Applied Computer Systems
ISSN 2255-8691 (online)
ISSN 2255-8683 (print)
December 2024, vol. 29, no. 2, pp. 30–42
https://doi.org/10.2478/acss-2024-0019
https://content.sciendo.com

Unveiling Trends of Chatbot and Conversational Agents: A Bibliometric Study

Tasnim K. Alasali[1], Omar Dakkak[2], İlker Türker[3*]
[1–3]*Faculty of Engineering, Department of Computer Engineering, Karabük University,78050, Karabük, Turkey*

***Abstract* – Recent years have seen remarkable growth and diversification in the study of chatbots and conversational agents. This research employs bibliometric and network-analytical methodology to thoroughly investigate the latest trends and themes in chatbot technology, a topic that has gained prominence in contemporary research discourse. The primary aim for this paper is to examine the evolution, prevailing trends, and provide an extensive overview of the chatbot field. Using the Web of Science core collection database, this study evaluates articles published from 1980 to 2024 by scanning over 7327 journal articles, ultimately focusing on 2622 key articles from prominent journals, institutions, and authors in the field. Key findings indicate a consistent increase in publication count related to chatbots recently. The study also identifies discrimination for critical areas such as advancements in artificial intelligence, machine learning, and natural language processing and underscores the importance of quantitatively assessing their impact and applications in diverse areas. Additionally, it sheds light on the collaboration among researchers, institutions, and nations in the development of this field. Furthermore, an analysis of written abstracts indicates a concentrated effort on enhancing user interactions and the technological progression of chatbots. The findings of this study provide insight into various sectors related to the development of chatbot technology in digital communication and AI advancement. Therefore, this bibliometric analysis offers a unique and in-depth view of the evolving chatbot research landscape, serving as a valuable guide for future research and strategic planning in this rapidly advancing area.**

***Keywords* – Bibliometric analysis, chatbot, conversational agent, conversational AI, dialogue systems, natural language processing.**

I. Introduction

Conversational AI, including chatbots and virtual agents, enables human-like computer interactions. Users ask questions, and the machine responds in a manner that simulates human conversation [1]. This technology allows machines to understand, interpret, and respond to human language naturally. Although conversational AI is based on advanced technologies that mimic human thought processes, it still faces many challenges and remains under development [1], [2].

Despite being relatively new, conversational AI has seen significant growth over the last decade, entering its second wave of research [3]–[5]. However, comprehensive bibliometric studies in this area are lacking, leaving a gap in the literature that this study aims to fill [6]. Our research provides an in-depth analysis of chatbot technology, identifying key trends and themes through bibliometric analysis and strategic coordination diagrams [3], [7], [8]. This research aims to chart a clear path for future chatbot studies by combining bibliometric analysis with strategic coordination diagrams. The rapid advancement in this field has garnered global attention, leading to the formation of innovative research clusters [9]–[12].

Our methodology involves a comprehensive bibliometric review of the existing literature on chatbots, focusing on articles sourced from the Web of Science (WoS) core collection. From approximately 7327 publications identified up to 2023, a refined selection of 2622 articles specifically centred on chatbots was analysed, excluding other types of publications like books and reviews [13]. This analysis explores the historical background, current trends, key issues, and terminologies in chatbot research. Additionally, the study examines the connections among researchers, institutions, and countries, identifying citation and co-citation patterns. By tracing the evolution of chatbot research, we highlight the most influential studies that have shaped the field. This detailed investigation offers valuable insights for future research directions and provides a solid theoretical foundation for the study of chatbot technology. It serves as a comprehensive guide for both new and experienced researchers to navigate the literature and emerging trends in this dynamic field.

Additionally, an in-depth review of the top 20 most globally cited publications on chatbots was undertaken to forecast the potential evolution of this field. The study addresses several pivotal research questions to thoroughly encompass the dynamic landscape of chatbot research:

RQ1: What are the trends and themes globally studied in chatbot literature?

RQ2: How have the principal research directions in chatbot literature evolved?

RQ3: In what ways are various stakeholders (authors, institutions, and countries) interconnected within this significant research domain?

RQ4: How are the central themes in chatbot research distributed in terms of centrality and density?

RQ5: What influence do centrality and density of key terms have on chatbot literature?

* Corresponding author's e-mail: iturker@karabuk.edu.tr
Article received 2024-04-15; accepted 2024-07-15

RQ6: What are the research gaps that can guide future studies in the field of chatbot technology?

As chatbots continue to weave their way into diverse sectors, understanding their academic roots and growth trajectories is increasingly vital. This study not only documents the historical importance of chatbot research but also provides a glimpse into its potential future, ensuring that the field expansion is thoroughly recorded and harnessed to enhance ongoing and future technological innovations [3].

This research aims to create a detailed overview of the chatbot and conversational agent field, filling a gap in comprehensive studies in this fast-developing area. Although chatbot research has grown, previous studies have not fully explored the main trends and topics in this field. The study uses a mix of bibliometric analysis and strategic diagrams to provide clear guidance for future research, examining the history, current developments, and major issues in chatbot studies.

The main goal of this research is to analyse how chatbot technology has evolved and its current trends, offering a broad view of this area. It reviews articles from 1980 to 2024 from the Web of Science database, focusing on significant articles from leading journals and authors. The study investigates important developments in AI, Machine Learning, and Natural Language Processing in chatbots, and seeks to understand their impact and use in different fields. It also looks at how researchers, institutions, and countries collaborate in chatbot technology development.

The unique contribution of this study is its detailed examination of the changing landscape of chatbot research, which is useful for future research and planning. The results are expected to improve the understanding of chatbot role and growth in digital communication and AI across various sectors.

This paper is organised as follows: Section II describes the methods used for gathering and analysing data, focusing on bibliometric and network analysis techniques. Section III discusses the results of the bibliometric study, covering trends in publications and major discoveries. Section IV explores the Discussion, examining what the research results mean. Section V recaps the main points and suggests areas for future study. This format helps provide a clear and thorough overview of the research on chatbots.

II. Data Collection Process

The research adopted a tripartite methodological framework to elucidate its principal findings, encompassing (i) bibliometric analysis, (ii) network analysis, and (iii) strategic coordination diagram analysis. Tracing the genesis of bibliometric analysis reveals its inception by Garfield and Sher in 1963 [14]. Although the definition of bibliometric analysis varies among scholars, it predominantly involves the utilisation of bibliometrics as a method to scrutinise academic texts, such as journal articles and their references, employing statistical techniques to construct a scientific domain landscape regarding a specific subject. This approach is extensively employed by a diverse array of professionals, including policymakers, research managers, data analysts, librarians, and scholars, particularly for evaluating the calibre of work in academic and research settings. Bibliometric methods, by providing a statistical overview of published research, have established themselves as an essential tool in both theoretical and practical evaluation of scientific inquiries [15]. These methodologies, increasingly reliant on statistical tools and mathematical software, are pivotal in discerning the key elements and trends within a research field [16], and in underpinning the performance validation of scholarly publications [17]. A variety of bibliometric analytical techniques are employed for this purpose, with co-authorship analysis (authors, institutions, and countries), co-citation, co-occurrence (keywords), and bibliographic coupling analysis being the most prominent methods [18], [19].

In the process of aggregating bibliographic data, Rowley and Slack [20] advocate for the application of structural coordination diagram methodologies to construct a comprehensive representation of the research landscape. This approach enables researchers to review existing literature thoroughly, depict its structure visually, and formulate future research trajectories. Our research adopts a four-phase strategy for collating published bibliographic information and developing a system tailored for the targeted research area, specifically Conversational Chatbots. This strategy focuses on quantifying pivotal articles, delineating the primary dimensions of the field under study, and investigating the nuances of recent advancements within existing research domains. This approach facilitates the delineation of a clearer route for aspiring researchers in this domain [21].

A. Database Selection

For the collection of data, we utilised the Web of Science (WoS) platform, widely recognised and employed by scholars in bibliographic research, as demonstrated in studies [22]–[24]. The Web of Science Core Collection database was the primary resource, encompassing an extensive array of over 20 300 journals, books, and conference proceedings, amounting to more than 71 million academic works [25]. Scholars have highly regarded the WoS database for its quality in archiving sources and its utilisation in various previous studies as a reliable and high-calibre data repository. WoS, operated by Clarivate Analytics and previously known as ISI Web of Science, stands out as the most expansive scientific research platform. It offers detailed information encompassing various aspects such as author/editor details, titles, sources, conference data, abstracts, reference lists, document types, conference sponsors, addresses, citation frequency, keywords, publisher details, ISSN/ISBNs, reference counts, abbreviations, page counts, IDS numbers, languages, Web of Science categories, research domains, funding details, accession numbers, author identifiers, usage counts, PubMed IDs, open access status, hot papers, and highly cited papers.

