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AI Chatbot Research: A Bibliometric Analysis of Advancements and Trends*

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Abstract: The meteoric rise of ChatGPT has ignited the so-called "chatbot tsunami," propelling AI chatbots into the vanguard of technology research and development. This study conducts a comprehensive review of AI chatbot research from 2000 to 2023, harnessing bibliometric and content analysis methods facilitated by VOSviewer software. Quantitative and visual analyses of 1,236 relevant documents retrieved from the Web of Science in May 2023 unveil AI chatbots as an interdisciplinary research domain. The most influential authors are identified from three distinct fields: human-computer interaction, human-related, and computer-related research. Key research foci encompass AI technologies, digital health and education, conversational AI, COVID-19 applications, customer service, and sentiment analysis. Building upon the bibliometric findings, we delineate the developmental trajectory of AI chatbot research and propose a conceptual framework to guide future endeavors. Furthermore, we outline prospective research avenues for AI chatbots, including advancements in AI capabilities, optimization of human-computer interaction design, and fostering interdisciplinary synergies. This comprehensive review elucidates the AI chatbot research landscape, offering valuable insights to steer both academic pursuits and industrial applications in this burgeoning field.

Keywords: Chatbots; Human-Computer Interaction; Conversational agents; Deep Learning; Bibliometric analysis

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1. Introduction

With the exponential growth of Internet data and advancements in artificial intelligence technology, communication methods have undergone significant transformations,[1] particularly in the realm of human-computer interaction (HCI) systems.[2] Chatbots, which offer effective HCI, have garnered considerable attention in both academia and industry.[3] The term "chatbot" is derived from "chatterbot" and was initially introduced by Michael Mauldin in 1997 to describe a conversational robot for human interaction.[4] According to the Lexico Dictionaries,[5] a chatbot is defined as "a computer program designed to simulate a conversation with a human user, particularly over the Internet." Currently, two primary types of chatbots exist.[6] The first type, referred to as rule-based bots, operates on predefined scripts and utilizes keyword matching to generate responses.[7] These systems resemble expert systems from the 1980s, which relied on a fixed set of rules to address specific queries. Rule-based bots are limited to scenarios they have been programmed for, making them less adaptable in conversation. The second type, known as AI chatbots or artificially intelligent conversational agents,[8] employs natural language processing (NLP) techniques to facilitate more dynamic interactions. Unlike their rule-

1 Allison, DeeAnn, "Chatbots in the Library: Is It Time?," *Library Hi Tech* 30, no. 1 (2012): 95-107.

2 Mocanu, Bogdan-Costel et al, "Odin IVR-Interactive Solution for Emergency Calls Handling," *Applied Sciences* 12, no. 21 (2022): 10844.

3 Miklosik, Andrej, Nina Evans, and Athar Mahmood Ahmed Qureshi, "The Use of Chatbots in Digital Business Transformation: A Systematic Literature Review," *IEEE Access* 9 (2021): 106530-106539.

4 Deryugina, O. V, "Chatterbots," *Scientific and Technical Information Processing* 37, no. 2 (2010): 143-147.

5 "Chatbot: Definition of Chatbot in English," *Lexico Dictionaries*. 2022. Accessed November 30, 2022. https://www.lexico.com/en/definition/chatbot.

6 Nirala, Krishna Kumar, Nikhil Kumar Singh, and Vinay Shivshanker Purani, "A Survey on Providing Customer and Public Administration-Based Services Using AI: Chatbot," *Multimedia Tools and Applications* 81, no. 16 (2022): 22215-22246.

7 Al-Rfou, Rami et al, "Conversational Contextual Cues: The Case of Personalization and History for Response Ranking," *arXiv preprint* arXiv:1606.00372, 2016.

8 Moussawi, Sara, Marios Koufaris, and Raquel Benbunan-Fich, "How Perceptions of Intelligence and Anthropomorphism Affect Adoption of Personal Intelligent Agents," *Electronic Markets* 31, no. 2 (2020): 343-364.

based counterparts, AI chatbots can learn from user interactions, enabling them to understand context and provide more relevant responses. This flexibility allows AI chatbots to engage in more fluid conversations and handle a wider range of inquiries.

AI chatbot has witnessed extensive utilization, with notable examples including Apple Siri, IBM Watson, Google Assistant, Microsoft Cortana, and Amazon Alexa.[9] Furthermore, AI chatbot has found applications in diverse domains such as education and training,[10] business and e-commerce,[11] as well as entertainment,[12] among others. In 2019, researchers began referring to this phenomenon as the "chatbot tsunami",[13] signifying its widespread impact. Subsequently, on November 30, 2022, OpenAI unveiled ChatGPT, an AI chatbot product that further intensified the ongoing "chatbot tsunami." ChatGPT swiftly garnered substantial attention, amassing over 1 million registered users within its first week of global launch, and within a mere two months, it amassed a user base of 100 million monthly active users.[14] According to market research reports, the AI chatbot market demonstrates significant potential.[15] Presently, researchers have an unprecedented

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9 Park, Namkee et al, "Use of Offensive Language in Human-Artificial Intelligence Chatbot Interaction: The Effects of Ethical Ideology, Social Competence, and Perceived Human likeness," *Computers in Human Behavior* 121 (2021): 106795.

10 Essel, Harry Barton et al, "The Impact of a Virtual Teaching Assistant (Chatbot) on Students' Learning in Ghanaian Higher Education," *International Journal of Educational Technology in Higher Education* 19, no. 1 (2022): 57; Guo, Kai, Jian Wang, and Samuel Kai Wah Chu, "Using Chatbots to Scaffold EFL Students' Argumentative Writing," *Assessing Writing* 54 (2022): 100666.

11 Jiang, Hua, Yang Cheng, Jeongwon Yang, and Shanbing Gao, "AI-Powered Chatbot Communication with Customers: Dialogic Interactions, Satisfaction, Engagement, and Customer Behavior," *Computers in Human Behavior* 134 (2022): 107329. https://doi.org/10.1016/j.chb.2022.107329.

12 Garcia-Mendez, Silvia et al, "Entertainment Chatbot for the Digital Inclusion of Elderly People without Abstraction Capabilities," *IEEE Access* 9 (2021): 75878-75891.

13 Grudin, Jonathan, and Richard Jacques, "Chatbots, Humbots, and the Quest for Artificial General Intelligence," In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (2019).

14 "What Is ChatGPT and Why Does It Matter? Here's What You Need to Know," *ZDNet*. December 7, 2022. Accessed December 9, 2022. https://www.zdnet.com/article/what-is-chatgpt-and-why-does-it-matter-heres-what-you-need-to-know/;"ChatGPT Has Gained 100 Million Users in Just 2 Months after Being Released," *TechJuice*. February 2, 2023. Accessed February 9, 2023. https://www.techjuice.pk/chatgpt-has-gained-100-million-users-in-just-2-months-after-being-released/.

15 "Global Chatbot Market - Growth, Trends, Covid-19 Impact, and Forecasts (2022 - 2027)," *Research and Markets*. 2022. Accessed September 4, 2022. https://www.researchandmarkets.com/reports/4622740/global-chatbot-market-growth-trends-covid-19.

opportunity to conduct large-scale real-world studies on AI chatbots.[16] However, there is a scarcity of data-driven quantitative studies that comprehensively address the current state and future trajectory of AI chatbot research as a whole and provide an objective evaluation alongside visual representations of the field's scientific knowledge.[17] Existing literature review studies primarily focus on the application of chatbots within specific domains or utilize narrative reviews and systematic literature reviews to evaluate and examine existing literature.[18] To holistically review research progress in the field of AI chatbots and anticipate future development directions, this paper employs bibliometric methods such as co-citation analysis, co-word analysis, and cluster analysis to quantitatively analyze and visually represent the existing research on AI chatbots based on data gathered from the Web of Science literature survey. By quantitatively consolidating the knowledge base and identifying research hotspots in AI chatbot research, our aim is to comprehend the overall development status, uncover research frontiers, and discern development trends. We believe that this endeavor will assist researchers and practitioners in conducting more effective theoretical research and practical applications in the domain of AI chatbots.

