Research Article

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Global Trends and Collaboration Dynamics in Large Language Model Research: A Bibliometric Analysis

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ABSTRACT

Large Language Models (LLMs) have spearheaded a significant transformation in artificial intelligence, rapidly becoming a focal point of scientific research. This study aims to comprehensively analyze the intellectual structure and temporal evolution of scientific publications on LLMs using bibliometric methods. The research data comprises 10,321 articles that met the specified criteria, retrieved from the Web of Science (WoS) Core Collection database using the search term "large language model". Performance analysis and science mapping techniques were applied using VOSviewer software for data analysis and visualization. Within this scope, co-authorship, co-citation, and keyword co-occurrence analyses were conducted to identify the key actors, collaboration networks, intellectual foundations, and primary research topics in the field. The analysis reveals that the field has shown exponential growth since 2023, is shaped by the leadership of the USA, and China and is rapidly expanding beyond its theoretical core into applied areas like medicine and education.

1. Introduction

Recent breakthroughs in artificial intelligence indicate a significant transformation that is dramatically affecting technological development. Large Language Models (LLMs) are pivotal to this shift, demonstrating advanced capacities in comprehending, interpreting, and producing natural language [1,2]. These deep learning models, containing billions or even trillions of parameters, are trained on extensive text datasets via self-supervised learning techniques [3]. LLMs have transformed the capabilities of artificial intelligence by exhibiting exceptional skill in several tasks, such as text generation, document summarization, cross-lingual translation, intricate question answering, and computer code generation [4].

The basis of this technological advancement is the Transformer architecture, presented by Vaswani et al. in 2017 [5]. In contrast to conventional Recurrent Neural Networks (RNNs), the Transformer architecture utilizes a "self-attention" mechanism that interprets text sequences holistically rather than in a sequential manner. This method facilitates enhanced modeling of long-range and intricate contextual interactions among words in a text, while markedly expediting training procedures via parallel processing capabilities [3,5]. This has facilitated the creation of models with hundreds of billions of parameters, including Bidirectional Encoder Representations from Transformers (BERT), the Generative Pre-trained Transformer (GPT) series, LLaMA, and PaLM [6,7].

The revolutionary potential of LLMs has been extensively acknowledged throughout the scholarly community. Research on LLM applications has demonstrated exponential growth in recent years, encompassing a wide range of areas including personalized diagnosis and treatment in medicine [8], automation of code generation and debugging in software engineering [9], development of customized learning experiences in education [10], and text analysis in the social sciences [11]. The rise of widely used models such as ChatGPT has prompted a swift increase in academic articles featuring the term "large language model" and its derivatives, resulting in an extensive and evolving body of literature [12-15].

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The swift and substantial growth of literature complicates the understanding of the field's current status, conceptual underpinnings, and research directions through conventional narrative review techniques. Naveed et al. observe that "the rapid developments and frequent breakthroughs in LLM research have rendered it challenging to grasp the overarching advancements in this field" [15]. Narrative reviews are inherently vulnerable to author bias, selective literature utilization, and subjective interpretation, which may be insufficient for offering a comprehensive viewpoint on this dynamic and diverse topic [16,17].

To overcome these challenges, bibliometric analysis, which employs mathematical and statistical tools to analyze large volumes of bibliographic data, has gained increasing prominence [17,18]. Bibliometric analysis offers the advantage of summarizing the developmental trends, intellectual structure, and core dynamics of a research field in an objective, comprehensive, and quantitative manner [17]. In contrast to the subjective nature of traditional reviews, this method provides a reproducible and transparent methodology for mapping the scientific landscape of a field [16,18]. This study will adopt two primary bibliometric approaches to map the LLM research area: Performance Analysis to identify the most productive and influential actors and Science Mapping to visualize the field's intellectual structure. The science mapping will involve analyses such as co-authorship, keyword co-occurrence, co-citation, and bibliographic coupling [17,18].

A review of the existing literature on LLMs reveals that a significant portion of bibliometric analyses focuses on more limited and specific areas rather than the entire field (Table 1). These studies typically concentrate on a particular application domain (e.g., medicine and health [8,19], software engineering [9], education [20,21]), a specific tool (e.g., ChatGPT [10,13,15,20,21]), or a related but broader concept such as "generative artificial intelligence" [22,23].

Table 1. Comparative summary of bibliometric analyses on large language models and related topics

Study (Author, Year)	Database	Focus Area/Topic	Time Period	Key Findings/Features
Damayanti et al. (2025) [9]	Scopus & WoS	LLMs in Software Engineering	2023-2024	Focus on software engineering education and code generation; weak international collaboration.
Gencer & Gencer (2025) [8]	WoS	LLMs in Healthcare Services	2021-2024	Increasing use in medical diagnosis and clinical documentation; leadership from USA, Germany, and UK.
Koo (2025) [15]	WoS	ChatGPT Research	2023-2024	Prominence of topics in education, medicine, and ethics; USA and China as most productive countries.
Oliński et al. (2024) [10]	Scopus	ChatGPT in Social Sciences	2023	Highlights the diversity of ethical, technological, and sociological perspectives in social sciences.
Ersöz et al. (2024) [22]	WoS	Generative Artificial Intelligence	2020-2024	Shows rapid growth in publications on Generative AI, led by computer science and engineering.
Fan et al. (2024) [12]	WoS	LLMs (General)	2017-2023	Summarizes trends in core algorithms, tasks, and vertical domains based on

				over 5000 articles.
This Study	WoS	LLMs (General)	2020-2025	Aims to deeply map the holistic intellectual structure and thematic evolution of the field using science mapping methods (co-citation, bibliographic coupling, etc.).

