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Knowledge Graphs in Information Systems: A Scopus Bibliometric Analysis of Research Evolution

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ABSTRACT

This study explores the evolution of knowledge graph research within the field of information systems through a comprehensive bibliometric analysis. Data were collected from Scopus and analyzed using quantitative techniques, including performance analysis and science mapping. Visualization was conducted using VOSviewer to examine co-authorship networks, citation structures, and keyword co-occurrence patterns. The results indicate a significant growth in publications, particularly after 2012, reflecting the increasing importance of knowledge graphs in data-driven environments. Co-authorship analysis reveals strong global collaboration, with dominant contributions from countries such as China and the United States. Citation analysis highlights foundational studies in bioinformatics, semantic networks, and graph-based learning as key drivers of the field. Meanwhile, keyword analysis shows a clear thematic shift from ontology and information management toward artificial intelligence, machine learning, natural language processing, and recommender systems. The overlay and density visualizations further confirm the emergence of application-oriented and AI-integrated research trends. Overall, this study provides a structured overview of the intellectual landscape of knowledge graph research and identifies future directions, particularly in the integration of knowledge graphs with advanced artificial intelligence technologies.

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1. INTRODUCTION

In recent years, the exponential growth of data-driven technologies has fundamentally reshaped how organizations manage, process, and extract value from information systems. The proliferation of big data—characterized by increasing volume, velocity, and variety—has created unprecedented opportunities for innovation, while simultaneously introducing significant challenges related to data integration, semantic interoperability, and knowledge discovery [1], [2]. In response to these challenges, knowledge graphs have emerged as a powerful paradigm for representing both structured and unstructured data within a unified, semantically enriched framework [3], [4]. By modeling entities and their relationships, knowledge graphs enable advanced reasoning capabilities, facilitate interoperability across heterogeneous systems, and support intelligent decision-making processes in complex digital environments.

The prominence of knowledge graphs was significantly amplified following their large-scale industrial adoption by Google in 2012, marking a pivotal shift toward semantic-based information retrieval. Since then, knowledge graphs have been increasingly integrated into a wide range of information systems applications, including recommendation systems, natural language processing, enterprise knowledge management, and artificial intelligence [5], [6]. Their ability to connect disparate data sources and generate contextual insights has positioned them as a core infrastructure in modern digital ecosystems, particularly within the broader trajectory of intelligent and data-centric systems [7], [8].

Despite their growing relevance, the research landscape of knowledge graphs remains highly fragmented and rapidly evolving. Existing studies are dispersed across multiple disciplines—such as computer science, information systems, and data science—and often employ diverse terminologies, methodologies, and analytical perspectives [9]–[11]. This fragmentation limits the ability of scholars and practitioners to develop a coherent understanding of the field's intellectual structure, key contributors, and emerging thematic directions. Furthermore, the accelerated convergence of knowledge graphs with advanced technologies, including machine learning and artificial intelligence, has intensified the complexity of the research domain, thereby reinforcing the need for a systematic and integrative synthesis.

Bibliometric analysis provides a rigorous and quantitative approach to addressing this challenge by enabling the systematic mapping of large-scale scientific literature. Through the examination of citation networks, co-authorship patterns, and keyword co-occurrence structures, bibliometric techniques allow researchers to identify influential publications, collaborative networks, and dominant research themes. The integration of visualization tools such as VOSviewer further enhances the analytical process by revealing hidden knowledge structures and thematic clusters within complex datasets. In this context, the use of the Scopus database ensures comprehensive coverage of high-quality academic publications, thereby strengthening the validity and reliability of the analysis.

Although prior studies have examined specific technical aspects or application domains of knowledge graphs, comprehensive bibliometric investigations that capture their evolution within the broader field of information systems remain limited. Existing research often relies on constrained datasets, short temporal scopes, or narrowly defined subfields, resulting in an incomplete understanding of the field's overall development. This gap is particularly critical given the rapid integration of knowledge graphs with emerging paradigms such as linked data, artificial intelligence, and semantic web technologies.