B. Identification of Keywords

In bibliometric research, the initial and crucial step involves the strategic selection of keywords for the search. For a detailed exploration and definition of conversational chatbots, various fundamental aspects were considered, each contributing significantly to our comprehensive understanding of these

chatbots and their operational mechanisms. Accordingly, a targeted search was conducted within the Web of Science (WoS) Core Collection database, focusing specifically on titles. The search incorporated a range of key terms, including: (TI=(chatbot) OR TI=(conversational agent) OR TI=(conversational AI) OR TI=(dialogue systems) OR TI=(Virtual Assistant) OR TI=(Artificial Conversational Entity) OR TI=(Interactive Agent) OR TI=(Automated Messaging) OR ALL=(Intelligent Virtual Assistant) OR TI=(Digital Assistant) OR TI=(Conversational Interface) OR TI=(AI Chatbot) OR TI=(Dialogue Generation) OR TI=(Dialogue Strategies) OR TI=(Dialogue Response)).

C. Preliminary Data Retrieval

The collection and exploration focused exclusively on journal articles, while conference papers, books, and book chapters were omitted due to the higher scholarly value attributed to journal articles, as indicated by Freire and Nicol [16] and Bao-Zhong Yuan [26]. The "all option" button of the WoS core collection was utilised for data extraction for further analysis. This approach yielded a total of 3575 articles, identified through the title search option and encompassing all the searched keywords.

D. Data Refinement Process

The earliest article identified that addressed conversational chatbot themes was traced back to 1979, with the term "DIALOG SYSTEMS" first appearing in titles during the 1980s. Although chatbots find applications in various domains, the focus of this review paper is limited to *engineering, computer science, education, and social science*. In the initial phase of the research, it was observed that some articles were categorised in more than one area. The removal of these overlapping articles resulted in a refined collection of 2000 unique articles ranging from 1980 to 2024. Subsequently, the Biblioshiny and Citespace software packages were utilised to process this data set of 2000 articles. The essential bibliographic information was downloaded in plain text format, a common format compatible with Biblioshiny, VOSViewer, and Citespace for processing.

III. Bibliometric Analysis

In modern bibliometric studies, several software tools with unique strengths and weaknesses are utilised. Popular ones include Biblioshiny, Citespace, HistCite, Publish or Perish, and BibExcel. Specifically, for the current research, Biblioshiny and Citespace were selected for their ability to flexibly handle data from diverse databases like Scopus and Web of Science, facilitating comprehensive data analysis and compatibility with network analysis tools such as Gephi, VOSViewer, and Pajek. However, HistCite is restricted to Web of Science, while Publish or Perish mainly works with data from Microsoft Academics and Google Scholar. A significant drawback of Biblioshiny and Citespace is their complex user interface, which requires extensive practice to navigate effectively.

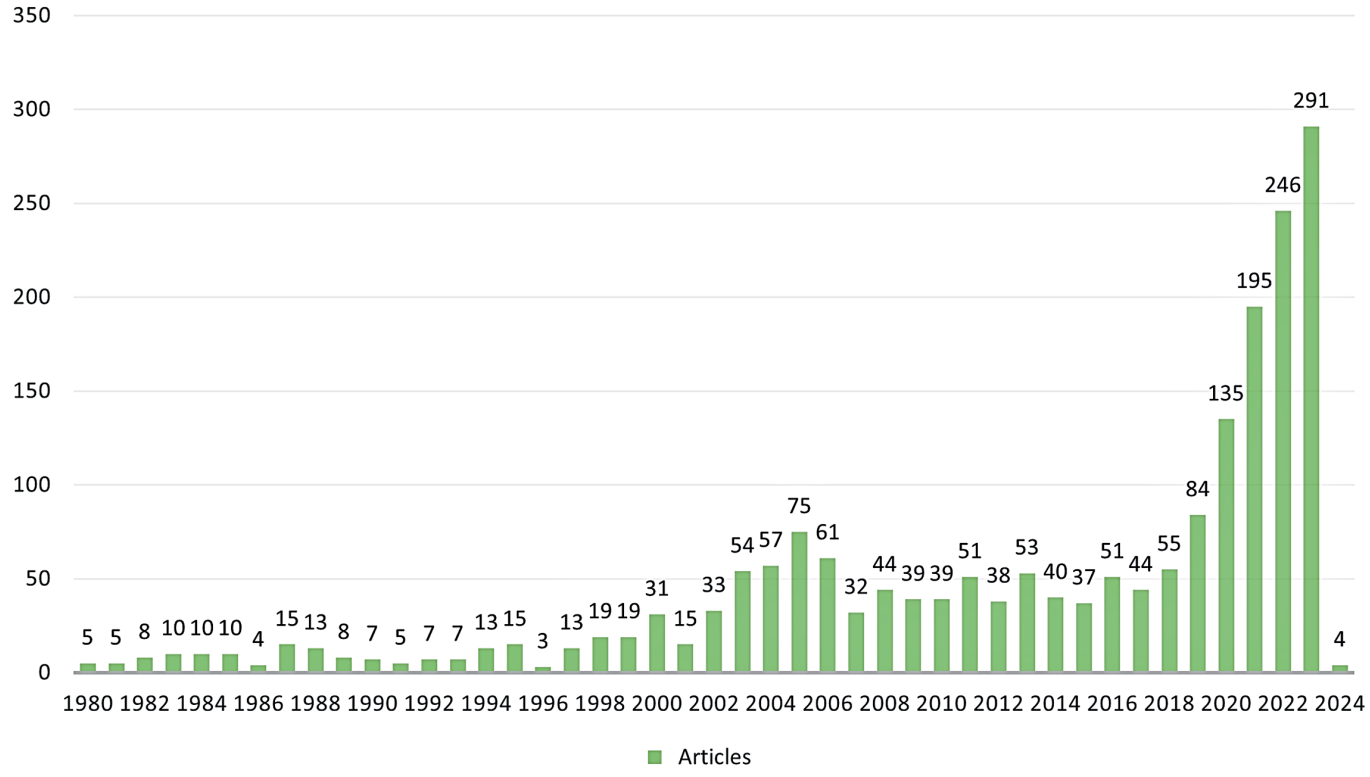

Fig. 1. Yearly evolution of published research in conversational chatbot development.

A. Publication Trend

Previous scholarly reviews indicate that the inception of dialog systems dates to the 1960s, initiated with the creation of ELIZA by Joseph Weizenbaum at the Massachusetts Institute of Technology [27]. Constructed from 1964 to 1966, ELIZA stands as a pioneering instance of dialog systems, engineered to simulate interaction through pattern matching and substitution techniques, thereby presenting a semblance of comprehension to its users. Furthermore, the term "DIALOG SYSTEMS" began appearing in the titles of academic publications indexed within the Web of Science Core Collection databases starting in 1980.

The bar chart illustrates a significant increase in scholarly output within the realm of conversational AI, as defined by a comprehensive array of search terms related to conversational technology and systems. Initial scholarly activity from 1980 to the early 2000s was minimal, rarely exceeding 20 publications annually. A noticeable escalation commenced post-2003, with substantial peaks occurring in 2008, 2014, and an especially sharp rise from 2018 onwards, culminating in 291 publications in 2023. This uptrend likely mirrors the technological advancements in AI, an expansion of research interests, and a broader incorporation of various sub-disciplines within conversational AI. The precipitous decline to four publications in 2024 reflects that the data was collected on 29 November 2023; therefore, 2024 was incomplete at the time of data collection.

B. Worldwide Contribution to Scholarly Publications

In the realm of worldwide research efforts, the USA occupies the premier position, as evidenced by Fig. 2, which presents an academic comparison of research output and the associated citation impact within the sphere of chatbot studies. The USA not only surpasses in the quantity of research with a total of 813 publications but also in the scholarly impact, amassing 7364 citations. This denotes the country's dominant research activities and its profound influence within the academic community. Following the USA, China's substantial contribution includes 630 publications, which have garnered 1752 citations, indicating a strong presence in the field. Nations such as Japan, Germany, and the UK also display substantial research outputs, with their publication counts closely aligned, yet they exhibit distinct citation impacts, pointing to varied levels of international research influence. The data further reveals active participation from countries such as South Korea, Spain, France, and Italy, each presenting significant scholarly outputs and citation figures, contributing to the rich tapestry of global innovation and dialogue in the domains of chatbot technology.