This study aims to address several key research questions within the field of AI chatbots: What are the prevailing research hotspots? What are the primary trends in the development of AI chatbot technology? What are the principal directions for their

16 Følstad, Asbjørn et al. "Future Directions for Chatbot Research: An Interdisciplinary Research Agenda." *Computing* 103, no. 12 (2021): 2915-2942; Rapp, Amon, Lorenzo Curti, and Arianna Boldi, "The Human Side of Human-Chatbot Interaction: A Systematic Literature Review of Ten Years of Research on Text-Based Chatbots," *International Journal of Human-Computer Studies* 151 (2021).

17 Liu, Li, and Vincent G. Duffy, "Exploring the Future Development of Artificial Intelligence (AI) Applications in Chatbots: A Bibliometric Analysis," *International Journal of Social Robotics* (2023): 14; Donthu, Naveen et al, "How to Conduct a Bibliometric Analysis: An Overview and Guidelines," *Journal of Business Research* 133 (2021): 285-296.

18 Kuhail, Mohammad Amin et al, "Interacting with Educational Chatbots: A Systematic Review," *Education and Information Technologies* 28, no. 1 (2022): 973-1018; Ramesh, Aishwarya, and Vaibhav Chawla, "Chatbots in Marketing: A Literature Review Using Morphological and Co-Occurrence Analyses," *Journal of Interactive Marketing* 57, no. 3 (2022): 472-496; Caldarini, Guendalina, Sardar Jaf, and Kenneth McGarry, "A Literature Survey of Recent Advances in Chatbots," *Information* 13, no. 1 (2022): 41; Niicolescu, Luminița, and Monica Teodora Tudorache, "Human-Computer Interaction in Customer Service: The Experience with AI Chatbots-A Systematic Literature Review," *Electronics* 11, no. 10 (2022): 1579.

application? Additionally, this study will investigate the challenges and opportunities encountered in the ongoing development and deployment of AI chatbot technologies. To address these questions, the study employs a bibliometric analysis approach, making several significant contributions to the field. First, it offers a comprehensive examination of the historical evolution and current trends in AI chatbot research, providing a foundational understanding of the trajectory of their development. Second, it establishes a structured research framework that delineates key themes and identifies potential future research directions. Finally, through an extensive analysis of the data, the study proposes prospective research pathways and offers valuable insights to guide both academic exploration and the practical advancement of AI chatbot technologies.

2.Research Methodology

2.1 Data Source and Processing

This paper was retrieved on May 7, 2023, from the Web of Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (AHCI), encompassing publications from 2000 to the present. The selected literature spans multiple disciplines-SCI-EXPANDED, SSCI, and AHCI-aiming to provide a comprehensive understanding of the research status and development trends in the field of AI chatbots. The chosen literature covers various aspects, such as technological advancements, application scenarios, user experience, and ethical considerations, which are all closely related to the research questions and themes. The research period is defined as 2000 to 2023 for several compelling reasons. Firstly, 2000 marks a significant period of rapid development in internet and artificial intelligence technologies, which laid the groundwork for the emergence and growth of AI chatbots. Following this year, there has been a steady increase in publications related to chatbots, ensuring a robust sample size for in-depth analysis. Additionally, the evolution of chatbot technology from an exploratory phase to one of accelerated development since 2000 makes this timeframe particularly suitable for capturing advancements in the field. It's important

to acknowledge that while chatbot technology existed prior to 2000, exemplified by the ELIZA chatbot developed at MIT in 1966, the ensuing years have seen a transformative shift in both the technology and its applications.

The search was limited to articles, review articles, and early access materials. To identify relevant literature on chatbots, the search terms utilized were "chatbot," "conversational agent", "dialog system"and "relational agent" as suggested by Camilleri and Troise.[19] Moreover, following the recommendations of Hwang and Tu,[20] the search terms for AI encompassed "artificial intelligence", "machine intelligence", "intelligent support" , "intelligent virtual reality", "machine learning" ,"intelligent agent*", "expert system*", "neural network*", "natural language processing" and "intelligent system". By formulating search formulas based on these two sets of search terms, a total of 1236 relevant documents were retrieved from the Web of Science. The full record and cited references of these documents were then obtained and utilized as the research data for this study.

2.2 Analytical Methods and Tools

Bibliometric methods play a significant role in evaluating research in scientific and applied fields.[21] The utilization of bibliometric software has become crucial in assessing and analyzing the research performance and efficiency of scientists, universities, and countries.[22] By employing bibliometric software, quantitative analysis of the retrieved literature data offers a comprehensive understanding of research hotspots, evolutionary trends, and research frontiers within the field.[23] In this study, we initially conducted a

19 Camilleri, Mark Anthony, and Ciro Troise, "Live Support by Chatbots with Artificial Intelligence: A Future Research Agenda," *Service Business* 17, no. 1 (2022): 61-80.

20 Hwang, Gwo-Jen, and Yun-Fang Tu, "Roles and Research Trends of Artificial Intelligence in Mathematics Education: A Bibliometric Mapping Analysis and Systematic Review," *Mathematics* 9, no. 6 (2021): 19584.

21 Ellegaard, O., and J. A. Wallin, "The Bibliometric Analysis of Scholarly Production: How Great Is the Impact?," *Scientometrics* 105, no. 3 (2015): 1809-1831.

22 Moral-Muñoz, José A. et al, "Software Tools for Conducting Bibliometric Analysis in Science: An Up-to-Date Review," *El Profesional de la Información* 29, no. 1 (2020): e290103.

23 Yan, Chunlai et al, "Knowledge Mapping of Research Data in China: A Bibliometric Study Using Visual

statistical analysis of the 1236 relevant literature sources obtained from AI chatbot research. Subsequently, we employed VOSviewer software (version 1.6.19), a commonly used bibliometric software, to import the complete records of the relevant literature and cited references. This facilitated descriptive and in-depth analyses, which formed the basis for subsequent discussions and conclusions. The research framework is illustrated in Figure 1.