Accordingly, this study seeks to address this gap by conducting a comprehensive bibliometric analysis of knowledge graph research within the domain of information systems using data indexed in Scopus. Specifically, the objectives of this study are to: (1) analyze publication trends and growth trajectories over time; (2) identify the most influential authors, institutions, and countries; (3) examine patterns of scientific collaboration; and (4) map the thematic evolution and emerging research directions through keyword co-occurrence analysis. By systematically uncovering the intellectual structure of the field, this study provides a holistic perspective on the development of knowledge graph research.

The findings of this study are expected to contribute both theoretically and practically. From a scholarly perspective, the study offers a structured synthesis of key themes, influential contributions, and research trajectories, thereby facilitating the identification of future research opportunities. From a practical standpoint, it highlights the strategic relevance of knowledge graphs in addressing real-world challenges within information systems. Ultimately, this study not only consolidates existing knowledge but also provides a forward-looking perspective on the role of knowledge graphs in shaping the future of data-driven and intelligent systems.

2. RESEARCH METHODS

2.1 Research Design

The research design combines two main components of bibliometric analysis: performance analysis and science mapping. Performance analysis focuses on evaluating the productivity and impact of publications, authors, institutions, and countries. Meanwhile, science mapping is used to visualize the relationships among research elements, such as co-authorship, co-citation, and keyword co-occurrence networks. By integrating these two approaches, the study provides both descriptive and relational insights into the development of knowledge graph research.

2.2 Data Source and Search Strategy

The dataset used in this study was retrieved from Scopus, one of the largest and most comprehensive abstract and citation databases of peer-reviewed literature. Scopus was selected due to its extensive coverage of high-quality journals, conference proceedings, and interdisciplinary publications, particularly within the domains of information systems and computer science. The data collection process employed a structured search strategy designed to capture relevant publications on knowledge graphs. Specifically, keywords such as "knowledge graph," "knowledge graphs," and their related variations were applied to titles, abstracts, and author keywords to ensure a broad yet relevant dataset. To improve data accuracy and relevance, strict inclusion and exclusion criteria were implemented. Only scholarly documents categorized as journal articles, conference papers, and review articles were included, while non-scholarly materials such as editorials, notes, and book reviews were excluded. Furthermore, the analysis was limited to publications written in English to ensure consistency in interpretation.

The temporal scope of the dataset spans from the early emergence of knowledge graph research to the most recent year available at the time of data retrieval. This comprehensive time frame enables a systematic examination of the evolution, growth patterns, and transformation of the research field over time. By capturing both the foundational phase and recent advancements, the dataset provides a robust basis for analyzing long-term trends, identifying shifts in research focus, and uncovering emerging directions within the knowledge graph literature.

2.3 Data Extraction and Cleaning

After retrieving the data from Scopus, the bibliographic information was exported in a compatible format CSV for further analysis, including key variables such as author names, publication titles, abstracts, keywords, publication years, affiliations, and citation counts. Subsequently, a data cleaning process was undertaken to ensure the accuracy and consistency of the dataset, which involved removing duplicate records, standardizing variations in author and institutional names, and merging synonymous keywords (e.g., "knowledge graph" and "knowledge graphs"). In addition, irrelevant or ambiguous terms were carefully filtered out to enhance the reliability of the keyword analysis, as this step is essential in bibliometric studies to prevent distortions in network visualization and clustering outcomes.

2.4 Data Analysis Techniques

The analysis in this study is divided into two main stages, namely descriptive analysis and network analysis. First, descriptive analysis was conducted to examine publication trends, including the number of publications per year, distribution by document type, and leading journals, thereby providing a comprehensive overview of the growth and development of knowledge graph research over time. Second, network analysis was performed to explore relationships among research entities, encompassing co-authorship analysis to identify collaboration patterns among authors, institutions, and countries, citation analysis to determine the most influential publications and authors based on citation counts, and keyword co-occurrence analysis to reveal the main research themes and their interconnections. To support these analyses and generate visualizations, this study utilizes VOSviewer, which enables the construction of network maps illustrating clusters of related items based on their co-occurrence or linkage strength, with the resulting visualizations interpreted to identify dominant research themes and emerging topics within the field [12], [13].

