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Human–AI Interaction Research (2005–2025): A Bibliometric Mapping Based on Scopus Data

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ABSTRACT

This study provides a comprehensive bibliometric analysis of Human–AI Interaction (HAI) research from 2005 to 2025 using data retrieved from the Scopus database. The objective is to map the intellectual structure, research trends, and thematic evolution of the field. A total of relevant publications were analyzed using bibliometric techniques, including co-authorship, co-citation, keyword co-occurrence, overlay, and density visualization, supported by VOSviewer. The results indicate a significant growth in HAI research, particularly after 2015, driven by rapid advancements in artificial intelligence technologies such as machine learning, deep learning, and large language models. The findings reveal that early research was predominantly technology-oriented, focusing on algorithm development and system performance, while more recent studies emphasize human-centered aspects such as trust, explainability, user experience, and ethical considerations. Network analysis shows that research collaboration is concentrated in developed regions, with strong contributions from North America, Europe, and East Asia, while participation from developing regions remains limited. Keyword analysis identifies major thematic clusters, including technical foundations, human-centered interaction, and application domains such as healthcare and decision-making. The study also highlights emerging topics such as generative AI and human–AI collaboration. Overall, this research provides a structured overview of the HAI research landscape and offers insights into future research directions, emphasizing the importance of interdisciplinary approaches and responsible AI development.

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1. INTRODUCTION

The rapid advancement of artificial intelligence (AI) technologies over the past two decades has fundamentally transformed the way humans interact with digital systems. From early rule-based systems to contemporary deep learning and generative AI models, the evolution of AI has shifted the paradigm of human–machine interaction toward more adaptive [1], [2], intelligent, and collaborative forms. Human–AI Interaction (HAI) has thus emerged as a critical interdisciplinary research domain that examines how humans perceive, trust, utilize, and collaborate with AI systems in various contexts, including healthcare, education, business, and governance [3], [4]. As AI

systems become increasingly embedded in everyday life, understanding the dynamics of interaction between humans and intelligent systems is no longer optional but essential for ensuring usability, effectiveness, and ethical alignment.

The growing prominence of HAI research is closely linked to the proliferation of advanced AI applications such as natural language processing, computer vision, and autonomous systems. Technologies like conversational agents, recommendation systems, and decision-support tools have reshaped user expectations, requiring systems to be not only functional but also interpretable, trustworthy, and human-centered [5]. Consequently, research in HAI has expanded beyond technical performance to include psychological, social, and ethical dimensions. Issues such as trust in AI, explainability, transparency, fairness, and user experience have become central themes, reflecting the need to align AI behavior with human values and cognitive processes. This interdisciplinary expansion has attracted contributions from fields such as computer science, human-computer interaction, cognitive psychology, sociology, and management studies [6], [7].

Despite the rapid growth of publications in this domain, the HAI research landscape remains fragmented, with diverse theoretical perspectives, methodological approaches, and application areas. While individual studies have explored specific aspects of HAI, there is still a lack of comprehensive synthesis that maps the overall intellectual structure and evolution of the field. Bibliometric analysis offers a systematic and quantitative approach to address this gap by analyzing large volumes of scientific literature to identify patterns of knowledge production, collaboration networks, and thematic development. Through techniques such as co-authorship, co-citation, and keyword co-occurrence analysis, bibliometric studies can uncover influential authors, core journals, emerging topics, and research frontiers.

Previous bibliometric studies in related areas, such as human-computer interaction or artificial intelligence, have provided valuable insights into technological development and research trends. However, a focused bibliometric mapping specifically addressing Human–AI Interaction over an extended time horizon remains limited. Given the accelerated growth of AI research, particularly after the widespread adoption of deep learning and the recent emergence of generative AI, there is a need to systematically examine how HAI research has evolved from 2005 to 2025. Such an analysis is crucial for identifying shifts in research focus, the emergence of new themes, and potential gaps that require further investigation.

