Postprint: Thematic Evolution and Interdisciplinary Research on Generative Artificial Intelligence

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Abstract

[Objective/Significance] Generative artificial intelligence has become a crucial driving force in the new wave of technological revolution and industrial transformation. Exploring its thematic evolution and interdisciplinary trends can provide valuable insights for the future development of researchers and related industrial sectors. [Method/Process] This paper conducts an analysis of thematic evolution and interdisciplinary trends based on literature data in the field of generative artificial intelligence from the Web of Science (WoS) Core Collection spanning 2014–2024, employing methods including statistical analysis, co-occurrence network analysis, and BERTopic topic clustering. [Results/Discussion] Overall, the research scale in the generative artificial intelligence field has expanded rapidly since 2022, with research topics diffusing to gradually cover nearly all disciplines. In terms of thematic evolution, technical methodology research has consistently maintained a dominant position, achieving gradual technological breakthroughs following the emergence of Transformer; ChatGPT has rapidly evolved into a hot topic, quickly finding applications in the medical and educational fields. Regarding interdisciplinary integration, the discipline of generative artificial intelligence is growing increasingly large in scale, with research papers exhibiting a trend of multidisciplinary fusion development; the interdisciplinary network centers on computer science and electrical engineering as core disciplines, progressively achieving cross-fertilization with medicine, materials science, physics, chemistry, mathematics, and other disciplines. To realize the development and application of generative artificial intelligence technology, conducting research on the principles, applicable problems, and application scenarios of technical methodologies for different disciplines has become essential.

Full Text

Topic Evolution and Interdisciplinary Research of Generative Artificial Intelligence

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Abstract: [Purpose/Significance] Generative Artificial Intelligence (GAI) has become a crucial driving force in the new wave of scientific and technological revolution and industrial transformation. Investigating its thematic evolution and interdisciplinary trends provides valuable references for researchers and future development across related industries. [Method/Process] This study analyzes the evolution of research themes and interdisciplinary integration trends in GAI based on literature data from the Web of Science (WoS) Core Collection spanning 2014-2024, employing statistical analysis, co-occurrence network analysis, and BERTopic thematic clustering. [Result/Conclusion] Overall, the research scale in GAI expanded rapidly after 2022, with research themes proliferating to cover nearly all disciplines. In terms of thematic evolution, technical methodology research has consistently dominated, achieving gradual breakthroughs following the emergence of Transformer. ChatGPT has rapidly emerged as a hot topic, quickly finding applications in medicine and education. Regarding interdisciplinarity, the scale of GAI-related disciplines continues to grow, with research papers demonstrating a trend toward multidisciplinary integration. The interdisciplinary network centers on computer science and electrical engineering, progressively achieving cross-fertilization with medicine, materials science, physics, chemistry, mathematics, and other fields. To realize GAI technology development and application, it has become essential to investigate the principles, applicable problems, and application scenarios of technical methods tailored to different disciplines.

Keywords: Generative artificial intelligence; Topic evolution; Interdisciplinarity; ChatGPT

Amidst the sweeping tide of digitalization, Generative Artificial Intelligence (GAI) has emerged as a shining star in the AI landscape, triggering a new round of technological revolution [**?**]. With the deep integration of big data, cloud computing, and deep learning technologies, human society is accelerating into an intelligent era, continuously expanding the boundaries of information generation and processing and broadening GAI application domains.

In recent years, GAI technologies and tools have found applications across education, healthcare, entertainment, arts, and numerous other fields. Examining the evolution of GAI holds significant importance for researchers to grasp cutting-edge technological directions and drive innovation and application. On one hand, analyzing thematic evolution trends helps dissect GAI' s developmental pathways and promote exploration of frontier technologies. On the other hand,

investigating interdisciplinary trends in GAI facilitates expanding disciplinary research boundaries, fostering collaborative innovation among computer science, electrical engineering, mathematics, and other disciplines, and promoting multidisciplinary knowledge flow, integration, and innovation.

Mapping the thematic evolution and interdisciplinary trends of GAI serves as a crucial means to understand and assess the field' s future development. Therefore, this study analyzes the evolution of research themes and interdisciplinary characteristics in GAI based on literature data from the WoS Core Collection (2014–2024), employing statistical analysis, co-occurrence network analysis, and thematic clustering to examine developmental trajectories and trends, thereby promoting further technological innovation and disciplinary collaboration in AI and its interdisciplinary domains.

1.1 Generative Artificial Intelligence Research

Generative artificial intelligence is a rapidly developing field that aims to learn the probability distribution of data through models capable of generating new samples similar to training data. This technology has widespread applications in images, text, audio, and other domains, demonstrating exceptional performance particularly in high-resolution image generation, design process optimization, and large language model applications.

