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Research Article

Exploring the Intersection of Hypernetworks and Information: A Bibliometric and BERTopic-Based Analysis

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ABSTRACT

The integration of hypernetworks into the information domain holds great promise for enhancing the interpretability of AI models, particularly in elucidating complex, multi-level relationships and dependencies. As technology continues to evolve rapidly, hypernetworks have emerged as a frontier paradigm, garnering increasing scholarly and industrial attention. These networks underscore the intricate interconnectivity and interdependence among technological components, thereby complicating the task of identifying high-potential emerging technologies amidst a proliferation of innovations. Consequently, the application, identification, and forecasting of hypernetworks in the information field have become pivotal areas of research. Addressing these challenges necessitates in-depth, interdisciplinary analyses to foster the innovative deployment of hypernetworks across diverse domains. This study presents a comprehensive examination of research on hypernetworks in the information field, employing bibliometric methods in conjunction with the BERTopic topic modeling approach. The results reveal underlying thematic structures and relationships within the literature, offering a deeper understanding of the evolving research landscape. While notable progress has been achieved-particularly in representation learning and model construction-significant challenges persist, including the optimization of hypernetwork models for real-world applications. Looking ahead, the advent of the big data era and the continuous evolution of artificial intelligence are expected to drive the expansion of hypernetwork research, both in depth and scope, ultimately leading to transformative developments in the field of information science and management.

Keywords: Artificial Intelligence, BERTopic, Bibliometric Analysis, Hypernetworks, Information Science.

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INTRODUCTION

With the rapid advancement of artificial intelligence and data-driven technologies, information systems have grown increasingly complex, characterized by high-order interdependencies among their components. Traditional network models, which primarily capture pairwise relationships, often fall short in representing the multi-dimensional structures inherent in such systems. To address these limitations, hypernetworks have emerged as a powerful modeling paradigm, capable of representing interactions among multiple entities within complex, heterogeneous environments.

The foundational concepts of hypergraph theory were first introduced by (Berge And Minieka, 1973), while (Estrada and Rodriguez-Velazquez, 2005), further proposed that any network representable by a hypergraph can be considered a hypernetwork. Unlike standard graphs, where edges connect exactly two nodes, a hyperedge in a hypergraph can simultaneously connect multiple nodes, whether homogeneous or heterogeneous. This multidimensional structure allows hypernetworks to transcend the binary constraints of traditional graphs and more effectively model complex systems.

Hypernetworks-particularly those grounded in hypergraph theory-thus provide a richer and more expressive framework for analyzing dynamic and heterogeneous systems. This modeling capacity enables a deeper and more granular understanding of intricate relationships among technologies, knowledge units, and information resources. Accordingly, hypernetworks have attracted growing interest in both academic research and practical applications.

In recent years, the application of hypernetworks has extended across diverse fields. In the supply chain domain, they have been used to model green reverse logistics and e-commerce-driven recycling systems, facilitating global optimization in multi-agent networks (Wang *et al*., 2010; Deng *et al*., 2008). In the financial sector, hypernetwork models have been employed to analyze complex interactions in internet finance, integrating capital flow

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and social relationships to explore market equilibrium and risk dynamics (Mi *et al*., 2018; Jing *et al*., 2023).

Within the information field, hypernetworks have demonstrated significant promise across multiple subdomains. They offer a flexible, multi-level structure for information organization and retrieval, wherein nodes may represent documents, keywords, or topics, while hyperedges capture the complex interrelations among them. This contributes to improved knowledge representation and retrieval performance. In social network analysis, hypernetworks support investigations into author collaboration networks, academic community structures, and citation relationships, allowing researchers to trace the evolution of research themes and collaborative patterns over time.

In this context, hypernetworks not only facilitate the integration and structuring of diverse information resources but also inspire novel methodologies in information science. Given their wide-ranging applicability and theoretical importance, a systematic exploration of hypernetwork research within the information field is both timely and essential.

Despite the growing body of research on hypernetworks and hypergraph-based models, the development of this area within the information domain remains highly fragmented. Existing studies span a wide range of application contexts-including representation learning, recommendation systems, information retrieval, security, transportation systems, and quantum information-while drawing on heterogeneous theoretical foundations and methodological traditions. As a result, it has become increasingly difficult to obtain a coherent overview of how this research area has evolved, which themes dominate the literature, and how different research directions are structurally connected.

Traditional narrative reviews, while valuable, are limited in their ability to systematically capture large-scale patterns, thematic structures, and longitudinal trends across a rapidly expanding and interdisciplinary body of literature. In this context, a scientometric approach is particularly well suited, as it enables quantitative mapping of the intellectual landscape, identification of research hotspots and emerging themes, and analysis of the evolution and interrelationships of topics over time.

Accordingly, this study adopts a scientometric perspective, complemented by embedding-based topic modeling, to provide a structured and reproducible analysis of hypernetwork-related research in the information domain. This approach allows us to move beyond individual case studies and offer evidence-based insights into the field's development trajectories, challenges, and future research opportunities.

This study aims to provide a systematic analysis of the research landscape, application scenarios, and development trends of hypernetworks in the information field. Specifically, it employs bibliometric analysis and BERTopic-based topic modeling to identify key research themes, structural patterns, and future directions. The main contributions of this paper are as follows:

1. It offers a comprehensive quantitative analysis of the evolution of hypernetwork-related research within the information field using bibliometric methods.
2. It integrates bibliometric mapping with embedding-based topic modeling to reveal the latent thematic structure, inter-topic relationships, and developmental trajectories of hypernetwork-related research in the information domain, thereby enabling opportunity-oriented interpretation beyond descriptive trend reporting.
3. It identifies current challenges and potential opportunities, providing valuable insights for future research and practical applications of hypernetworks in information science.

To provide a structured overview of the research, this paper is organized as follows: Section 2 introduces the data sources and methodological framework; Section 3 analyzes keyword co-occurrence patterns in the hypernetwork information field; Section 4 examines research progress using BERTopic modeling; Section 5 discusses future outlooks; and Section 6 concludes with a summary of key findings and implications.