To this end, the study will seek to answer the following research questions:

1. What is the trend in publication and citation performance of LLM research over the years?
2. Who are the most productive and influential (most cited) authors, institutions, countries, and journals in LLM research?
3. What is the structure of the global collaboration network among authors, institutions, and countries, and which actors play a central role in this network?
4. What are the foundational studies (most co-cited) that form the intellectual basis of LLM research?
5. What are the main thematic clusters and current research hotspots in LLM research? How have these themes evolved over time?

2. Materials and Methods

This study adopts a bibliometric analysis method to map the intellectual structure and evolution of scientific output in the LLM field. Bibliometric analysis is a powerful tool for overcoming the subjective nature of traditional literature reviews by providing a quantitative panorama of a research area through the statistical analysis of publication and citation data [17,18].

2.1. Research scope and data collection process

The dataset for this research was obtained from the Web of Science (WoS) Core Collection database, which is considered a standard for bibliometric analyses due to its coverage of interdisciplinary and high-impact publications [24, 25]. The data collection was performed on June 2, 2025.

The search strategy was designed to capture the terminological core of the field. The following query was used in the "Topic" field of WoS (which includes article title, abstract, author keywords, and Keywords Plus):

TS=("large language model" OR "large language models")

The initial query yielded a total of 22,766 publications of various types. To ensure the scope and consistency of the analysis, the dataset was limited to "articles" that have undergone peer review and represent the matured body of knowledge in the field. After this filtering process, the final dataset for analysis consisted of 10,321 articles.

2.2. Data analysis and visualization

Bibliographic data were analyzed and visualized using VOSviewer. VOSviewer is a prominent tool in the literature, recognized for its sophisticated functionalities in constructing, displaying, and analyzing bibliometric networks [25,26]. The subsequent analyses were performed to address the study questions:

- **Performance Analysis:** The temporal development of the research field was determined by examining the annual distribution of publications. The most productive and influential authors, institutions, countries, and journals were identified.

- **Science Mapping:** Diverse network analyses were employed to elucidate the intellectual and social architecture of the discipline. This encompassed co-authorship analysis to elucidate scientific collaboration networks, co-citation analysis to pinpoint foundational works constituting the intellectual framework of the field, bibliographic coupling to delineate contemporary research fronts, and keyword co-occurrence analysis

to ascertain thematic structures.

3. Findings

This section presents the findings from the bibliometric analysis of scientific publications on LLMs. The analyses reveal the research area's temporal development, interdisciplinary nature, key actors, intellectual foundations, and current thematic focuses.

3.1. Annual growth of publications

An examination of the temporal trend of academic publications on LLMs reveals that the research area is exhibiting a highly dynamic and exponential growth pattern. While academic interest in the topic was quite limited until 2022 (a total of 32 articles), a significant turning point occurred in 2023, with the number of publications soaring to 750. This sudden increase can be interpreted as an academic reflection of the release of advanced and widely accessible LLMs like ChatGPT at the end of 2022.

The most striking finding of this research is the acceleration observed in 2024 and 2025. In 2024, the number of publications increased more than fivefold compared to the previous year, reaching 4,121. More importantly, as of the data collection date of June 2, 2025, the number of articles published in the first five months of the year (4,494) had already surpassed the total output of the entire year of 2024 (4,121). This indicates accelerating momentum, with LLMs becoming a remarkably productive research topic (Figure 1).

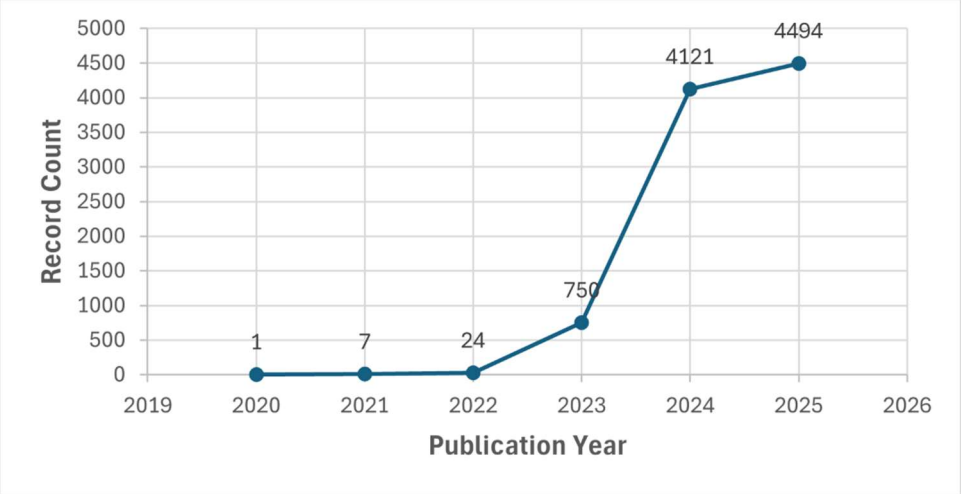

Figure 1. Annual change in the number of articles on LLMs

3.2. Disciplinary distribution of publications

To understand the position and impact of LLM research within the scientific landscape, the Web of Science (WoS) categories of the published articles were examined. The findings confirm that, as expected, the core of LLM research lies within computer science and engineering disciplines, such as "Computer Science, Information Systems" (1,840 articles), "Computer Science, Artificial Intelligence" (1,500 articles), and "Engineering, Electrical & Electronic" (1,342 articles). These categories indicate that the fundamental algorithmic and theoretical infrastructure of the technology is being developed in these fields.