The concept of GAI was not explicitly proposed at a specific moment but rather gradually evolved and formed with the development of artificial intelligence technologies. GAI' s development can be traced back to the 2013 introduction of Variational Auto-Encoders (VAE), which could encode data like autoencoders and decode to generate multiple new content variants, with early applications including anomaly detection (e.g., medical image analysis) and natural language generation [**?**]. In 2014, the emergence and development of Generative Adversarial Networks (GAN) [**?**] made it possible to generate relatively realistic images, text, and other content [**?**], greatly advancing GAI technology. In 2017, Google proposed the Transformer architecture [**?**], representing a major turning point in deep learning and considered one of the powerful foundation models underlying GAI tools. In applications of the Transformer model, Tu et al. [**?**] proposed SWCGAN by combining Swin Transformer and CNN advantages, providing a new method for remote sensing image super-resolution measurement. In 2022, text-to-image applications such as Dall-E2, Midjourney, and Stable Diffusion attracted widespread attention. By late December, the emergence of the ChatGPT generative large language model greatly promoted GAI applications in text generation, language translation, summarization, and multiple other domains. During 2023–2024, GAI rapidly became a research hotspot, with existing studies demonstrating its broad application across multiple research fields and driving the emergence of large model-based research paradigms [**?**]. Yao et al. [**?**] provided a novel perspective for observing and analyzing AI field development trends and research priorities through AI marker mining methods. Chen Xiaofeng et al. [**?**] demonstrated that GAI has been widely applied across all

aspects of scientific research, identifying potential issues such as content homogenization and academic fraud. Additionally, some scholars have explored future application scenarios of GAI, highlighting key unresolved issues including model interpretability, security, and sustainability [**?**, **?**].

In summary, while the exact timing of the first proposal of the term "generative artificial intelligence" is difficult to trace, its conceptual and technical foundations gradually formed and evolved during AI field development. From early rule-based exploration to statistical model-based content encoding and recent deep learning breakthroughs, GAI has progressively achieved domain-spanning from simple text generation to complex images, videos, audio, and even code. Particularly, large language model applications are profoundly transforming scientific research paradigms and multiple industries. However, alongside tremendous development opportunities, GAI also faces challenges in interpretability, bias, and ethics [**?**].

1.2 Research on Topic Evolution and Interdisciplinary Studies

Topic evolution research primarily includes methodological improvements and optimization of topic evolution analysis and application studies in specific domains, with detailed research content shown in Table 1 . Regarding methodological research, scholars have proposed numerous domain topic identification and evolution analysis methods based on scientific research data from internal and external disciplinary characteristics, promoting the application development of topic evolution analysis across different fields. For application studies in specific domains, scholars have employed thematic clustering techniques such as LDA and BERTopic to identify core topics in particular fields and analyze their evolution, thereby more accurately grasping development trends. Table 1 also reveals that topic evolution method research remains in the exploratory stage, with most practices adopting relatively mature thematic models.

Interdisciplinary research primarily includes methodological improvements and optimization of interdisciplinary analysis and application studies in specific domains, with detailed research content shown in Table 2 . Regarding methodological research, existing studies have promoted more quantitative and efficient interdisciplinary research through interdisciplinary measurement indicators, interdisciplinary characteristic analysis frameworks, and models. In practical applications, scholars have focused on revealing interdisciplinary phenomena in specific fields to clarify the objects and processes of interdisciplinary integration. Similar to topic evolution research, interdisciplinary characteristic method research remains exploratory, with most studies still employing relatively mature methods such as content analysis and statistical analysis.

In summary, research on topic evolution and interdisciplinarity in specific domains represents an important direction in current scientific research. However, studies specifically targeting GAI' s topic evolution and interdisciplinary characteristics are lacking. Scholars have applied advanced technical methods

to explore topic evolution and interdisciplinary phenomena within specific domains, providing directional guidance and decision-making support for related fields. Regarding methodological applications, co-occurrence network analysis is widely used in both topic evolution and interdisciplinary research, BERTopic represents a relatively mature and advanced technology for topic evolution analysis, and statistical analysis serves as a general research method for interdisciplinary characteristic analysis. Moreover, existing studies typically analyze topic evolution or interdisciplinarity from a single perspective in specific domains. From a research field perspective, GAI, as a technological frontier and research hotspot, focuses on technological innovation and application expansion, yet its core thematic development and interdisciplinary characteristics have not been comprehensively analyzed and discussed. Therefore, this study selects the GAI field to explore its thematic development trajectory and interdisciplinary characteristics from both topic evolution and interdisciplinary perspectives.