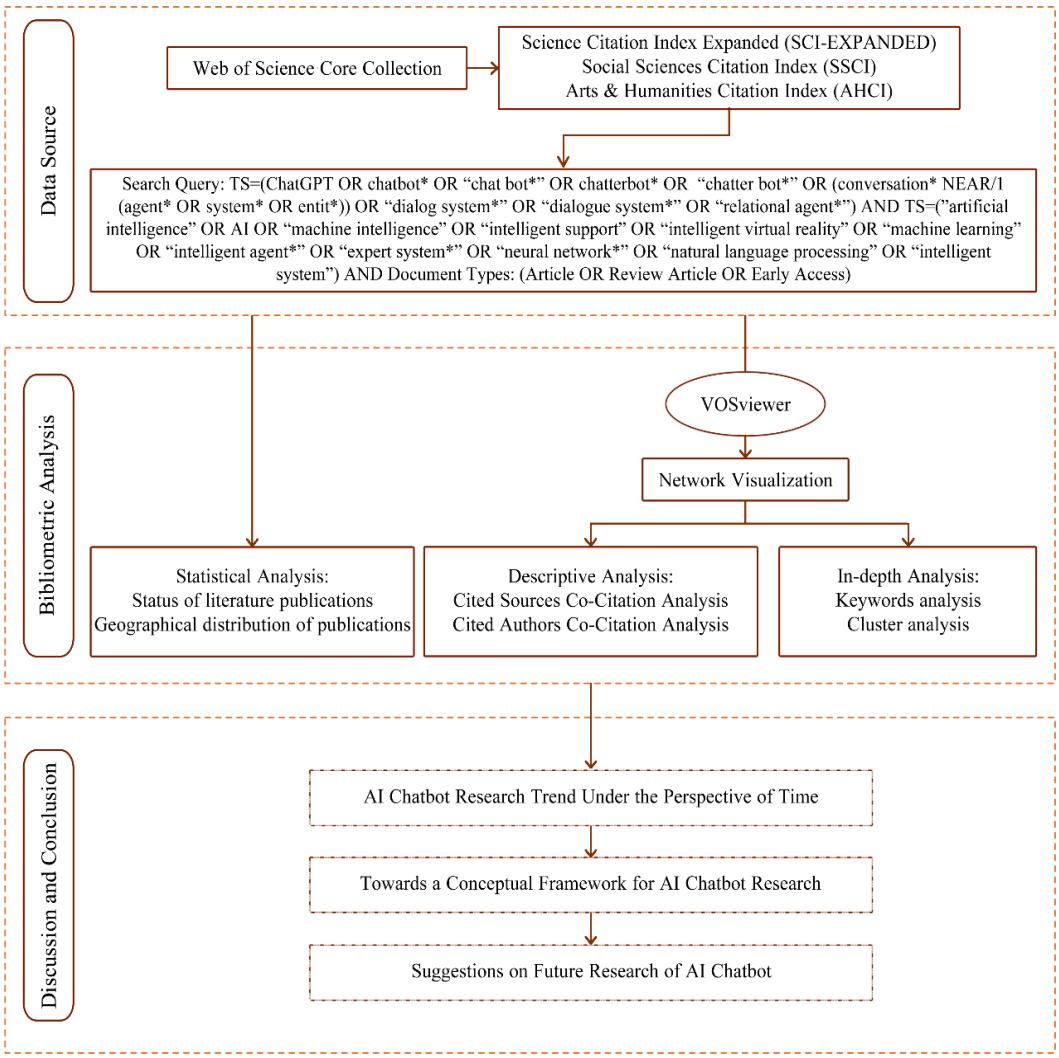

Figure 1. The structure of this paper

Analysis," *Library Hi Tech* (2022): 19.

3. Bibliometric Analysis

3.1 Publication Year Analysis

Figure 2 depicts the publication trends in the field of AI chatbot research over the past two decades. The data reveals a remarkable increase in the number of publications, with six papers published in 2000 and a notable surge to 323 papers in 2022. This signifies a more than 53-fold rise in annual publications during this period (2000 vs. 2022). From 2000 to 2016, the annual publication count ranged from 2 to 21 in the AI chatbot subject area. Conversely, starting in 2017 (with 23 papers), the number of annual publications experienced a substantial and rapid growth trend. By 2022, the annual publication count had increased more than 14-fold compared to 2017. As of May 7, 2023, a total of 168 related papers have already been published. Overall, the publication analysis indicates that AI chatbot research has undergone an exploration phase (2000-2016) followed by a period of rapid development (2017-2023). After over two decades of progress, the cumulative number of publications in AI chatbot research has surpassed 1200, signifying a substantial academic accumulation in the field.

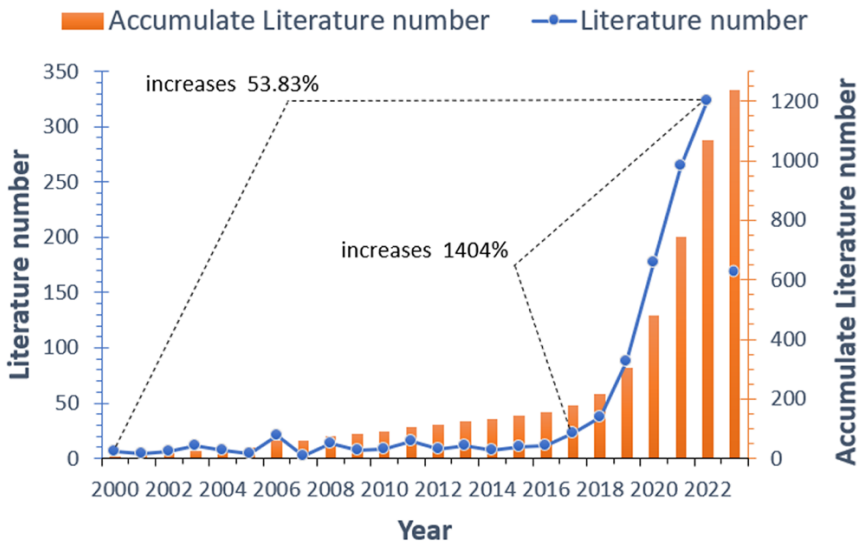

Figure 2. Statistic of publications

3.2 Geographical Distribution Analysis

Table 1 presents the top 10 countries or regions in AI chatbot research. Over the course of the past two decades, AI chatbot research has involved 86 countries or regions across the globe. Among the countries with the highest number of documents, the United States leads the way with 285 papers, constituting 23.058% of the total. Following closely is China with 222 papers, representing 17.961% of the total. Additionally, England, South Korea, Australia, India, and other countries have also made notable contributions. These top ten countries or regions collectively account for 90.858% of the total publications on AI chatbots, indicating a significant concentration of research activity.

Table 1. The geographical distribution (Top 10)

Country/region	Count	Percentage	Country/region	Count	Percentage
USA	285	23.058	INDIA	76	6.149
PEOPLES R CHINA	222	17.961	SPAIN	74	5.987
ENGLAND	115	9.304	GERMANY	64	5.178
SOUTH KOREA	90	7.282	TAIWAN	63	5.097
AUSTRALIA	79	6.392	JAPAN	55	4.45

3.3 Cited Sources Co-Citation Analysis

Figure 3 illustrates the mapping of cited sources using co-citation analysis conducted with VOSviewer. Co-citation analysis, a well-established method in bibliometrics, was introduced in 1973 and has since become widely employed in empirical studies examining the structure of scientific communication.[24] The aim of co-citation analysis is to identify the most influential literature, the authors responsible for its publication, and the sources

[24] Gmür, Markus, "Co-Citation Analysis and the Search for Invisible Colleges: A Methodological Evaluation," *Scientometrics* 57, no. 1 (2003): 27-57.

that have published it by examining co-citation relationships and their frequencies. Consequently, source co-citation analysis focuses on books, journals, conferences, or other sources that disseminate research findings. In this study, sources with a citation frequency exceeding 20 were selected, resulting in 494 out of the 22,610 sources in the dataset meeting the established criteria.

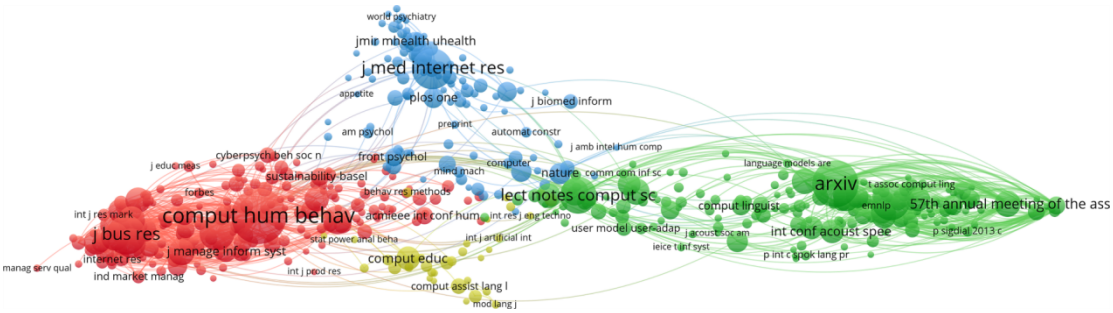

Figure 3. The mapping of cited sources co-citation analysis

Figure 3 reveals the diverse range of sources within the AI chatbot research domain, encompassing journals, conferences, books, and arXiv. Notably, *Computers in Human Behavior*, *Journal of Medical Internet Research*, and *Lecture Notes in Computer Science* occupy central positions within this research area and display close proximity to other sources. The visualization in Figure 3 highlights the interdisciplinary nature of AI chatbot research, which draws upon a variety of disciplines including Computer Science, Experimental Psychology, Business, and others, indicating significant cross-fertilization between these fields.