However, a significant result of the analysis is the pronounced interdisciplinary nature of the subject. The high ranking of diverse fields such as "Medical Informatics" (708), "Health Care Sciences & Services" (625), "Education & Educational Research" (362), and "Linguistics" (199) demonstrate that LLMs have transcended their role as a theoretical model. This distribution reveals that technology is being actively adopted to solve practical problems in various sectors, including medicine, education, and the social sciences. The inclusion of the "Multidisciplinary Sciences" category with 550 publications further confirms the strength of this interdisciplinary interaction (Figure 2).

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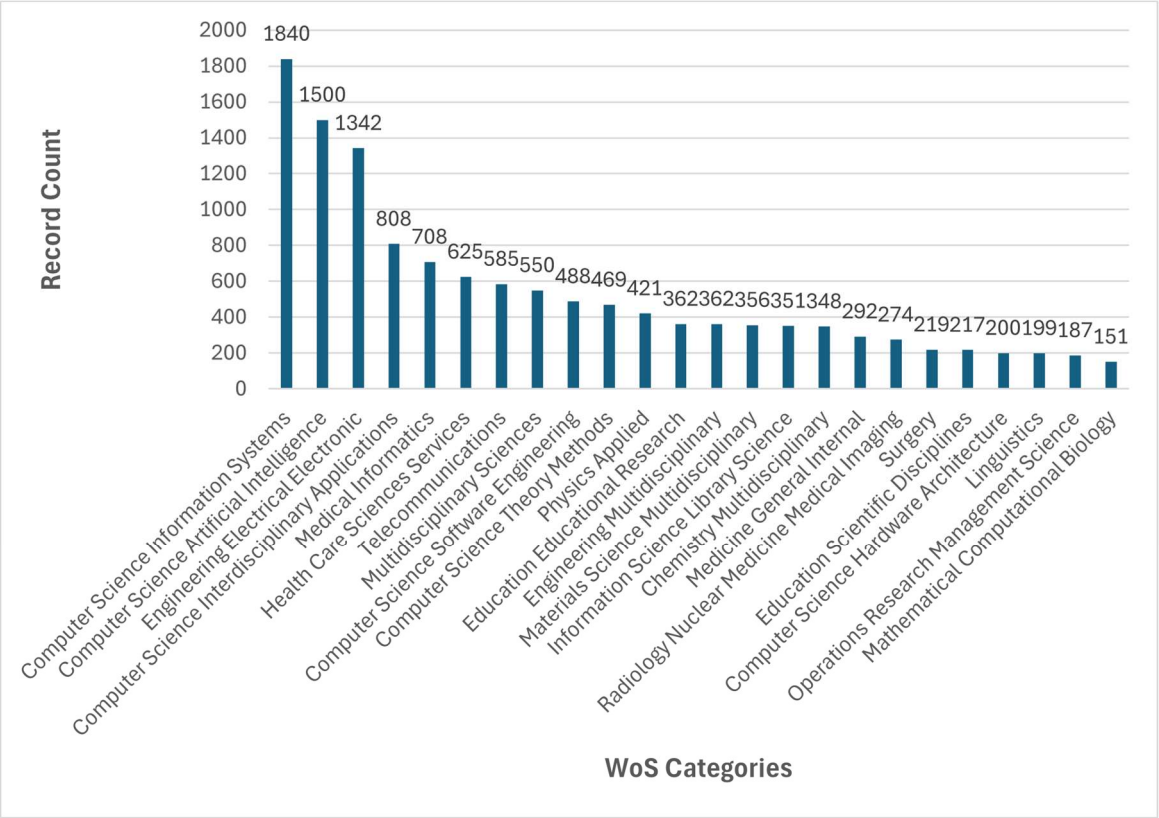

Figure 2. Distribution of LLM articles by web of science categories

3.3. Scientific collaboration networks: co-authorship analysis

Co-authorship analysis was conducted to identify the scientific collaboration network among researchers and the central actors within this network. The analysis, based on authors with at least 15 publications, revealed the collaboration dynamics in the field. Authors with the highest total link strength emerge as the most central and collaborative researchers. According to this metric, Xu, Hua (total link strength: 100), Liu, Tianming (99), and Liu, Wei (87) were identified as the most collaborative figures.

In terms of productivity, Klang, Eyal (23 articles) is the most prolific author, followed by Seth, Ishith (20 articles) and Li, Xiang (19 articles). The fact that highly collaborative authors like Xu, Hua and Liu, Wei are also among the most productive suggests a potential positive correlation between productivity and collaboration in the field.