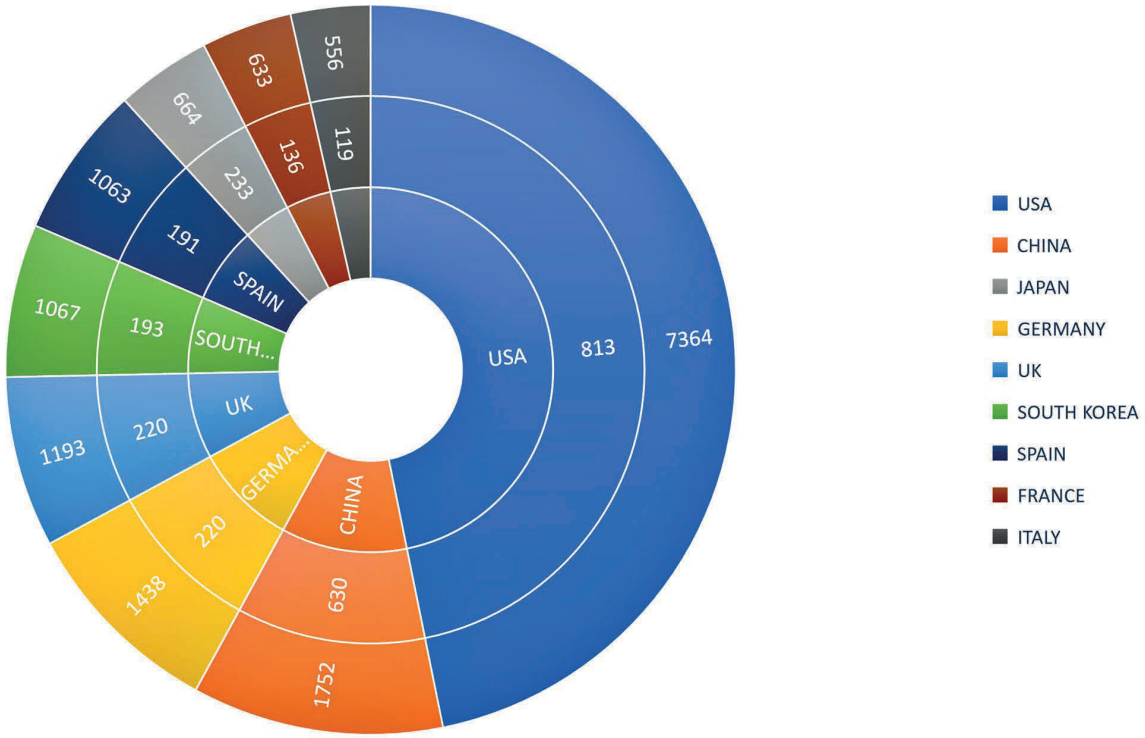

Fig. 2. Comparative analysis of research output and citation impact in chatbot studies across leading countries (total publications and citations).

C. Institution and Journal Contribution Review

In the arena of chatbot research, the affiliations listed in Table I have made notable contributions, as the University of Granada leads with 32 articles and a commendable h-index of 12, signifying a focal point for scholarly impact in the field. The Centre National de la Recherche Scientifique (CNRS) follows with 31 articles and an h-index of 10, reinforcing its stature as a crucible for high-calibre research. Notably, the University of

California System, with an h-index of 11, and the University of Pittsburgh, with an h-index of 12, demonstrate the potency of their research through elevated citation metrics, which are reflective of the depth and reach of their academic work.

TABLE I
TOP INSTITUTIONS HAVING HIGH INFLUENCE ON CHATBOT STUDIES

Affiliations	Articles	h-index	Citation	Average citation per item
University Of Granada	32	12	410	12.81
Centre National De La Recherche Scientifique (CNRS)	31	10	338	10.9
University Of California System	24	11	567	23.63
Microsoft	22	11	724	32.91
University Of Edinburgh	22	10	256	11.64
Carnegie Mellon University	20	9	446	22.3
International Business Machines (IBM)	20	10	366	18.3
Pennsylvania Commonwealth System of Higher Education (PCSHE)	20	12	671	33.55
University Of Texas System	20	12	347	17.35

The data suggests that these institutions serve as hubs for chatbot research, with their work significantly shaping the discourse within this rapidly evolving field. The high citation rates, particularly from entities like Microsoft and the Pennsylvania Commonwealth System of Higher Education, highlight the practical impact and theoretical advancements their research contributions have brought to the field. These institutions, including the University of Texas System, stand out not only for their prolific output but also for their research influence and integration into the broader scientific community, enhancing our understanding and development of conversational chatbot technologies.

Such affiliations are instrumental in advancing chatbot research, providing a collaborative nexus for innovation and inquiry that drives the field forward. Their articles often reflect a synergy of interdisciplinary approaches, from computational linguistics to cognitive science, underscoring the multifaceted nature of chatbot development. The sustained increase in publication volume and citations is a testament to the growing importance of chatbots in various sectors, from customer service to mental health, and indicates a thriving academic interest poised to continue its upward trajectory.

D. Keyword Frequency and Relevance Analysis

Using keywords is crucial in highlighting the main focus of an article, allowing readers to grasp its central theme and purpose quickly [28]. In our analysis, we examined 5989 keywords from various disciplines, including 4550 “author keywords” and 1439 “keywords plus”. “Keywords plus” are terms that appear frequently in the titles and abstracts of cited references, offering additional insights beyond the author’s own keywords. Using VOSViewer’s layout algorithm, we identified the 22 most common “author keywords” that appeared at least 20 times and the 22 most common “all keywords” (which include both “author keywords” and “keywords plus”) that appeared at least 35 times.

Figure 3 illustrates these commonly used keywords. While some keywords appeared in both “author keywords” and “all keywords”, the “all keywords” category in Part B of Fig. 3 also included broader terms related to mythological aspects drawn from titles and abstracts. Conversely, Table II lists the top 20 “keywords plus” that were most frequently used in the VOSViewer analysis.

TABLE II
TOP 10 CHATBOT RESEARCH KEYWORDS USING “KEYWORDS PLUS” APPROACH

Keywords	Occurrences	Total link strength
Communication	41	32
Design	57	30
Framework	29	19
Impact	25	27
Information	32	21
Language	36	24
Management	29	24
Model	62	27
Performance	26	24
Recognition	26	13

