A Bibliometric Review of Research on Intelligent Personal Assistants: Present Status, Development, and Future Directions

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Abstract:

Voice assistants based on Artificial Intelligence (AI) are computer programs that use natural language processing (NLP) and machine learning (ML) algorithms to recognize and respond to voice commands and queries in a human-like way. These voice assistants use speech recognition technology to understand spoken commands and questions, process them, and provide relevant responses. The objective of this study is to examine the intellectual framework and effectiveness of voice assistants and to analyze the literature produced by renowned researchers in terms of authors, keywords, and major organizations. This review seeks to offer valuable insights into the growing body of literature on virtual assistants.

In this article, the authors have used the bibliometric method to systematically summarize the current state of voice assistant research. They analyzed 563 articles related to Voice assistants from the Scopus database between 2002 and 2023 using the R-Studio 'Biblioshiny' tool. The analysis includes an examination of the core journals, articles, authors, institutions, and relevant countries to determine the most influential voice assistants literature. This study also provides a detailed understanding of Co-occurrence network, Co-citation network and Co-word analysis. The authors have also used thematic maps to identify the different research topics of voice literature and have grouped them into four clusters, including Motor themes, Niche themes, Emerging themes, and Basic themes. The article concludes by discussing the limitations of the study and highlighting future research directions.

Keywords: Virtual Assistants, Voice Assistants, VBA, Digital Voice Assistant.

Introduction:

In recent years, Artificial Intelligence (AI) has emerged as a crucial subject of discussion for both individuals and organizations, especially in light of the increasing popularity of Voice Assistants (VAs) (Guzman, 2019). The primary aim of this research is to investigate the present condition of research on voice assistants.

Voice assistants are technological systems that utilize artificial intelligence (AI) and comprise software and hardware components. These systems are designed to interact with users and provide responses to their commands or inquiries (Verma et al., 2021) Voice assistants like Siri, Cortana, Alexa, and Google Assistant allow users to interact with their devices by voice. These software agents listen for a keyword, record the user's voice, and send it to a specialized server that processes and interprets it. Depending on the command, the server can supply the assistant with the necessary information to complete tasks, play media, or access connected devices, and the number of services and devices supporting voice commands growing rapidly(Hoy, 2018). According to (Hoy, 2018) through the use of natural language processing and machine learning, a voice assistant is able to comprehend and interpret the language spoken by the user and provide an immediate response. According to (Milhorat P. et al., 2014), voice assistants are one type of integrated AI application, which belong to a diverse and expanding range of advanced AI technologies and applications. As noted by scholars (Koehler, 2018) and (Parise et al., 2016) voice assistants and AI have the potential to revolutionize businesses by simplifying processes, automating intricate tasks, and improving customer service.

Voice assistants can perform a wide range of tasks, such as playing music, setting alarms, making phone calls, sending text messages, providing weather updates, answering trivia questions, and controlling smart home devices. Additionally, voice assistants can integrate with various services and third-party apps, allowing users to order food, shop online, and book travel, among other things.

As per (Sundar et al., 2017), due to the remarkable expansion of voice-based technology, an increasing number of individuals are engaging with voice assistants in a manner that emulates their interactions with humans in their day-to-day activities. According to (Guzman, 2019) the introduction of voice assistants on mobile devices provided people with their initial chance to communicate effectively and purposefully with artificial intelligence. Voice assistants have become popular due to their ability to provide hands-free and convenient assistance in performing various tasks such as making phone calls, sending messages, setting reminders, and controlling smart home devices. Additionally, advances in natural language processing and machine learning have made them more accurate and reliable, resulting in widespread adoption. Finally, voice assistants have been integrated into a

variety of devices such as smartphones, smart speakers, and cars, making them easily accessible to a large number of users. As technology advances, the capabilities of voice assistants are continually expanding, and they are becoming more intelligent and useful in our daily lives.

The use of bibliometric analysis has become popular in various fields for assessing research performance namely management, (Podsakoff et al., 2008); entrepreneurship,(Landström et al., 2012); innovation (Fagerberg et al., 2012); accounting (Merigó & Yang, 2017). Bibliometric approaches allow for a comprehensive evaluation of a research field, including analyses of leading researchers, countries, and institutions (Bjork et al., 2014). While primarily quantitative, bibliometric analyses can also provide qualitative insights, and they are capable of evaluating a large number of publications easily. In the present study, bibliometric analysis was employed to examine research on voice assistants and identify emerging trends relevant to the field's development.

In the past few years, studies have been conducted to analyze voice assistants worldwide using the Scopus database ((Agarwal et al., 2022); (Lim et al., 2022)). These studies have provided a comprehensive understanding of the origins and growth of research and practical applications in the area of voice assistants. (Lim et al., 2022) observed that the majority of articles (more than 65%) were published from 2019 to 2021. The author also presented insight into the multidisciplinary scope of conversational commerce is evident in the top 10 sources that have published research on this topic, which belong to the fields of computers and digitalization, business, communication and knowledge management, and psychology.

(Agarwal et al., 2022) pointed out that The largest contributor to the area of chatbots and virtual assistants in terms of published documents is the United States, with 17% of the total production. The study has found that The Open University, Peking University, Politecnico di Milano, and Microsoft Corporation are the leading contributors in terms of the number of documents published each year in the area of chatbots and virtual assistants. This information can be useful for future researchers who want to investigate this area further.

Research Methodology:

The study on voice assistants followed a systematic process, which involved several steps to evaluate the relevant research literature. Initially, the researchers identified the relevant keywords and shortlisted the research papers based on them. Then, they applied a set of filters to refine the data set and ensure that only the pertinent research papers were considered. Finally, they selected the appropriate bibliometric and network mapping tools for conducting the research study. The methodology used in this study is illustrated in Figure 1. The research conducted in this study utilizes the literature review methodology recommended by 15 (Rowley & Slack,

2004). This methodology is widely recognized by scholars who have published bibliometric research in various fields, including (Pinto et al., 2020). This research also employed the typical five-step process of bibliometric analysis, which includes Study Design, Data Collection, Data Analysis, Data Visualization, and Interpretation, as described by (Borner et al., 2003) and (Zupic & Čater, 2015)

The primary goal of this research is to examine the present status of voice assistant research by utilizing bibliographic data obtained from the Scopus database spanning from the years 2002 to 2023.

In the Study Design stage, following were the main research questions:

What is the overview of research development in the field of voice assistants?

What are the common keywords used in the area of virtual assistants by using bibliometric analysis?

Who are the most cited authors contributing to the research?