In contrast, an examination of citation counts, which reflects research impact, reveals a different profile. The most cited author is Mesko, Bertalan (751 citations), whose total link strength in the co-authorship network is zero. This suggests his impact may stem from niche or interdisciplinary work outside large collaboration networks. This finding indicates that research impact is not always directly correlated with the highest productivity or the most intensive collaboration, highlighting the existence of different author profiles and impact mechanisms in the field (Figure 3).

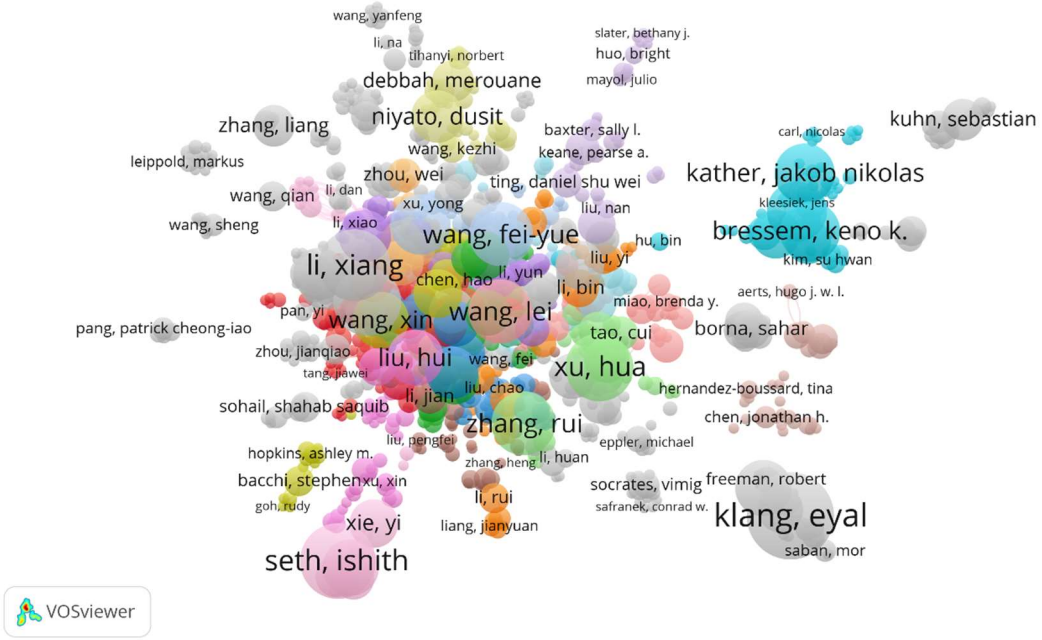

Figure 3. Co-authorship network map in the LLM field

3.4. Intellectual influence flow: author citation analysis

To map the intellectual influence structure and the flow of scientific ideas in the LLM field, an author-to-author citation analysis was performed. Based on citation counts, the leading authors shaping the scientific agenda of the field are Mesko, Bertalan with 751 citations, Liu, Siru with 689 citations, and Yu, Philip S. with 581 citations. The work of these authors plays a pivotal role in shaping the current literature.

When compared with the co-authorship analysis, it was observed that the authors with the highest citation counts are not necessarily the actors with the most extensive collaboration networks. For example, the fact that Mesko, Bertalan, the most cited author, does not hold a central position in the co-authorship network suggests that a researcher's scientific impact may not be directly proportional to their participation in large collaboration networks. This finding demonstrates that original work conducted by individuals or small groups also has the potential to create high impact in the field (Figure 4).

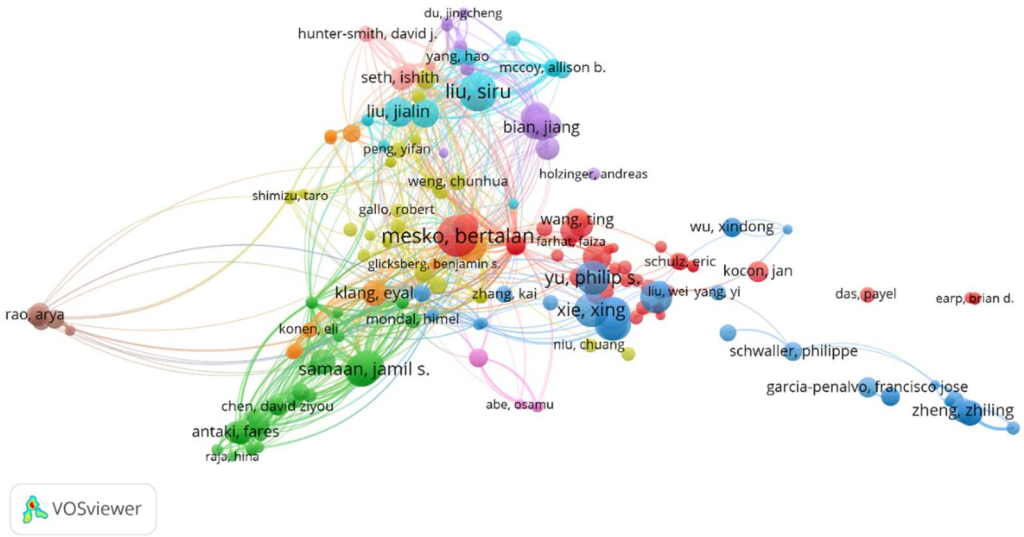

Figure 4. Author citation network map in the LLM field

3.5. Global distribution of scientific impact: country and institution analyses

An examination of the global distribution of scientific impact reveals that the United States leads with 31,848 citations, receiving nearly three times more citations than the People's Republic of China (11,138 citations). The United Kingdom ranks third with 8,506 citations. The USA is also the most productive country with 3,116 publications, indicating that its high productivity translates into a high number of citations. However, the fact that the UK (709 publications) receives more citations than Germany (712 publications) despite having a similar number of publications suggests a higher average citation impact for UK-affiliated publications (Figure 5).