3.4 Cited Authors Co-Citation Analysis

Figure 4 depicts the co-citation analysis of cited authors using VOSviewer. The analysis focuses on authors within the published literature. For this study, authors who received more than 50 citations were considered, resulting in a selection of 59 authors out of the total 35,359 authors in the dataset. Figure 4 illustrates that co-citations among authors in the AI chatbot research field can be classified into three primary categories: human-computer interaction researchers, human-related researchers, and computer-related

researchers.

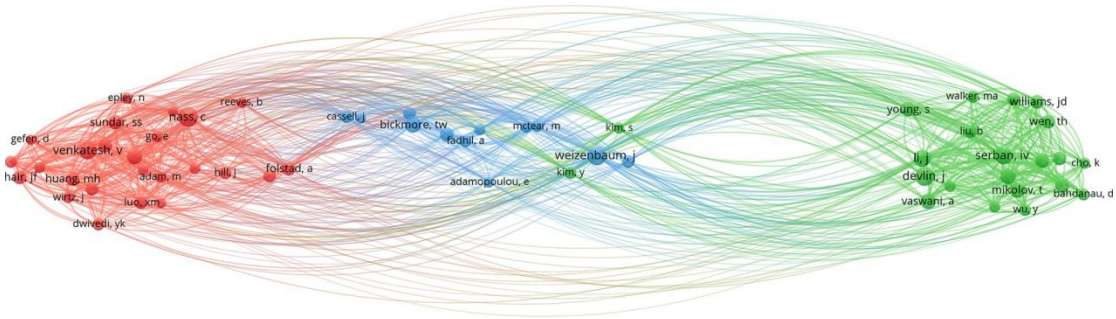

Figure 4. The mapping of cited authors co-citation analysis

The first category pertains to human-computer interaction researchers, primarily represented by the blue area in Figure 4, which includes notable Figures such as Turing and Weizenbaum. HCI refers to the interaction between machines and humans, enabling machines to better comprehend human intentions and engage in natural language communication. Turing's seminal work on the Turing test laid the foundation for the study of HCI.[25] In 1966, the Massachusetts Institute of Technology developed and introduced the world's first chatbot named ELIZA, a significant milestone in this field.[26] Since then, chatbot technology has undergone numerous iterations and advancements alongside the progress of artificial intelligence, attracting continuous research and exploration from scholars throughout its extensive history. These HCI researchers have furnished the theoretical groundwork for AI chatbot research. Simultaneously, theoretical investigations into HCI will play a pivotal role in establishing an autonomous academic community dedicated to AI chatbot research.

The second category encompasses human-related researchers, predominantly represented by the red area in Figure 4, including Nass, Venkatesh, Huang, Araujo, and others. Notably, in the 1990s, Professor Nass pioneered the examination of human social responses to computers from psychological and sociological perspectives, revealing that

[25] Turing, Alan M., and J. Haugeland, "Computing Machinery and Intelligence," In *The Turing Test: Verbal Behavior as the Hallmark of Intelligence*, 29-56. 1950.

[26] Weizenbaum, Joseph, "ELIZA-A Computer Program for the Study of Natural Language Communication between Man and Machine," *Communications of the ACM* 9, no. 1 (1966): 36-45.

individuals unconsciously apply social rules and expectations to computer interactions.[27] Venkatesh et al. delved deep into the theory of user acceptance and consumer acceptance of information technology.[28] In 2018, Huang et al. proposed the theory of AI job substitution. Araujo explored anthropomorphic design cues and communicative agency framing for AI chatbots in the same year.[29] Araujo's publications have emerged as highly influential contributions in the field of AI chatbot research. It is evident that human-related researchers in diverse humanities and social science disciplines such as psychology, sociology, communication, management, and business have conducted research related to AI chatbot users, thereby establishing the humanistic foundation for contemporary AI chatbot research.

The third category comprises computer-related researchers, primarily represented by the green area in Figure 4, including Serban, Young, Williams, Walker, and others. Notably, Young et al. presented a principled mathematical framework in 2010 for modeling uncertainty in spoken dialogue systems using partially observable Markov decision processes (POMDPs). In 2012, Walkerdeveloped a reinforcement learning-based spoken dialogue system to acquire optimal dialogue strategies through interaction with human users.[30] Serban et al. addressed the multi-round dialogue problem in 2016 using a

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27 Nass, Clifford, and Youngme Moon, "Machines and Mindlessness: Social Responses to Computers," *Journal of Social Issues* 56, no. 1 (2000): 81-103; Nass, Clifford, Jonathan Steuer, and Ellen R. Tauber, "Computers Are Social Actors," In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1994.

28 Venkatesh, Viswanath et al, "User Acceptance of Information Technology: Toward a Unified View," *MIS Quarterly* 27, no. 3 (2003): 425-478; Venkatesh, Viswanath, James Y. L. Thong, and Xin Xu, "Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology," *MIS Quarterly* 36, no. 1 (2012): 157-178.

29 Huang, Ming-Hui, and Roland T. Rust, "Artificial Intelligence in Service," *Journal of Service Research* 21, no. 2 (2018): 155-172; Araujo, Theo, "Living up to the Chatbot Hype: The Influence of Anthropomorphic Design Cues and Communicative Agency Framing on Conversational Agent and Company Perceptions," *Computers in Human Behavior* 85 (2018): 183-189; Young, Steve et al, "The Hidden Information State Model: A Practical Framework for POMDP-Based Spoken Dialogue Management," *Computer Speech & Language* 24, no. 2 (2010): 150-174.

30 Walker, Marilyn A, "An Application of Reinforcement Learning to Dialogue Strategy Selection in a Spoken Dialogue System for Email," *Journal of Artificial Intelligence Research* 12 (2000): 387-416.

hierarchical seq2seq architecture.[31] Williams et al. introduced the Hybrid Code Network HCN in 2017, incorporating domain knowledge modules and behavioral templates to achieve comparable or superior performance with less training data, which can be optimized through supervised learning, reinforcement learning, or a combination of both. [32] Collectively, the diverse research endeavors by computer-related researchers in computer science and artificial intelligence over the past two decades lay the technical foundation for contemporary AI chatbot research.

3.5 Author Keywords Co-Occurrence Analysis

Co-word analysis is a content analysis method introduced in 1983, which utilizes keywords that describe the content of scientific literature as fundamental components for mapping or tracing patterns and trends in terminological relevance.[33] It is commonly employed in conjunction with cluster analysis, wherein multivariate statistical techniques are applied to establish keyword clusters. This approach helps identify themes or research areas within the scientific literature, enabling the exploration of hotspots and frontiers for future research.

In this study, co-word analysis of author keywords was conducted on a dataset consisting of 1236 documents in the field of AI chatbot research using VOS viewer. Prior to the analysis, data cleaning and term merging were performed in VOS viewer. For instance, different expressions such as “chatterbot”, “conversational agent”, “dialog system” and “ChatGPT” were standardized as “chatbot”, while various expressions related to AI were unified as “artificial intelligence”. Subsequently, author keywords with a co-occurrence frequency of at least 8 were selected. Out of the 3321 keywords in the dataset,

[31] Serban, Iulian et al, “Building End-to-End Dialogue Systems Using Generative Hierarchical Neural Network Models,” *Proceedings of the AAAI Conference on Artificial Intelligence* 30, no. 1 (2016).

[32] Williams, Jason D., Kavosh Asadi, and Geoffrey Zweig, “Hybrid Code Networks: Practical and Efficient End-to-End Dialog Control with Supervised and Reinforcement Learning,” *arXiv preprint* arXiv: 1702.03274, 2017.

[33] Wang, Zhong-Yi, Gang Li, Chun-Ya Li, and Ang Li, “Research on the Semantic-Based Co-Word Analysis,” *Scientometrics* 90, no. 3 (2011): 855-875.

64 keywords met the specified criteria. The resulting co-occurrence analysis graph of author keywords is depicted in Figure 5.

