Analysis of Research Hotspots and Frontier Development of Knowledge Graph Construction

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Abstract. The knowledge graph construction is a crucial area of focus in the domain of artificial intelligence. To gain an insight into this field of study, we employed the use of Citespace.v.6.1. R2 and bibliometric analysis to create the knowledge graphs between 2012 and 2021, exploring various aspects such as annual publications, relevant institutions, research hotspots, and frontiers. We arrived at several key findings. Firstly, the number of research results is increasing yearly, but the research institutions remain distributed . Secondly, the technology employed in each link of the construction process is in constant development, but its accuracy, basic principles, and theories require further refinement. Thirdly, Frontier research such as deep learning and domain knowledge graph construction continues to improve and develop. Through this study, we hope to help knowledge graph builders to summarize, reflect, and improve the level and quality of research in this field.

Keywords: Knowledge graph construction · Hotspots · Frontier development · Visualization analysis

1 Introduction

With the continuing development of science and technology, humans have experienced four technological revolutions, from the early steam engine era with the purpose of enhancing physical strength to the era of electric automation aimed at improving efficiency to the information-driven era with the purpose of improving perception, and finally to the current era of artificial intelligence for the purpose of improving cognition. In the 21st century, when artificial intelligence, big data, and the Internet are booming, people expect faster and more accurate access to information. At present, there have been single breakthroughs in the development of artificial intelligence in specific fields. In other words, AI can surpass human intelligence at the level of local intelligence. For example, IBM Watson defeated the human champion in the knowledge contest, and Deepstack defeated Texas Hold'em human champion. Artificial intelligence is rapidly integrating into all walks of life to advance the development of society as a whole.

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However, judging from the development history, AI still has some limitations. Since the first-generation AI is mainly based on knowledge bases and inference machines to simulate human reasoning and thinking, its existence depends entirely on expert knowledge and is time-consuming. It is difficult to construct modeling based on knowledge and experience, and thus the scope of application is very limited. The second-generation AI is based on deep learning to simulate human perception. Its limitations are that the algorithms are very weak, relying on high-quality labeled big data, unsupervised large pre-trained language models and powerful computing power. Therefore, they are faced with such bottlenecks as being unexplainable and unreliable. Since Google proposed the concept of knowledge graphs in 2012, people began to combine knowledge graphs with deep learning to tackle the difficulties facing artificial intelligence.

Cognitive artificial intelligence can be realized through various means, among which knowledge graphs stand out as a crucial one. Researchers both domestically and internationally have devoted significant efforts to constructing knowledge graphs, generating practical insights and highlighting key research areas along the way. To this end, this study employs CiteSpace v.6.1.R2 to construct a visual knowledge graph centered around "knowledge graph construction," based on relevant research articles published in the Web of Science database from January 2012 to December 2021. Through analyzing article counts, publication frequency, centrality, and keywords, the study provides an reflection of research hotspots and frontiers over the past decade. Such insights can shed light on the current state of research, highlight key areas of focus and limitations, and facilitate developmental progress of knowledge graph construction research.

2 Definition of Knowledge Graph Construction

In 2012, Google first proposed the concept of a knowledge graph [1]. Knowledge graphs are thought of as semantic networks representing connections between entities. Wikipedia explains the Knowledge graph as Google's web compilation of facts and data to provide contextual meaning for its searches [2]. Mayank et al. (2019) described the knowledge graph as a graph-based approach, which provides a machine-readable knowledge base including entities, events, facts, relationships, and other elements. Dieter (2020) and Zhang (2021) et al. also regard the knowledge graph as a huge multilateral semantic net of nodes and edges. In a word, a knowledge graph is a structured representation of semantic knowledge and an interactive network of entities.