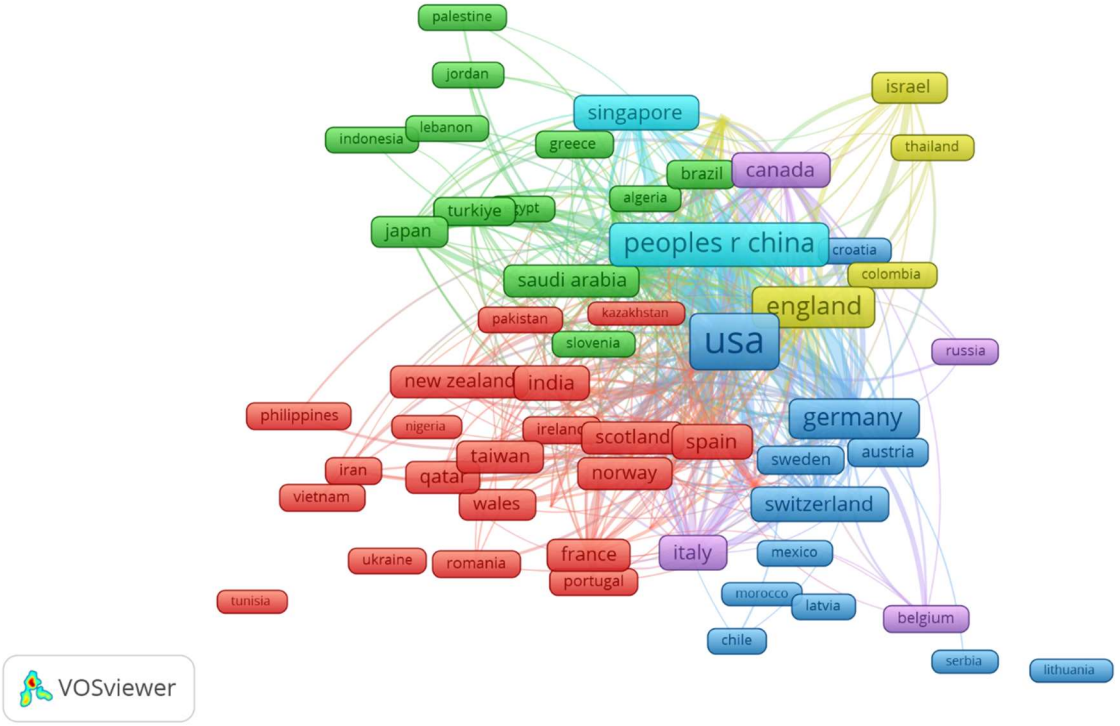

Figure 5. Country citation network map in the LLM field

A similar trend is evident at the institutional level. Stanford University (USA) leads the field in both productivity and impact, with 179 publications and 3,652 citations. It is followed by the Massachusetts Institute of Technology (MIT) (85 publications, 2,377 citations) and New York University (NYU) (65 publications, 2,070 citations). The ability of institutions like MIT and NYU to achieve high citation counts with fewer publications than Stanford indicates the high average impact of the research produced at these institutions (Figure 6).