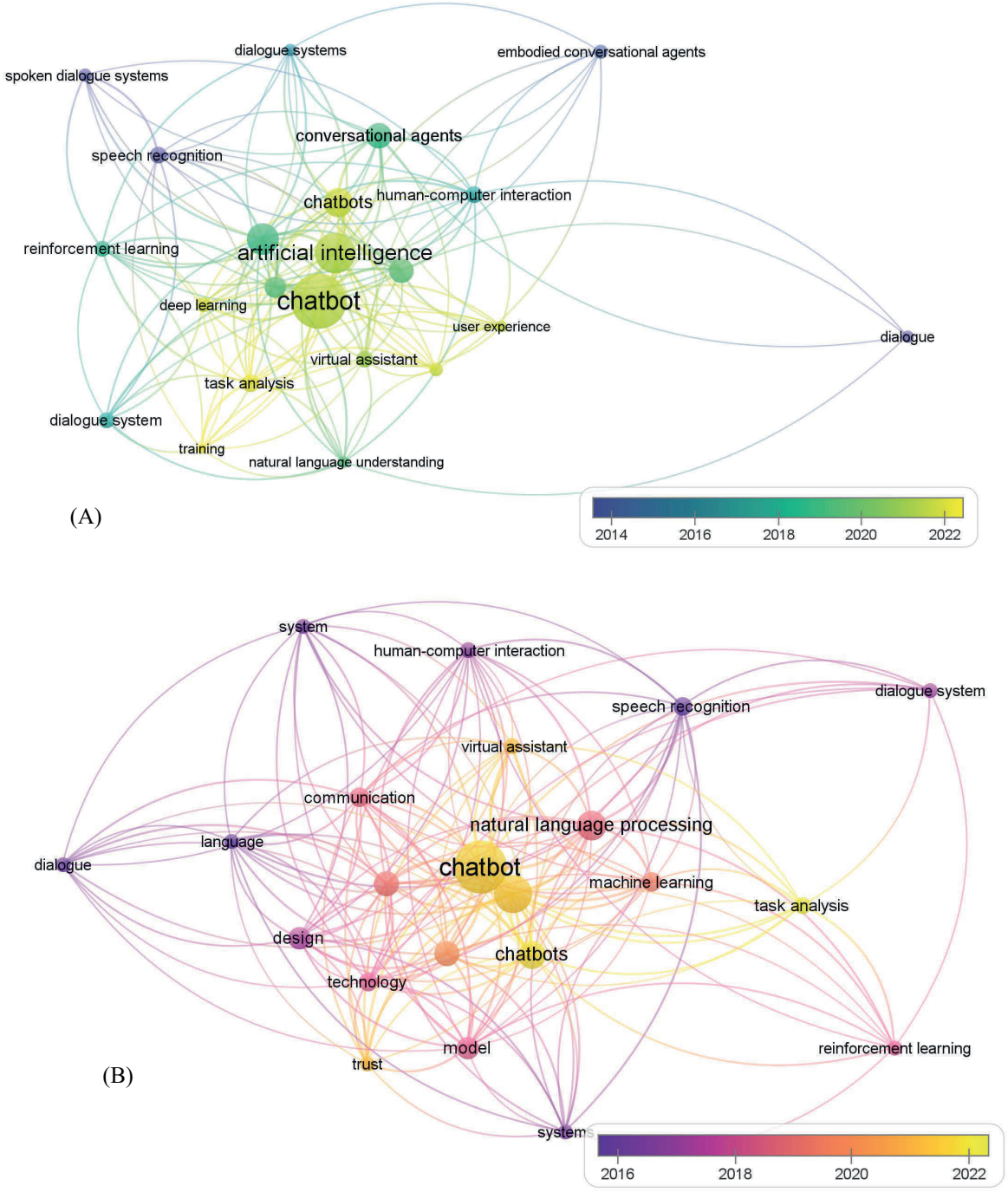

Fig. 3. Network of top 22 chatbot research keywords co-occurrence: (A) Based on author keywords; (B) Based on combined keywords from authors, titles, and abstracts. Node size reflects keyword frequency, and curve proximity indicates relatedness.

E. Exploring the Publication Network

From the outset of bibliometric research, the practice of creating bibliometric networks or "science maps" has become increasingly influential, offering a visual representation of the relationships and linkages within specialised fields. This form of network visualisation is a powerful tool for identifying patterns in scholarly communications, encompassing everything from journal and article interconnections to collaboration networks among authors, institutions, and even geographic regions, as well as keyword co-occurrence networks. In bibliometrics, analysis is often conducted using a two-dimensional framework of "nodes" and "edges". Nodes represent entities such as publication titles, authors, institutions, and keywords, while edges symbolise the connections and relationships between these entities.

Commonly analysed connections include citation linkages between documents, keyword co-occurrence networks, and

institutional co-authorship networks based on citations. In these networks, the thickness of the edges often measures the strength or significance of the connections between nodes. To achieve the analytical goals of such a study, robust network analysis tools are essential. Among the available software options, Pajek, Biblioshiny, VOSViewer, HistCite, Gephi, and CitespaceV are notable, with Biblioshiny and VOSViewer being preferred for their user-friendly interfaces, ability to manage diverse data types, and sophisticated algorithms for network analysis [16]. While CitespaceV offers an in-depth analysis, its steep learning curve and less flexible user interface have been noted [21]. Therefore, despite some limitations of VOSViewer in precise network analysis, its combination with the bibliometric capabilities of Biblioshiny offers a comprehensive solution for visualising and interpreting bibliometric data.

F. Co-citation Network Analysis

As the research landscape becomes increasingly global and interconnected, citation analysis has evolved as a critical tool for understanding the relationships and collaborations among scholars from various disciplines. This analytical approach is essential for evaluating the impact and thematic coherence within specific research domains [28]. Co-citation analysis employs a network of nodes, representing articles, and edges, denoting the co-citation relationship when multiple articles cite the same work. For instance, articles X and Y are considered co-cited if they both appear in the reference list of article Z. Highly co-cited articles, frequently referenced together, are recognized as closely related and part of the same field. This method has been applied using the Biblioshiny application to identify closely associated research.

In our analysis, using the Louvain algorithm, we mapped the co-citation network of articles (A), and authors (B), as illustrated in Fig. 4. This figure indicates that key publications [27], [29], [30] and others occupy central positions in the network, indicative of their significance in co-citation frequency. The Louvain algorithm is a highly effective hierarchical clustering method grounded in graph theory. It works by iteratively adjusting the position of nodes to maximise the modularity of the community structure, ultimately leading to the most optimal division of the network into communities [31]. The analysis also highlights key authors, such as Jason D. Williams, Joseph Weizenbaum, and Justine Cassell, who feature prominently among the top co-cited authors based on the frequency of co-citations.

Gong et al. [28] advocate for the clustering of co-cited articles to map out the network structure based on the strength and proximity of nodes, facilitating a detailed cartographical analysis. Our study presents a clear categorisation of network nodes, analysing their "betweenness" and "closeness", i.e., measures of network centrality and cluster proximity, respectively. This clustering allows us to identify core thematic groups within the co-citation network, revealing underlying patterns of scholarly communication and collaboration. Such methodological segmentation has become integral to social network analysis, providing a lens through which to view the complex web of scholarly interactions [32]–[34].

G. Highly Cited Articles in Chatbot

In the landscape of chatbot research, the most cited works are pivotal in pinpointing influential studies and scholars within the field. Utilising the *Biblioshiny* tool, the analysis captures the 10 most globally cited papers, as detailed in Table III. It is noteworthy that a number of these papers have received only a single citation locally. In this context, "Local citation" refers to how often a paper is cited within the dataset of 2000 selected articles, while "Global citation" accounts for the total number of times a paper is cited across the Web of Science database. The research reveals a significant divergence between local and global citations, indicating that chatbot research garners extensive interest across various academic domains, as evidenced by citations outside the immediate scope of chatbot-focused studies. For instance, the article [35] is highly cited globally with 200 citations, indicating a broad impact, yet it shows minimal citations locally, with just one citation. This contrast underscores the paper wider academic relevance and influence beyond the chatbot research community.

TABLE III
TOP 10 GLOBALLY CITED CHATBOT RESEARCH ARTICLES

Article	Local citation	Global citation
[32]	11	176
[36]	42	402
[37]	28	311
[38]	55	247
[35]	1	200
[39]	19	190
[40]	17	188
[41]	13	178
[42]	0	177

H. Evaluation of Core Chatbot Research Themes

Law et al. [43] introduced a method known as strategic coordination mapping to analyse knowledge domains within a specific area of study. This approach helps visualise the connections between different research frameworks, enabling an understanding of current trends, research trajectories, and the relationships between various research themes. It employs a two-dimensional model that focuses on both centrality and density metrics. The horizontal axis (X-axis) measures the centrality, indicating the interconnectedness within the field, while the vertical axis (Y-axis) reflects the density, assessing the concentration of connections within a research area. High density points to a rich intersection of ideas within the field, indicating a robust area of study. High centrality signifies the extent to which a particular group of research is interconnected with a broader discipline, with greater centrality pointing to more significant and influential research clusters