Which universities are most contributing in this area?

Which countries have the highest number of documents in this area?

What are the main research directions and developmental trends during this period?

The study intends to achieve this by examining bibliographic data gathered from the Scopus database spanning the years 2002 to 2023.

Data collection

Database selection for literature search:

The bibliometric analysis commenced with the selection of a database for conducting the search for research papers related to voice assistants and the Scopus database was chosen for the literature search. According to Falagas et al. (2008), the Scopus database comprises more than 20,000 journals published by top publishers like Emerald, Elsevier, Inderscience, and Springer. This database houses the most extensive collection of research papers that undergo peer review across various fields, including social sciences, arts, humanities, science, and technology. Researchers frequently use them to carry out bibliometric analyses, as they make it easy to export datasets from research papers into different tools for bibliometric and network mapping purposes.

Keyword identification

Identifying relevant keywords is a crucial step in conducting bibliometric analysis, as having a comprehensive list of keywords allows for a thorough and all-encompassing search within the chosen field of study. By using a specific keyword string, such as "Virtual Assistants" OR "Voice-based Assistants" OR "Voice Assistants" OR "VBA" OR "Personal Intelligent Assistants" OR "Smart Speaker" OR "Smart Voice Assistant" OR "Intelligent Personal Assistant" OR "Digital Voice Assistant" OR "Conversational Assistants", all research articles within that domain can be included in the search. The search

terms were selected after an academic brainstorming session involving experts in the field, who identified keywords relevant to voice assistants. This search was conducted on 29th March 2023 covering the period from 2002 to 2023 which yielded 6040 papers from Scopus.

Data filtration

In order to narrow down the dataset and focus on relevant research literature, multiple filters were applied. The datasets mentioned above were refined excluding books and conference papers, resulting in a selection of 2388 high-quality research articles with final publication for analysis. Research papers within the subject areas of social sciences, business management, and psychology were included in the final dataset for time period between 2002 to 2023 which resulted in 602 articles. Articles written in English were chosen and only genuine and published findings in journals were considered for inclusion in the data set. The final dataset for further analysis consisted of the 563 research papers retrieved from the Scopus database. This marked the conclusion of the selection process. Figure 1 provides a brief methodology adopted for this bibliometric review.

Figure 1: Methodology for Bibliometric Review

Steps	Stage	Output
Step 1	Selection of Database for Literature Search	Scopus
Step 2	Study Design	Research Questions
Step 3	Keyword Identification	"Virtual Assistants" OR "Voice-based Assistants" OR "Voice Assistants" OR "VBA" OR "Personal Intelligent Assistants" OR "Smart Speaker" OR "Smart Voice Assistant"OR "Intelligent Personal Assistant" OR "Digital Voice Assistant" OR "Conversational Assistants"
Step 4	Initial Result	6040 research papers from Scopus
Step 5	Data Filtration	Research Papers in the final stage of Publication: 5941 Document type limited to articles: 2388 Time period -2002 to 2023: 2266 Subject Area: Social sciences, Business management, and Psychology:602 Source- Journal:595 English only: 563
Step 6	Bibliometric and Network Mapping Tools	R Studio: Biblioshiny

Bibliometric and network mapping tools

There are various software options available for conducting bibliometric analysis and network visualization. The chosen software for bibliometric analysis was Bibliometrix, an R-language tool that provides extensive analysis capabilities for researchers. Additionally, the user-friendly app Biblioshiny, which is available within the Bibliometrix package, was used for non-coders to conduct bibliometric analysis. The data set used for the analysis was downloaded in CSV formats from Scopus. The keyword co-occurrences analysis was conducted, including the most cited author keywords, and co-authorship links between countries involved in the domain were also examined. Furthermore, data were summarized at various points using Microsoft Excel.

Data Analysis

Descriptive statistics

Table 1 presents the primary information regarding publications related to Voice assistants between 2002 and 2023. Over the past 21 years, there have been 563 articles published on this topic across 326 journals. The ratio of authors per document is 2.89. The statistics indicate that a total of 1628 authors contributed to the articles, with an average of 2.89 authors per article and a collaborative index of 3.26. 81 (5%) articles were authored by a single individual, while 1547 (95%) were produced by multiple authors. The articles were of high quality, as evidenced by their average citation count of 13.33 per article.

Table 1 The primary results of the Scopus dataset in the field of Voice Assistants

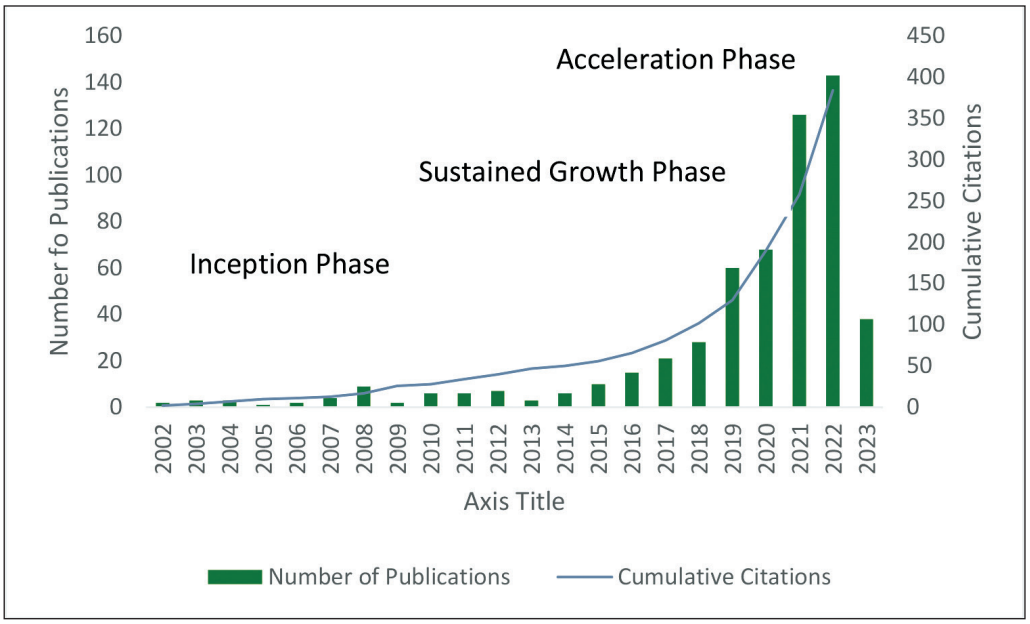
Description	Results
Timespan	2002:2023
Sources (Journals, Books, etc)	326
Average years from publication	3.62
Average citations per documents	13.33
Average citations per year per doc	3.068
References	29599
Article	563
Keywords Plus (ID)	2274
Author's Keywords (DE)	1942
Authors	1628
Author Appearances	1774
Authors of single-authored documents	81
Authors of multi-authored documents	1547
Single-authored documents	88
Documents per Author	0.346
Authors per Document	2.89
Co-Authors per Documents	3.15
Collaboration Index	3.26