Knowledge graph construction mainly refers to the knowledge graph's logical structure and technical system construction process. One aspect is the logical structure construction process. The knowledge graph consists of the data and the mode layers. Knowledge is stored in a graph database in units of fact at the data layer. Since truths mainly express through "entity-relationship-entity" or "entity-attribute-value", the data stored in the graph database forms a network of interconnected entity relationships. In terms of mode, it uses the ontology library's ability to support axioms, rules, and constraints to standardize the relationship between entities, relationships, and entity types and attributes. The ontology library is equivalent to the mold of the knowledge base, making this layer at the core of the logical structure of the knowledge graph. Another aspect of the knowledge graph is constructing a technical system. There are two effective methods: top-down and bottom-up. Top-down means that structured data sources such as encyclopedia websites use to extract ontology and pattern information from high-quality data and add it to the knowledge base. The bottom-up method uses technical means to remove resource models from publicly collected data, select new models with high confidence, and add them to the knowledge base after manual review. The top-down approach emerged in the early days when knowledge graph extraction and processing technology were immature. As technology develops, most knowledge graph constructions use the bottom-up approach. Scholars have varying views on the research into constructing knowledge graph systems. Liu et al. [3], categorize knowledge graph construction into three main stages; knowledge extraction, fusion, and processing. Yan et al. organize knowledge graph construction into three parts: entity extraction, relationship extraction, and knowledge reasoning. In contrast, Wang et al. suggest that knowledge graph construction systems comprise four main components: natural language processing, fusion, calculation, and application of knowledge. In summary, despite differences in opinions among scholars, knowledge extraction, fusion, and reasoning are widely seen as core components of knowledge graph construction. The bottom-up construction method is the direct approach adopted in the current study. This process typically involves knowledge graph builders using automatic or semi-automatic technical means to extract facts from raw data and store them in the knowledge base' s data and pattern layers.

3 Data Source and Research Method

To conduct this study, we searched the Web of Science for articles published from January 2012 to December 2021 that discussed knowledge graph construction. We applied a filter to narrow the search results, selecting only English articles categorized as “Article”. After screening the results, we refined and organized the data, ultimately identifying 561 English articles relevant to the study.

To visually analyze the original data, we utilized the knowledge graph software Citespace through emergent analysis and clustering analysis. Firstly, we installed Citespace.v.6.1.R2. (64-bit). Secondly, we accessed the import/export option in the Data tab of the software and selected the WOS option. We then input the folder path for input and output directories and performed de-duplication. After that, we provided the software with the data and project directory paths from the respective folders. We also set the time range interval and node types (e.g., Institutions, Keywords, and References) in Tim Slicing and Node Types, respectively. Finally, we initiated the GO command in the execution operation area to generate a visual knowledge graph. Generally, the indicators that measure the analysis results of Citespace software mainly include the clustering modularity (Q value) and the average clustering silhouette (S value). When $Q > 0.3$, the knowledge graph's clustering structure is considered significant; when $S > 0.5$, the clustering is considered appropriate [4]. The Citespace.v.6.1.R2(64-bit) adopted in this study can achieve literature co-occurrence analysis using a clustering graph, and the graphs formed satisfy the above two indicators ($Q > 0.3$, $S > 0.5$), thereby improving the credibility of the study. The analysis will cover several aspects, including the volume of articles published throughout the years, the participating research institutions, the popular research themes, and the cutting-edge innovations in this field.

Table 1. Publication year and number of articles on knowledge graph construction research

Year of Publication	Number of articles
2012	14
2013	26
2014	37
2015	28
2016	36
2017	39
2018	50
2019	74
2020	118
2021	139
Total	561

4 Research Results

4.1 Statistical Analysis of Chronological Publications

The publication year and annual publication distribution can reflect the research popularity and publication speed in this field. The study searched and counted English journal papers on knowledge graph construction from Jan. 2012 to Dec. 2021 on the web of science. Through weighting and refinement, 561 journal papers were finally compiled, as shown in Table 1. It can be seen that from 2012 to 2021, the number of publications on knowledge graph construction has been increasing year by year. Between 2012 and 2015, the average number of papers published annually was around 26. Since 2015, the number of papers published each year has risen dramatically. After 2020, there has been a significant increase in the number of published papers related to knowledge graph construction, indicating a period of rapid growth and increased research efforts in this field. This trend highlights the growing importance of knowledge graph construction and its emerging status as a prominent research topic.

4.2 Statistical Analysis of Research Institutions

By importing the original data into Citespace.v.6.1.R2, the publication institution was visualized through the Institution module, and a knowledge graph of the cooperative relationships of research institutions was generated from Jan. 2012 to Dec. 2021. As illustrated in Fig. 1, the nodes represent the research institutions involved in the construction of knowledge graphs. With a total of 263 nodes and 182 connections, the graph has a network density of 0.0053. This suggests that the level of cooperation among research institutions is not particularly strong.