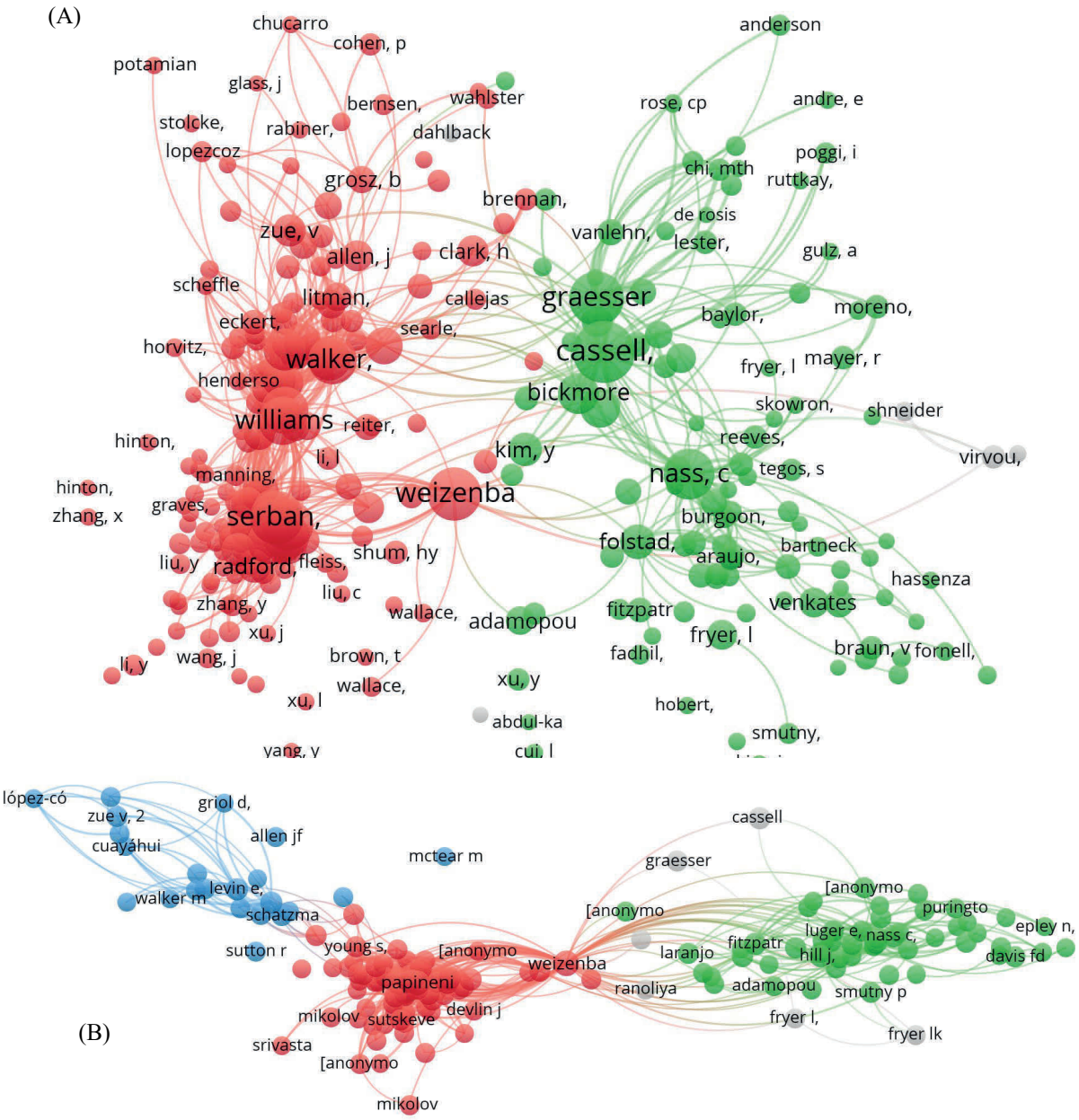

Fig. 4. Co-citation mapping: (A) Reference co-citation network; (B) Author co-citation network. Varied colours denote distinct research fields. Circle sizes reflect the frequency of co-citations, and the proximity between circles illustrates the strength of their association.

The "task analysis" cluster, with a CallonCentrality of 0.143372619 and a CallonDensity of 9.031773649, is identified as a "*Motor Theme*" within chatbot research. It commands a pivotal position, evidenced by its high rank in both centrality (4) and density (6), and a notable frequency of 208. This suggests that "task analysis" is a driving force in the literature, integrating foundational concepts crucial to advancing chatbot studies. The "chatbot" cluster, characterised by the highest CallonCentrality of 0.241098813 and a significant CallonDensity of 6.172871153, ranks as a "*Basic Theme*". Despite its lower density rank (2) compared to its centrality (6), it is prevalent in the literature with 642 occurrences, indicating a strong influence in core discussions of the chatbot field. However, the comparative analysis suggests that the density of research in this area has room to grow and solidify.

Clusters such as "dialogue system" and "virtual assistants" fall into the "*Emerging or Declining Themes*" and "*Niche Themes*" quadrants, respectively. The "dialogue system" cluster, with lower centrality and density values, may represent a more methodological or instrumental aspect of chatbot research, indicating that while not central, it plays a crucial role in the field periphery. In contrast, the "virtual assistants" cluster, with a high density but lower centrality, reflects a well-developed but specialised area of research within the chatbot domain.

Overall, centrality and density rankings of these clusters, alongside their frequency within the research corpus, highlight the diverse nature of chatbot research, from well-established to specialised themes, each contributing uniquely to the field ongoing development.

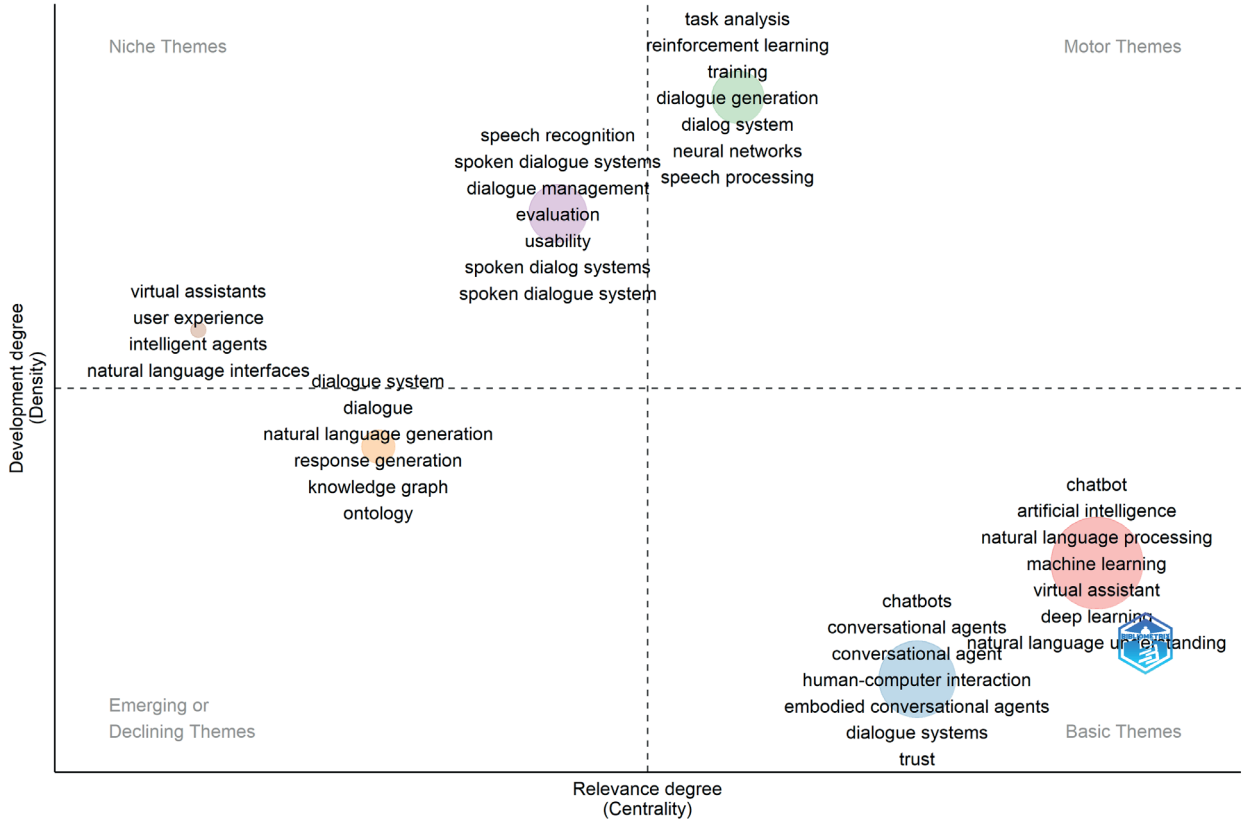

Fig. 5. Analysis of principal themes using strategic coordination diagram. The horizontal axis represents centrality (relevance degree), while the vertical axis indicates density (development degree). The size of the circles corresponds to the frequency of the themes, and the colour reflects the thematic cluster or category.

IV. Discussion

The core aim of this investigation was to dissect the critical features of chatbot systems and shed light on the evolution of scholarly discussions in this realm, thus charting a course for subsequent inquiry. To dissect the theoretical constructs and practical implications of chatbots, methodologies grounded in bibliometric analysis and network visualisation were employed. Additionally, a rigorous examination of the globally most-cited works provided a structured exploration pertinent to the prevailing scholarly queries. In subsequent sections, this study delves into the conceptual framework adopted, identifies lacunae within the existing body of work, and proposes potential research trajectories to bridge these gaps.

The process of data curation was meticulous, with a focus on a curated set of keywords that capture the full spectrum of chatbot capabilities, from their operational functionality to their seamless integration. This includes an examination of the evolution from simple programmed interactions to sophisticated AI-enabled conversational capabilities alongside foundational AI concepts such as natural language processing, machine learning, and cognitive computing. In parallel, issues of user privacy, data integrity, and the ethical deployment of AI were also considered. These facets have been the subject of extensive investigation by various scholars in the domain of chatbot innovation [44], [45]. Figure 6 provides a detailed representation of how institutions around the world have engaged in scientific collaboration focused on specific keywords.