METHODOLOGY

Type of Study and Data Source

This study adopts a scientometric research design combined with embedding-based topic modeling to systematically analyze the development of hypernetwork-related research in the information domain. Scientometric methods are used to quantitatively map publication patterns, keyword structures, and research trends, while topic modeling is employed to uncover latent thematic structures and their evolution over time.

The bibliographic data were retrieved from the Web of Science Core Collection (SCI-EXPANDED), which provides high-quality and standardized metadata suitable for scientometric analysis.

Study Population, Sample, and Data Processing

The study population consists of scholarly publications addressing hypernetworks, hypergraphs, and related higher-order network models within the information domain. A topic-based search strategy was designed to capture relevant literature, using combinations of hypernetwork-related terms and information-oriented keywords.

The search strategy on Web of Science was: TS= ((("supernetwork" OR "super-network" OR "hypernetwork" OR "hyper-network" OR "hypergraph" OR "hyper-graph") AND ("text mining" OR "text analytics" OR "text data mining" OR "information retrieval"

OR "natural language processing" OR "streaming media" OR "multimodal" OR "library" OR "information" OR "text"))), selecting SCI-EXPANDED, with a time span covering all years.

The initial search retrieved 1315 records. These records were screened based on titles, abstracts, and keywords to exclude papers unrelated to information science applications or higher-order network modeling. After this screening process, a final sample of 1000 articles was retained for analysis.

For bibliometric analysis, full records and cited references were extracted. For topic modeling, article abstracts were used as the primary textual corpus. Standard preprocessing steps were applied, including tokenization, lowercasing, and stop-word removal.

SCI-EXPANDED was selected because research on hypernetworks/hypergraphs is primarily published in computer science, engineering, and mathematically oriented venues, for which SCI-E provides relatively comprehensive coverage and more standardized bibliographic records that facilitate reproducible scientometric mapping. We acknowledge that AI-enabled studies are also widespread in the social sciences-especially in knowledge management and Library and Information Science (LIS)-and some relevant publications may therefore be indexed in SSCI. However, based on our preliminary screening, explicitly hypernetwork/hypergraph-centered studies appear comparatively less frequent in these SSCI-oriented outlets. Accordingly, we treat database coverage as a limitation and identify extending the corpus to SSCI and other databases as an important direction for future research.

Analytical Framework and Methods

The overall analytical framework of this study consists of two complementary components: bibliometric analysis and BERTopic-based topic modeling, introduced by (Grootendorst, 2022). Bibliometric techniques are employed to analyze publication trends and keyword co-occurrence structures, while topic modeling is used to identify latent research themes and their temporal evolution. This integrated framework enables both macro-level structural mapping and micro-level thematic interpretation of the literature.

Bibliometric Analysis

Bibliometric analysis was conducted to examine publication outputs, keyword co-occurrence patterns, and the evolution of research focus over time. Keyword co-occurrence networks were constructed using VOSviewer, where node size represents keyword frequency and link strength reflects co-occurrence intensity. Temporal attributes were incorporated to visualize the emergence and development of key research topics.

BERTopic Modeling

To identify latent thematic structures within the literature, we employed BERTopic, an embedding-based topic modeling approach that integrates document embeddings, dimensionality reduction, clustering, and class-based term weighting. Document embeddings were generated using the pre-trained all-MiniLM-L6-v2 model. UMAP was applied for dimensionality reduction, followed by HDBSCAN for clustering semantically similar documents. Topic representations were generated using class-based TF-IDF (c-TF-IDF), enabling the extraction of representative keywords for each topic (Figure 1).

Analysis of Keywords in the Hypernetwork Information Field

To examine the structural characteristics and co-occurrence patterns of keywords in hypernetwork-related research, a keyword co-occurrence network was constructed using VOSviewer, with node attributes reflecting frequency and average publication year.

Core keywords in hypernetwork research within the field of information science include: "hypergraph learning," "hypergraphs," "clustering," "hypernetwork," "recommender systems," "feature extraction," "hypergraph regularization," "deep learning," "link prediction," "optimization," "task analysis," "feature selection," "hypergraph neural network," "machine learning," "data mining," "graph," "graph neural networks," "hypergraph clustering," "hypergraph partitioning," and "complex networks," as shown in Figure 2.

Several newer keywords can be observed, including: "graph neural networks," "self-supervised learning," "attention mechanism," "graph convolution network," "data models," "hypergraph convolution," "hypergraph neural network," and "social network." These new keywords indicate a shift in trends in information science research based on hypernetworks. The introduction of emerging technologies such as graph neural networks, self-supervised learning, and attention mechanisms provides more powerful tools for tasks such as information retrieval, classification, and recommendation. Meanwhile, the study of graph convolution networks and hypergraph convolution offers new ways to address complex relationships and structural issues in information networks. The exploration of hypergraph neural networks suggests that a deeper understanding of hypergraph structures will advance the development of information organization and retrieval. The integration of social networks highlights a growing focus on user interaction and information sharing within the field of information science.

The introduction of these new technologies will drive innovation and development in the field of information field, offering cutting-edge solutions for information science and knowledge management.

We note that this co-occurrence mapping is intended to provide a structural snapshot and emerging signals; temporal dynamics are further examined at the topic level via the topic-intensity evolution analysis (Section 4.3).

Note: Each sphere represents a keyword, with the size of the sphere indicating the frequency of the keyword's occurrence. The color represents the average year of keyword appearance, with darker colors indicating earlier appearances and lighter colors indicating later appearances. The lines represent the strength of co-occurrence.