Table 2 shows that out of the selected articles, Chinese Acad Sci has published 23, whereas institutions such as Zhejiang Univ, Harbin Inst Technol, Beijing Univ Posts &

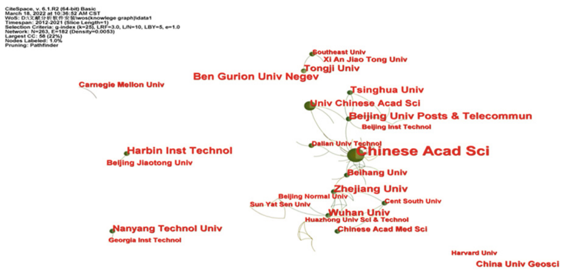

Fig. 1. Distribution of research institutions of knowledge graph construction.

Telecommun, and Ben Gurion Univ Negev published 8 articles each. Tsinghua Univ and Wuhan Univ have published 7 articles each. Among them, Chinese Acad Sci (0.07), Zhejiang Univ (0.04), Wuhan Univ (0.03), and Beihang Univ (0.04) have a high centrality. Here, centrality refers to the degree to which nodes representing one research institution connect with other nodes in the network. It indicates that in the network of research institutions, the above institutions have more significant influence and importance in knowledge graph construction research.

Table 2. Ranking of research institutions of knowledge graph construction

Count	Centrality	Institution
23	0.07	Chinese Acad Sci
8	0.04	Zhejiang Univ
8	0.01	Beijing Univ Posts & Telecommun
8	0	Harbin Inst Technol
8	0	Ben Gurion Univ Negev
7	0.03	Wuhan Univ
7	0	Tsinghua Univ
6	0.01	Univ Chinese Acad Sci
6	0	Tongji Univ
6	0	Nanyang Technol Univ
5	0.04	Beihang Univ
5	0	China Univ Geosci
4	0	Xi'an Jiao Tong Univ
4	0	Natl Univ Def Technol
4	0	Eindhoven Univ Technol
4	0	Chinese Acad Med Sci
4	0	Carnegie Mellon Univ
4	0	Beijing Jiaotong Univ

4.3 Keywords Analysis of Research Hotspots

Keywords are an essential index of literature retrieval, which can reflect the topic and main content of the literature. Statistical analysis of keywords can provide a comprehensive understanding of hot topics in this field. One can determine the pivotal points based on how often the keyword appears, that is, the hot spot of the study. The more frequently the keyword appears, the more popular the study is. However, centrality, as an essential indicator for judging research hotspots in a certain field, reflects the importance of individuals in the network. In a certain period, the research popularity of related issues is analyzed by ranking keywords. Issues that are frequently occurring and possess a high degree of centrality usually depict as the burning topics in this field.

In this study, Citespace.v.6.1.R2 is used to create the 2012–2021 keyword knowledge graph for the research and analysis of knowledge graph construction, as shown in Fig. 2. After processing the literature data, use the keyword module to sort the keywords related to knowledge graph construction. In the screening process, keywords with high citation frequency and high centrality are obtained after removing keywords such as knowledge, chart, and structure. These keywords include model, presentation, framework, system, ontology, understanding, network, design, natural language processing, classification, algorithms, patterns, text mining, big data, etc. Table 3 lists the top 19 keywords based on centrality value, revealing the hot issues in this research field.

To explore the closeness between high-frequency and highly centralized keywords and further discover hot spots in knowledge graph construction research, we used the Citespace.v.6.1.R2 software Keyword module. We trimmed the nodes of search terms to form a visual knowledge graph of keyword centrality (see Fig. 2). The graph can reflect the hot topics in this field from 2012 to 2021. Among them, the keywords model, representation, big data, ontology, framework, classification, etc., have a high centrality, which reflects the high attention paid by the academic community to these issues in the research of knowledge graph construction, and also shows that these research hotspots have a high impact on other research issues in this field.