This study aims to fill this gap by conducting a comprehensive bibliometric analysis of HAI research based on data retrieved from the Scopus database. The period of 2005–2025 is selected to capture both the early development and the recent surge in AI-driven interaction studies. By employing bibliometric tools and network visualization techniques, this research seeks to map the intellectual structure of the field, analyze publication trends, identify leading contributors, and explore thematic evolution. Specifically, the study addresses the following objectives: (1) to examine the growth and distribution of HAI publications over time; (2) to identify the most influential authors, institutions, and countries; (3) to analyze collaboration patterns within the research community; and (4) to uncover key research themes and emerging trends through keyword analysis.

The significance of this study lies in its ability to provide a structured and holistic overview of the HAI research landscape. For researchers, it offers a foundation for understanding the development of the field and identifying promising areas for future inquiry. For practitioners and policymakers, it highlights critical issues such as trust, ethics, and user-centered design that must be addressed to ensure the responsible deployment of AI systems. Ultimately, this bibliometric mapping contributes to advancing the discourse on Human–AI Interaction by bridging fragmented knowledge and guiding future research

toward more integrative and impactful directions.

2. RESEARCH METHODS

This study employs a quantitative bibliometric approach to systematically map and analyze the development of Human–AI Interaction (HAI) research. Bibliometric analysis is used to evaluate scientific output, identify research trends, and uncover the intellectual structure of the field through large-scale publication data. The research is designed as a bibliometric mapping study using secondary data obtained from the Scopus database, which is selected due to its broad coverage of peer-reviewed literature across disciplines such as computer science, engineering, and social sciences. The analysis focuses on publications from 2005 to 2025 to capture both the early stages and recent advancements in HAI research. This study integrates performance analysis to assess publication output and citation impact, along with science mapping techniques to visualize relationships among research elements.

Data were collected from Scopus using a structured search query that includes key terms related to Human–AI Interaction, such as "human-AI interaction," "human-machine interaction," and "human-centered AI." The search was applied to titles, abstracts, and keywords to ensure comprehensive coverage. The inclusion criteria consist of publications indexed in Scopus between 2005 and 2025, including peer-reviewed journal articles, conference papers, and review articles written in English and relevant to HAI. Exclusion criteria include non-scholarly documents such as editorials, notes, and book reviews, as well as studies not directly related to the topic. The final dataset was exported in CSV format, containing metadata such as authors, titles, abstracts, keywords, affiliations, citations, and references.

Data analysis was conducted using VOSviewer to generate bibliometric network visualizations [8], [9]. The analysis includes descriptive statistics to examine publication trends and citation patterns, co-authorship analysis to identify collaboration networks among authors, institutions, and countries, co-citation analysis to reveal influential publications and the intellectual structure of the field, and keyword co-occurrence analysis to identify major research themes and emerging topics. The results are visualized through network maps, where nodes represent research elements and links indicate their relationships. Prior to analysis, the dataset underwent a data cleaning process, including the removal of duplicate records, standardization of author names and institutional affiliations, merging of similar keywords, and elimination of irrelevant or incomplete data, ensuring the reliability and consistency of the findings.