2.1 Basic Approach

To conduct GAI topic evolution and interdisciplinary analysis, this study builds upon literature bibliographic data in the field, constructs relevant datasets, and combines statistical analysis, co-occurrence network analysis, and topic clustering to perform domain research theme identification, evolution, and interdisciplinary integration analysis, thereby deeply analyzing research hotspots and interdisciplinary development trends in GAI. The specific approach is illustrated in Figure 1 [Figure 1: see original paper].

The core steps for topic evolution and interdisciplinary analysis are explained below:

(1) **Research Theme Identification**. Based on preprocessed abstract collections, the BERTopic model identifies themes for each year [**?**]. A pretrained BERT model converts abstract texts [**?**] into vector representations. Cosine similarity calculates similarity between abstract vectors. Due to high word vector dimensionality, dimensionality reduction is required, for which UMAP is selected. HDBSCAN further clusters the reduced abstract vectors to ultimately obtain research themes and their representative vocabulary documents for specific time periods.

(2) **Theme Similarity Calculation**. Based on research themes from different years, cosine similarity between adjacent time windows is calculated using representative vocabulary documents output from topic clustering results to construct a theme similarity matrix. Results with similarity greater than 0.3 are retained for theme evolution analysis, thereby examining the evolution trends of GAI thematic content over the past 11 years.

(3) **Disciplinary Co-occurrence Network Construction**. First, it should be noted that if a paper contains multiple disciplinary categories, these categories form co-occurrence relationships; if a paper belongs to only one disciplinary category, no co-occurrence relationship exists. Second,

disciplinary co-occurrence networks are constructed across different time windows. NetworkX calculates network structural characteristic values, and Gephi visualizes disciplinary cross-development changes.

2.2 Data Sources

Generative artificial intelligence gradually formed during AI development, achieved breakthroughs after the 2014 emergence of generative adversarial networks, and became a research hotspot in the past two years. Therefore, this study limits data collection to 2014 and onward. In the WoS Core Collection, the following retrieval strategy was formulated based on relevant concepts [**?**, **?**]: TS= "generative adversarial networks" OR TS= "variational autoencoders" OR TS= "natural language generation" OR TS= "image synthesis" OR TS= "generative artificial intelligence" OR TS= "generative AI" OR TS= "ChatGPT" OR TS= "large language model" . The search timeframe spans January 1, 2014, to October 30, 2024, with document type limited to "article," yielding 18,739 papers. Following data preprocessing principles [**?**], data not meeting research objectives were removed, resulting in 18,157 final records. The specific process is shown in Figure 2 [Figure 2: see original paper].

2.3 Research Stage Division

Given that this study focuses on the GAI field—where technological methods update rapidly with short cycles compared to other fields [**?**]—and time period divisions should not be overly dense or sparse [**?**], the following division was made based on key milestones in GAI development. The emergence of variational autoencoders and generative adversarial networks in 2013–2014 laid a solid foundation for GAI development. The Transformer architecture emerged in 2017, greatly advancing deep learning. OpenAI released ChatGPT on November 30, 2022, and formally launched its paid plan to users in February 2023. Based on these milestones, this study divides the dataset into 3-year time windows: 2014–2016 (pre-Transformer), 2017–2019 (post-Transformer), 2020–2022 (pre-ChatGPT), and 2023–2024 (post-ChatGPT).

3.1 Overview of Generative Artificial Intelligence Publications

This study compiled statistics on basic domain information. Descriptive statistics on the number of publications in GAI from 2014–2024 are shown in Figure 3 [Figure 3: see original paper].

Following the emergence of Transformer architecture, the number of GAI publications grew rapidly. As shown in Figure 3, publication growth was slow before 2017. After the 2017 Transformer architecture emergence, which greatly improved natural language processing efficiency and effectiveness and gradually expanded to computer vision, audio processing, and other technical domains, publication numbers began growing by hundreds annually. Following ChatGPT' s emergence in late 2022, GAI publications grew by thousands annually,

far exceeding the growth rate during 2018–2022.

3.2 Generative Artificial Intelligence Topic Evolution Analysis

Based on BERTopic clustering results, the thematic content and scale across time windows are shown in Table 3 .