Knowledge graph construction is a knowledge representation technique based on big data, ontologies, taxonomies, and frameworks. It can represent complex knowledge in a visual graph, making it easier to comprehend and utilize. Models, representations, big data, ontologies, classification, and frameworks are the foundations of knowledge graph construction and are closely related to knowledge graph construction. Big data can provide a wealth of raw data, thus providing enough information for knowledge graph construction. Ontology, classification, and framework can provide a unified representation of knowledge, which makes the knowledge graph construction more effective. In conclusion, the importance of these techniques in the knowledge graph construction process is that they can help the knowledge graph builder better collect, organize, and understand the knowledge to build the knowledge graph. According to Fig. 2, it is essential to explain that model and representation play a crucial role in knowledge graph construction. A model describes the entities and relations in the knowledge graph, and the relationships between them, which can help us structure complex knowledge to understand better and describe knowledge. Representation is the method used to express the entities and relations in the knowledge graph. It can help to define the entities and associations in the knowledge graph in a form that the machine can understand so that the device can

Table 3. Centrality of the knowledge graph construction keywords

Count	Centrality	Keywords
22	0.23	model
14	0.21	representation
6	0.16	big data
24	0.13	framework
12	0.13	ontology
11	0.13	classification
31	0.11	system
9	0.09	web
9	0.08	comprehension
10	0.07	management
6	0.07	pattern
6	0.07	text mining
5	0.07	design
2	0.06	integration
8	0.05	network
7	0.05	Natural language processing
12	0.04	semantic web
11	0.04	algorithm
7	0.04	data mining

better understand and process the knowledge. Therefore, models and representations have critical technical significance in the process of knowledge graph construction, and their influence is more prominent. It also indicates that the current difficulties in knowledge graph construction technology are highlighted in model construction and precise knowledge representation learning. At the same time, it also reflects that the research in this field is more concentrated in the preliminary stages. More in-depth analysis of late high-level construction technology must be strengthened and developed.

Results have been obtained on knowledge graph construction through sorting and analyzing keyword lists and visual graphs. The keywords identified in this study mainly focus on the technical aspects of knowledge graph construction, such as knowledge extraction, fusion, and reasoning. These keywords provide a valuable reference for further research on graph construction and its technicalities.

(1) Keywords analysis of knowledge extraction research

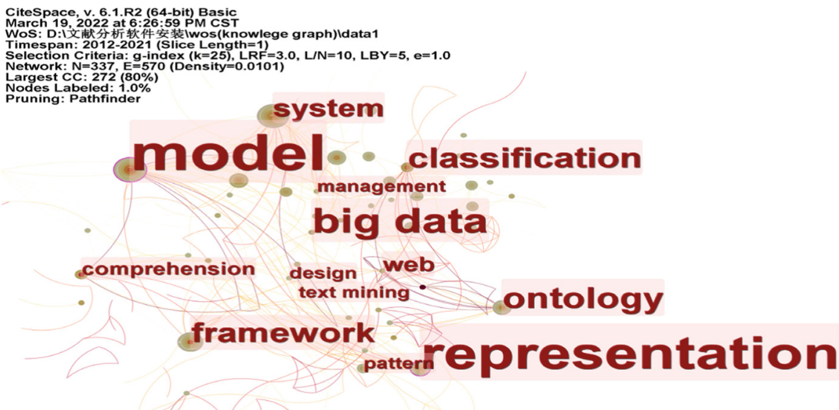

Fig. 2. Visualization graph of keywords with high centrality.

Knowledge extraction involves identifying and capturing valuable insights from diverse data sources and consolidating them into a knowledge graph, which is the foundation for generating large-scale knowledge structures. This process entails crucial techniques, such as detecting entities, recognizing relationships, and extracting attributes. Accurate entity identification is vital to semantic comprehension and underlies effective knowledge graph creation. By detecting key entities and classifying them, subsequent complex knowledge structure extraction, relationship classification, and attribute extraction can occur. Achieving entity recognition involves marking the essential entity's boundaries in the Text and categorizing it before proceeding to extraction. This often happens through machine learning algorithms that rely on natural language processing, deep learning, semantic understanding, text and data mining, and analysis. Commonly discussed core issues in knowledge extraction include recognition, models, comprehension, framework, text mining, data mining, natural language processing, and classification. A study propose a neural machine reading model. This study emphasizes using procedural texts to construct a dynamic knowledge graph to monitor the state changes of participating entities. The rise of deep learning paves the way for pre-trained language models, which have proven to be effective in entity recognition and are gaining more attention as they continue to evolve. However, from the analysis of keyword frequency, there are not enough keywords for deep learning. In addition, knowledge graph construction emphasizes big data for automated acquisition and the scale of knowledge. This differs from traditional expert systems and knowledge engineering, so "big data" is currently a hot keyword often mentioned in the knowledge extraction process.