3. RESULTS AND DISCUSSION

3.1 Author Collaboration Analysis

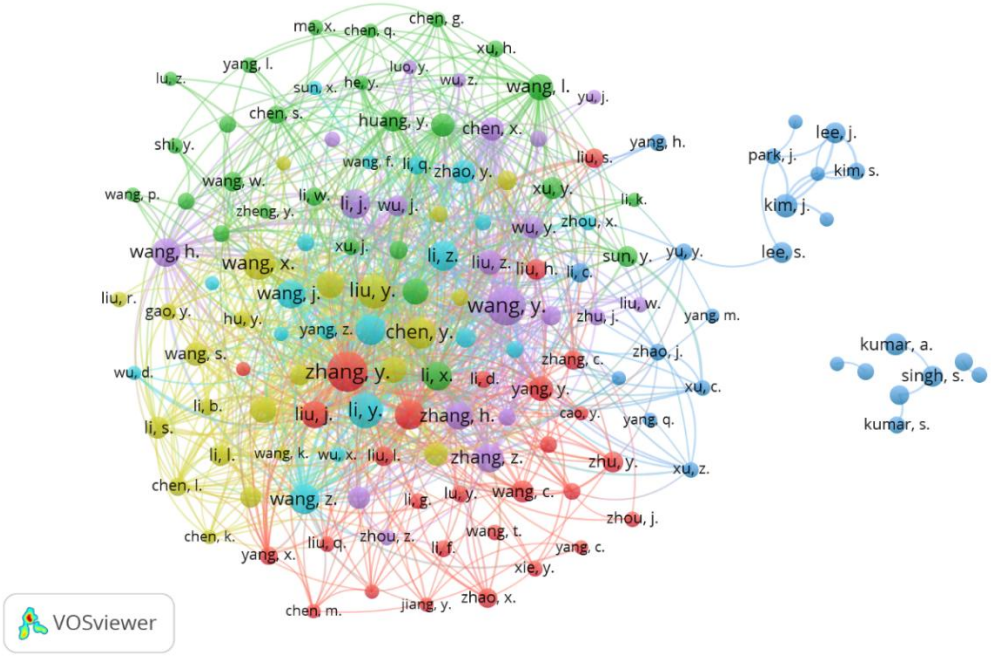

Figure 1. Author Visualization
Source: Data Analysis

Figure 1 illustrates the co-authorship network in Human–AI Interaction (HAI) research, revealing a densely connected and highly clustered collaboration structure. The visualization shows several dominant clusters, indicated by different colors, which represent groups of authors who frequently collaborate within the same research communities. The central area is densely populated, suggesting that a core group of researchers—primarily with common surnames such as Wang, Liu, Zhang, and Chen—play a significant role in shaping the field through strong internal collaboration. These authors appear as larger nodes, indicating higher publication productivity and stronger link strength. In contrast, smaller and more isolated clusters on the periphery (e.g., groups involving authors like Kim, Lee, and Kumar) reflect more localized or emerging collaborations with limited integration into the global network. This pattern suggests that while HAI research is growing and collaborative, it is still somewhat concentrated around specific geographic or institutional hubs, particularly in East Asia. The presence of both dense central clusters and scattered peripheral groups highlights an evolving research landscape, where established networks dominate knowledge production, but opportunities remain for broader international collaboration and integration across regions.

3.2 Citation Analysis: Influential Publications

Table 1. Most Cited Article

Citations	Author and Year	Title	Publication
4044	[10]	ChatGPT for good? On opportunities and challenges of large language models for education	Learning and Individual Differences
2194	[11]	Artificial intelligence for decision making in the era of Big Data â€“ evolution, challenges and research agenda	International Journal of Information Management

Citations	Author and Year	Title	Publication
1989	[12]	ChatGPT: A comprehensive review on background, applications, key challenges, bias, ethics, limitations and future scope	Internet of Things and Cyber-Physical Systems
1811	[13]	How artificial intelligence will change the future of marketing	Journal of the Academy of Marketing Science
1560	[14]	DARPA's explainable artificial intelligence program	AI Magazine
1397	[15]	Causability and explainability of artificial intelligence in medicine	Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery
1329	[16]	Guidelines for human-AI interaction	Conference on Human Factors in Computing Systems - Proceedings
1301	[17]	Generative Agents: Interactive Simulacra of Human Behavior	UIST 2023 - Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology
1269	[18]	Artificial intelligence in digital pathology â€" new tools for diagnosis and precision oncology	Nature Reviews Clinical Oncology
1252	[19]	Artificial intelligence in drug discovery and development	Drug Discovery Today