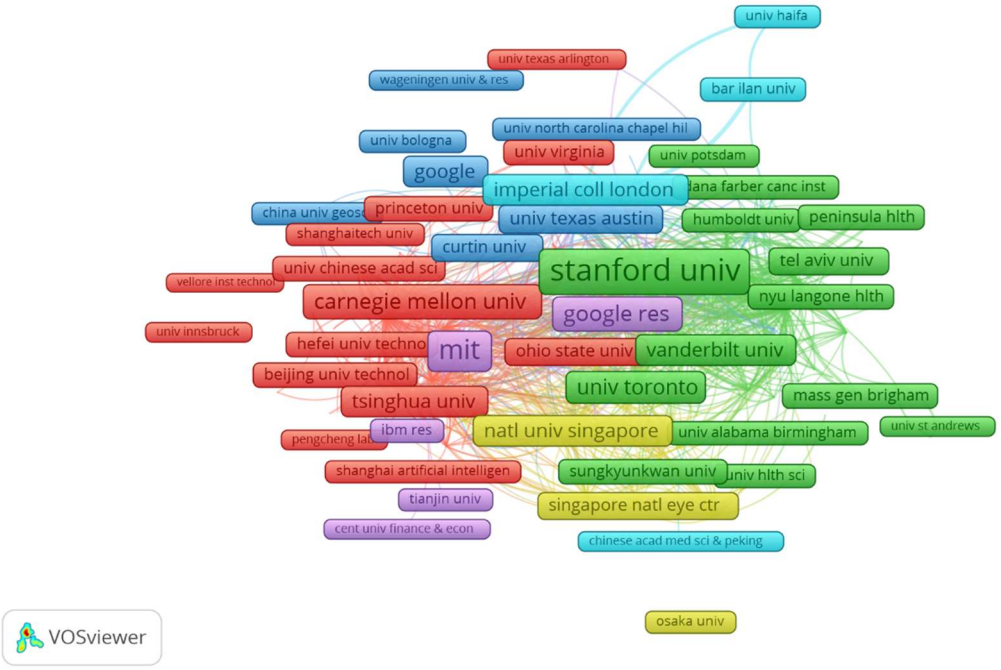

Figure 6. Institution citation network map in the LLM field

3.6. Conceptual structure of the field: keyword analysis

Keyword co-occurrence analysis, used to determine the conceptual structure and thematic focuses of LLM research, reveals a multi-layered structure. The network map (Figure 7) illustrates a research landscape that develops around interrelated yet distinct thematic clusters:

- **Core Concepts and NLP Tasks (Blue Cluster):** Located at the center of the map, this cluster forms the theoretical and technical backbone of the field, featuring fundamental concepts like "large language models" and "natural language processing" alongside core NLP tasks such as "sentiment analysis" and "information extraction."

- **Technical Architecture and Advanced Applications (Red Cluster):** This cluster combines technical infrastructure elements like "transformers" and "reinforcement learning" with advanced application areas such as "robotics" and "software," highlighting the potential of LLMs to transform fields like autonomous systems.

- **Societal Impacts and Human-AI Interaction (Green Cluster):** This cluster focuses on the role of technology in education with terms like "education" and "higher education," while also representing research centered on human-AI interaction, societal impact, and ethical dimensions through concepts like "ai ethics," "impact," and "chatbot."

- **Medicine and Health Applications (Yellow and Purple Clusters):** Keywords such as "clinical decision support," "diagnosis," and "surgery" indicate the rapid integration of LLMs into the medical and healthcare services sector and show that they are being actively researched for critical applications in this area.

This thematic distribution proves that while the LLM field is shaped around a solid technical core, its influence is rapidly expanding into interdisciplinary areas such as medicine, education, and robotics.

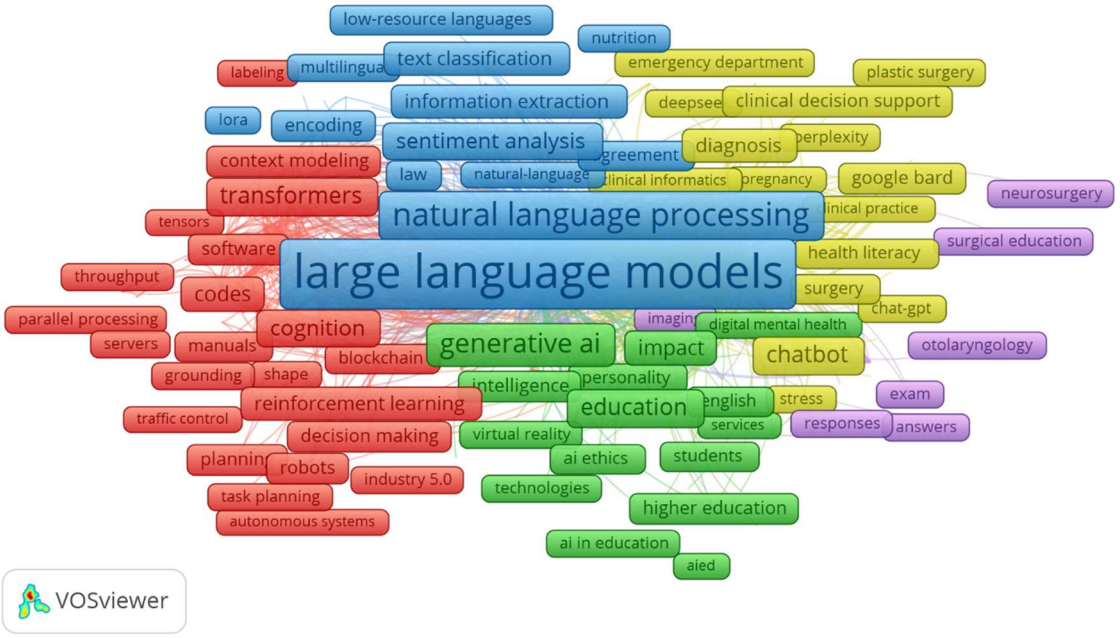

Figure 7. Co-occurrence map of keywords used in publications

3.7. Current research fronts: bibliographic coupling analysis

Bibliographic coupling analysis, used to identify current research fronts in a field, groups studies and authors that share common references. In the analysis at the publication level (Figure 8), a distinction was observed between the most cited publications (e.g., Lin, 2023b; Dwivedi, 2023) and those with the highest link strength in the network, which play a central role within current research clusters (e.g., Chang, 2024b; Min, 2024). This indicates that while citation count reflects a publication's established impact, link strength better represents its role as an intellectual bridge within an active research stream.