Publication Output and Growth Trend

Figure 1 displays the yearly count of published articles alongside the total number of citations. Researchers have recently become more intrigued by this topic, with a sharp rise in the number of published articles 2018 onwards. According to statistics from Biblioshiny software, the annual growth

rate is 15.05%. From 2002 to 2023, research on Voice Assistants has been increasing with some variations (as shown in Figure 2). This period can be divided into three phases: The inception Phase (2002-2009), the sustained growth phase (2010-2017), and the acceleration phase (2018-2023). During the inception phase, only 26 articles (5% of the sample) were published, which is almost equivalent to 3.25 articles per year. The steady growth period had 74 articles (13% of the sample) with an improved average of 9.25 articles per year. However, after 2018, there was a significant increase in publication trends with 463 articles (82% of the sample) published, representing an impressive average of 77.16 articles per year. The reason why the line for 2023 shows a decrease is that the data was only gathered until March 2023. Nevertheless, it's crucial to acknowledge that studies regarding this matter are still ongoing and finding a lot of research attention. During the time span of 2002-2015, there was not a significant rise in the number of accumulated citations. However, since 2015, there was a steep increase in citations due to a surge in publications.

Figure 2 Annual number of publications and its cumulative citation values in the domain of Voice Assistants



Three-Fields Plot

Figure 3 displayed below depicts a three-field plot showing the interrelationships between a list of journal names, authors, and topics. The links between these three elements are displayed in gray, starting from the journal names, followed by the authors, and then linked to the topics of their publications. The size of the rectangles in each list represents the number of papers associated with that element.

The leftmost element in the plot represents the journals. Seven journals are indexed in this plot, with the top journal being the Proceedings Of The Acm On Human-Computer Interaction, which published the most papers on the topic of voice assistants. The brown rectangle represents this journal and is connected to several authors.

The middle element contains the authors' names. The authors who published articles in the indexed journals are linked to the journal elements such as Garg R and Ahmad I who are linked to Proceedings Of The Acm on Human-Computer Interaction, while those who did not publish in indexed journals are not linked to any journal such as Lopatovska I and Dizon G. The plot shows top15 authors. The rectangle's size in the plot corresponds to the number of papers published by each author, with Lopatovaska I, Dizon G, and Mols A contributing the most to the listed journals.

Each author is also associated with frequently used keyword topics on the right. The third element contains the most frequently used keyword topics in the papers. Fourteen keyword topics are listed, with "assistants" being the most frequently used and appearing in almost all of the registered authors' publications followed by "Intelligent" and "smart".

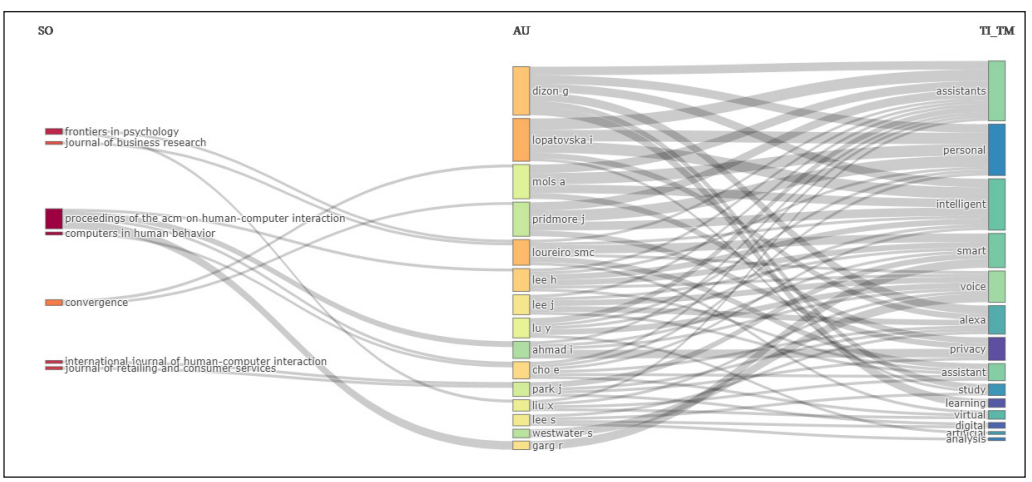
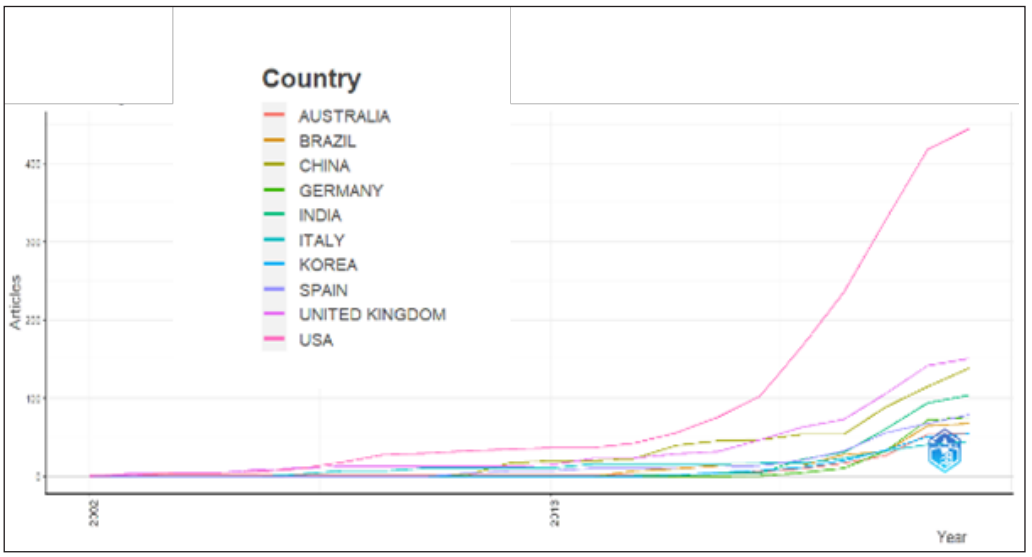


Figure 3: Three-field plot

Contribution by Nations

Figure 4 illustrates the number of articles pertaining to voice assistants, of the top 10 countries and ranging from 2002 to 2023. The USA stands out in this field with a noteworthy contribution, compared to other nations in the region followed by UK, China and India. The number of publications relating to this topic has been steadily increasing each year. While countries such as Korea and Italy also exhibit interest in voice assistants, their numbers have only slightly increased. Other countries have also conducted research in this field, but their contributions have not been consistent. Post 2020, a steady increase in the number of articles in this research area is observed.