Progress Analysis of Hypernetwork Information field Research Based on BERTopic

Identification of Information Science Topics Based on Hypernetworks

For BERTopic, document embeddings were generated using the pre-trained SentenceTransformer model all-MiniLM-L6-v2. We reduced embedding dimensionality using UMAP (n_neighbors=15, n_components=5, min_dist=0.0, metric='cosine', random_state=13). We then clustered documents with HDBSCAN (min_cluster_size=5, min_samples=5, metric='euclidean', cluster_selection_method='eom', prediction_data=True), where min_cluster_size controls the smallest allowable topic size and affects noise assignment. Topic representations were computed using class-based TF-IDF (c-TF-IDF) within BERTopic. We used an n-gram range of (1, 3) for topic keyword extraction and did not compute topic probabilities (calculate_probabilities=False). Finally, to improve interpretability, we reduced the initial topic set to 16 (resulting in 14 substantive topics after merging) using the built-in topic reduction procedure.

By training the BERTopic topic model, the model identified 14 topics in information field research based on hypernetworks. The top 10 keywords for each topic are shown in Figure 3.

Topic 0 focuses on hypernetworks and graph neural networks in information science research. The studies cover elements such as network structures, the importance of hypergraphs, specific methods or theories used for modeling, discussions related to information, specific research methods, and graph structures. In addition, this topic also addresses user interaction with social networks, particularly regarding user behavior or needs in information systems, as well as the relationships within social networks. The in-depth exploration of this topic helps us better understand the application of hypernetworks in information field, and their connections to key concepts such as network models, information, and user interactions (Ma *et al*., 2022), proposed a novel representation learning method called p-Laplacian-based Hypergraph Neural Networks (pLapHGNN), which integrates higher-order manifold information in hypergraphs to significantly improve the classification performance of both unstructured and graph-structured data (Wu *et al*., 2021). Introduced a model called Dual-view HyperGraph Neural Network (DHGNN), which combines graph neural networks and hypergraphs. By comprehensively considering both node topology and attribute information, the model addresses challenges such as sparse structural information in graph embeddings, insufficient modeling of nonlinear relationships in attribute semantic spaces, and the heterogeneity of structural and attribute information (Yu *et al*., 2021). Proposed an innovative social recommendation method, leveraging a multi-channel hypergraph convolution network to effectively capture higher-order user relationships. By encoding common higher-order user relationship patterns with hypergraphs, the model demonstrated superior performance compared to current leading methods across multiple real-world datasets. The introduction of self-supervised learning during training further enhanced the model's ability to capture different types of higher-order connection information, as supported by extensive experimental validation and ablation studies.

Topic 1 focuses on keywords related to hypernetworks, highlighting specific research directions. The studies center around hypergraphs as core elements and introduce concepts related to fuzzy logic, addressing uncertainty or fuzziness in hypernetworks. The keywords also include information processing, dissemination, or management, emphasizing specific models or methods used, which are closely related to hypernetwork modeling. Set theory may play a crucial role in the organization of hypergraph structures or elements, and aspects such as systems, graph structures, fundamental theories, related theories, and research processes are also explored in this topic. Topic 1 offers an in-depth perspective on the application and interpretation of hypernetworks within different theoretical frameworks, covering various important concepts and research directions related to hypernetworks (Luqman *et al*., 2019). Presented a more effective division of universal sets through m-polar fuzzy hypergraphs, which is clearer compared to traditional hypergraph representations (Alvin *et al*., 2021). proposed a framework for statically generating UML sequence diagrams from object-oriented source code. By using hypergraph representations and user query guidance, the framework effectively supports program comprehension and demonstrated its effectiveness in experiments with 30 Android application corpora (Zhang *et al*., 2023). proposed using hypergraph neural networks for android malware detection, improving performance by capturing complex function relationships (Gong and Wang, 2021). Introduced a hesitant fuzzy hypergraph model based on hesitant fuzzy sets and fuzzy hypergraphs. They studied its basic graph operations, discussed the equivalence between hesitant fuzzy formal concept analysis and hesitant fuzzy information systems, and established algorithms for multi-attribute decision-making problems in the context of granular computing. The effectiveness of the model was verified through case studies (Meng *et al*., 2023). Explored the distribution of entanglement in imperfect quantum networks, introducing "concurrence percolation" to highlight a quantum advantage and improve understanding of network resilience beyond classical percolation theory.

Topic 2 focuses on the key role of labels and features in hypernetworks. This topic emphasizes the application of labels, including the labeling of nodes or edges within a hypernetwork, as well as the use of network features. Network features are critical for the modeling and analysis of hypernetworks. Additionally, the topic addresses social media network issues based on hypernetworks, highlighting the importance of considering multiple aspects or elements within a hypernetwork, meaning that nodes or edges in a hypernetwork can have multiple labels. Topic 2 provides insights into the effective use of labels and features for description and analysis within hypernetworks (Sperlì *et al*., 2016). Defined a novel Multimedia Social Network (MSNs) data model based on hypergraph data structures, which succinctly captures and represents various relationships in social networks and multimedia sharing systems. This model provides a foundation for applications such as impact analysis and multimedia recommendation, and offers strategies for learning hypergraphs from social data (Flora *et al*., 2016). Proposed an innovative multimedia social network data model, also based on hypergraph data structures, which efficiently captures and represents various relationships in social media networks. They introduced user and multimedia ranking functions to support different applications and demonstrated its effectiveness in multimedia information retrieval tasks through experiments.

Topic 3 focuses on the application of clustering analysis in hypernetworks. This topic covers spectral clustering methods, the use of matrices and tensors, and the identification of clusters within the structure of hypernetworks. It highlights the diverse methods and techniques employed to understand the patterns and organizational structure of hypernetworks (Gao *et al*., 2019). Proposed a novel multi-view low-rank factorization method for data containing multi-view features. By applying multi-manifold regularization, the method encourages consensus data representations to move smoothly across the underlying manifolds, effectively discovering consistent semantics between different view features, and achieved promising clustering performance on real-world datasets (Li *et al*., 2022). Introduced an incomplete multi-view subspace clustering method that preserves higher-order correlations (HCP-IMSC) (Zhang *et al*., 2022) proposed a new semi-supervised multi-view clustering method called dual hypergraph regularized part-shared non-Negative Matrix Factorization (DHPS-NMF), designed to address the clustering problem for multi-view data (Xiao *et al*., 2024). Proposed an SSEIR model based on hypernetwork theory to improve information dissemination in online social networks, capturing complex interactions and diffusion dynamics.