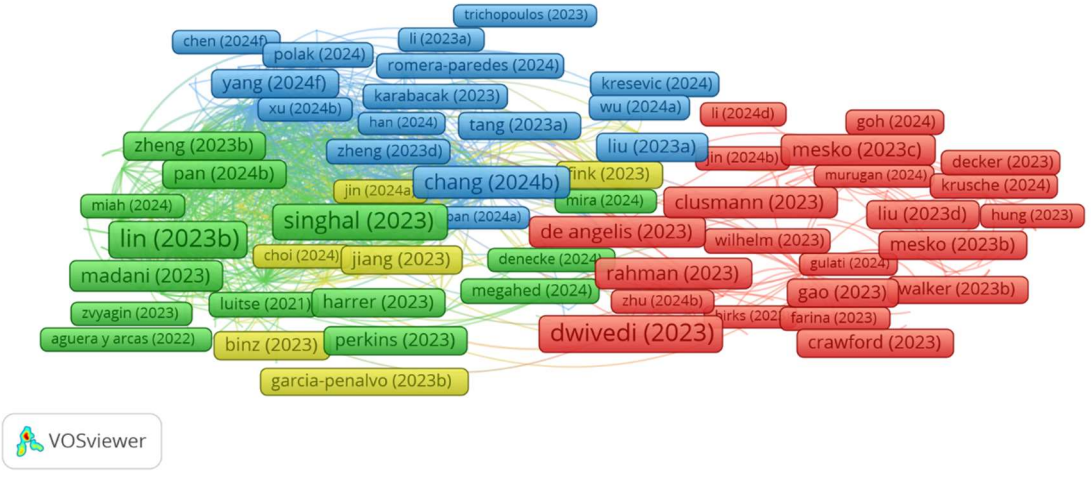

Figure 8. Bibliographic coupling network map of publications

A similar analysis at the author level (Figure 9) confirms this finding. Liu, Siru stands out with both a high citation count and high link strength, showing that she is a central figure in current research fronts as well as having high overall impact. In contrast, the fact that Kather, Jakob Nikolas, who has the highest link strength, is not among the top three most cited authors reveals that this author and his associated research group are leading a specific and highly active research front within the LLM field.

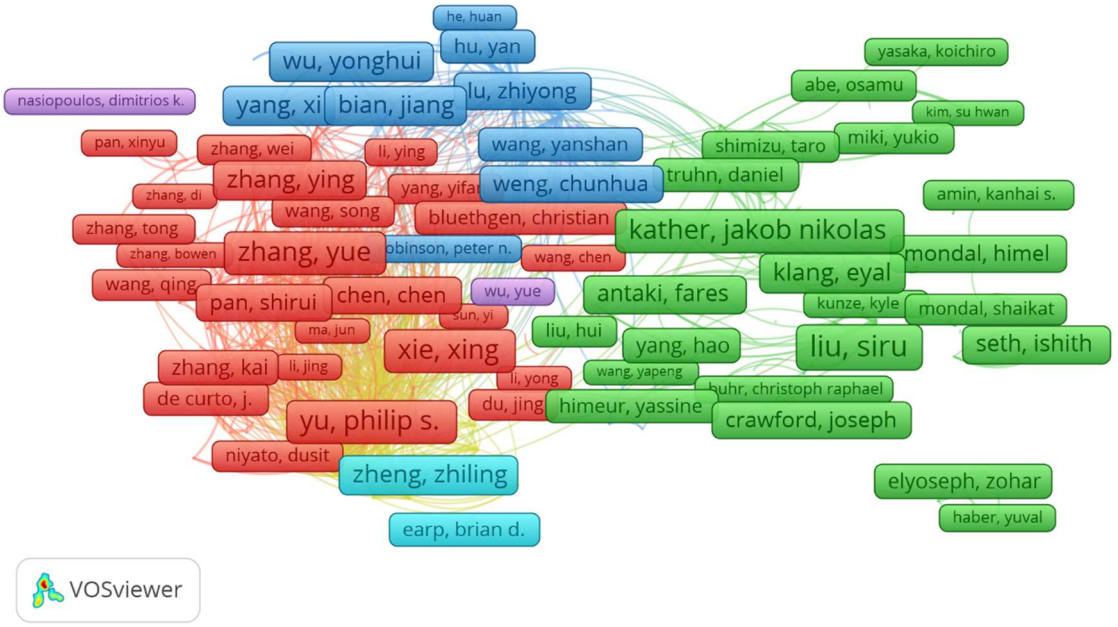

Figure 9. Bibliographic coupling network map of authors

4. Results and Discussion

LLMs have triggered a paradigm shift in artificial intelligence, generating extensive scientific literature in a very short period. This rapid and comprehensive growth makes it difficult to grasp the field's general trends, intellectual foundations, and future trajectory using conventional methods. In this context, this study aimed to map the intellectual structure and evolution of "large language model" research through a bibliometric analysis of 10,321 articles from the Web of Science (WoS) Core Collection database.

The findings of this study offer significant implications for the current dynamics and future of LLM research. First, the extraordinary and accelerating momentum of scientific production in the field is noteworthy. Academic interest has grown exponentially, especially after late 2022, with the proliferation of advanced and accessible models. The fact that the number of articles produced in the first five months of 2025 has already surpassed the total for the entire previous year is evidence that research activities in this area are continuing at an unprecedented pace.