Figure 4: Number of articles by nations in the field of voice assistants (2002-2023)



Contribution by Institutions

Table 2 displays the top 10 affiliations based on the number of articles published in Voice Assistants. Among these affiliations based on countries, United States has a maximum representation of 6 (UC, PI, UF, DU ASU, and CMU) while Korea (KU), China (CSU), United Kingdom (UN), and Australia (MU) had 1 affiliation each. UC has the highest number of publications, with 22 articles, followed by PI with 17, KU with 15, UF with 15, and CSU with 11. The list is arranged based on the number of publications from the highest to the lowest.

Table 2 Top 10 most productive affiliations publishing in the area of Voice Assistants

Order	Affiliations	Country	Articles
1	University Of California (Uc)	United States	22
2	Pratt Instituteny (Pi)	United States	17
3	Korea University (Ku)	Korea	15
4	University Of Florida (Uf)	United States	15
5	Central South University (Csu)	China	11
6	Depaul University (Du)	United States	11
7	Arizona State University (Asu)	United States	10
8	University Of Nottingham (Un)	UK	10
9	Carnegie Mellon University (Cmu)	United States	9
10	Monash University (Mu)	Australia	9

Contribution by Journals

Table 3, the quality of the top 10 journals with the highest number of articles related to voice assistants is presented. These journals are ranked based on Scopus categories, with all of them falling under Q1. The study revealed that 5 journals are from the United States while 3 journals are from Switzerland and 2 from the United Kingdom. The most frequently used journals by authors were the "Proceedings of the Acm on Human-Computer Interaction" and the "Computers In Human Behaviour" having 24 and 14 articles respectively.

Table 3: Top 10 most active journals publishing in the field of Voice Assistants

Order	Journals	Articles	Nation of Journals	Cite Score 2021*	SJR*	h-Index**	Scopus Quartile**
1	Proceedings Of The Acm On Human-Computer Interaction	24	United States	5.6	.617	38	Q1
2	Computers In Human Behaviour	14	United Kingdom	14.9	2.174	203	Q1
3	Computer Applications In Engineering Education	13	United States	4.2	.594	32	Q1

4	Frontiers In Psychology	11	Switzer-land	4	.873	133	Q1
5	International Journal Of Human-Computer Interaction	10	United States	7.3	.963	76	Q1
6	Journal Of Retailing And Consumer Services	10	United Kingdom	11.4	2.261	104	Q1
7	Journal Of Business Research	8	United States	11.2	2.316	217	Q1
8	Psychology And Marketing	8	United States	4.9	1.2	124	Q1
9	Sustainability (Switzerland)	8	Switzer-land	5	.664	109	Q1
10	Water (Switzerland)	7	Switzer-land	4.5	.716	69	Q1

Most productive authors

Table 4 provides significant information about the top 10 authors who have published the most works related to Voice assistants while Figure 5 presents the annual publication count for these authors.

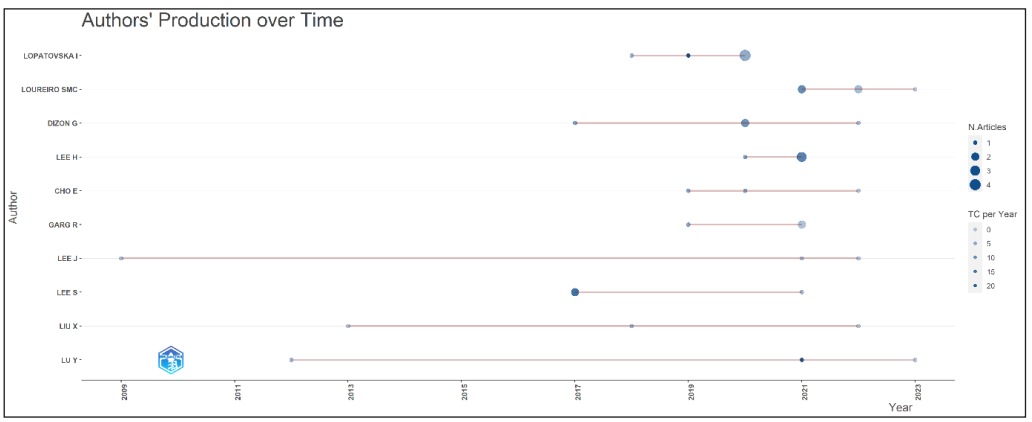


Figure 5: Authors' Production over Time

Pratt Institute's author Lopatovska Irene V. has the highest number of publications with 6 articles. Four authors have a total citation index exceeding 300, with Loureiro S.M.C. having 4583 citations. The United States has the highest number of authors (4), followed by Japan with 2 authors in the Top 10 authors list. Figure 5 shows that Lee, Joonghwa has been consistently conducting research on voice assistants from 2009 to 2022 while Lu Y has been active in this research area from 2012 to 2023. In the Top 10 authors list, most of them have been focused on this subject for the past 3 to 4 years, including the top 3 authors.

Collaboration between author groups is depicted in Figure 6, which was generated using Biblioshiny software based on the methodology outlined in the article. 7 groups of authors collaborate on voice assistants, with 3 research groups having the most publications, headed by Loureiro Smc (Iscte – Instituto Universitário de Lisbo, Portugal) , Mols, Anouk (Erasmus Universiteit Rotterdam, Netherland) , and Ahmad, Imtiaz, Indiana University, United States.