Topic 4 delves into the dynamics related to paths, activities, and time in hypernetworks. The core keywords include Travel, Activity, Time, Model, Network, Transport, Choice, Equilibrium, Supernetwork, and Multimodal. The research focuses on modeling and understanding the behavioral and temporal dimensions within hypernetworks, covering aspects such as network structure, transportation, decision-making, and multimodal considerations. This provides valuable insights into the dynamic characteristics of paths and activities in hypernetworks (Liao *et al*., 2014). Introduced temporal uncertainty in multi-state hypernetworks and proposed a modeling method for reliable activity travel patterns, based on the concept of α-shortest paths (Parvaneh *et al*., 2014). Introduced a new model in multi-state hypernetworks, treating subjective travel time as a function of different types of travel information provided. Using Bayes' theorem, the model captures the belief updates of individuals regarding expected travel time after receiving new travel information, to predict daily activity travel choices (Ye *et al*., 2024). Proposes a DSTHGCN model that combines graph and hypergraph convolutions, with an outlier removal mechanism to improve performance in intelligent transportation systems (Lu *et al*., 2024). Proposes HGTMFS, a hypergraph transformer-based multimodal summarization framework, which models high-order relationships across text and images to improve cross-modal interactions and performance.

Topic 5 focuses on the partitioning problem in hypernetworks, involving key concepts such as algorithm, matrix representation, sparse matrix, parallel computing, and distributed computing. The research focuses on optimizing the partitioning of nodes or elements to improve computational efficiency and explores methods to reduce computational complexity. In the context of hypernetwork partitioning, the study explores foundational theories to identify key technologies during the partitioning process, providing important insights to address complexity and improve computational performance (Akbudak *et al*., 2013). Proposed two cache size-aware row and column reordering methods based on One-Dimensional (1D) and Two-Dimensional (2D) top-down sparse matrix partitioning. The 1D method is implemented using a column network hypergraph model, while the 2D method is improved by enhancing the row-column network hypergraph model.

Topic 6 focuses on information security and covert transmission, with core keywords including information, code, access, channel, message, secret, picod, hypergraph, problem, and covert. The research involves methods for processing, transmitting, and managing information, with a particular emphasis on coding, access control, message passing, and issues related to information security and confidentiality. Hypernetworks may serve as an application domain. Overall, Topic 6 provides the foundation for understanding key issues in information security and covert transmission (Kinoshita and Morizumi, 2022), used a hypergraph model and blockchain to manage issues related to sensitive information leakage in database systems, especially information leakage caused by covert channels and inference attacks

(Kinoshita and Morizumi, 2017) explored a hypergraph-based model designed to prevent the leakage of information through inference attacks.

Topic 7 focuses on the connections between knowledge, manufacturing, and design. Core keywords include knowledge, manufacturing, design, product, network, innovation, model, base, co-creation, and service. The research explores the application and management of knowledge in manufacturing and design processes, emphasizing the importance of innovation, collaboration, and services. Networks play a crucial role in manufacturing or collaborative innovation, while research on co-creation and services highlights the trend towards service-oriented manufacturing and design. Overall, Topic 7 offers insights into knowledge management, underscoring the key factors of innovation and collaboration in these fields (Volpentesta and Felicetti, 2012). Proposed a method for constructing a research capability map within scientific communities, using directed hypergraphs to represent scientific capabilities and establishing a many-to-many relationship between researchers and their research capabilities through the analysis of scientific papers, providing a useful tool for fostering cooperation and knowledge sharing in scientific communities (Wang *et al*., 2019). Proposed a hypernetwork model from the "user-knowledge-product" perspective to integrate co-creation information between users, knowledge, and products, building three sub-networks: co-creation user network, knowledge network, and product network. They validated the model's feasibility and effectiveness in discovering, managing, and utilizing co-created knowledge through case studies (Wang *et al*., 2019). Introduced a co-creation network supermodel for product innovation, integrating user, knowledge, and product information. They constructed three sub-networks-co-creation users, knowledge, and product networks-to enhance the accuracy of discovering and managing co-creation knowledge, and validated the proposed model's feasibility and effectiveness through a case study in a well-known co-creation community for user discovery, product innovation knowledge mining, and dynamic innovation knowledge prediction.

Topic 8 focuses on image processing, search, and social image domains. Core keywords include image, visual, search, image search, hypergraph, tag, social, social image, ranking, and method. This research covers various aspects of image processing, visual technologies, image search, and the application of images in social media. Keywords like hypergraph and tag suggest the multi-level and multi-modal characteristics of the research, exploring the role of images within hypernetwork structures (Bouhlel *et al*., 2020). Proposed a hypergraph-based image search re-ranking method that considers both the relevance and diversity of search results. By introducing an elastic network regularization regression model, they constructed a probabilistic regression hypergraph that improved the model's performance (Gao *et al*., 2013). Introduced a hypergraph learning method that utilizes both visual and textual information to estimate the relevance of user-tagged images. By constructing a social image hypergraph, their model effectively models and learns both visual and textual terms, providing a richer representation for image relevance and retrieval.