Source: Scopus, 2026

Table 1 highlights the most cited articles in Human–AI Interaction and related domains, revealing a strong emphasis on both technological advancement and human-centered implications of AI. The dominance of highly cited works such as ChatGPT for good? On opportunities and challenges of large language models for education and Artificial intelligence for decision making in the era of Big Data – evolution, challenges and research agenda indicates that recent discourse is heavily shaped by the emergence of large language models and AI-driven decision-making systems. These studies not only attract high citation counts but also signal a shift toward examining the societal, educational, and managerial impacts of AI. Foundational works such as DARPA's explainable artificial intelligence program and Guidelines for human-AI interaction further demonstrate the central role of explainability and design principles in shaping HAI research. Additionally, the presence of interdisciplinary applications—ranging from marketing and healthcare to drug discovery—suggests that HAI is not confined to a single field but operates across multiple domains. Overall, the citation patterns reflect a convergence between technical innovation and human-centric concerns, where trust, ethics, explainability, and practical implementation become key drivers of scholarly influence in the field.

3.3 Keyword Co-Occurrence and Research Themes

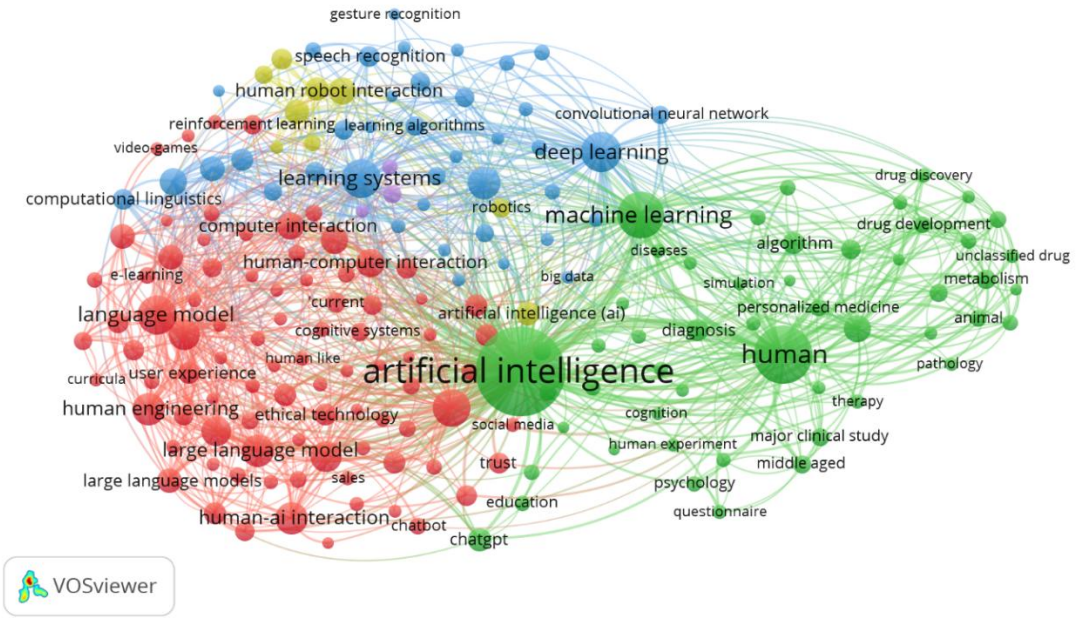

Figure 2. Network Visualization
Source: Data Analysis

Figure 2 presents the keyword co-occurrence network, illustrating the conceptual structure and thematic clusters within Human–AI Interaction (HAI) research. The visualization reveals three dominant clusters: the red cluster centers on human-centered and interaction-oriented themes such as "human-ai interaction," "large language model," "user experience," and "ethical technology," indicating a strong focus on usability, trust, and the societal implications of AI. The blue cluster is more technically oriented, highlighting terms like "machine learning," "deep learning," "learning systems," and "speech recognition," which represent the computational backbone of AI development. Meanwhile, the green cluster emphasizes application domains, particularly in healthcare and life sciences, with keywords such as "human," "diagnosis," "drug development," and "personalized medicine." The central positioning of "artificial intelligence" as the largest node reflects its role as the core concept connecting all subfields. The dense interconnections between clusters suggest a high level of interdisciplinarity, where technical advancements are increasingly integrated with human-centered concerns and real-world applications. This pattern indicates that HAI research is evolving toward a more holistic paradigm, combining algorithmic innovation with ethical, experiential, and domain-specific considerations, particularly in high-impact sectors like healthcare.