(2) Keywords analysis of knowledge fusion research

Creating a cohesive and simplified knowledge graph requires integrating various graphs using knowledge fusion technology. The process involves utilizing ontology matching and entity alignment standard techniques to establish connections and achieve consistency. Essentially, it's about linking information into a unified whole. The keywords that represent the main concerns in knowledge integration research include integration, pattern, ontology, and network. In addition to multimodal data fusion, one of the most significant challenges in knowledge fusion is accurately linking extracted entities from textual data to their corresponding entities in the limited context of the knowledge base. The highly regarded knowledge fusion technology is primarily demonstrated through alignment of large-scale entities, unsupervised alignment, improvement of embedded representation, multi-view alignment, and other such models. A study [5] presents a virtual knowledge graph paradigm that facilitates data fusion and accessibility. This paper discussed an entity alignment framework based on multi-view knowledge graph embedding. There is a certain degree of progress. However, from the perspective of keyword frequency analysis, embedded representation enhancement, unsupervised alignment, and other specific technology research still needs to be improved.

(3) Keywords analysis of knowledge reasoning research

Knowledge reasoning is constructing knowledge by extracting implicit information from the existing knowledge base, consequently expanding and enriching the ontology. It involves critical technologies such as an inference engine, inference algorithm, and inference system. Reasoning ability, including abstraction, deduction, induction, cognition, and comprehension, is a critical trait that differentiates humans from other animals. Since the advent of artificial intelligence, achieving machines with human-like reasoning abilities has been a significant objective. Recently published literature indicates that technologies like natural language processing, data mining, interpretation, and algorithms are crucial in facilitating knowledge graph reasoning. For example, A study [6] propose a first order probabilistic language inference method called ProPPR, which extends the stochastic logic program and emphasizes short derivation. At the same time, the importance of further mining more complex logical structure of rules is emphasized. This highlights a hot issue in knowledge graph inference research.

4.4 Frontier Analysis of Knowledge Graph Construction Research

This research employed co-citation analysis of primary data using the "Reference" function in the Node Type section of Citespace (v.6.1.R2) The co-citation reference graph is then clustered, and the LLR algorithm yields clustering outcomes. Articles and words chosen by this technique illustrate research knowledge and represent certain aspects of knowledge graph construction's research frontier (See Fig. 3 for details). These subject words mainly are relational learning analysis, overlapping relation, structured query construction, learning framework, Persian knowledge graph, scholarly knowledge graph construction, multi-word term, medical knowledge graph, attention-oriented perspective, virtual landslide disaster environment, etc. This indicates that these topics are at the forefront of ongoing research.

From the perspective of literature co-citation cluster analysis, the current research frontier focuses on the following types of issues: First, in the aspect of natural language processing technology, the research on overlapping relation, multi-word terms, structured query construction, and attention-oriented topic model construction technology is cutting-edge; Second, in the aspect of deep learning, the topic research such as relational learning analysis and learning framework receives more attention; Thirdly, in the construction of domain kn owledge graph, the research on the construction technology of

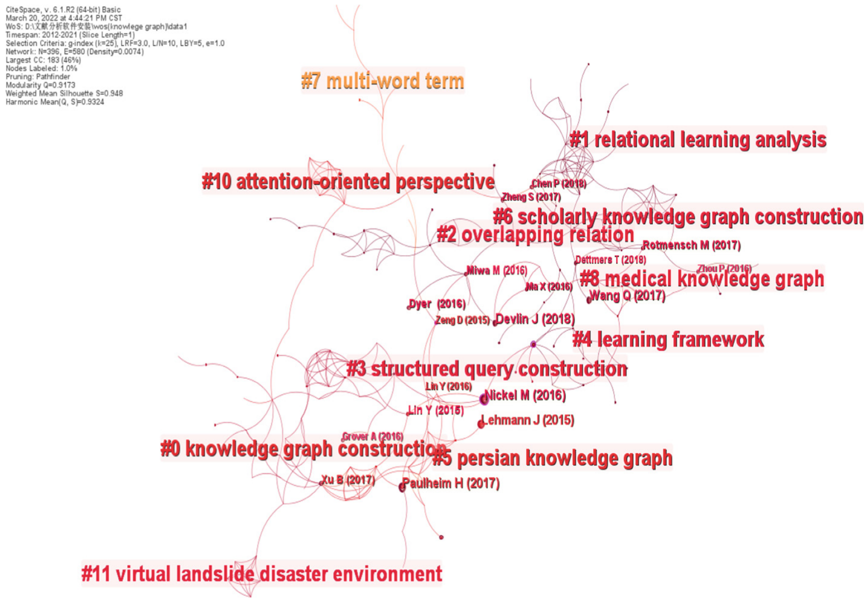

Fig. 3. Visualized graph of co-citation reference clustering.

medical knowledge graph, geological and geographical environment knowledge graph, academic knowledge graph and Persian knowledge graph is more prominent.