Topic 9 focuses on network security, risk management, and intrusion detection. Core keywords include network, risk, system, credit, intrusion, base, detection, attack, supernetwork, and model. This research addresses network structure analysis and design, risk assessment and management, as well as intrusion detection and attack defense issues. The presence of keywords

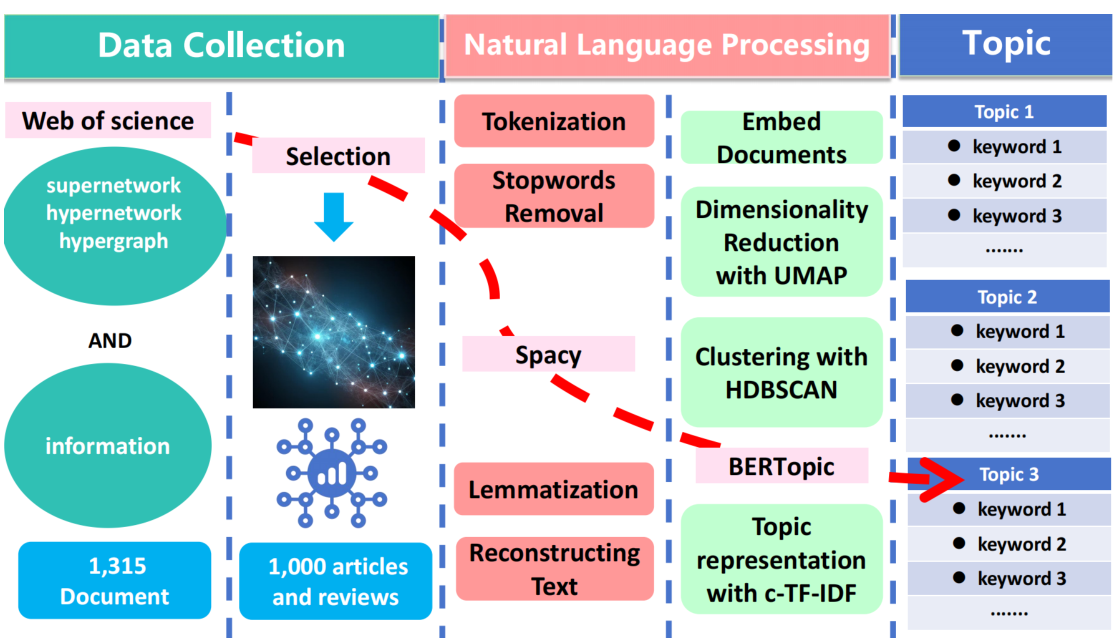

Figure 1: Flowchart of data processing and BERTopic analysis.

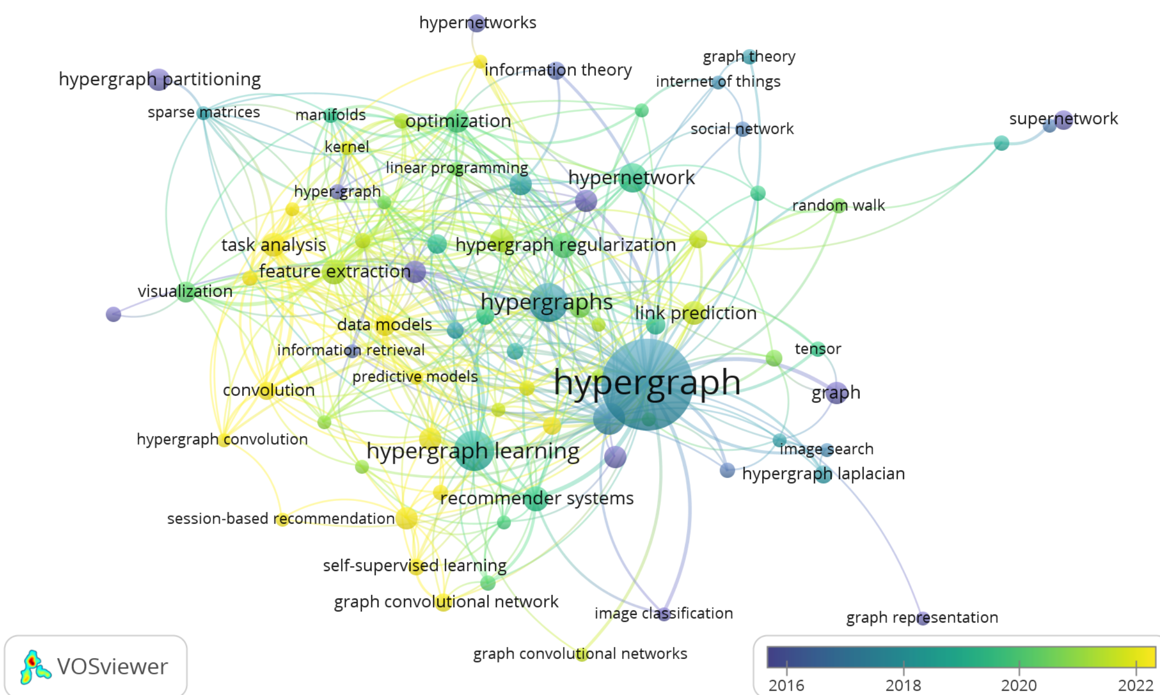

Figure 2: Keyword Evolution Diagram of Information field Research Based on Hypernetworks.

such as hypernetwork and credit risk suggests a multi-layered nature to the research, with models used to describe risk and intrusion detection within network systems (Chen *et al.*, 2020). Developed a two-layer network model to analyze credit risk contagion between banks and corporate counterparts, with a particular focus on non-revocable loans. Through theoretical analysis and computational experiments, they revealed the evolution mechanism and influencing factors of credit risk contagion in the two-layer network. This study provides theoretical and methodological support for assessing credit risk and optimizing risk resilience, contributing valuable insights into network security and risk management (Xia *et al.*, 2024). Proposes a privacy-preserving, hypergraph-based link prediction algorithm (HWA) that improves performance by integrating self-attention and GCN.

Topic 10 explores issues related to hypergraphs, uniformity, batch processing, and encoding. The core keywords include hypergraph, uniform, batch, uniform hypergraph, code, batch code, asynchronous, graph, and ideal. This research focuses on the concept of uniformity within hypergraph structures and how batch processing and encoding methods can be used to achieve ideal properties. The presence of batch coding and asynchronous processing suggests a particular focus on key techniques and challenges related to handling large-scale data or systems where operations occur asynchronously. This theme provides insights into understanding the uniformity and encoding characteristics within hypergraphs, emphasizing research into ideal models in batch processing and asynchronous environments (Riet *et al.*, 2018). Proposed a novel asynchronous batch code model that allows asynchronous parallel recovery of encoded database information symbols. This model highlights the asynchronous characteristics of graphical batch codes, which are crucial for improving efficiency and resilience in large-scale data processing systems.