2.5 *Reliability and Validity*

To ensure the reliability and validity of the findings, several measures were implemented. First, the use of Scopus as a data source ensures that the dataset consists of high-quality, peer-reviewed publications. Second, the search query and inclusion criteria were carefully designed to minimize bias while maximizing the relevance of the selected studies. Third, the data cleaning process was conducted systematically to reduce inconsistencies and potential errors within the dataset. Furthermore, the application of established bibliometric tools and techniques enhances the robustness of the analysis, where the integration of performance analysis and science mapping provides a comprehensive understanding of both the quantitative performance and the structural dynamics of the research field.

3. RESULTS AND DISCUSSION

3.1 *Author Collaboration Analysis*

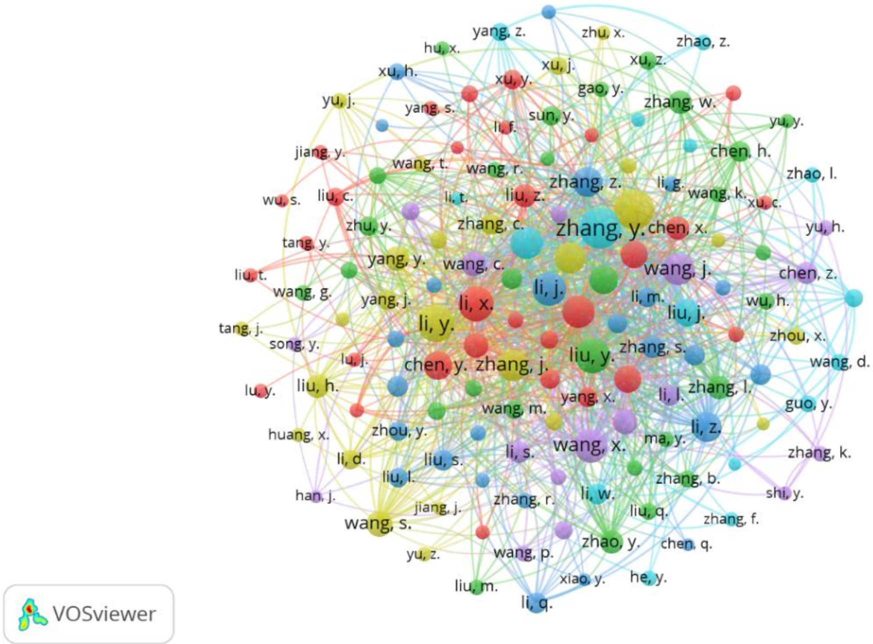

Figure 1. Author Visualization
Source: Data Analysis

Figure 1 presents the author co-authorship visualization generated using VOSviewer, illustrating the collaborative structure within knowledge graph research. The network is densely connected, indicating a high level of collaboration among researchers, with several prominent nodes such as “Zhang, Y.,” “Wang, J.,” and “Li, Y.” appearing as central actors due to their larger node sizes and extensive linkages. These authors function as key hubs in the network, contributing significantly to knowledge production and collaboration intensity. The presence of multiple color-coded clusters reflects distinct research groups or communities that are interconnected, suggesting interdisciplinary and cross-institutional cooperation. Notably, the dominance of authors with East Asian names, particularly from China, highlights the country's strong contribution and leadership in this field. Overall, this visualization demonstrates that knowledge graph research is highly collaborative, with a complex and well-integrated global research network that facilitates the rapid dissemination and development of ideas.

3.2 *Citation Analysis: Influential Publications*

Table 1. Most Cited Article

Citations	Author and Year	Title	Publication
5161	[14]	An automated method for finding molecular complexes in large protein interaction networks	BMC Bioinformatics
4834	[15]	Modeling Relational Data with Graph Convolutional Networks	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)
4383	[16]	The KEGG resource for deciphering the genome	Nucleic Acids Research
3384	[17]	Graph convolutional neural networks for web-scale recommender systems	Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining
2064	[18]	Graph convolutional networks for text classification	33rd AAAI Conference on Artificial Intelligence, AAAI 2019, 31st Innovative Applications of Artificial Intelligence Conference, IAAI 2019 and the 9th AAAI Symposium on Educational Advances in Artificial Intelligence, EAAI 2019
1546	[19]	Computing topological parameters of biological networks	Bioinformatics
1315	[20]	Recommender Systems: The Textbook	Recommender Systems: The Textbook
1296	[21]	BabelNet: The automatic construction, evaluation and application of a wide-coverage multilingual semantic network	Artificial Intelligence
1273	[22]	RippleNet: Propagating user preferences on the knowledge graph for recommender systems	International Conference on Information and Knowledge Management, Proceedings
1220	[23]	Thed KEGG databases at GenomeNet	Nucleic Acids Research