Figure 6 Collaborative network among authors in the field of Voice assistants

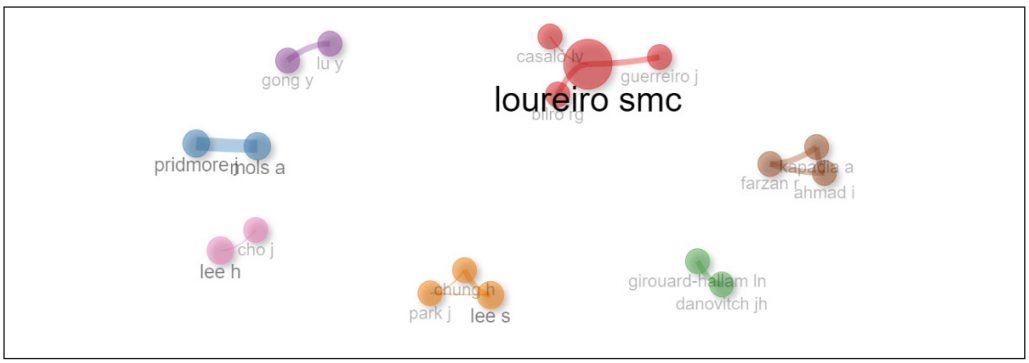


Table 4: Top 10 most productive authors publishing in the field of Voice assistant

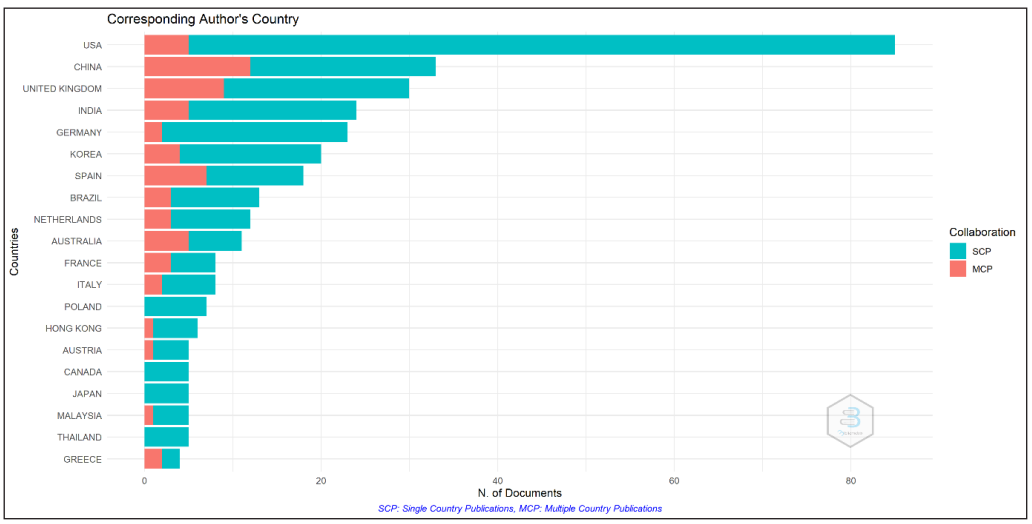
Order	Authors	Institutions	Country	Number of Articles	H-index	Total Citations
1	Lopatovska, Irene V.	Pratt Institute	United States	6	12	720
2	Loureiro S.M.C.	Iscte – Instituto Universitário de Lisbo	Portugal	5	36	4583
3	Dizon, Gilbert	Himeji Dokkyo University	Japan	4	7	195

4	Hansol Lee	Stanford University	United States	4	2	23
5	Cho, Erin	The New School	United States	3	15	1157
6	Garg, Radhika	School of Information Studies	United States	3	6	184
7	Lee, Joonghwa	University of North Dakota	United states	3	10	309
8	Mols, Anouk	Erasmus Universiteit Rotterdam	Netherlands	3	5	83
9	Liu, Xiaochen	Ritsumeikan University	Japan	3	2	1
10	Pridmore, Jason	Erasmus Universiteit Rotterdam	Netherlands	3	10	219

Corresponding Author's Country

Figure 6 displays the correlation between the articles written by authors for single-country publishers (shown in turquoise) and multi-country publishers (shown in red). The United States, China, and United Kingdom have the most significant number of authors producing texts and materials.

Figure 6 Corresponding Author's Country



Source Dynamics

Figure 7 displays how resources have grown over the years based on annual events. The graphs exhibit the changes in different fields with each year being associated with keywords like voice assistants. There are six groups depicted in the graphs, and since 2018 production of articles that were related to voice assistants had the highest growth rates.

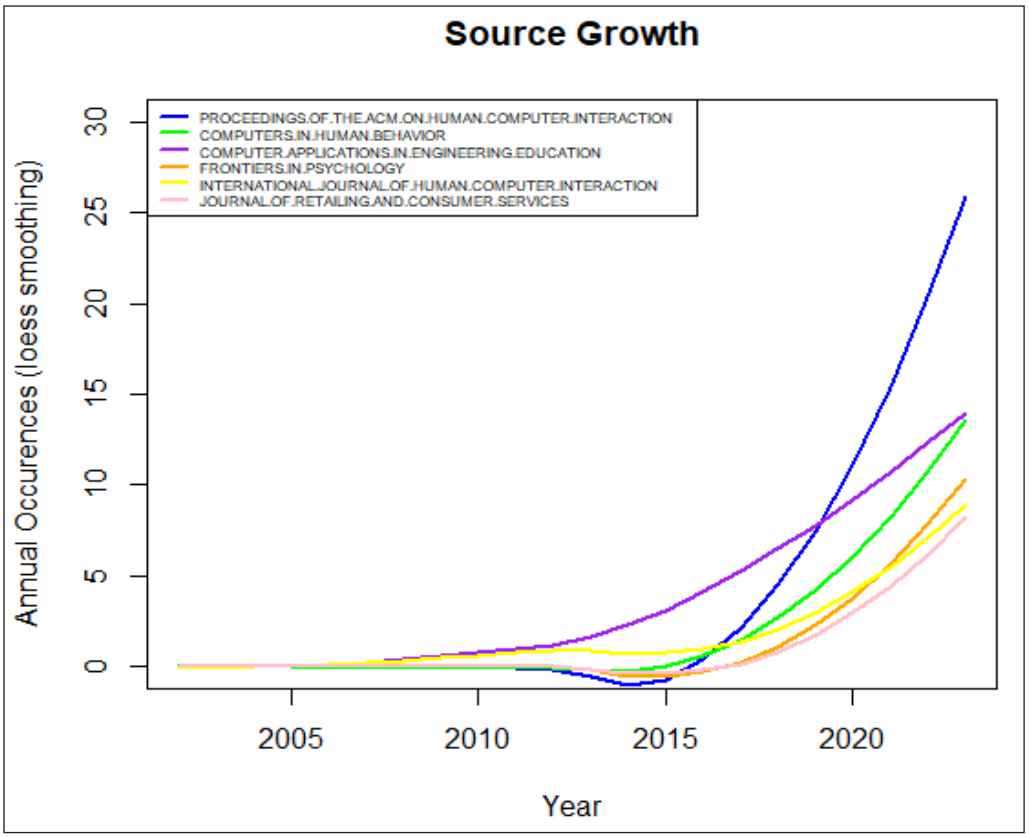


Figure 7: Source Dynamics

Highly cited papers

In Table 5, the top 100 authors with the highest citation are listed, along with a brief explanation of their content and the publishers with the highest citation.