5 Discussion of Research Status

The current investigation examines the data on knowledge graph construction in the WoS database from 2012 to 2021 using Citespace as a visual analysis tool. However, it is necessary to discuss the research status further.

5.1 Research Institutions are Scattered and Cooperation is not Close

Our preliminary analysis demonstrates that an increasing number of researchers are participating in knowledge graph construction research teams, which indicates the significance of this area in the era of artificial intelligence. However, our comprehension and grasp of the knowledge graph are just at their beginning stage, entailing further in-depth studies. Besides, our analysis of the institutions involved in knowledge graph construction reveals that although research establishments, such as the Chinese Academy of Sciences, Wuhan University, Zhejiang University, and Beijing University of Aeronautics and Astronautics have notable connections with other research institutions and exert a significant influence on knowledge graph construction research, the research scope remains relatively dispersed. Thus, to address this urgent issue, there is a need to enhance regional cooperative research and cross-border collaboration, which is the future trend.

5.2 The Technical Accuracy and Basic Theoretical Research at Each Stage of Knowledge Graph Construction are Slightly Insufficient

An analysis of current hotspots reveals that technological advancements are leading to continuous improvement in all stages of knowledge graph construction, including identification, integration, extraction, and reasoning. The critical technical words are model, representation, ontology, network, design, natural language processing, framework, classification, comprehension, semantic web, pattern, text mining, algorithm, big data, management, etc., which are the focus of knowledge graph construction research. Among them, the keywords model, representation, big data, ontology, framework, classification, etc., are closely related to other key technologies, which are the basic and core of the research on the overall construction of the knowledge graph. For instance, there has been a significant advancement in the exploration and implementation of various algorithmic and multi-modal technologies in the widespread utilization of general knowledge base technology. It indicates that knowledge graph construction technology is growing with artificial intelligence's continuous growth and technical needs. However, the research of knowledge graph construction is still in its infancy and needs further improvement in all aspects. For example, more efforts need in multilingual automation, accurate identification, and extraction techniques. To ensure the quality and credibility of knowledge, it is also necessary to solve the problem of accurate traceability of knowledge sources. The difficulties of unsupervised alignment, large-scale entity alignment, and embedded representation enhancement in knowledge fusion technology need to be further solved. How to deeply integrate explicit knowledge in the form of symbols and tacit knowledge in the form of data to realize the precise integration of knowledge and data at the level of perception has always been an urgent problem to solve in the research of artificial intelligence. In addition, due to the current knowledge graph model training based on the assumption of knowledge invariance, pre-training knowledge becomes more and more necessary. However, because the current understanding of pre-training technology is not deep enough in theory and method research, it will also pose some challenges to the text pre-training model research.

5.3 Frontier Research Such as Deep Learning and Domain Knowledge Graph Construction Continues to Improve and Develop

From the perspective of the frontier, the research on relational learning analysis, overlapping relationships, structured query construction, learning framework, Persian knowledge graph construction, medical knowledge graph construction, geo-geographic environment knowledge graph construction, academic knowledge graph construction, multi-word terms, attention-oriented topic model construction, and other aspects are the forefront of knowledge graph construction at present. It shows that natural language processing technology is constantly improving. Machine deep learning research has made some progress, And the research on the construction of domain knowledge graphs represented by medical knowledge graphs has made significant progress. Although these frontier researches reflect our efforts and advanced achievements in studying knowledge graph construction to some extent, many aspects must be improved and developed. For example, the visual display of knowledge graph construction is not perfect enough to meet the complex demand of knowledge graph display; The security and reliability of domain knowledge graph construction are not high enough. In the large-scale application of specific fields, the research on the evaluation technology of knowledge graph construction is insufficient, and the research on knowledge graph construction technology in the field of education needs further development.