Source: Scopus, 2026

Table 1 highlights the most cited articles in the domain of knowledge graph and related research, reflecting the foundational and highly influential contributions that have shaped the field. The most cited work by G.D. Bader and C.W.V. Hogue (5,161 citations) emphasizes early advancements in network analysis within bioinformatics, indicating that the roots of knowledge graph research are strongly connected to biological data modeling. Similarly, highly cited studies such as Schlichtkrull et al. on graph convolutional networks and Ying et al. on recommender systems demonstrate the growing integration between knowledge graphs and deep learning techniques, particularly in handling relational and large-scale data. The presence of seminal resources like KEGG by Kanehisa et al. further reinforces the importance of structured knowledge representation in scientific discovery. Additionally, works such as BabelNet by Navigli and Ponzetto and RippleNet by Wang et al. highlight the evolution toward semantic networks and application-driven models in recommendation systems. Overall, the citation distribution indicates a shift from domain-specific network analysis (e.g., bioinformatics) toward more generalized, scalable, and AI-driven approaches, confirming that knowledge graph research has progressively expanded into interdisciplinary and application-oriented areas within information systems.

3.3 Keyword Co-Occurrence and Research Themes

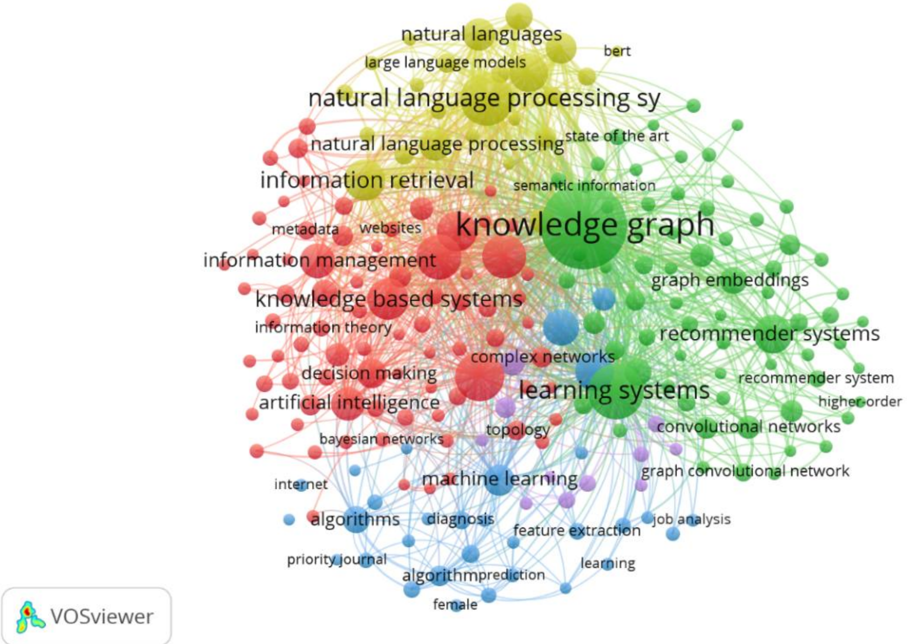

Figure 2. Network Visualization
Source: Data Analysis

Figure 2 presents the keyword co-occurrence network visualization generated using VOSviewer, illustrating the conceptual structure of knowledge graph research within information systems. The term "knowledge graph" appears as the most central and dominant node, indicating its pivotal role as the core theme connecting various research domains. The network is divided into several color-coded clusters that represent major thematic areas. The green cluster is strongly associated with application-oriented topics such as recommender systems, graph embeddings, and learning systems, reflecting the practical implementation of knowledge graphs in intelligent systems. The red cluster emphasizes foundational concepts, including information management, knowledge-based