(Hoy, 2018) with 397 citations explored the fundamental workings and shared features of modern voice assistants, along with the privacy and security issues associated with them, and possible future uses for these devices. It was recommended that as voice assistants gain greater popularity, librarians should become familiar with their functionality and consider their potential use for providing library services and resources.

(Bolton et al., 2018) aimed to investigate advancements in customer experience at the intersection of digital, physical, and social domains. It particularly

examined experiences that involve novel technology-based services, such as digital twins and automated social presence (i.e., virtual assistants and service robots). The article proposed a three-dimensional space, encompassing low to high digital density, low to high physical complexity, and low to high social presence, that produces eight octants to conceptualize future customer experiences. Additionally, it discussed important societal issues such as privacy, security, and transparency and proposes potential service innovation strategies in these areas. The conceptual framework integrated knowledge about customer experiences in digital, physical, and social realms in a novel manner, providing insights for future service research, managers, and public policy makers.

(Lau et al., 2018) examined people's reasons for and against adopting smart speakers, their perceptions and concerns regarding privacy, and their privacy-seeking behaviors regarding smart speakers. The researchers conducted a diary study and interviews with seventeen smart speaker users and non-users. The non-users cited a lack of trust in speaker companies or did not see the usefulness of smart speakers. In contrast, users expressed few concerns about privacy, but their justifications suggested an incomplete understanding of privacy risks and a complicated trust relationship with the companies. It was found that users often prioritize convenience over privacy and vary in the level of consideration they give to privacy trade-offs.

Table 5 : A summary of the articles with the highest number of citations.

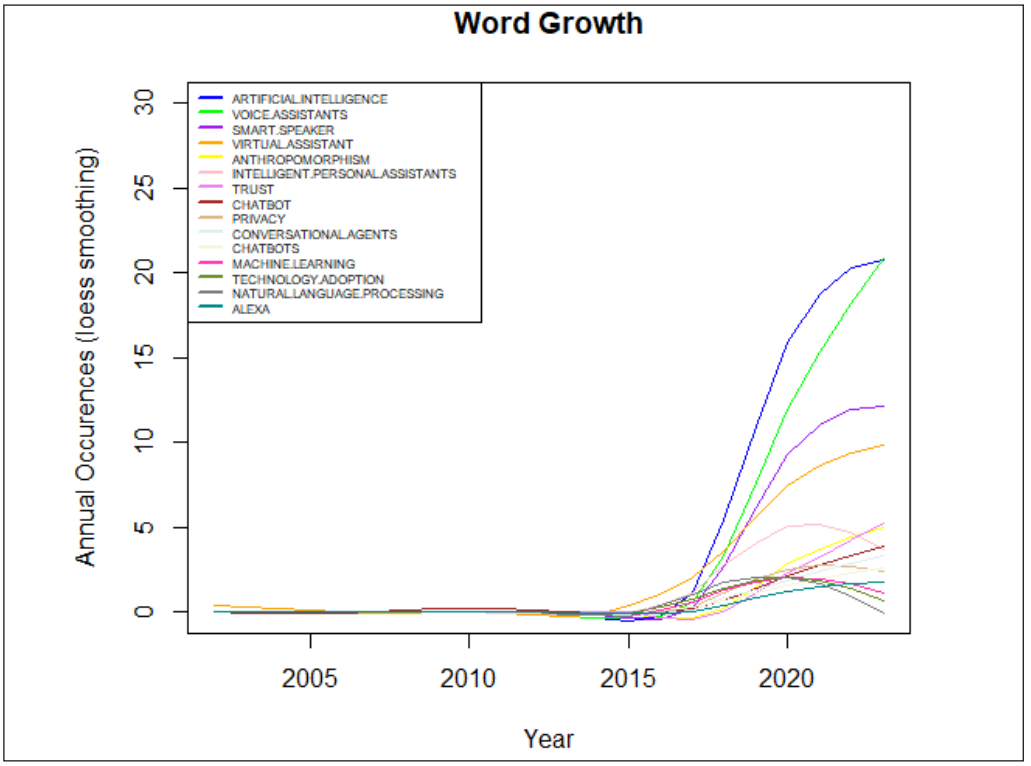
Order	Paper	Total Citations	TC per Year
1	HOY MB, 2018, MED REF SERV Q	397	66
2	BOLTON RN, 2018, J SERV MANAGE	309	52
3	LAU J, 2018, PROC ACM HUM COMPUT INTERACT	280	47
4	MCLEAN G, 2019, COMPUT HUM BEHAV	217	43
5	HOYER WD, 2020, J INTERACT MARK	174	44
6	STEINHOFF L, 2019, J ACAD MARK SCI	163	33
7	PUNTONI S, 2021, J MARK	140	47
8	HAN S, 2018, IND MANAGE DATA SYS	128	21
9	LOPATOVSKA I, 2019, J LIBRARIANSH INF SCI	119	24
10	FERNANDES T, 2021, J BUS RES	118	39
11	ANGELIS A, 2017, SOC SCI MED	114	16
12	MORIUCHI E, 2019, PSYCHOL MARK	104	21
13	CHUNG H, 2017, DIGIT INVEST	102	15
14	PRADHAN A, 2019, PROC ACM HUM COMPUT INT.	84	17