Between 2014–2024, driven by deep learning technology, GAI research themes gradually diffused into multiple domains, rapidly focusing on generative AI models after ChatGPT' s emergence. Table 3 shows four time windows. From the perspective of key GAI technological milestones, during 2014–2016, GAI was in the preliminary exploration stage, primarily focusing on image synthesis and text generation. During 2017–2019, the Transformer architecture' s emergence prompted initial GAI development, with attention to image synthesis, text generation, and data model training optimization, while beginning to apply GAI technology to biomedicine, such as medical image segmentation and HiC data processing. During 2020–2022, building on previous stages, GAI technology achieved rapid development and gradual application in medical imaging, traffic data monitoring, risk prediction, engineering, materials science, and other domains. During 2023–2024, GAI rapidly became a research hotspot after ChatGPT' s emergence, forming a new paradigm represented by large language models and quickly finding applications in medical research.

Further extracting themes with cosine similarity greater than 0.3 across adjacent time windows, the topic evolution path is illustrated in Figure 4 [Figure 4: see original paper].

Between 2014–2024, GAI research themes evolved from technological innovation and breakthroughs to domain applications and then to major technological breakthroughs.

At the technical theme level, research themes involving algorithms and models demonstrate strong continuity and vitality, with GAI technology continuously innovating and optimizing alongside AI technological upgrades. As shown in Figure 4, themes related to image and text generation and model training emerged continuously throughout 2014–2024, focusing primarily on model iteration optimization and performance enhancement, providing the technical foundation and prerequisites for GAI innovation breakthroughs.

At the application theme level, GAI technology applications in medical image processing, diagnosis, and treatment have continued to deepen, while personalized scenario applications of large language models like ChatGPT remain in the exploration stage. As shown in Figure 4, examining ChatGPT as a typical GAI representative, the 2023–2024 themes focused on this area by inheriting and integrating multiple themes from 2020–2022. Through continuous technological fusion and innovation, new GAI technology breakthroughs have been achieved, with ChatGPT applications in education realized within a short timeframe. As GAI explores applications in medical Q&A [**?**] and pharmaceutical scientific

research [**?**], developing GAI technologies for specific scenarios represents a development direction in the AI field.

3.3 Quantitative Characteristics of Interdisciplinary Research in Generative Artificial Intelligence

Using the number of disciplines involved in all sample papers each year as the statistical object, the changing trend of disciplinary categories in GAI over the past 11 years is shown in Figure 5 [Figure 5: see original paper].

Disciplinary participation in GAI research has gradually increased, with nearly all disciplines engaging in GAI-related research after ChatGPT' s emergence. As shown in Figure 5, the number of disciplinary categories involved in GAI has grown rapidly. The WoS disciplinary category count remains approximately 254, indicating that since 2023, virtually all disciplines have conducted GAI-related research.

Statistical analysis was conducted on papers involving more than two disciplines, and the proportion of papers with different numbers of interdisciplinary integrations was calculated relative to the total number of papers, as shown in Figure 6 [Figure 6: see original paper].

The maturation of Transformer models and GAN technology has driven interdisciplinary integration trends in GAI, with the number of interdisciplinary studies steadily increasing. Figure 6 reveals several patterns: First, the maximum number of disciplines involved in a single paper is six, with the proportion of six-discipline integration papers continuing to rise, particularly showing a clear upward trend since 2020. Second, four- and five-discipline integration trends resemble six-discipline integration, with obvious upward trends in proportions after 2019. Third, the proportion of two- and three-discipline integration papers gradually declined after 2019. Further analysis indicates that natural language processing achieved tremendous leaps in 2019, with Transformer models gaining dominance in NLP while GAN technology evolved to generate high-resolution, indistinguishable faces, driving multidisciplinary integration and application of GAI. Overall, GAI demonstrates a trend toward multidisciplinary integration, evidenced by the gradual shift from two- and three-discipline integration to four-, five-, and six-discipline integration in papers.

3.4 Development Path of Interdisciplinary Research in Generative Artificial Intelligence

Based on data from the four time windows, disciplinary co-occurrence networks were constructed, and basic network structural metrics including node count, edge count, and network density were calculated, as detailed in Table 4 .

The scale, integration degree, and disciplinary influence of GAI interdisciplinary research have gradually expanded. Table 4 reveals three key trends: First, the scale of interdisciplinary research in GAI has gradually increased, with growing

numbers of nodes and edges and increasing disciplinary nodes and co-occurrence frequencies. Second, interdisciplinary integration in GAI has diversified. While the scale expanded, network density continuously decreased, indicating that more disciplines are participating in interdisciplinary research with more dispersed research directions. As AI technological methods mature, an increasing number of disciplines require theories and methods from other disciplines to solve their own problems. Third, influential disciplines have gradually emerged in GAI, forming a relatively stable disciplinary system. Average degree centrality and average closeness centrality have gradually increased, indicating the emergence of disciplines with significant local and global influence. Meanwhile, average betweenness centrality has gradually decreased, possibly because various disciplines have developed more autonomous research capabilities.