systems, and artificial intelligence, highlighting the theoretical underpinnings of the field. Meanwhile, the yellow cluster is centered around natural language processing and large language models, indicating the growing integration between knowledge graphs and language-based AI technologies. The blue cluster focuses on machine learning techniques, algorithms, and feature extraction, demonstrating the methodological advancements supporting knowledge graph development. Overall, this visualization reveals a highly interconnected and multidisciplinary research landscape, where knowledge graphs serve as a bridge between semantic technologies, artificial intelligence, and real-world applications, while also indicating emerging trends toward the convergence of knowledge graphs with advanced AI and language models.

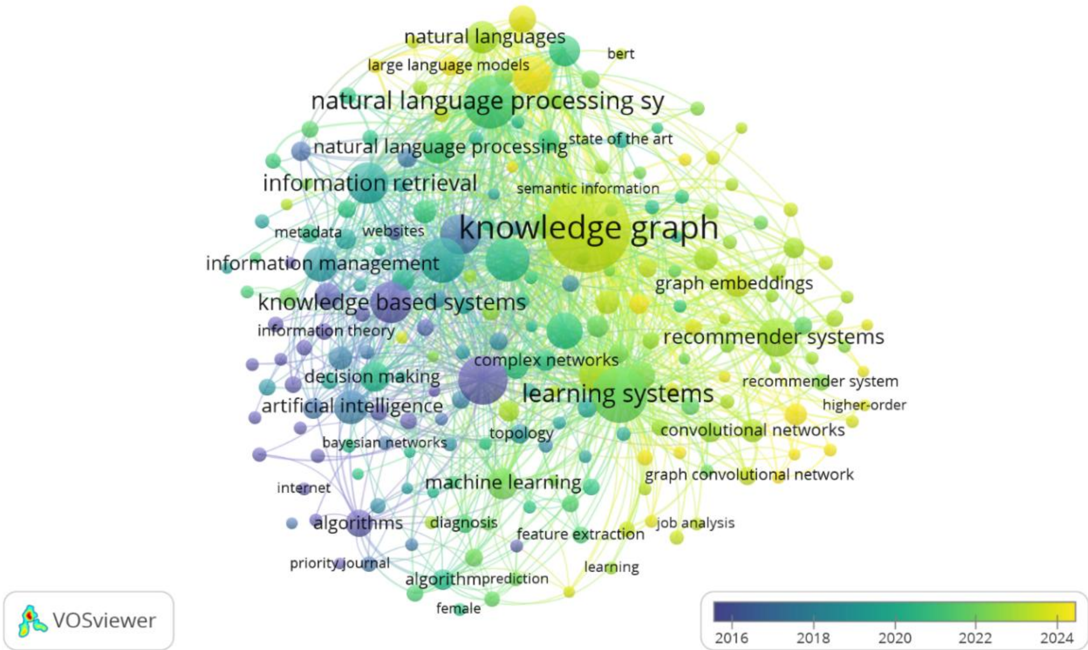

Figure 3. Overlay Visualization
Source: Data Analysis

Figure 3 presents the overlay visualization generated using VOSviewer, which illustrates the temporal evolution of research topics in knowledge graph studies. The color gradient—from blue (earlier years) to yellow (more recent years)—indicates how research themes have developed over time. Early-stage research (around 2016–2018), represented by darker blue tones, is concentrated on foundational topics such as algorithms, artificial intelligence, information theory, and knowledge-based systems, highlighting the initial focus on theoretical and methodological development. As the field progresses (2019–2021), green tones dominate areas such as machine learning, complex networks, and learning systems, reflecting a transition toward integrating knowledge graphs with advanced computational techniques. In the most recent period (2022–2024), indicated by yellow hues, emerging topics such as natural language processing, large language models, graph embeddings, and recommender systems become more prominent. This shift suggests a strong movement toward application-driven and AI-integrated research. Overall, the overlay visualization demonstrates that knowledge graph research has evolved from foundational theories to more sophisticated, data-driven, and application-oriented approaches, with increasing convergence toward modern artificial intelligence and language technologies.