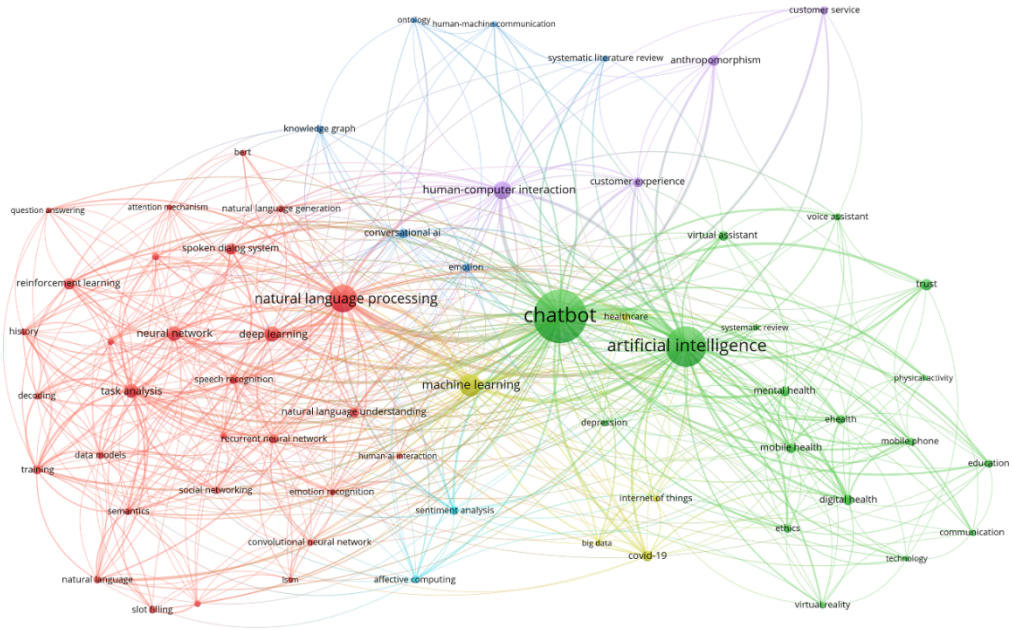

Figure 5. The mapping of author keywords co-occurrence analysis

Figure 5 illustrates the outcomes of the co-word analysis conducted on author keywords in the domain of AI chatbot research, revealing six distinct clusters denoted by different colors. Within each color cluster, the keywords share close associations. Table 2 summarizes the primary concepts and key phrases identified within these six clusters based on the findings depicted in Figure 5.

Table 2. Research concepts and hot topics

Cluster	Concept	Nodes(*n*=64)
1	AI technologies	Attention mechanism, BERT, convolutional neural network, data models, decoding, deep learning, emotion recognition, feature extraction, history, human-AI interaction, intent detection, LSTM, natural language, natural language generation, natural language processing, natural language understanding, neural network, question answering, recurrent neural network, reinforcement learning, semantics, slot filling, social networking, speech recognition, spoken dialog system, task analysis, training, transformer, visualization (n=29)

2	Digital Health and Education	Artificial intelligence, chatbot, communication, depression, digital health, education, ehealth, ethics, mental health, mobile health, mobile phone, physical activity, systematic review, technology, trust, virtual assistant, virtual reality, voice assistant (n=18)
3	Conversational AI	Conversational AI, emotion, human-machine communication, knowledge graph, ontology, systematic literature review (n=6)
4	COVID-19	Big data, COVID-19, healthcare, internet of things, machine learning (n=5)
5	Customer Service	Anthropomorphism, customer experience, customer service, human-computer interaction (n=4)
6	Sentiment Analysis	Affective computing, sentiment analysis (n=2)

Figure 5 and Table 2 delineate the six distinct research focal points within the AI chatbot domain, as revealed by the high-frequency author keyword co-occurrence analysis conducted using VOS viewer. These research hotspots encompass AI technologies, digital health and education, conversational AI, COVID-19, customer service, and sentiment analysis.

3.5.1 Research Related to AI technologies

Cluster 1 (Red): This cluster, which comprises 29 keywords, stands as the largest cluster in our study. Notably, all these keywords revolve around AI technologies. Consequently, we have designated “AI technologies” as the primary cluster name and research direction within the AI chatbot domain. In this regard, we conducted a comprehensive analysis encompassing speech recognition, natural language processing (NLP), and deep learning.

First and foremost, speech recognition is a technology that employs machines to recognize, comprehend, and convert speech signals. In certain real-world intricate speech environments, such as scenarios with distant sound sources, low signal-to-noise ratio, room reverberation, echo interference, and multiple-source signal interference, the speech recognition task becomes exceedingly challenging. [34] Presently, prevalent speech

[34] Graves, A., and N. Jaitly, “Towards End-to-End Speech Recognition with Recurrent Neural Networks,” In

recognition technologies primarily rely on deep neural networks for model development and training. Furthermore, existing neural networks are continually enhanced to cater to distinct application scenario demands and data characteristics.

Secondly, Natural Language Processing (NLP) is widely employed in HCI and encompasses various techniques, including syntactic analysis, information extraction, machine translation, semantic analysis, and text mining. These techniques serve as effective methods for analyzing, processing, and comprehending natural language.[35] At present, the primary focus of NLP revolves around researching and applying enhanced models based on GPT and BERT, such as GPT-3, GPT-4, LaMDA, and Instruct GPT.[36]

Thirdly, deep learning is a machine learning technique that employs multilayer neural networks to emulate the cognitive processes of the human brain, enabling the performance of intricate learning tasks using extensive data. Within AI chatbots, deep learning is employed for various tasks, including semantic analysis, natural language generation, intent recognition, and conversation state tracking, resulting in promising outcomes.[37] Presently, with the widespread application and advancement of GPT and BERT, featuring Transformer as the architecture in the NLP community, the utilization of deep learning techniques allows for the creation of more intelligent chatbots that offer users more convenient services.

Proceedings of the International Conference on Machine Learning, Beijing, China, June 22-24, 2014; Chorowski, J. et al, "Attention-Based Models for Speech Recognition," In *Proceedings of the 29th Annual Conference on Neural Information Processing Systems (NIPS)*, Montreal, Canada, December 7-12, 2015.

35 "Improving Language Understanding with Unsupervised Learning," *OpenAI Blog*. June 11, 2018. Accessed February 9, 2023. https://openai.com/blog/language-unsupervised/; Devlin, Jacob et al, "BERT: Pre-Training of Deep Bidirectional Transformers for Language Understanding," *arXiv preprint* arXiv:1810.04805, 2018.

36 Brown, Tom et al, "Language Models Are Few-Shot Learners," *Advances in Neural Information Processing Systems* 33 (2020): 1877-1901; OpenAI, "GPT-4 Technical Report," *arXiv preprint* arXiv:2303.08774, 2023; Thoppilan, Romal et al, "LaMDA: Language Models for Dialog Applications," *arXiv preprint* arXiv:2201.08239, 2022; Ouyang, Long et al, "Training Language Models to Follow Instructions with Human Feedback," *Advances in Neural Information Processing Systems* 35 (2022): 27730-27744.

37 Shumanov, Michael, and Lester Johnson, "Making Conversations with Chatbots More Personalized," *Computers in Human Behavior* 117 (2021): 106627.

3.5.2 Research Related to Digital Health and Education

Cluster 2 (Green) comprises 18 keywords primarily associated with the implementation of AI chatbots in digital health, education, and related functionalities.

First, AI chatbots have the potential to revolutionize the healthcare industry by offering personalized solutions and enhancing patient prognosis. In recent years, significant advancements have been made in the application of AI chatbots in digital health, mental health, and depression. Specifically, the application of AI chatbots in digital health encompasses mental health, healthy eating, physical activity, and various physical disorders.[38] It is worth noting that the healthcare industry possesses unique characteristics such as data sensitivity and life-safety considerations, leading to scholars dedicating their efforts to researching, designing, and developing AI chatbot systems in the realms of digital health and mental health.[39] In conclusion, the aim of applying AI chatbots in the healthcare industry is not to disrupt traditional medical relationships but to serve as an effective complement and enhancement, particularly in areas like patient self-care and medical consultation services. However, due to the challenge of limited access to AI algorithm training data in the healthcare industry, the application of AI chatbots in this sector will remain a focal point and a challenging aspect of future research.