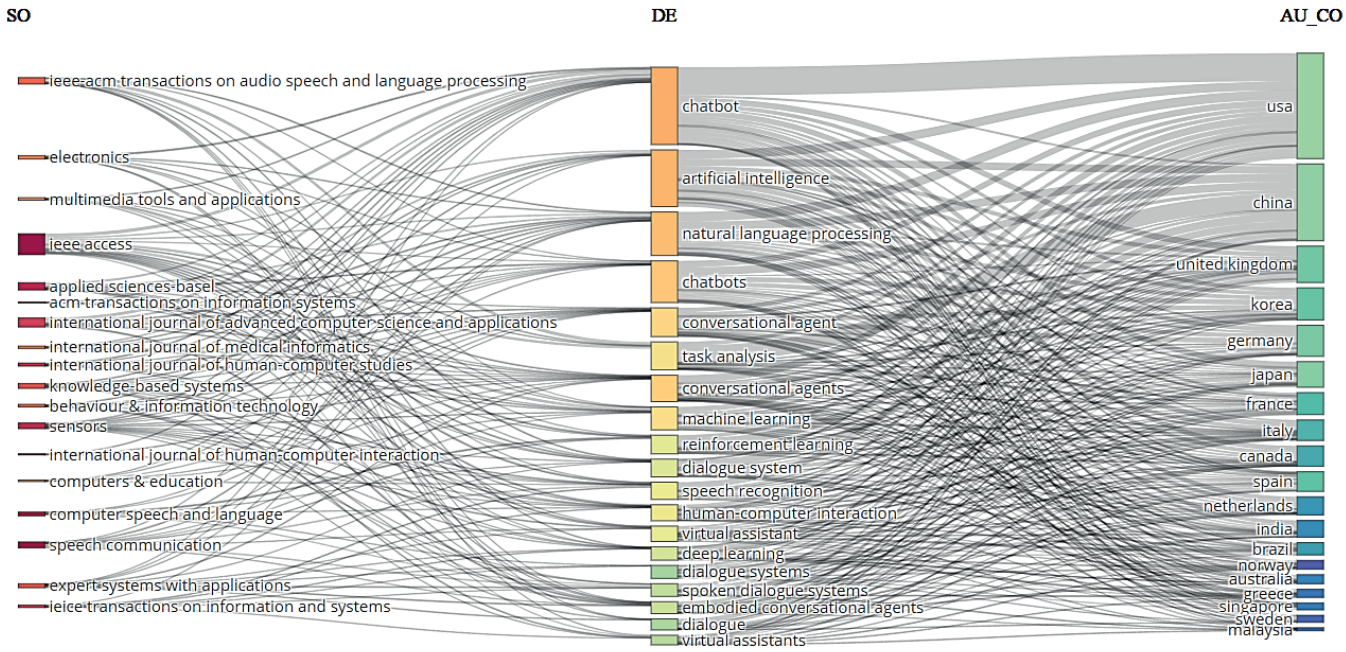

Fig. 6. A collaborative map comprising three elements: Institutions, keywords, and countries, all related to chatbots. The first element illustrates the institutions involved, the second shows the keywords associated with their work, and the third highlights the countries focusing on these keywords. The curved lines indicate the relationships among these elements, and the size of each element in the plot reflects the frequency of their occurrence.

Moreover, Fig. 7 shows the collaborative network involving the USA, China, and the UK, highlighting the significant role these countries play in addressing global issues related to chatbots. Given that chatbots are a prominent area of research in artificial intelligence, there has been considerable advancement in this field. The development of conversational agents is not solely due to their critical importance; rather, the application of chatbots spans a wide range of themes, as outlined in Table IV.

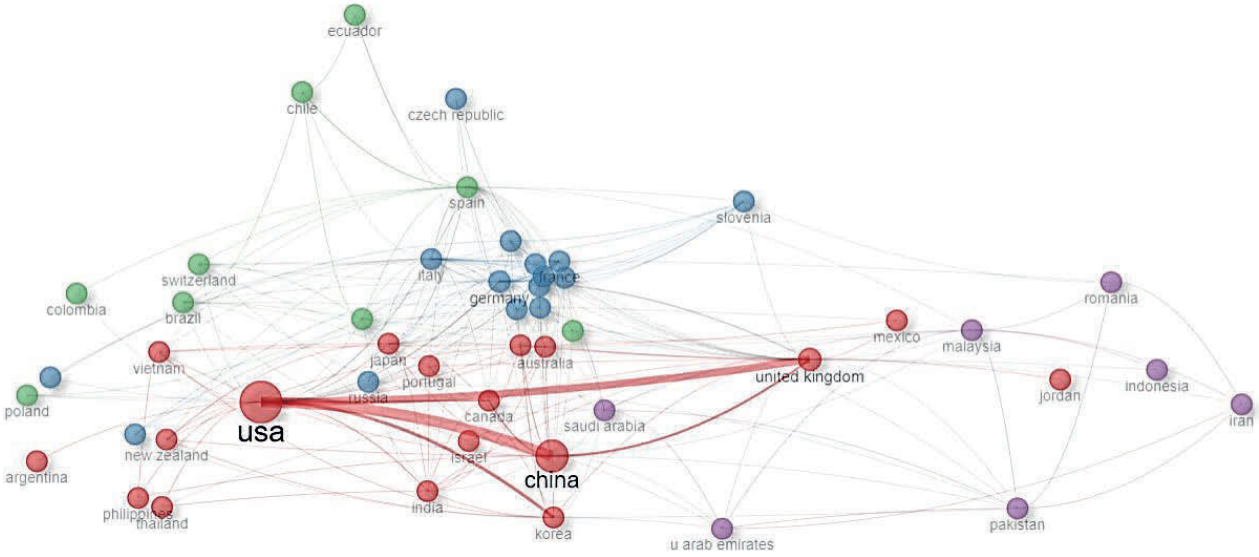

Fig. 7. Global collaborative network in chatbot research.

TABLE IV
PRINCIPAL THEMES IDENTIFIED THROUGH CO-CITATION CLUSTERING ANALYSIS

Cluster	Keywords
Chatbot	Artificial Intelligence, Chatbot, Conversational Agent, Covid-19, Deep Learning, Education, Empathy, Human-Computer Interaction, Information Retrieval, Internet of Things, Machine Learning, Natural Language, Processing, Natural Language Understanding, Trust, Virtual Assistant.
Conversational Agents	Communication, Conversational Agents, Conversational Ai, Dialogue, Dialogue Systems, Embodied Conversational Agent, Knowledge Graph, Ontology, PDA, Virtual Reality.
Dialogue System	Dialog Systems, Natural Language Generation, Neural Network, Response Generation.
Embodied Conversational Agents	E-Learning, Embodied Conversational Agents, Human-Robot Interaction, Intelligent Agents, Intelligent Tutoring Systems, Natural Language Interfaces, User Experience, Virtual Assistants.
Speech Recognition	Affective Computing, Dialogue Management, Emotion Recognition, Evaluation, Human-Machine Interaction, Sentiment Analysis, Speech Understanding, Spoken Dialogue Systems, Usability, User Modelling.
Task Analysis	Data Models, Dialog System, Dialogue Generation, Neural Networks, Reinforcement Learning, Semantics, Speech Processing, Task Analysis, Training, Transformers.

The study notes a consistent growth in chatbot-related research, highlighting extensive collaboration among authors, institutions, and countries. This suggests that the field is both well-established and uniform in its development. The non-linear trend in chatbot publications signifies the integration of diverse fields like Artificial Intelligence (AI), Machine Learning (ML), Natural Language Processing (NLP), Human-Computer Interaction (HCI), Data Science, Customer Service, Healthcare, E-commerce, Education, Psychology, and Linguistics. These areas collectively draw keen interest from researchers with varied backgrounds. A comprehensive bibliometric review offers valuable insights to a broad readership, presenting a clear and structured understanding of this research domain. The study employs quantitative methods to analyse data from the Web of Science platform, providing an in-depth evaluation of the chatbot research field using robust approaches.

Chatbot principles manifest in multiple forms, primarily centring on AI use to mimic human conversation. This variety extends from basic, rule-based systems for simple queries to sophisticated AI bots that adapt and learn from user interactions. Chatbots facilitate both immediate and time-shifted communication, thereby enhancing user experiences in sectors such as customer service, healthcare, education, and e-commerce. The functionality of these chatbots varies greatly, influenced by the complexity of their technology and the specific requirements they aim to fulfil.

For future research directions, the study advocates for an in-depth investigation into the existing lacunae within the realm of chatbot technology. This entails a comprehensive exploration of the multifaceted and interdisciplinary characteristics of chatbots, which integrate diverse fields such as AI, ML, and NLP. Furthermore, it is imperative to examine the impact of research centred on chatbots on both technological development and societal dynamics. The study also underscores the significance of understanding the long-term implications of this research on the global landscape of digital communication and the progression of AI technologies.