Order	Paper	Total Citations	TC per Year
15	SHAH H, 2016, COMPUT HUM BEHAV	82	10
16	ABDELSALAM HME, 2006, IEEE TRANS E M	80	4
17	PITARDI V, 2021, PSYCHOL MARK	79	26
18	DE BELLIS E, 2020, J RETAIL	76	19
19	KOWALCZUK P, 2018, J RES INTERACT MARK	76	13
20	GUZMAN AL, 2019, COMPUT HUM BEHAV	74	15
21	STRAYER DL, 2017, CAN J EXP PSYCHOL	66	9
22	HU Q, 2021, INT J INF MANAGE	65	22
23	LUTZ C, 2019, HUM BEHAV EMERG TECHNOL	65	13
24	PENG H, 2012, J AFFECTIVE DISORD	64	5
25	POUSHNEH A, 2021, J RETAIL CONSUM SERV-a	61	20
26	MCLEAN G, 2021, J BUS RES	59	20
27	FOEHR J, 2020, J ASSOC CONSUM RES	55	14
28	TOADER D-C, 2020, SUSTAINABILITY	52	13
29	MORIUCHI E, 2021, PSYCHOL MARK	51	17
30	SUN Y, 2017, ACM TRANS INF SYST	49	7
31	CHOPRA K, 2019, INT J RETAIL DISRTIB MANAGE	47	9
32	DIZON G, 2017, TESOL J	47	7
33	HASAN R, 2021, J BUS RES	46	15
34	GUZMAN AL, 2020, HUM MACH COMMUN	43	11
35	CHÉRIF E, 2019, RECH APPL MARKETING	43	9
36	BAWACK RE, 2021, INT J INF MANAGE	42	14
37	STRUYFS H, 2015, J ALZHEIMER'S DIS	41	5
38	LI X, 2021, COMPUT HUM BEHAV	40	13
39	XU Y, 2021, COMPUT EDUC	40	13
40	TUBARO P, 2020, BIG DATA SOC	40	10

Word Dynamics

In order to demonstrate the changes in keyword usage within the study, the frequency of each word is analyzed and compared to others on a yearly basis. The term "dynamics" in this context refers to the behaviour of a particular element or subject across multiple dimensions. As depicted in Figure 8, the keywords "artificial intelligence" and "voice assistants" exhibited the most significant changes in the texts between 2013 and 2015.

Figure 8 Word Dynamics



The most popular keywords

Apart from the research exploration carried out on the topics of voice assistants, Table 6 presents the commonly employed keywords and their corresponding frequency.

Table 6: The commonly used terms or phrases that are prevalent in research related to voice assistants

Terms	Frequency	Terms	Frequency
artificial intelligence	91	learning	7
voice assistants	82	vba	7
smart speaker	58	amazon echo	6
virtual assistants	51	augmented reality	6
anthropomorphism	19	conversational agent	6
intelligent personal assistants	19	deep learning	6
trust	17	gender	6

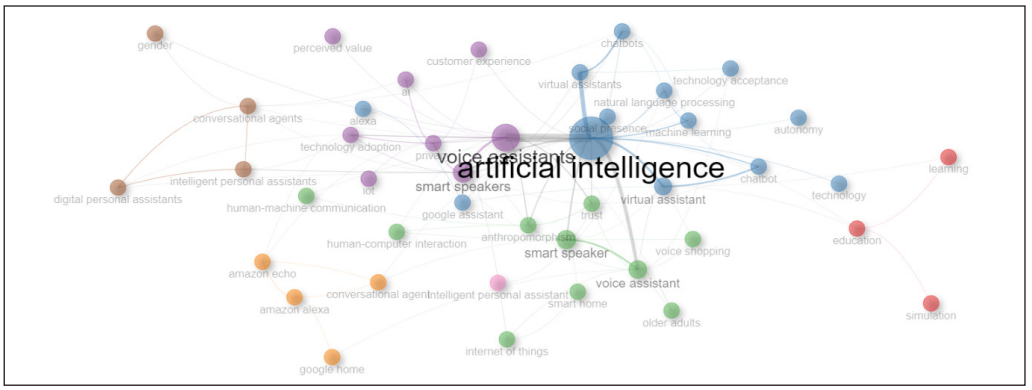
chatbot	16	google assistant	6
privacy	15	human-machine communication	6
conversational agents	13	intelligent virtual assistant	6
chatbots	11	smart home	6
machine learning	11	technology acceptance	6
technology adoption	11	autonomy	5
intelligent personal assistant	10	collaboration	5
natural language processing	10	communication	5
ai	9	digital personal assistants	5
Alexa	8	e-commerce	5
education	8	google home	5
human-computer interaction	8	iot	5
Internet of things	8	older adults	5
simulation	8	perceived value	5
social presence	8	voice shopping	5
technology	8	consumer behaviour	4
amazon alexa	7	covid-19	4
customer experience	7	customer engagement	4

Co-occurrence Network

Various techniques and methods are used to create scientific maps, which involve the use of vocabulary. Keywords play a crucial role in understanding the conceptual structure of a research domain. Researchers examine the occurrence of keywords in the title, abstract, or body of the article to determine their cognitive relation within a single set of documents. By analysing the frequency of vocabulary occurrence, researchers can identify scientific subjects and uncover their correlations based on thematic content. Comparing maps created at different periods can reveal how scientific knowledge has evolved.

This study aims to investigate how the fields of Voice Assistants are formed and interconnected. Grouping keywords in clusters can reflect their relationships. Each cluster contains a different number of subject keywords. The software used in the analysis allows researchers to view the location of a keyword to other words and clusters by clicking on it. Cluster analysis is a classification technique that helps group objects based on their similarities or differences. By using this analysis method, researchers can extract scientific subjects and uncover their relationships to the subject matter directly.

Figure 9: Co-occurrence network (Author's Keyword)

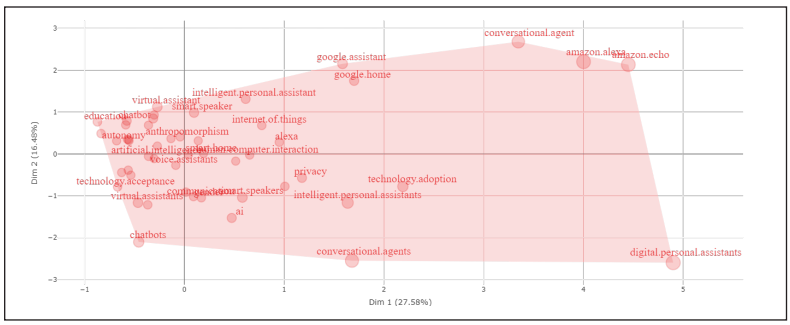


The image labelled as Figure 9 shows a co-occurrence network based on the author's keywords. The clusters in the figure are identified by blue, green, orange, purple, and red colours, which represent the related groups of keywords. Through the analysis of the documents, it was found that terms such as "artificial intelligence", "natural language processing","anthropomorphism," "chatbots", "human-computer interaction," "internet of things" "are frequently used in the field of voice assistants. By drawing co-occurrence maps at different time periods, researchers can observe the changes and consistencies in the concepts and terms related to the field of social media and information systems.

Factorial Analysis

Co-Word Analysis:- The purpose of co-word analysis is to visualize the conceptual framework of a bibliographic collection by examining the co-occurrences of words. The factorial analysis is performed using Dimensionality reduction Techniques i.e. Multidimensional Scaling (MDS) based on the author's keywords. In Figure 10 the outcomes are visualized on a two-dimensional map to illustrate the conceptual structure of the field and identify groups of documents that share similar concepts.