6 Future Prospects

6.1 Enhancing International Cooperation in Building Knowledge Graphics

Although the construction of the knowledge graph is still in its infancy based on recent research, it must be acknowledged that the research team and its findings are evolving rapidly. With the increasing demand for the development of artificial intelligence, enhancing international cooperation and technical exchange in research will become a significant trend in promoting the development of artificial intelligence.

6.2 Enhance the Effectiveness and Accuracy of Multi Domain Knowledge Graph

In recent years, there has been a growing interest in developing knowledge graph construction in artificial intelligence with the aim of practical application and addressing technical challenges. Progress has been made, indicating a shift towards constructing domain-specific knowledge graph applications from the general application. This highlights the importance of building knowledge graphs that cater to specific needs. So it is necessary to strengthen the construction and application of knowledge graph technology in diverse areas, such as medical, military, judicial departments, social platforms, and education, and to improve the accuracy of the constructed knowledge graphs.

6.3 Strengthen the Research and Development of Advanced Stage Technology for Knowledge Graph Construction

The advanced stage technology technologies for constructing a knowledge graph include relationship extraction, ontology learning, semantic parsing, and knowledge representation learning. These advanced technologies can improve the accuracy and efficiency of constructing a knowledge graph, making it more comprehensive, accurate, and structured, thus providing better support for applications such as artificial intelligence. So improving the quality of knowledge graph data, enhancing algorithm performance, supporting multimodal data fusion, and promoting knowledge application are important directions for improving advanced knowledge graph technology. At the same time, it is necessary to continuously explore the theoretical and technical issues behind knowledge graphs and promote the continuous upgrading and evolution of knowledge graph technology.

6.4 Adhere to the Ethical and Moral Principles of Knowledge Graph Construction

The beginning of the knowledge graph itself was a discovery of how human memory works. With the development of practice, it gradually combines the characteristics of the Internet and artificial intelligence. Its importance lies in helping human beings to carry out cognitive activities in the complex and abundant information and expanding the scope of human understanding. With the progress of knowledge graph construction technology, we will usher in a world of artificial intelligence with the collaboration of knowledge graph technology and big data. However, the basic construction of a knowledge graph is still for the survival and development of human beings, endowed with human goodness. So future research should pay more attention to the ethic value of knowledge graph construction. On the one hand, we should strengthen the development and application of knowledge graph construction technology in the field of education, on the other hand, we should also pay attention to reducing the growth of non-ethical technology of technology utilitarianism, and use knowledge graph construction to create an authentic, excellent and beautiful world.

7 Conclusion

The Citespace statistical software draws visual knowledge graphs through bibliometric analysis from Jan. 2012 to Dec. 2021. The data collected was scrutinized by analyzing factors such as the frequency of articles published in a particular year, the institutions involved in the research, research hotspots, and research frontiers. Because English literature has particular difficulties in keyword setting, classification, and division, manual data screening is time-consuming and laborious, and the time range of screening is limited, increasing the burden of research conclusions. Although the co-citation analysis method is widely used, the time delay is the biggest challenge for frontier detection. It takes a certain period for an article to be published, to have cited information, or to achieve high citation. So there will be a slight error in using the frontier research of co-citation analysis. In future research, we will improve our techniques, form a knowledge graph of relevant topics, and strengthen analysis and accurate conclusions. And enhance the sustainability and efficiency of research.

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References

1. Amit, S.: Introducing the Knowledge Graph: Things, not strings. (2012) https://www.blog.google/products/search/introducing-knowledge-graph-things-not/
2. Wikipedia.: Knowledge graph. Network https://encyclopedia2.thefreedictionary.com/Knowledge+Graph (2022). Accessed 8 February 2022

3. LiuQiao, L. Y., DuanHong, L. Y.: Knowledge graph construction techniques. *Journal of Computer Research and Development*. 53(3), 582(2016)
4. Chen, Y, et al. :Methodology Function of CiteSpace Knowledge Graph . *Science Research*. 2, 242-253(2015)
5. Xiao, G., et al.:Virtual knowledge graphs: An overview of systems and use cases. Data Intelligence. 1(3),201-223(2019)
6. Wang, W.Y., et al:. Efficient inference and learning In a large knowledge base. Machine Learning. 100(1): 101-126(2015)