Second, AI chatbots hold significant potential in the field of education and can aid students in comprehending learning materials while assisting teachers in delivering enhanced guidance.[40] Presently, AI chatbots find widespread application across various educational disciplines, encompassing early education, STEM education, and language education. Their implementations include collaborative learning, mobile/game-based

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[38] Chakraborty, S. et al, "Large-Scale Textual Datasets and Deep Learning for the Prediction of Depressed Symptoms," *Computational Intelligence and Neuroscience* (2022): 5731532; Chew, H. S. J, "The Use of Artificial Intelligence-Based Conversational Agents (Chatbots) for Weight Loss: Scoping Review and Practical Recommendations," *JMIR Medical Informatics* 10, no. 4 (2022): e32578.

[39] Hassan, A. et al, "Development of NLP-Integrated Intelligent Web System for E-Mental Health," *Computational and Mathematical Methods in Medicine* (2021): 1546343.

[40] Pérez, José Quiroga, Thanasis Daradoumis, and Joan Manuel Marquès Puig, "Rediscovering the Use of Chatbots in Education: A Systematic Literature Review," *Computer Applications in Engineering Education* 28, no. 6 (2020): 1549-1565.

learning, distance learning, and affective learning.[41] These AI chatbots can autonomously assume instructor roles or collaborate with human instructors.[42] Moreover, experimental findings have indicated that students exhibit increased learning outcomes and academic performance when engaged with AI chatbots compared to traditional learning methods. Consequently, the utilization of AI chatbots in education possesses the potential to revolutionize conventional learning and teaching practices. Nevertheless, the implementation of AI chatbots in education is still in its nascent stage, and various ethical and practical challenges persist. The current scarcity of empirical studies on AI chatbots in education exemplifies these challenges.[43] In conclusion, AI chatbots have emerged as promising tools in education, offering ample opportunities for further research and innovative practices within the field.

3.5.3 Research Related to Conversational AI

Cluster 3 (Blue): Comprised of 6 keywords, "Conversational AI" has been chosen as the name of the third cluster and as a research direction for AI chatbot studies.

Conversational AI refers to the technology that encompasses speech and text recognition, natural language processing, intent and emotion understanding, and enables interactions resembling those between humans and machines. It serves as a fundamental component of AI chatbots and encompasses various research areas, such as human-machine communication, sentiment modeling, knowledge graph integration, and ontology development. Achieving a deeper understanding of human-computer communication is vital for creating engaging chatbot experiences, ontologies contribute to knowledge organization and retrieval within chatbots, knowledge graphs provide structured

41 Chen, X. L. et al, "Artificial Intelligent Robots for Precision Education: A Topic Modeling-Based Bibliometric Analysis," *Educational Technology & Society* 26, no. 1 (2023): 171-186.

42 Chen, Lijia, Pingping Chen, and Zhijian Lin, "Artificial Intelligence in Education: A Review," *IEEE Access* 8 (2020): 75264-75278.

43 Hwang, Gwo-Jen, and Ching-Yi Chang, "A Review of Opportunities and Challenges of Chatbots in Education," *Interactive Learning Environments* (2021): 1-14. https://doi.org/10.1080/10494820.2021.1952615.

representations of information and enhance chatbots' conversational capabilities, and emotional intelligence plays a crucial role in effective human-robot communication.[44] In summary, Conversational AI technologies possess extensive research potential to enhance machines' comprehension, processing, and response to human language and intentions.

3.5.4 Research Related to COVID-19

Cluster 4 (Yellow): Comprising of 5 keywords, we have chosen "COVID-19" as the designated cluster name and research focus for AI chatbot research.

The global outbreak of COVID-19 has resulted in a significant number of confirmed cases, and AI chatbots have been utilized to carry out specific pre-hospital triage tasks in medical response to COVID-19, the New Coronary Pneumonia Screening System, and the New Coronary Pneumonia Diagnostic Model.[45] Moreover, COVID-19 has also contributed to a surge in mental health disorders worldwide, and AI chatbots have shown promising applications in supporting mental health during the COVID-19 pandemic.[46] Additionally, the COVID-19 crisis has witnessed an influx of information, often

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44 Ho, A., J. Hancock, and A. S. Miner, "Psychological, Relational, and Emotional Effects of Self-Disclosure after Conversations with a Chatbot," *Journal of Communication* 68, no. 4 (2018): 712-733. https://doi.org/10.1093/joc/jqy026; Tian, Junrui et al, "Intention Model-Based Multi-Round Dialogue Strategies for Conversational AI Bots," *Applied Intelligence* 52, no. 12 (2022): 13916-13940. https://doi.org/10.1007/s10489-022-03288-8; Yoo, SoYeop, and OkRan Jeong, "EP-Bot: Empathetic Chatbot Using Auto-Growing Knowledge Graph," *Computers, Materials & Continua* 67, no. 3 (2021): 2807-2817; Firdaus, Mauajama et al, "EmoSen: Generating Sentiment and Emotion Controlled Responses in a Multimodal Dialogue System," *IEEE Transactions on Affective Computing* 13, no. 3 (2022): 1555-1566.

45 Lai, L. et al, "Digital Triage: Novel Strategies for Population Health Management in Response to the COVID-19 Pandemic," *Healthcare (Amsterdam, Netherlands)* 8, no. 4 (2020): 100493; de Campos Filho, A. S. et al, "Content and Usability Validation of an Intelligent Virtual Conversation Assistant Used for Virtual Triage During the COVID-19 Pandemic in Brazil," *Computers, Informatics, Nursing* 40, no. 11 (2022): 779-785; Ur Rehman, Muneeb et al, "IoT & AI Enabled Three-Phase Secure and Non-Invasive COVID-19 Diagnosis System," *Computers, Materials & Continua* 71, no. 1 (2022): 423-438.

46 Jiang, Q., Y. Zhang, and W. Pian, "Chatbot as an Emergency Exit: Mediated Empathy for Resilience via Human-AI Interaction During the COVID-19 Pandemic," *Information Processing & Management* 59, no. 6 (2022): 103074; Nelekar, Shreeya et al, "Effectiveness of Embodied Conversational Agents for Managing Academic Stress at an Indian University (ARU) During COVID-19," *British Journal of Educational Technology* 53, no. 3 (2021): 491-511

accompanied by disinformation on the internet, posing significant challenges to public health. In this context, AI chatbots have played a prominent role in managing COVID-19-related information.[47] To summarize, the COVID-19 pandemic has exposed a notable disparity between healthcare resources and patient needs, and AI chatbots have emerged as valuable tools in assisting individuals with their healthcare requirements during this challenging period.

3.5.5 Research Related to Customer Service

Cluster 5 (Purple): Comprised of 4 keywords, "Customer Service" has been chosen as the fifth cluster name and research direction for AI chatbot studies.

There is significant commercial value in implementing AI chatbots in the field of customer service, as they have found wide-ranging applications in replacing or augmenting manual customer service in the business sector. Numerous studies have focused on anthropomorphism, exploring the human-like attributes of chatbots.[48] Additionally, a substantial body of research has examined customer experience, satisfaction, and other factors closely associated with customer service.[49] In summary, AI chatbots have become practical tools in the business realm, increasingly replacing traditional human customer service. Moving forward, attention should be given to human-machine interaction and anthropomorphic design to enhance customer service experiences and generate greater

47 Pandey, R. et al, "A Machine Learning Application for Raising WASH Awareness in the Times of COVID-19 Pandemic," *Scientific Reports* 12, no. 1 (2022): 810.

48 Lu, Lincoln et al, "Measuring Consumer-Perceived Humanness of Online Organizational Agents," *Computers in Human Behavior* 128 (2022): 107092; Crolic, Cammy et al, "Blame the Bot: Anthropomorphism and Anger in Customer–Chatbot Interactions," *Journal of Marketing* 86, no. 1 (2022): 132-148.