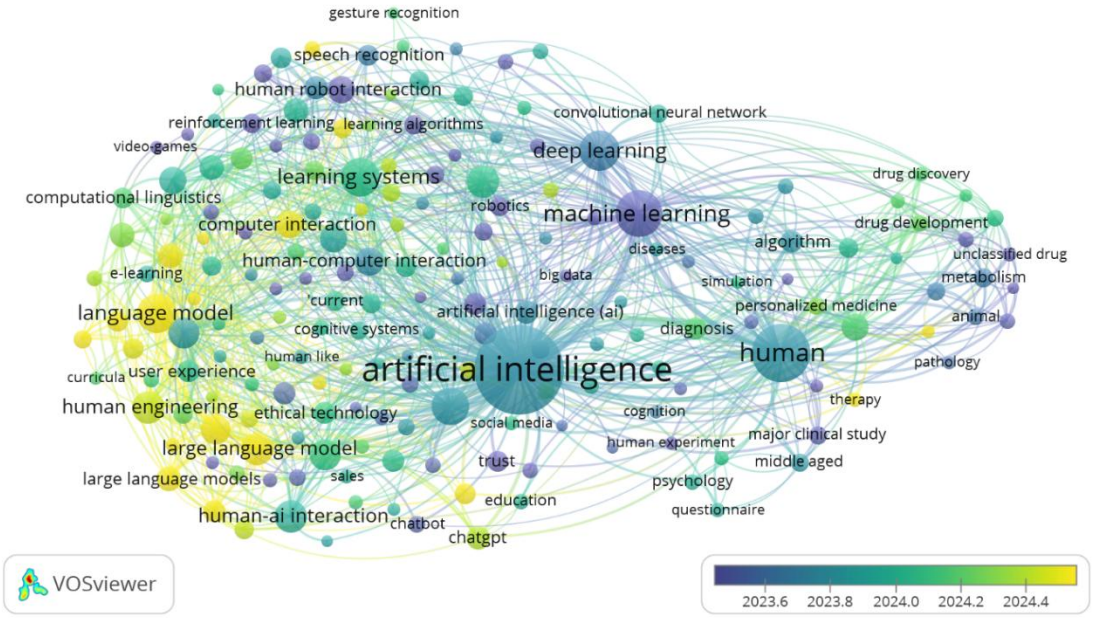

Figure 3. Overlay Visualization
Source: Data Analysis

Figure 3 presents the overlay visualization of keyword evolution, highlighting the temporal development of research themes in Human–AI Interaction (HAI). The color gradient—from blue (earlier period) to yellow (more recent period)—indicates how topics have shifted over time. Earlier research (blue tones) is dominated by foundational and technical themes such as "machine learning," "deep learning," "learning systems," and "speech recognition," reflecting the initial focus on algorithm development and system capabilities. As the field progresses, more recent topics (green to yellow tones) emerge, including "large language model," "ChatGPT," "human-ai interaction," "trust," "ethical technology," and "user experience," signaling a clear transition toward human-centered and application-oriented research. Notably, the appearance of generative AI-related terms in the most recent spectrum underscores the significant impact of large language models on current HAI discourse. Additionally, the persistence of terms like "human" and "artificial intelligence" across all periods indicates their role as stable core concepts connecting evolving themes. Overall, this visualization demonstrates that HAI research is moving beyond purely technical concerns toward a more integrative approach that emphasizes ethics, usability, and real-world implementation, particularly in response to the rapid advancement of generative AI technologies.