V. CONCLUSIONS

The current study provides a bibliometric view on chatbots and conversational agents providing a comprehensive summary of current state-of-art in a statistical manner. Research findings indicate a robust annual scientific production rate of 10.3 % in chatbot research, suggesting a bright future for this field. This research has focused on identifying trends, themes, and potential advancements in chatbot technology, particularly in AI and conversational technology, while also considering the broader societal implications of these developments. The evolving dynamics of chatbot technology, with significant emphasis on artificial intelligence and user interaction, form the core areas of exploration. Notably, the most influential publications in chatbot research tend to be concentrated among a relatively small group of researchers. With the field reaching maturity, there is an increasing trend of scholars contributing to various sub-areas within the domain of conversational AI.

The year 2023 emerged as the most prolific in terms of publication volume in this area. The study highlights computer science and engineering as the predominant subject areas, with 57.613 % of publications focusing on multidisciplinary computer science topics. The United States and China are identified as the leading countries in chatbot research productivity. Journals such as “IEEE ACCESS” and “SPEECH COMMUNICATION” are recognised as the most prominent publication venues with 92 and 85 articles, respectively. The co-keyword analysis reveals that topics such as chatbots, artificial intelligence, natural language processing, conversational agents, and task analysis are among the most popular, as indicated by the frequency of these terms in author keywords. The study also notes that chatbot research, as per the author affiliations and the scope of top journals, extends beyond just core domains. It encompasses a broad spectrum of fields including Artificial Intelligence, Machine Learning, and Natural Language Processing, demonstrating the interdisciplinary nature of chatbot research.

This study offers an in-depth background and valuable insights that will assist academics, researchers, and

policymakers in comprehending the influence of chatbot-focused research on technology and society. It illuminates the potential long-term effects of these studies on global digital communication and the advancement of AI. The study is one of a few that comprehensively addresses the gap in chatbot research, and it stands to benefit significantly from related scholarly work in this area. The research delineates the various stages through which the chatbot discipline has evolved, facilitating an understanding of the history of this research field. It also emphasises the most cited studies to identify key topics and debates, thereby aiding in a more nuanced understanding of how to shape the future of this burgeoning field.

References

[1] S. Singh and H. Beniwal, "A survey on near-human conversational agents," *Journal of King Saud University-Computer and Information Sciences*, vol. 34, no. 10, pp. 8852–8866, Nov. 2022. https://doi.org/10.1016/j.jksuci.2021.10.013

[2] S. Kusal, S. Patil, J. Choudrie, K. Kotecha, S. Mishra, and A. Abraham, "AI-based conversational agents: A scoping review from technologies to future directions," *IEEE Access*, vol. 10, pp. 92337–92356, Aug. 2022. https://doi.org/10.1109/ACCESS.2022.3201144

[3] B. Luo, R. Y. K. Lau, C. Li, and Y. Si, "A critical review of state-of-the-art chatbot designs and applications," *Wiley Interdiscip. Rev. Data Min. Knowl. Discov.*, vol. 12, no. 1, Nov. 2022, Art. no. e1434. https://doi.org/10.1002/widm.1434

[4] A. Piyatumrong, C. Sangkeettrakarn, S. Witdumrong, and J. Cherdgone, "Chatbot technology adaptation to reduce the information gap in R&D center: A case study of an IT research organization," in *2018 Portland international conference on management of engineering and technology (PICMET)*, Honolulu, HI, USA, Aug. 2018, pp. 1–9. https://doi.org/10.23919/PICMET.2018.8481988

[5] C.-H. Li, K. Chen, and Y.-J. Chang, "When there is no progress with a task-oriented chatbot: A conversation analysis," in *Proceedings of the 21st International Conference on Human-Computer Interaction with Mobile Devices and Services*, Oct. 2019, Art. no. 59. https://doi.org/10.1145/3338286.3344407

[6] J. Chen, F. Guo, Z. Ren, X. Wang, and J. Ham, "Human-chatbot interaction studies through the lens of bibliometric analysis," *Universal Access in the Information Society*, pp. 1–20, Oct. 2023. https://doi.org/10.1007/s10209-023-01058-y

[7] A. Ahmed, N. Ali, M. Alzubaidi, W. Zaghouani, A. Abd-Alrazaq, and M. Househ, "Arabic chatbot technologies: A scoping review," *Computer Methods and Programs in Biomedicine Update*, vol. 2, 2022, Art. no. 100057. https://doi.org/10.1016/j.cmpbup.2022.100057

[8] F. X. R. Baskara, "Bridging the culture gap: Challenges and limitations of using chatbots in intercultural education," in *NATIONAL SEMINAR OF PBI (English Language Education)*, 2023.

[9] A. Alsharhan, M. Al-Emran, and K. Shaalan, "Chatbot adoption: A multiperspective systematic review and future research agenda," *IEEE Transactions on Engineering Management*, vol. 71, pp. 10232–10244, Aug. 2023. https://doi.org/10.1109/TEM.2023.3298360

[10] M. Verma, "Novel study on AI-based chatbot (ChatGPT) impacts on the traditional library management," *International Journal of Trend in Scientific Research and Development (IJTSRD)*, vol. 7, no. 1, pp. 961–964, Feb. 2023. https://www.researchgate.net/publication/368608640_Novel_Study_on_AI-Based_Chatbot_ChatGPT_Impacts_on_the_Traditional_Library_Management

[11] S. K. Abbas, Z. Szabó, and A. Kő, "Current trends of development in chatbot systems," *Specialusis Ugdymas*, vol. 1, no. 43, pp. 1157–1168, May 2022. http://sumc.lt/index.php/se/article/view/134

[12] M. W. Ashfaque, "Analysis of different trends in chatbot designing and development: A review," *ECS Transactions*, vol. 107, no. 1, 2022, Art. no. 7215. https://doi.org/10.1149/10701.7215ecst

[13] A. Sarkar, H. Wang, A. Rahman, W. H. Memon, and L. Qian, "A bibliometric analysis of sustainable agriculture: based on the Web of Science (WOS) platform," *Environmental Science and Pollution Research*, vol. 29, pp. 38928–38949, Mar. 2022. https://doi.org/10.1007/s11356-022-19632-x

[14] E. Garfield and I. H. Sher, "New factors in the evaluation of scientific literature through citation indexing," *American Documentation*, vol. 14, no. 3, pp. 195–201, Jul. 1963. https://doi.org/10.1002/asi.5090140304

[15] O. Ellegaard and J. A. Wallin, "The bibliometric analysis of scholarly production: How great is the impact?" *Scientometrics*, vol. 105, pp. 1809–1831, Jul. 2015. https://doi.org/10.1007/s11192-015-1645-z

[16] R. Freire and C. J. Nicol, "A bibliometric analysis of past and emergent trends in animal welfare science," *Animal Welfare*, vol. 28, no. 4, pp. 465–485, Nov. 2019. https://doi.org/10.7120/09627286.28.4.465

[17] E. Raparelli and S. Bajocco, "A bibliometric analysis on the use of unmanned aerial vehicles in agricultural and forestry studies," *Int. Journal of Remote Sensing*, vol. 40, no. 24, pp. 9070–9083, Jan. 2019. https://doi.org/10.1080/01431161.2019.1569793

[18] J. A. Moral-Muñoz, E. Herrera-Viedma, A. Santisteban-Espejo, and M. J. Cobo, "Software tools for conducting bibliometric analysis in science: An up-to-date review," *Profesional de la Información*, vol. 29, no. 1, Jan. 2020. https://doi.org/10.3145/epi.2020.ene.03

[19] W. Li, R. Jiang, Y. Zhao, J. Xie, J. Zhu, and R. Cao, "Water ecological environment protection under changing environment: a systematic review and bibliometric analysis," *Journal of Coastal Research*, vol. 93, no. sp1, pp. 9–15, 2019. https://doi.org/10.2112/SI93-002.1

[20] J. Rowley and F. Slack, "Conducting a literature review," *Management Research News*, vol. 27, no. 6, pp. 31–39, Jun. 2004. https://doi.org/10.1108/01409170410784185

[21] B. Fahimnia, J. Sarkis, and H. Davarzani, "Green supply chain management: A review and bibliometric analysis," *International Journal of Production Economics*, vol. 162, pp. 101–114, Apr. 2015. https://doi.org/10.1016/j.ijpe.2015.01.003

[22] N. Elshaboury, E. M. Abdelkader, A. Al-Sakkaf, and T. Zayed, "A critical review and bibliometric analysis on applications of ground penetrating radar in science based on web of science database," *Engineering*, vol. 4, no. 1, pp. 984–1008, Mar. 2023. https://doi.org/10.3390/eng4010059

[23] W. Liu *et al.*, "Postural deformities in Parkinson's disease: A bibliometric analysis based on web of science," *Heliyon*, vol. 9, no. 3, Mar. 2023, Art. no. e14251. https://www.sciencedirect.com/science/article/pii/S2405844023014585