Topic 11 focuses on Unmanned Aerial Vehicle (UAV) communication within networks, with particular attention to issues such as interference, spectrum management, and routing. The core keywords include network, UAV, interference, model, wireless, multicast, routing, spectrum, problem, and channel. This research primarily targets the development of communication models and routing schemes tailored for UAV networks, aiming to address specific issues like communication interference, spectrum management, and challenges in wireless communication. Key research areas include spectrum management and wireless communication, which are critical for optimizing UAV network performance. UAV technology and multicast communication reflect the specific application scenarios in this field (Zhu *et al.*, 2017). Used a hypergraph model to accurately describe the complex interference relationships between cells in a network. They proposed a method for modeling the multi-channel access problem as a local, non-cooperative hypergraph game. This approach helps address interference issues in UAV communication networks and provides a framework for more efficient spectrum and routing management.

Topic 12 focuses on brain networks, functional connectivity, and research related to brain diseases such as Alzheimer's disease. The core keywords include brain, brain network, network, functional, disease, brain region, region, method, Alzheimer's disease, and Alzheimer. This research is centered around revealing functional patterns within brain networks, especially in the context of brain diseases such as Alzheimer's disease. The keywords cover various aspects, including brain structure, functional connectivity, diseases, and research methods. Overall, Topic 12 provides key insights into understanding the role of brain networks and functional connectivity in brain disease research (Ji *et al*., 2022). Proposed a novel Hypergraph Attention Network (FC-HAT) for functional brain network classification. By constructing dynamic hypergraphs, each brain network is modeled as a hypergraph to preserve higher-order information (Zhang *et al*., 2022). Introduced a fusion model for automated brain disease diagnosis based on Brain Connectivity Networks (BCN). This model integrates structural brain network features from Diffusion Tensor Imaging (DTI) with hypergraph-based functional connectivity information constructed from functional MRI data.

Topic 13 explores issues related to the field of quantum information, emphasizing key concepts such as quantum states, entanglement, and hypergraphs. The core keywords include quantum, state, hypergraph state, entanglement, hypergraph, quantum information, qubit, configuration, protocol, and entanglement configuration. This topic focuses on areas like quantum computing, quantum communication, and quantum information processing. It provides important insights into new protocols and concepts within the quantum information field (Pal *et al*., 2006). studied the generation of multipartite entangled states on spatially separated nodes in distributed environments

Figure 3: Hypernetwork and Information field Keywords Based on BERTopic.

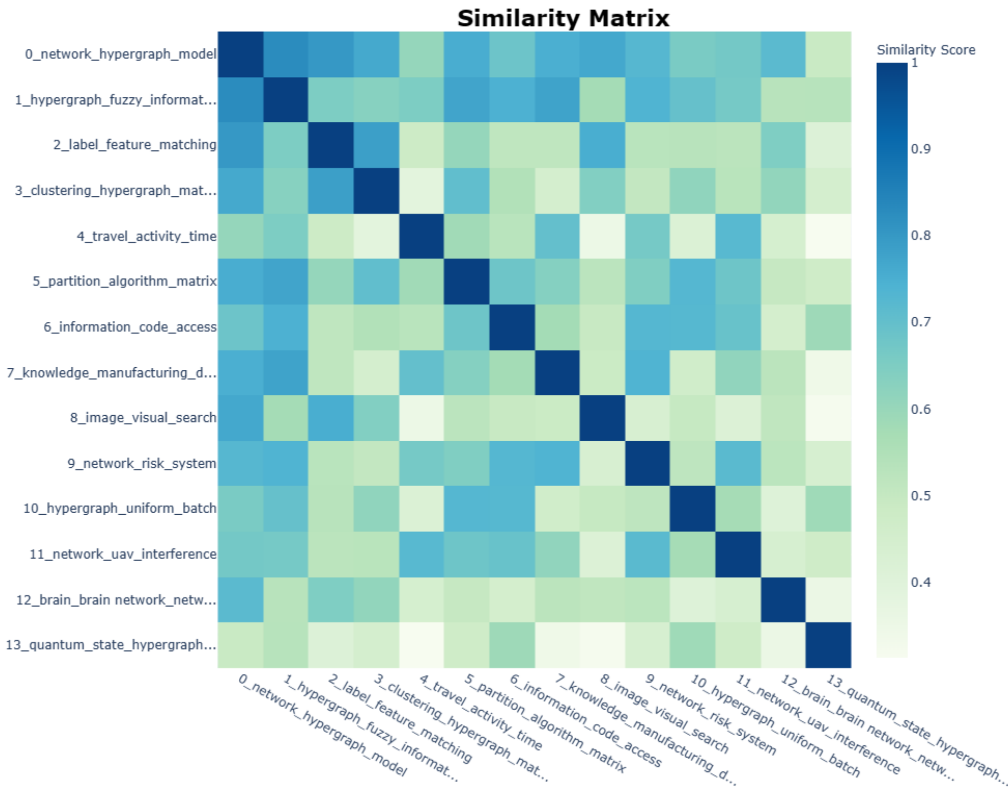

Figure 4: Topic Similarity Heatmap for Information field Based on Hypergraphs.

using LOCC (local operations and classical communication) transformations. They explored the partial order relations between equivalence classes of entanglement configurations, communication complexity, and incomparable configurations, involving the combinatorial properties of hypergraphs and hypertrees.

Research on Topic Similarity in Information field Based on Hypergraphs

In this study, inter-topic similarity was computed based on the topic representations generated by BERTopic. Each topic was represented as a vector using class-based TF-IDF (c-TF-IDF), which captures the importance of terms within a topic relative to the entire corpus. Cosine similarity was then used to quantify pairwise similarity between topic vectors, forming the basis for the topic similarity heatmap and hierarchical clustering analysis.

