraction, and knowledge map creation, as well as suggesting future paths for these technologies' advancement in intelligent systems.

Ahmad Tarmizi (2024): The manuscript underlines how AI-powered NLP improves knowledge mapping by powering the processing of free material, increasing the efficiency and accuracy of retrieval. Better organization and access to silent knowledge are made possible by this optimization, which eventually supports well-informed decision-making in complex networks. In AI-powered libraries, NLP improves knowledge management. The study investigates the use of NLP to classify tacit knowledge.

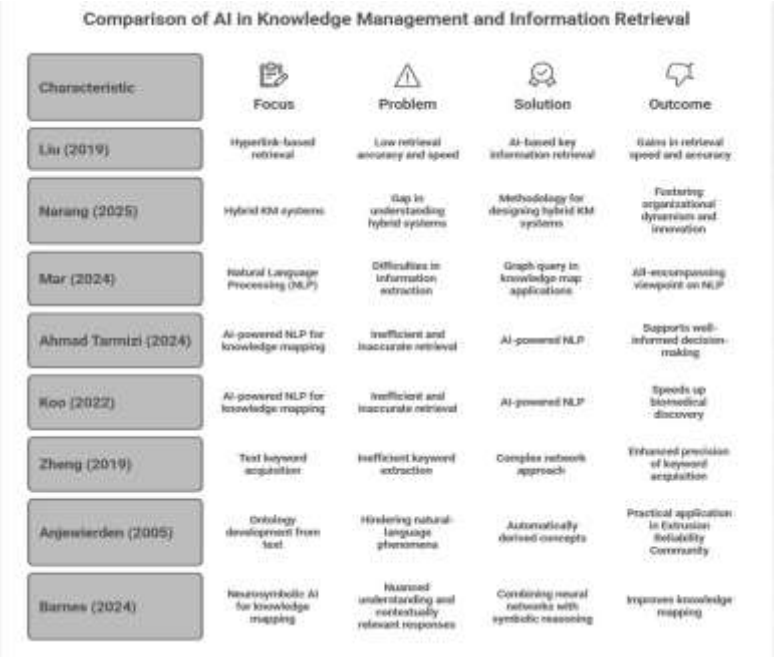
Koo, E (2022):extracting pertinent information from large biomedical texts, finding hidden connections, and arranging data into organized knowledge graphs, AI-powered natural language processing improves knowledge mapping. In complicated networks, this procedure lowers errors, lessens information overload, and improves research productivity. Through knowledge mapping, epistemic AI speeds up biomedical discovery. For insights, the platform integrates network analysis, AI, and NLP.

Zheng (2019): Epistemic AI accelerates biomedical discovery through knowledge mapping. Platform combines NLP, AI, and network analysis for research insightsThe paper introduces a method and system for acquiring text keywords based on a complex network approach. It addresses the need for improved accuracy in extracting keywords from text, which is crucial for various applications in natural language processing. The existing methods may lack efficiency in keyword extraction, highlighting a gap that this research aims to fill.The proposed method involves preprocessing text, converting it into a network structure, and using k-core decomposition to identify core vocabulary as keywords. The innovation lies in leveraging the network structure of text to enhance the precision of keyword acquisition.

Anjewierden (2005): The paper addresses the challenge of developing ontologies from text messages generated by Communities of Practice (CoPs) for the purposes of metadating, markup, and retrieval. Knowledge-mapping tools are highlighted as essential for enabling users to quickly identify relevant information and expertise within these communities. The research identifies natural-language phenomena that

hinder the effectiveness of a straightforward approach to knowledge mapping. The paper aims to enhance the functionality of knowledge-mapping tools through the use of automatically derived concepts. The practical application of these tools is demonstrated in the context of the Extrusion Reliability Community at Basell.

Barnes (2024): The paper highlights that neurosymbolic AI enhances accuracy in tasks like Named Entity Recognition by combining neural networks with symbolic reasoning, which can improve knowledge mapping in complex networks through nuanced understanding and contextually relevant responses.



Conclusion:

This paper set out to address the growing challenges associated with extracting, organizing, and retrieving knowledge from large volumes of unstructured and complex textual data. Traditional manual and rule-based knowledge management approaches are increasingly inadequate in modern, data-intensive environments, leading to inefficiencies, limited semantic understanding, and reduced decision-making effectiveness. In response, this study proposed an AI-driven knowledge mapping framework that integrates advances in natural language processing, large language models, knowledge graphs, and hybrid knowledge management principles.

By systematically combining lexical, syntactic, and semantic NLP techniques—such as keyword extraction, named entity recognition, relationship extraction, and semantic similarity analysis—the proposed framework demonstrates how unstructured textual content can be transformed into structured and meaningful knowledge maps. The incorporation of network-based analysis and graph querying further enhances knowledge integration, visualization, and retrieval, enabling faster and more accurate discovery of relevant information within complex and interconnected knowledge domains.A key contribution of this work lies in its emphasis on a hybrid and ethical approach to knowledge management, where AI-driven automation is complemented by human contextual validation. This balance not only improves knowledge accuracy and reduces bias but also strengthens trust, transparency, and accountability in AI-enabled systems. The framework also highlights the importance of capturing both explicit and tacit knowledge, facilitating access to hidden insights that are often overlooked in conventional knowledge management practices.The study contributes to the existing body of literature by synthesizing insights from epistemic AI, neurosymbolic AI, complex network theory, and knowledge graph construction into a unified conceptual model. This model offers practical guidance for the development of intelligent knowledge mapping systems applicable across diverse domains, including libraries, engineering, biomedical research, and organizational learning.In conclusion, the proposed AI-driven knowledge mapping framework advances the design of scalable, efficient, and trustworthy knowledge systems capable of supporting improved information retrieval, informed decision-making, and continuous learning. Future research may focus on empirical validation of the framework, domain-specific implementations, and the exploration of emerging AI techniques to further enhance the effectiveness of intelligent knowledge mapping in dynamic digital ecosystems.

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