49 Pillai, Rajasshrie, and Brijesh Sivathanu, "Adoption of AI-Based Chatbots for Hospitality and Tourism," *International Journal of Contemporary Hospitality Management* 32, no. 10 (2020): 3199-3226; Ruan, Yanya, and József Mezei, "When Do AI Chatbots Lead to Higher Customer Satisfaction Than Human Frontline Employees in Online Shopping Assistance? Considering Product Attribute Type," *Journal of Retailing and Consumer Services* 68 (2022): 103059; Lee, Crystal T., Ling-Yen Pan, and Sara H. Hsieh, "Artificial Intelligent Chatbots as Brand Promoters: A Two-Stage Structural Equation Modeling-Artificial Neural Network Approach," *Internet Research* 32, no. 4 (2022): 1329-1356.

business value.

3.5.6 Research Related to Sentiment Analysis

Cluster 6 (Turquoise): Comprising of 2 keywords, "Sentiment Analysis" has been chosen as the sixth cluster name and research direction within AI chatbot research.

In the AI chatbot domain, the application of affective computing and sentiment analysis is primarily focused on personalized customer service, mental health support, and user sentiment feedback. Researchers have explored effective computing approaches and investigated the specific application of sentiment analysis in AI chatbots.[50]The convergence of affective computing, sentiment analysis, and AI chatbots represents a rapidly evolving field with significant potential to transform HCI.

4.Discussion

4.1 AI chatbot Research Trend Under the Perspective of Time

Examining the present state of AI chatbot research and the trends in publications, it is evident that AI chatbot research has been consistently increasing over the past two decades, with a particularly notable surge in the last five years. The temporal evolution mapping of keywords in the six AI chatbot clusters, along with the average year of publication values for each keyword analyzed in VOSviewer, is illustrated in Figure 6, following the clusters and their key phrases depicted in Figure 5.

As depicted in Figure 6, the evolution of AI technologies has garnered significant attention since 2000. Beginning in 2017, researchers have not only focused on AI

[50] Cambria, Erik et al. "SenticNet 7: A Commonsense-Based Neurosymbolic AI Framework for Explainable Sentiment Analysis." In *Proceedings of the Thirteenth Language Resources and Evaluation Conference*, Marseille, France, 2022; Shuang, Kai et al, "Interactive POS-Aware Network for Aspect-Level Sentiment Classification," *Neurocomputing* 420 (2021): 181-196; Jain, Rishit et al, "Real-Time Sentiment Analysis of Natural Language Using Multimedia Input," *Multimedia Tools and Applications* (2023): 16; Kim, Taekyung et al, "Robots, Artificial Intelligence, and Service Automation (RAISA) in Hospitality: Sentiment Analysis of YouTube Streaming Data," *Electronic Markets* 32, no. 1 (2022): 259-275.

technologies but also dedicated considerable effort to the design of HCI in real-world commercial applications. In summary, the research trajectory of AI chatbot can be characterized as a progression from traditional chatbots to AI chatbots and subsequently to large-scale commercial applications. This progression has been facilitated by the combined contributions of AI technology, HCI design, and commercial applications, ultimately leading to the current phenomenon of the ChatGPT tsunami. In terms of the temporal evolution of specific keywords, two main trends can be observed: (1) the continuous enhancement of AI chatbot intelligence, encompassing keywords such as speech recognition, emotional computing, machine learning, natural language processing, and deep learning; (2) a focus on the harmonious symbiosis of AI development, HCI design, and commercial applications, as indicated by keywords like anthropomorphism, customer services, customer satisfaction, customer experience, and customer acceptance. It is evident that future AI chatbots will undergo further upgrades to become more intelligent, enabling them to collaborate more effectively with humans and assist in solving increasingly complex problems through learning and reasoning. Simultaneously, the future development of AI chatbots will be characterized by highly intelligent systems integrated into large-scale commercial applications, representing significant features of their advancement. For more research trends and directions, see Section 4.3.

4.2 Towards a Conceptual Framework for AI chatbot Research

Utilizing the product development model of AI chatbot, the analysis in this paper focuses on the interpretation of the 64 high-frequency author keywords associated with AI chatbot research. These keywords are categorized into three levels: AI development, HCI design, and application scenarios. By refining this analysis, a conceptual framework encompassing the key aspects of AI chatbot research is presented, as illustrated in Figure 7.

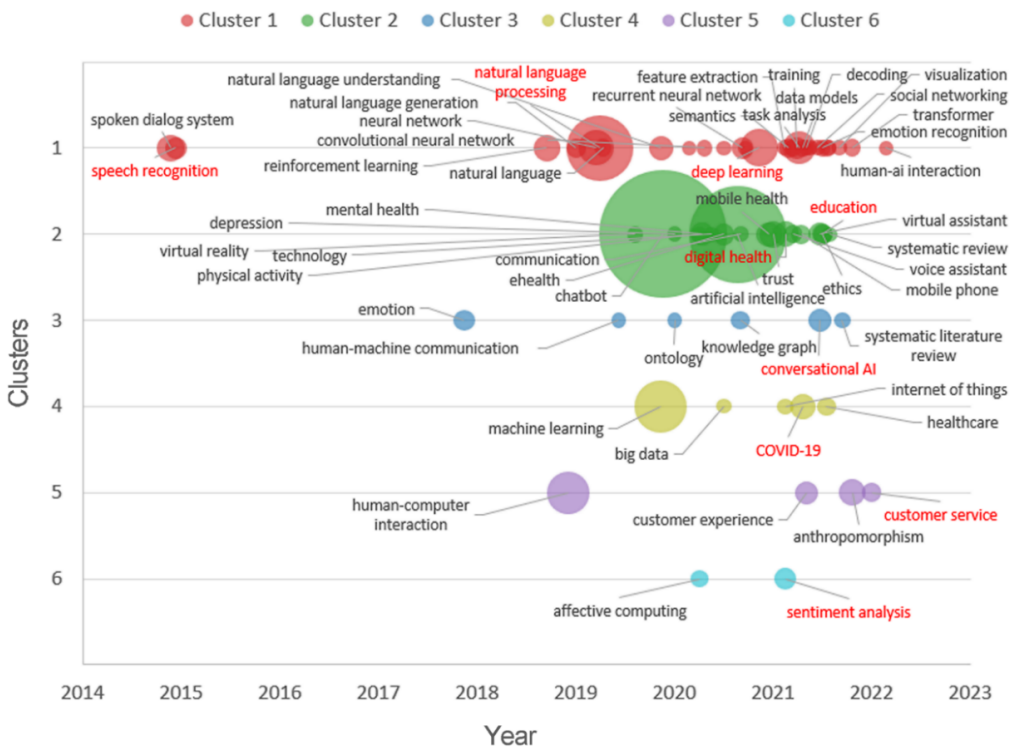

Figure 6. The temporal evolution mapping of keywords

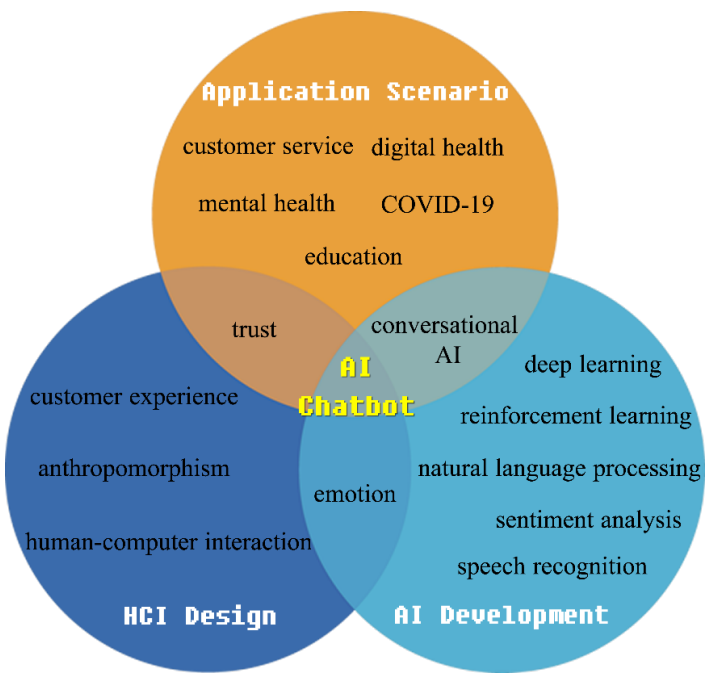

Figure 7. Conceptual framework for AI chatbot research

Conversational AI encompasses a wide range of AI technologies that facilitate and enhance “intelligent” interactions between computers and humans. These technologies include speech recognition, affective computing, natural language processing, deep learning, reinforcement learning, as well as various other methods of intelligent analysis related to HCI, such as text, speech, image, touch, and gesture. Among these AI development-related keywords, natural language processing and deep learning hold significant importance in the context of conversation management for AI chatbots. Specifically, natural language processing and deep learning techniques need to address research tasks such as semantics, sentiment analysis, natural language generation, intent detection, and task analysis.