Based on the 14 topics derived from the BERTopic model, we constructed a topic similarity map for information field based on hypergraphs (Figure 4). Topic similarity helps us understand the relationships between different topics, allowing us to identify commonalities and differences. By analyzing topic similarity, we can assess whether the topic model has successfully captured the underlying structure in the data and examine the interconnections between different topics.

From the map, it can be observed that, except for Topic 1 and Topic 2 (which show a higher degree of similarity with each other), the similarity between other topics is relatively low. This is likely due to the fact that Topics 1 and 2 are more focused on the mechanisms of hypergraphs, while the other topics are primarily concerned with the applications of hypergraphs. Notably, Topics 12 and 13 exhibit the lowest similarity with the other topics. The topic relationship tree is presented in Figure 5.

Evolution Analysis of Topic Intensity Based on Hypernetwork Information field

By combining the document support rate of topics in different time windows, a topic intensity evolution map is plotted, with the final result shown in Figure 6. It can be observed that the overall trend of the topics exhibits steady growth and continuity year by year, with no decaying topics. This indicates that hypernetwork-based information field research has received widespread attention and practical application. As a tool capable of revealing complex interrelationships between elements, hypernetworks are likely to present significant opportunities in the field of information field.

According to the distribution of topics extracted by the BERTopic model in each year, hypernetwork-based information field was in its infancy between 1995 and 2010, with the majority of research output concentrated between 2011 and 2023. After 2015, Topic 1 showed a dominant development trend, suggesting that graph neural networks have increasingly played a more significant role in the development of hypernetworks.

Outlook

The findings of this study can be contextualized by comparing them with existing scientometric and topic-modeling research on complex networks, hypergraphs, and information science. Previous studies have primarily relied on traditional bibliometric techniques or probabilistic topic models (e.g., LDA) to map research trends in network science and information systems. While these approaches have provided valuable macroscopic insights, they often struggle to capture semantic relationships and thematic overlaps in highly interdisciplinary and rapidly evolving fields.

In contrast, our results demonstrate that embedding-based topic modeling, when integrated with bibliometric analysis, enables a more fine-grained identification of research themes and their structural relationships. The emergence of learning-oriented topics (e.g., hypergraph neural networks and self-supervised learning) observed in this study is consistent with recent reviews emphasizing the growing role of deep learning in higher-order network analysis. At the same time, our topic similarity analysis reveals a clearer separation between mechanism-oriented and application-oriented research streams than has been reported in earlier studies, suggesting an increasing specialization within the field.

Nevertheless, our approach also has limitations. Similar to other topic-modeling-based scientometric studies, the results are influenced by data source selection, text representation choices, and clustering parameters. Moreover, while BERTopic enhances semantic coherence, it may produce fragmented topics when research themes overlap extensively. These limitations indicate that our findings should be interpreted as complementary to, rather than a replacement for, qualitative expert reviews.

Overall, by comparing our findings with prior work and critically evaluating their strengths and weaknesses, this study contributes a balanced and evidence-based understanding of hypernetwork research in the information domain.

With the widespread application of hypergraphs and hypernetwork models in fields such as information science, social networks, and quantum computing, the potential for hypergraphs in multi-level and multi-domain modeling will further drive the depth of related research. This study explores the innovative applications of hypergraphs and hypernetworks in areas such as information transmission, social recommendation, intelligent transportation, and knowledge management. As technology continues to advance and demand becomes more diversified, the scope of hypernetwork applications and the depth of research will show the following development trends in the future.

First, the application of hypernetworks in multimodal data integration and recommendation systems will become a hot research topic. For example, the multi-channel hypergraph convolutional network method proposed by (Yu *et al*., 2021) has achieved significant success in social recommendation, and it is expected that future research can further expand to multimodal data fusion, combining text, images, and voice information to improve the accuracy and intelligence of recommendation systems. As the complexity of information flow increases on social networks and digital platforms, hypergraph-based recommendation algorithms are expected to become an important part of personalized recommendation systems.

Secondly, the potential of hypergraphs in large-scale data processing and computational optimization is also worthy of attention. In the areas of hypergraph partitioning, matrix representation, and sparse matrix computation, more and more algorithms and optimization methods have been proposed (e.g., Akbudak *et al*., 2013) cache-aware matrix reordering method). As the scale of data continues to grow, efficiently partitioning hypergraphs and processing large-scale data will become one of

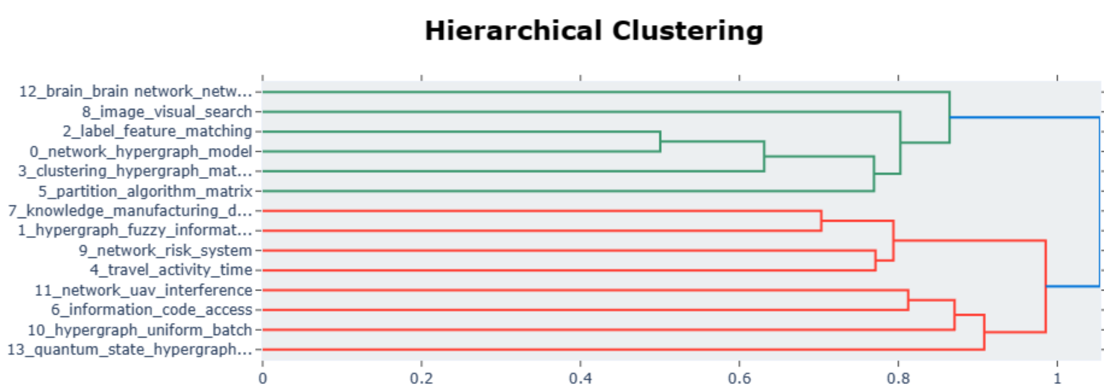

Figure 5: Topic Relationship Dendrogram for Information field Based on Hypergraphs.