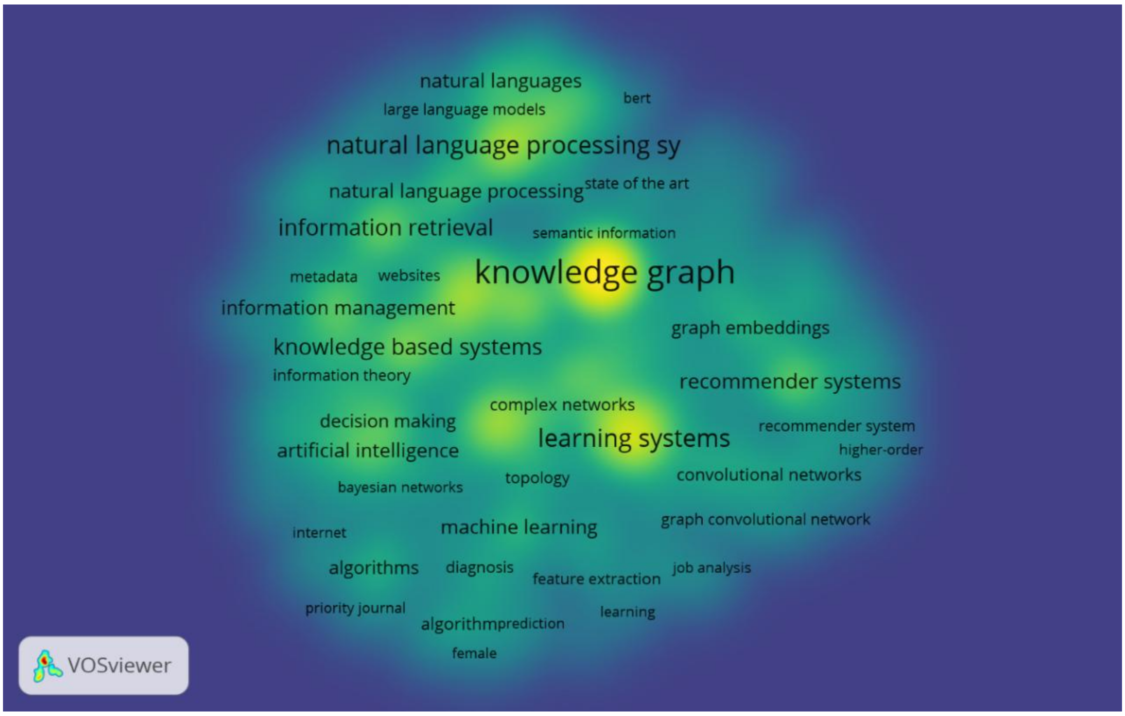

Figure 4. Density Visualization
Source: Data Analysis

Figure 4 presents the density visualization generated using VOSviewer, which highlights the concentration and intensity of research topics within the knowledge graph domain. The areas with brighter yellow-green colors indicate higher research density, showing that terms such as “knowledge graph,” “learning systems,” and “natural language processing” are the most frequently studied and interconnected topics. These high-density regions suggest that current research is heavily focused on the integration of knowledge graphs with machine learning and language processing technologies. In contrast, areas with darker blue tones represent less frequently explored or emerging topics, such as specific algorithmic approaches or niche applications. The distribution of density also reflects the central role of knowledge graphs as a hub connecting multiple subfields, including information retrieval, recommender systems, and artificial intelligence. Overall, this visualization demonstrates that the research landscape is both concentrated around core themes and simultaneously expanding toward new interdisciplinary areas, indicating a mature yet continuously evolving field.

3.4 Discussion

The findings of this bibliometric analysis provide a comprehensive understanding of how knowledge graph research has evolved within the field of information systems, both in terms of intellectual structure and thematic development. One of the most prominent insights is the rapid growth of publications, particularly after the mainstream adoption of knowledge graphs by Google. This growth reflects not only increasing academic interest but also the strong practical relevance of knowledge graphs in addressing complex data integration and semantic challenges in modern information systems [24], [25]. The transition from relatively slow early development to exponential growth indicates that the field has entered a mature and expansionary phase, driven by technological advancements and real-world applications.