The success of AI chatbots in various human-related activities largely depends on the level of HCI design. HCI design factors play a crucial role in imitating human interaction and meeting user expectations. Among these factors, anthropomorphism is the core keyword associated with imitating human interaction. Considering its correlation with customer service and the temporal trend, anthropomorphism is expected to be a prominent research area and frontier in the field of AI chatbot HCI design. Meeting users' expectations is another critical aspect of HCI design. The core keywords associated with meeting users' expectations are customer experience and trust. The ability of AI chatbots to perform artificial replacement tasks effectively relies on their continuous improvement of customer experience and their ability to gain users' trust. Consequently, these keywords serve as the foundation and focal point of HCI design in the context of AI chatbots.

The success of ChatGPT is poised to catalyze increased investment in AI chatbot research and development by global IT companies, consequently accelerating the widespread commercial deployment of various AI chatbot products across diverse industries. Based on the distribution of current high-frequency keywords, the primary application scenarios for AI chatbots presently encompass customer service, digital health, mental health, COVID-19, and education. It is anticipated that future AI chatbot application scenarios will encompass nearly all human-related activities.

4.3 Suggestions on Future Research of AI chatbot

AI chatbots have gained extensive utilization globally. To foster the ongoing and profound advancement of AI chatbots, this paper draws upon the findings of the literature analysis to propose the following recommendations for future research in this field.

4.3.1 Continuously upgrade the intelligent technology

Firstly, enhancing the natural language processing capabilities and deep learning techniques of AI chatbots is crucial to facilitate a better and more precise comprehension of user language and intent, thereby enabling more accurate service provision. One of the key challenges for AI chatbots in the future lies in comprehending conversation context and generating emotionally rich and personalized responses.

Secondly, augmenting the machine learning capabilities of AI chatbots enables them to effectively anticipate user intentions based on their interaction history, leading to faster service delivery. Additionally, incorporating reinforcement learning techniques allows AI chatbots to continuously learn from multiple iterations, thereby enhancing service efficiency.

Furthermore, leveraging big data techniques can enhance the data mining capabilities of AI chatbots, improve their conversation management systems to enhance semantic understanding and response accuracy, and elevate their sentiment analysis capabilities to enhance user communication experiences. Research indicates a substantial focus from numerous authors on the AI capabilities of chatbots, [51]with the continuous enhancement of AI chatbot intelligence technology remaining a prominent area for future investigation.

4.3.2 Focus on the HCI design

Chatbots, particularly those employed for customer service, have garnered a

[51] Cui, F., Q. Cui, and Y. Song, "A Survey on Learning-Based Approaches for Modeling and Classification of Human-Machine Dialog Systems," *IEEE Transactions on Neural Networks and Learning Systems* 32, no. 4 (2021): 1418-1432.

reputation for being unreliable among consumers.[52] On one hand, to advance future research on chatbot HCI design, scholars can integrate chatbot user experience models, measurement, and evaluation methods to conduct comprehensive studies aiming to enhance service quality and user satisfaction.[53] On the other hand, despite providing round-the-clock service in various domains such as sales, support, and marketing, chatbots still face low customer acceptance.[54] Therefore, a key area for future research lies in influencing and enhancing the design of chatbot HCI based on current research to continuously improve user acceptance, engagement, experience, satisfaction, and trust in AI chatbots from a design-oriented perspective.

4.3.3 Strengthen the promotion of interdisciplinary research and practice

AI chatbots exhibit a notable interdisciplinary nature, as evident from citations and keywords stemming from diverse fields in related studies. Previously, AI research primarily focused on the realm of computer science.[55] However, the rapidly expanding research on chatbots currently embraces significant interdisciplinary aspects, encompassing fields such as informatics, management and marketing, media and communication sciences, linguistics and philosophy, psychology and sociology, engineering, design, and HCI. Looking ahead, further interdisciplinary efforts are essential to advance AI technologies, enhance human-intelligence interaction systems, and continually enhance the applicability of AI chatbots across various domains and scenarios, thereby maximizing their value.

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52 Kaplan, A. D. et al, "Trust in Artificial Intelligence: Meta-Analytic Findings," *Human Factors* 65, no. 2 (2023): 337-359.

53 Mostafa, Rania Badr, and Tamara Kasamani, "Antecedents and Consequences of Chatbot Initial Trust," *European Journal of Marketing* 56, no. 6 (2021): 1748-1771.

54 Ashfaq, Muhammad et al, "I, Chatbot: Modeling the Determinants of Users' Satisfaction and Continuance Intention of AI-Powered Service Agents," *Telematics and Informatics* 54 (2020): 101473; Rese, Alexandra, Lena Ganster, and Daniel Baier, "Chatbots in Retailers' Customer Communication: How to Measure Their Acceptance?," *Journal of Retailing and Consumer Services* 56 (2020): 102176.

55 Aoki, Naomi. "An Experimental Study of Public Trust in AI Chatbots in the Public Sector." *Government Information Quarterly* 37, no. 4 (2020): 101490.

5.Conclusion

This paper provides a comprehensive review of the AI chatbot research literature from 2000 to 2023, utilizing bibliometric and content analysis methods such as co-citation analysis, co-word analysis, and cluster analysis. Through a visual examination and in-depth interpretation of the references and author keywords from 1236 related articles, a systematic analysis was conducted. The statistical analysis reveals that AI chatbot research has progressed through an initial exploration phase (2000-2016) and a subsequent phase of rapid development (2017-2023). Through the examination of cited authors using co-citation analysis, it was observed that influential authors in the field of AI chatbot can be categorized into three groups: human-computer interaction, human-related, and computer-related researchers. These three types of authors contribute theoretical, humanistic, and technical foundations to AI chatbot research. Additionally, co-citation analysis of cited sources demonstrates the interdisciplinary nature of AI chatbot as a research field, highlighting cross-fertilization between various disciplines. Through an in-depth analysis of co-word analysis, it is evident that the research focus of AI chatbot centers around AI technologies, digital health and education, conversational AI, COVID-19, customer service, and sentiment analysis. Building upon the findings of the bibliometric analysis, this study summarizes the developmental trends of AI chatbot, proposes a conceptual framework for AI chatbot research, and provides suggestions for future research directions in the field.

This study has certain limitations that should be addressed in future research. Primarily, the analysis is based on data from the Web of Science database, which may not cover all relevant AI chatbot studies. Additionally, the bibliometric and content analysis methods used here, including keyword-driven hotspot analysis with VOSviewer software, may overlook some essential literature and limit the theoretical depth of the analysis. The study's timeframe, ending in November 2023, further restricts it from reflecting the latest advancements and emerging areas in the fast-evolving AI chatbot field, which has seen accelerated growth since 2017. To address these limitations, future research could adopt a combination of systematic reviews and meta-analyses, thereby providing a more

comprehensive and in-depth examination of AI chatbot developments.

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