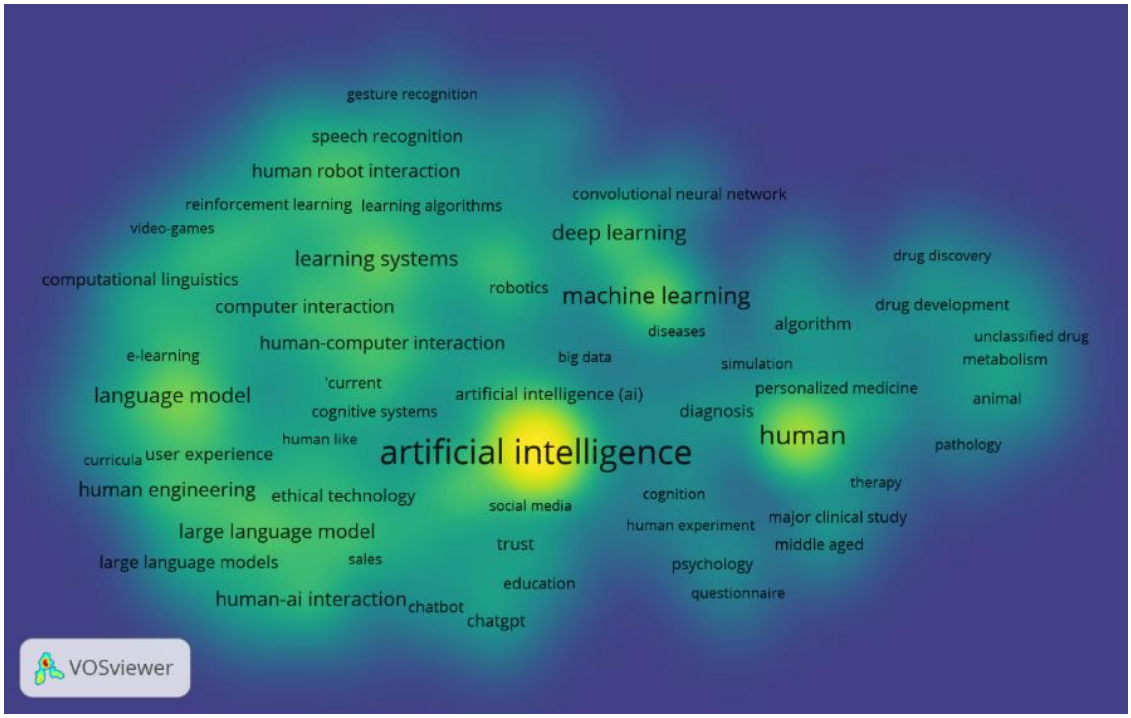

Figure 3. Density Visualization
Source: Data Analysis

Figure 4 presents the density visualization of keyword distribution in Human–AI Interaction (HAI) research, highlighting the concentration and intensity of frequently studied topics. The areas shown in bright yellow indicate high-density regions, with "artificial intelligence" and "human" emerging as the most dominant and central themes in the field. Surrounding these core concepts are moderately dense areas (green shades) representing closely related topics such as "machine learning," "deep learning," "learning systems," and "human-computer interaction," which form the technical and interactional backbone of HAI research. Additionally, terms like "large language model," "human-ai interaction," "trust," and "ethical technology" appear in relatively dense regions, reflecting their growing importance in recent studies. In contrast, less dense areas (blue shades) indicate more specialized or emerging topics, such as applications in healthcare ("drug development," "therapy," "diagnosis") and niche computational domains. This distribution suggests that while the field is anchored by foundational AI and human-centered concepts, it is simultaneously expanding into diverse application areas and ethical considerations. Overall, the density visualization underscores a mature yet evolving research landscape, where core themes remain stable but are continuously enriched by new directions driven by technological advancements and societal needs.