Furthermore, the co-authorship analysis reveals that knowledge graph research is highly collaborative and globally distributed. The dominance of countries such as China and the United States suggests that research leadership is concentrated in regions with strong investments in artificial intelligence and data science. At the same time, the presence of interconnected clusters in the collaboration network indicates that knowledge production is not isolated but rather supported by active international partnerships [3], [4], [26]. This collaborative structure is essential in a multidisciplinary field like knowledge graphs, where contributions from computer science, information systems, and domain-specific expertise must be integrated.

From a citation perspective, the results highlight the foundational role of early works in shaping the direction of the field. Highly cited studies in areas such as bioinformatics, semantic networks, and graph-based learning demonstrate that knowledge graph research is built upon a diverse set of scientific traditions. Over time, however, there has been a clear shift toward more application-driven and computationally advanced topics, particularly those involving graph convolutional networks, recommender systems, and large-scale data processing. This shift indicates that the field is moving beyond theoretical exploration toward practical implementation and innovation.

The keyword co-occurrence and overlay visualizations further reinforce this evolution by showing how research themes have transitioned over time. Early studies focused on fundamental concepts such as ontology, information management, and knowledge-based systems, which provided the theoretical backbone for knowledge graph development. In contrast, more recent research emphasizes the integration of knowledge graphs with machine learning, natural language processing, and large language models. This convergence reflects a broader trend in information systems, where semantic technologies are increasingly combined with data-driven approaches to enhance system intelligence and performance.

Additionally, the density visualization reveals that certain topics—particularly "knowledge graph," "learning systems," and "natural language processing"—have become central hubs within the research landscape. These high-density areas indicate not only frequent usage but also strong interconnections with other topics, suggesting that they serve as core drivers of innovation. At the same time, the presence of lower-density areas highlights opportunities for future research, particularly in niche applications and emerging interdisciplinary domains.

Overall, the results suggest that knowledge graph research has undergone a significant transformation from a primarily theoretical field into a dynamic, application-oriented discipline. The increasing integration with artificial intelligence and machine learning technologies points to a future where knowledge graphs will play a critical role in enabling intelligent, explainable, and context-aware information systems. However, this evolution also presents challenges, including issues related to scalability, data quality, and interoperability, which require further investigation.

In conclusion, this study demonstrates that knowledge graph research is not only growing in volume but also diversifying in scope and impact. The insights derived from this bibliometric analysis provide valuable guidance for researchers seeking to identify emerging trends and research gaps, as well as for practitioners aiming to leverage knowledge graphs in real-world applications. The continued convergence of semantic technologies and artificial intelligence is expected to further accelerate innovation in this field, making knowledge graphs a cornerstone of future information systems development.

4. CONCLUSION

This study provides a comprehensive bibliometric overview of the development and evolution of knowledge graph research within the field of information systems. The findings indicate that the domain has experienced rapid and sustained growth, particularly following its large-scale adoption by Google, which significantly accelerated both academic and industrial interest. The increasing number of publications reflects the growing recognition of knowledge graphs as a critical technology for managing complex and heterogeneous data while enabling intelligent decision-making processes. In addition, the analysis reveals that knowledge graph research is highly collaborative and globally distributed, with strong contributions from leading countries and institutions. The co-authorship network underscores the importance of interdisciplinary collaboration, while citation analysis highlights the enduring influence of foundational studies that continue to shape contemporary research directions.

Furthermore, the thematic evolution analysis demonstrates a clear shift in research focus, moving from foundational areas such as ontology and semantic web technologies toward more advanced and application-oriented domains, including machine learning, natural language processing, and recommender systems. This transition reflects the maturation of the field and its increasing alignment with broader developments in artificial intelligence. The visualization results also emphasize the role of knowledge graphs as a bridging concept that connects multiple research domains, while the identification of emerging topics indicates ongoing expansion and diversification. Overall, knowledge graph research has evolved into a dynamic and multidisciplinary field with significant theoretical and practical implications, where future studies are expected to focus on scalability, data quality, and deeper integration with advanced AI technologies, providing valuable directions for both researchers and practitioners.

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