The global distribution of scientific production indicates that the United States leads in publication volume and citations, with China and the United Kingdom following in rank. The dominance of US-based institutions, including Stanford University, MIT, and NYU, is evident at the institutional level. This suggests that these actors are pivotal in the advancement of LLM technology and in influencing its scientific agenda.

This study has demonstrated the complex dimensions of scientific impact within a research domain. The results indicate that the most prominent authors do not necessarily participate in the largest collaboration networks. The observation that Mesko, Bertalan, the most cited author, is not central in the co-authorship network indicates that original research by individuals or small groups can serve as a significant reference in the literature. This indicates that influence in the LLM domain arises from a broad range of sources, encompassing both individual contributions and extensive collaborative networks.

Keyword analysis and the distribution of WoS categories indicate that the conceptual structure of LLM research is anchored in a robust technical core and is swiftly expanding its impact on other fields. Computer science and engineering provide the theoretical foundation of technology; however, the prominence of fields such as medicine, education, and ethics in publications and discussions indicates that LLMs have emerged as a crucial technology for addressing practical issues.

Bibliographic coupling analysis has mapped the current research fronts of the field. This analysis revealed a distinction between highly cited publications with established impact and those with a central position in the network that are shaping current debates. This finding offers researchers a roadmap not only to identify the foundational works of the field but also to track the central publications that guide active research streams and inspire new studies.

From an engineering and applied science perspective, these findings provide a strategic macro-level view of the LLM landscape. The emergence of distinct keyword clusters such as "robotics," "software," "clinical decision support," and "autonomous systems" serves as a clear indicator of the most active and promising areas for engineering innovation. For software engineers, the prominence of terms like "codes" and "software" highlights the intense research focus on automating software development, debugging, and testing. For biomedical and health technology engineers, the strong presence of medical applications ("diagnosis," "surgery") signals a critical opportunity to develop robust, reliable, and ethically-aligned LLM-based tools for clinical environments. Similarly, the "education" cluster points to a growing demand for educational technologies that leverage LLMs for personalized learning. This bibliometric map, therefore, acts as a guide for engineers to identify high-impact research areas, potential industry-academia collaboration hubs (e.g., Stanford, MIT), and emerging application domains where technical expertise is critically needed.

5. Conclusion

This study presents a detailed bibliometric analysis of the large language model research landscape, highlighting its rapid growth, principal contributors, intellectual framework, and thematic development. The analysis indicates that although the field is grounded in computer science, its influence is swiftly extending into significant application domains, including medicine, software engineering, and education. The United States and its prominent academic institutions currently lead in productivity and impact, influencing the global research agenda.

This study offers a comprehensive overview that aids researchers, institutions, and policymakers in grasping the current landscape of the field, pinpointing key actors, identifying emerging research topics, and uncovering potential collaboration opportunities. This study delineates foundational works and current research trends, providing orientation for both newcomers and experienced individuals in this intricate and rapidly evolving field.

Future research should extend this macro-level analysis to offer more direct insights for the engineering community. A structured framework for forthcoming bibliometric studies in engineering encompasses:

Detailed Examination of Technical Trends: Future research should focus on tracking the prevalence and evolution of specific model architectures (e.g., Mixture-of-Experts, state-space models), fine-tuning techniques (e.g., LoRA, QLoRA), and important datasets, rather than relying on general keywords. This would offer engineers a quantitative perspective on the technical approaches that are gaining traction.

Aligning Research with Engineering Challenges: Mapping publications to persistent engineering challenges represents a significant area of investigation. Key challenges include model efficiency (e.g., quantization, pruning), reduction of hallucinations, assurance of data privacy, and attainment of real-time performance in robotics and autonomous systems applications. An analysis of software engineering integration through a bibliometric study on the intersection of LLMs and software engineering can examine trends in code generation, automated testing, and AI-assisted debugging, thereby elucidating the impact of LLMs on the software development lifecycle.

Dynamics of Collaboration Between Industry and Academia: Examining the co-authorship networks between leading technology companies and academic institutions may reveal essential pathways for technology transfer and identify the key contributors who convert foundational research into applicable engineering solutions.

Future research can connect high-level trends with the specific, actionable knowledge necessary for engineers to innovate and develop the next generation of LLM-powered technologies by exploring more technically-grounded avenues.

This study's limitations must be acknowledged. The analysis relies solely on the Web of Science (WoS) Core Collection database. Although WoS serves as a standard for high-impact research, the exclusion of other databases such as Scopus or preprint archives like arXiv may result in the omission of pertinent publications, especially those related to early-stage research prevalent in the rapidly evolving field of computer science. This study provides a snapshot of a dynamic field at a specific time (June 2025); the research landscape is expected to evolve rapidly.

The methodology offers a quantitative overview of the field's structure at a high level. The text does not provide a qualitative analysis of technical specifics, including specific model architectures, training datasets, or evaluation benchmarks relevant to engineers involved in implementation. This limitation highlights the necessity for more detailed, technically oriented analyses in subsequent research.

Conflict of Interest Statement

The author declare that there is no conflict of interest

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