Based on the interdisciplinary co-occurrence network, the top 50% of edges by weight were selected for visualization, as shown in Figure 7 [Figure 7: see original paper].

Overall, the quantity and depth of GAI interdisciplinary integration continue to increase. Specifically, core foundational disciplines include computer science and electrical engineering, with major interdisciplinary fields comprising medicine, materials science, physics, chemistry, and mathematics. In recent years, interdisciplinary fields have expanded to environmental science, agricultural science, finance, and others, broadening the scope of cross-disciplinary applications.

During 2014–2016, GAI was in the theoretical exploration and preliminary application stage, with an interdisciplinary network already formed. Core disciplines primarily included computer science and electrical engineering, laying the theoretical foundation for GAI development.

During 2017–2019, with enhanced big data and computing capabilities, GAI began to be applied in image processing and other domains, with interdisciplinary integration deepening. Core disciplines included computer science and electrical engineering, while materials science, biology, and chemistry became important interdisciplinary fields.

During 2020–2022, breakthroughs in deep learning technology greatly advanced GAI development, with interdisciplinary integration networks becoming more complex and tightly connected. Core disciplines included computer science, artificial intelligence science, and electrical engineering. GAI interdisciplinary integration accelerated, with rapid development in application research across medicine, environmental science, materials science, chemistry, biology, mathematics, and other disciplines.

During 2023–2024, GAI has gradually achieved deep integration with more disciplines, forming a more complex and diversified interdisciplinary network. Core disciplines include computer science, electrical engineering, artificial intelligence science, and biomedical sciences. In interdisciplinary integration, GAI has been widely applied in finance, healthcare, environmental protection, education, and

other industries, gradually forming industry-specific personalized solutions and application scenarios.

4 Summary and Discussion

This study examines GAI' s developmental pathways and evolution trends from the perspectives of topic evolution and interdisciplinarity, based on nearly 11 years of literature data from the WoS Core Collection, using statistical analysis, network co-occurrence analysis, and topic clustering. The aim is to provide directional guidance for scholars in related fields and help China gain initiative in the new round of scientific and technological revolution.

The main conclusions are as follows: First, GAI research is in a period of rapid development, with continuously expanding research themes, scale, and influence across a broad range of disciplines. Second, GAI development exhibits technological coherence, with strong thematic continuity and substantial content scale. Technological breakthroughs are reflected in gradual innovation and optimization in image generation following the Transformer architecture's emergence, and revolutionary breakthroughs realized through ChatGPT' s appearance. Third, technological innovation constitutes the core of GAI development. The growth of ChatGPT and similar GAI models relies on AI technological progress, rapidly emerging as hot topics and quickly expanding into medical and educational applications, with clear trends toward personalized scenarios. Fourth, interdisciplinary trends in GAI continue to rise, with recent research covering nearly all disciplines and increasing numbers of interdisciplinary papers. Fifth, interdisciplinary application fields of GAI continue to expand. The interdisciplinary network centered on computer science and electrical engineering continues to grow, with deepening applications in biomedicine, materials science, education, and other domains.

Based on these findings, we further discuss GAI development trends. First, technological advancement and performance improvement: As GAI algorithms and models continue to strengthen, such as through multimodal technology development [**?**], more new technologies and methods will emerge, further diffusing and transforming research themes. Second, continuous deepening of technical methodology research: As GAI technology advances and application scenarios expand, ethical and moral issues will gradually emerge [**?**], necessitating in-depth investigation into core principles and applicable scenarios of domain technical methods to formulate policies and laws more scientifically and targeted. Third, deepening cross-industry applications: Thematic evolution and interdisciplinary analysis show that GAI has played important roles in healthcare, finance, education, and numerous other industries [**?**], with application domains continuing to deepen and expand.

This study has several limitations. First, the data collection strategy focused on themes directly related to GAI. Since AI technology constitutes the foundational condition for GAI development with broader research themes and in-

terdisciplinary scope, our dataset may have omitted some GAI-related content. Second, this study analyzed only scientific literature data, which has certain time lags and may not fully capture the latest GAI developments.

Therefore, future research should consider integrating multi-source data including papers, patents, conference reports, and social media to expand the GAI dataset and fuse multiple data types, thereby obtaining higher-quality results and better understanding GAI development trends.

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Note: Figure translations are in progress. See original paper for figures.