3.4 Discussion

The findings of this bibliometric analysis reveal that Human–AI Interaction (HAI) research has undergone a significant transformation, evolving from a predominantly technology-driven field into a more interdisciplinary and human-centered domain. The rapid growth of publications, particularly after 2015, reflects the accelerating integration of AI technologies into various aspects of society, which in turn has intensified scholarly attention toward how humans interact with intelligent systems. This shift is clearly supported by the keyword and overlay analyses, where early research focused on technical foundations

such as machine learning and deep learning, while more recent studies emphasize themes such as trust, explainability, user experience, and ethical considerations. This transition indicates that the success of AI systems is no longer determined solely by computational performance but also by their ability to align with human expectations, values, and cognitive processes [5], [20], [21].

The co-authorship and citation analyses further highlight the concentration of knowledge production within specific geographic and institutional hubs, particularly in developed regions such as North America, Europe, and East Asia. While this concentration has contributed to strong research networks and rapid knowledge advancement, it also reveals an imbalance in global participation. The relatively limited contribution from developing regions suggests that HAI research may not fully capture diverse socio-cultural contexts, which are crucial for designing inclusive and adaptable AI systems. Expanding collaboration across regions and disciplines is therefore essential to ensure that HAI research reflects a broader range of user experiences and societal needs.

Another important insight from this study is the central role of explainability and trust as emerging pillars of HAI research. Highly cited works and dense keyword clusters consistently point to explainable AI (XAI) and trust as critical factors influencing user acceptance and effective human–AI collaboration. As AI systems become increasingly autonomous and are deployed in high-stakes domains such as healthcare, finance, and education, the demand for transparency and accountability becomes more urgent. This trend underscores the necessity of integrating ethical frameworks and human-centered design principles into AI development, moving beyond purely technical optimization toward responsible innovation [22], [23].

Furthermore, the density and network visualizations demonstrate that HAI research is characterized by strong interdisciplinarity, bridging fields such as computer science, psychology, healthcare, and management. This convergence reflects the complex nature of human–AI systems, which require both technical robustness and an understanding of human behavior. The emergence of application-specific clusters, particularly in healthcare and decision-making contexts, indicates that HAI is increasingly oriented toward real-world problem solving. However, this also raises new challenges related to bias, fairness, privacy, and long-term societal impact, which remain underexplored in some areas.

Despite the progress observed, several research gaps remain. There is a need for more longitudinal and empirical studies that examine the long-term effects of human–AI interaction on individuals and organizations. Additionally, while recent research has begun to address ethical concerns, there is still limited integration of these considerations into practical system design and policy frameworks. Future research should therefore focus on developing standardized guidelines and evaluation metrics for ethical and trustworthy AI interaction.

In conclusion, the discussion highlights that HAI research is entering a more mature phase characterized by a balance between technological innovation and human-centered considerations. The field is moving toward a holistic understanding of interaction, where usability, trust, ethics, and contextual relevance are as important as algorithmic performance. These findings provide a foundation for future research directions that prioritize inclusivity, interdisciplinary collaboration, and the responsible development of AI systems that effectively serve human needs.

4. CONCLUSION

This study demonstrates that Human–AI Interaction (HAI) research has experienced significant growth and transformation over the past two decades. The field has evolved from a predominantly technical orientation into a more interdisciplinary and human-centered domain, incorporating insights from computer science, social sciences, and applied fields. Bibliometric findings indicate that core topics such as machine learning and artificial intelligence remain central, while emerging themes—including trust, explainability, ethical AI, and large language models—are increasingly shaping the research landscape. The analysis also reveals a strong concentration of research output in specific geographic regions, highlighting the need for broader global participation to generate more inclusive and context-sensitive perspectives. Furthermore, the increasing emphasis on ethical and human-centered considerations reflects a growing awareness of the need to align AI development with societal values and user needs. Despite these advancements, several challenges persist, particularly in addressing issues related to bias, transparency, and long-term societal impact. Overall, HAI research is entering a more mature phase marked by a balance between technological innovation and human considerations. Future studies should emphasize interdisciplinary collaboration, expand contributions from underrepresented regions, and develop frameworks that support the responsible and sustainable integration of AI into human environments. This study contributes by offering a comprehensive mapping of the field and serving as a foundation for future research.

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