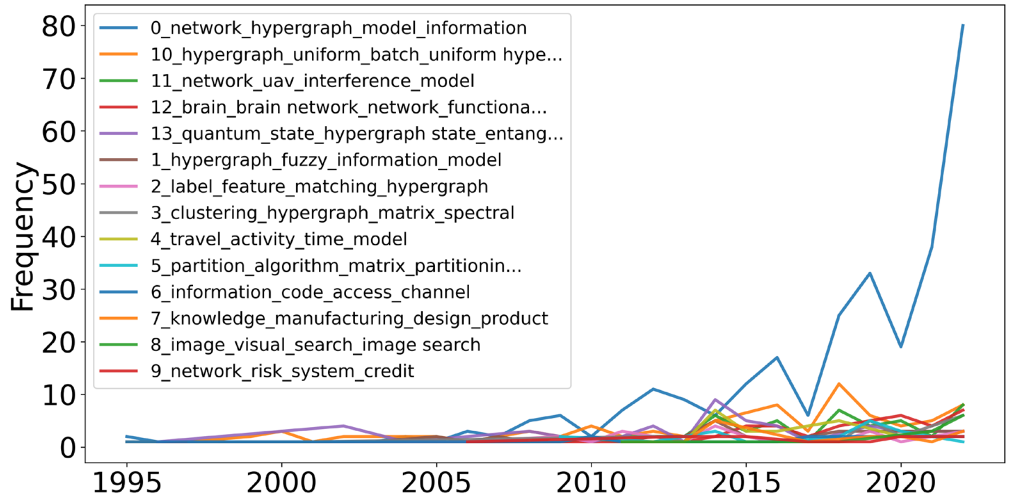

Figure 6: Evolution of Topic Intensity in Hypernetwork and Information Research Based on BERTopic.

the key challenges. In the future, the development of distributed computing and parallel processing technologies will drive further progress in this area, particularly in the efficient implementation of graph neural networks and hypergraph neural networks.

Third, cross-disciplinary fusion innovation will be an important direction to promote the development of hypernetwork research. As a flexible modeling tool, hypergraphs can effectively integrate knowledge and information from different fields, especially in the context of cross-disciplinary innovation environments (e.g., technological innovation, social innovation). For instance, the hypergraph-based co-creation network model proposed by (Wang *et al*., 2020) provides a new perspective for product innovation by integrating user, knowledge, and product information, promoting deeper co-creation and collaborative innovation. In the future, cross-disciplinary collaboration will further advance the application of hypergraphs in fields like ecology, economics, sociology, and more, facilitating knowledge sharing and integration.

Additionally, hypergraphs in quantum information science present a new direction for development. As quantum computing and quantum communication technologies continue to mature, hypergraph-based quantum information models can help address the complexity issues in existing quantum communications, such as entanglement and configuration of quantum states (Pal *et al*., 2006). In the future, with the progress of quantum technologies, hypergraph-based quantum information processing models may become essential tools to solve bottlenecks in quantum computing.

Finally, with the continuous development of intelligent systems and artificial intelligence technologies, self-supervised learning and deep learning methods will play an increasingly important role in learning and reasoning with hypergraphs. By combining self-supervised learning with graph neural networks, hypergraphs will be better able to handle and extract complex higher-order relationships, providing more accurate analysis and prediction capabilities for intelligent systems.

In summary, research on hypergraphs and hypernetworks will continue to expand their application areas and promote innovative development in fields such as information science, social networks, intelligent transportation, and quantum communication. Future research will not only focus on theoretical innovations but also demonstrate their powerful modeling and computational capabilities in practical applications. It is hoped that this study will provide theoretical guidance for future related research and further advance the application of hypergraphs in complex system modeling.

CONCLUSION

As the information age continues to evolve, the complexity and challenges of information field are increasingly growing. Traditional methods of information processing are no longer sufficient to meet the demands of large-scale, high-dimensional data management and analysis. Hypernetworks, as a new type of graph structure, bring fresh ideas and methods to the field of information field with their ability to model high-order, multi-level relationships. Through hypernetworks, we can gain a more comprehensive and accurate understanding of the complex relationships between data, thereby enhancing the intelligence and flexibility of information field systems.

This paper explores the application prospects of hypernetworks in information field and analyzes their potential in areas such as knowledge management, information retrieval, big data analysis, and intelligent decision support. With continuous advancements in technology and the expanding range of application scenarios, hypernetworks will play an increasingly important role in driving the innovation of information field systems, optimizing data flow, and promoting intelligent decision-making.

However, despite the broad application prospects of hypernetworks, there are still many technical and practical issues that need further exploration and resolution. For example, how to efficiently construct hypernetwork models in large-scale data, how to handle sparse relationships in hypernetworks, and how to integrate machine learning and deep learning algorithms to enhance the effectiveness of hypernetwork applications are all directions that deserve deeper research.

In the future, with the continued development of information field technologies, hypernetworks are expected to become one of the core technologies in the field of information field, driving the establishment and improvement of intelligent, collaborative information field systems. It is believed that in the near future, hypernetworks will have a profound impact on information field and decision support across various industries, becoming a key technology for realizing data-driven intelligent management.

Despite the contributions of this study, several limitations should be acknowledged. First, the analysis is based on publications retrieved from the Web of Science Core Collection, which may not fully capture relevant studies indexed in other databases or published in non-English venues. Second, the results of topic modeling are influenced by text representation choices and clustering parameters, which may affect topic granularity and boundary definition. Third, as with most scientometric studies, our findings reflect aggregated patterns in the literature rather than causal relationships.

Future research may address these limitations by incorporating multiple data sources, integrating alternative topic modeling approaches for robustness comparison, and combining quantitative mapping with qualitative expert evaluation. In addition, extending the analysis to social science-oriented databases could further enrich the understanding of hypernetwork research in knowledge management and library and information science contexts.

Ethical considerations were carefully taken into account in this study. All data analyzed were obtained from publicly available bibliographic databases, and no personal or sensitive information was involved. Nevertheless, we acknowledge that algorithmic modeling and topic interpretation may introduce biases related to data coverage, language, and model assumptions. We therefore emphasize the importance of responsible interpretation of scientometric results and caution against using such analyses as the sole basis for evaluative or policy decisions.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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