[24] T. Talan and M. Demirbilek, "Bibliometric analysis of research on learning analytics based on Web of Science database," *Informatics in Education*, vol. 22, no. 1, pp. 161–181, Mar. 2023. https://doi.org/10.15388/infedu.2023.02

[25] S. Huang *et al.*, "A bibliometric analysis of the trends and evolution on inhalation injury research," *Journal of Burn Care & Research*, vol. 45, no. 2, pp. 438–450, Mar. 2023. https://doi.org/10.1093/jbcr/irad172

[26] B.-Z. Yuan and J. Sun, "Bibliometric analysis of rice and climate change publications based on Web of Science," *Theoretical and Applied Climatology*, vol. 150, no. 1–2, pp. 347–362, Aug. 2022. https://doi.org/10.1007/s00704-022-04169-3

[27] J. Weizenbaum, "ELIZA – a computer program for the study of natural language communication between man and machine," *Communications of the ACM*, vol. 9, no. 1, pp. 36–45, Jan. 1966. https://doi.org/10.1145/365153.365168

[28] R. Gong, J. Xue, L. Zhao, O. Zolotova, X. Ji, and Y. Xu, "A bibliometric analysis of green supply chain management based on the Web of Science (WOS) platform," *Sustainability*, vol. 11, no. 12, Jun. 2019, Art. no. 3459. https://doi.org/10.3390/su11123459

[29] C. Nass, J. Steuer, and E. R. Tauber, "Computers are social actors," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Apr. 1994, pp. 72–78. https://doi.org/10.1145/191666.191703

[30] K. Papineni, S. Roukos, T. Ward, and W.-J. Zhu, "Bleu: a method for automatic evaluation of machine translation," in *Proceedings of the 40th Annual Meeting of the Association for Computational Linguistics*, Jul. 2002, pp. 311–318. https://doi.org/10.3115/1073083.1073135

[31] J. Zhang, J. Fei, X. Song, and J. Feng, "An improved Louvain algorithm for community detection," *Mathematical Problems in Engineering*, vol. 2021, no. 1, Nov. 2021, Art. no. 1485592. https://doi.org/10.1155/2021/1485592

[32] J. Cassell and K. R. Thorisson, "The power of a nod and a glance: Envelope vs. emotional feedback in animated conversational agents," *Applied Artificial Intelligence*, vol. 13, no. 4–5, pp. 519–538, Nov. 1999. https://doi.org/10.1080/088395199117360

[33] W.-L. Shiau, Y. K. Dwivedi, and H. S. Yang, "Co-citation and cluster analyses of extant literature on social networks," *International Journal of Information Management*, vol. 37, no. 5, pp. 390–399, Oct. 2017. https://doi.org/10.1016/j.ijinfomgt.2017.04.007

[34] Y. Chen, Y. Liu, and K. Xu, "Characteristics and mechanism of agricultural transformation in typical rural areas of eastern China: A case study of Yucheng City, Shandong Province," *Chinese Geographical Science*, vol. 20, pp. 545–553, Nov. 2010. https://doi.org/10.1007/s11769-010-0430-4
[35] J. N. Bailenson, K. Swinth, C. Hoyt, S. Persky, A. Dimov, and J. Blascovich, "The independent and interactive effects of embodied-agent appearance and behavior on self-report, cognitive, and behavioral markers of copresence in immersive virtual environments," *Presence*, vol. 14, no. 4, pp. 379–393, Aug. 2005. https://doi.org/10.1162/105474605774785235
[36] J. D. Williams and S. Young, "Partially observable Markov decision processes for spoken dialog systems," *Computer Speech & Language*, vol. 21, no. 2, pp. 393–422, Apr. 2007. https://doi.org/10.1016/j.csl.2006.06.008
[37] A. C. Graesser, P. Chipman, B. C. Haynes, and A. Olney, "AutoTutor: An intelligent tutoring system with mixed-initiative dialogue," *IEEE Transactions on Education*, vol. 48, no. 4, pp. 612–618, Nov. 2005. https://doi.org/10.1109/TE.2005.856149
[38] E. Levin, R. Pieraccini, and W. Eckert, "A stochastic model of human-machine interaction for learning dialog strategies," *IEEE Transactions on Speech and audio Processing*, vol. 8, no. 1, pp. 11–23, Aug. 2000. https://doi.org/10.1109/89.817450
[39] L. Ciechanowski, A. Przegalinska, M. Magnuski, and P. Gloor, "In the shades of the uncanny valley: An experimental study of human–chatbot interaction," *Future Generation Computer Systems*, vol. 92, pp. 539–548, Mar. 2019. https://doi.org/10.1016/j.future.2018.01.055
[40] A. C. Graesser, K. VanLehn, C. P. Rosé, P. W. Jordan, and D. Harter, "Intelligent tutoring systems with conversational dialogue," *AI Magazine*, vol. 22, no. 4, pp. 39–51, Dec. 2001. https://doi.org/10.1609/aimag.v22i4.1591
[41] S. Kopp, L. Gesellensetter, N. C. Krämer, and I. Wachsmuth, "A conversational agent as museum guide–design and evaluation of a real-world application," in *Intelligent Virtual Agents: 5th International Working Conference, IVA 2005,* Kos, Greece, Sep. 2005, pp. 329–343. https://doi.org/10.1007/11550617_28
[42] L. Zhou, J. Gao, D. Li, and H.-Y. Shum, "The design and implementation of Xiaolce, an empathetic social chatbot," *Computational Linguistics*, vol. 46, no. 1, pp. 53–93, Mar. 2020. https://doi.org/10.1162/coli_a_00368
[43] J. Law, S. Bauin, J. Courtial, and J. Whittaker, "Policy and the mapping of scientific change: A co-word analysis of research into environmental acidification," *Scientometrics*, vol. 14, no. 3–4, pp. 251–264, Sep. 1988. https://doi.org/10.1007/BF02020078
[44] S. Zhou, J. Silvasstar, C. Clark, A. J. Salyers, C. Chavez, and S. S. Bull, "An artificially intelligent, natural language processing chatbot designed to promote COVID-19 vaccination: A proof-of-concept pilot study," *Digital Health*, vol. 9, Mar. 2023. https://doi.org/10.1177/20552076231155679
[45] M. Karyotaki, A. Drigas, and C. Skianis, "Chatbots as cognitive, educational, advisory & coaching systems," *Technium Social Sciences Journal*, vol. 30, no. 1, pp. 109–126, Apr. 2022. https://doi.org/10.47577/tssj.v30i1.6277

Tasnim Alasali is a PhD student at Karabük University, specialising in AI and cybersecurity. With expertise in machine learning for DDoS detection in SDN environments, Tasnim is interested in conducting developing innovative cybersecurity solutions. Holding M.Sc. in Computer Engineering, she is dedicated to advancing digital security through cutting-edge research and practical applications.
E-mail: tasnimalasali1993@gmail.com
ORCID iD: https://orcid.org/0009-0009-4780-5088

Omar Dakkak is an Assistant Professor at the Faculty of Engineering, Department of Computer Engineering, Karabük University, Türkiye. He received his B.E. degree in Telecommunication Engineering from Ittihad University (Syria). He completed his PhD in Computer Science and M.Sc. from Universiti Utara Malaysia (UUM). In his PhD, he worked on scheduling problems in Grid Computing, analysing the performance of the scheduling policies based on real workloads for better Quality of Service (QoS) criteria and building scheduling mechanisms considering High-Performance Computing (HPC) applications requirements through simulation approach using real workloads. His research interests include scheduling algorithms, performance evaluation, optimization in scheduling, and analysing datasets on HPC platforms. He conducted several studies in other research areas such as cloud computing, IoT, WAN, IoV, energy efficiency for WSN, MANET and modelling and simulation for electrical systems.
E-mail: omardakkak@karabuk.edu.tr
ORCID iD: https://orcid.org/0000-0001-9767-5685

İlker Türker was born in Karabük, Turkey in 1980. He received the B.S. degree from Electronics and Telecommunications Engineering Department of Istanbul Technical University, Istanbul, Turkey; in 2001 and the M.S. degree in Electronics Engineering from Zonguldak Bülent Ecevit University, Zonguldak, Turkey; in 2006, and the PhD degree from Computer Engineering Department of Karabuk University, Karabuk, Turkey, in 2013. From 2002 to 2013, he was a Senior Lecturer at Karabuk University (formerly under Z. Karaelmas University administration). Since 2013, he has been working at the Computer Engineering Department of Karabuk University; currently as a full Professor. His research interest includes complex networks, graph representative learning, time series classification, medical classification, deep learning, and social network analysis.
E-mail: iturker@karabuk.edu.tr
ORCID iD: https://orcid.org/0000-0001-7577-4658