Figure 10 : Conceptual structure map, Factorial analysis (CA)



Thematic Maps

According to Cobo et al. (2011), to facilitate a more thorough analysis of the voice assistant's research topics, the identified topics are arranged into a strategic chart. Thematic analysis is a method used to analyse and track the development of thematic areas within a scientific field. This helps in identifying gaps in research and predicting future trends. Thematic maps are used for lexical analysis, and they are derived from clusters of keywords that are considered themes. Thematic maps are a powerful visual tool that helps in analysing themes based on the quadrant in which they are located. Figure 4 displays a thematic map, where the X-axis represents centrality and the Y-axis represents density. Density indicates the evolution of the chosen theme, while centrality measures the significance of the selected theme. The thematic map is divided into four quadrants based on author keywords. Author keywords provide relevance and expert judgment of the literature thus justifying optimal theme distribution of voice assistants literature.

Theme map is primarily divided into 4 quadrants namely:-

1) Upper Right quadrant Q1: Motor themes

"Motor themes" refer to a significant area of research that has gained considerable momentum in terms of its development. This quadrant represents a theme in research which are most relevant and displays main or driving themes as these have high centrality and density. This cluster includes conversational agents, AI, Alexa, digital personal assistants, and e-commerce.

2) Upper Left Quadrant Q2: Niche Themes

The second quadrant on the top left, Q2, pertains to "Niche Themes," which refers to research topics that have undergone extensive development but are considered relatively specialized within the present field. This cluster includes. Such isolated themes include perceived value, augmented reality, and gender as main themes.

3) Lower Left Quadrant Q3: Emerging Themes

Represent themes that are disappearing or emerging. VBA is the main theme in this quadrant

4) Lower Right Quadrant Q4: Basic Themes

The fourth quadrant on the bottom right, Q4, pertains to "Basic Themes," which refers to fundamental themes that cut across essential or fundamental research topics.

The basic research directions include artificial intelligence, voice assistants, education and simulation.

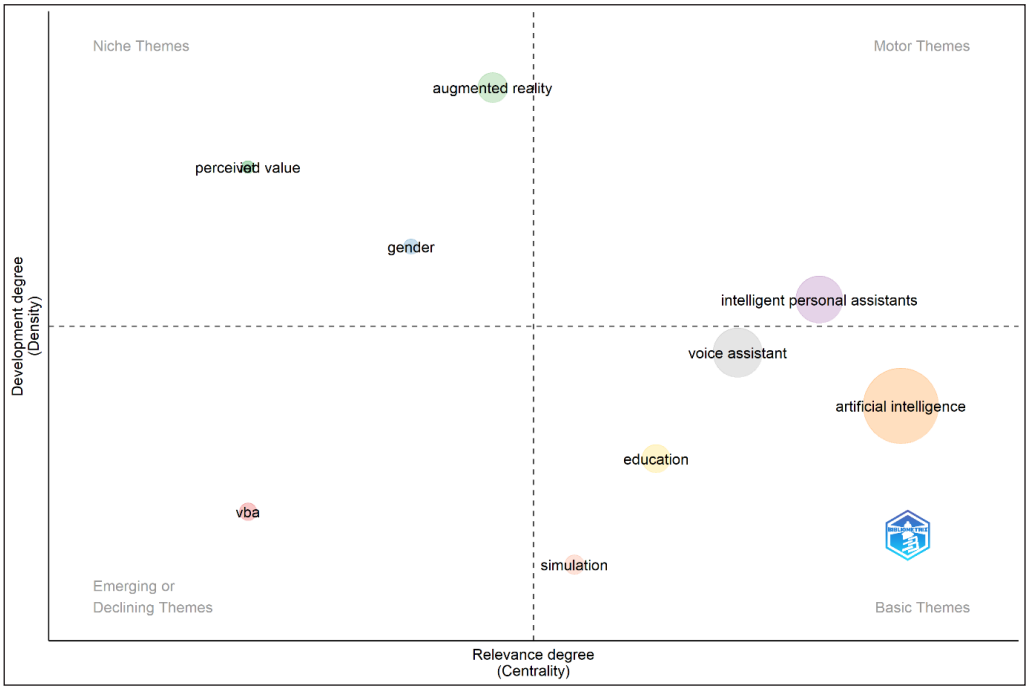


Figure 11: Thematic Maps

Table 7: Thematic Maps: Cluster wise Keywords and themes

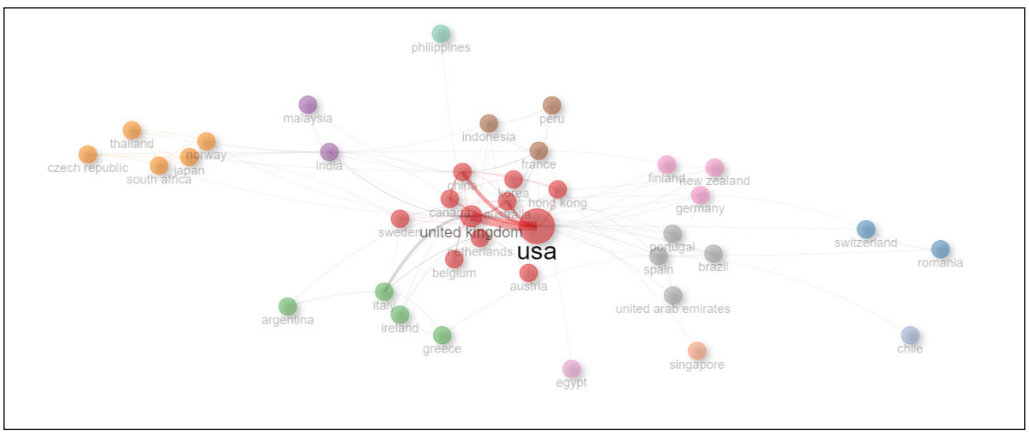
Cluster Representation	**Theme**	**Keywords in Clusters**
Intelligent Personal Assistants	Motor theme	conversational agents, ai, alexa, digital personal assistants, e-commerce
Voice Assistants	Basic theme	voice assistant, intelligent personal assistant, internet of things, smart home, technology acceptance, communication, google home
Education	Basic theme	education, learning
Artificial Intelligence	Basic theme	artificial intelligence, voice assistants, smart speaker, smart speakers, virtual assistant, virtual assistants, anthropomorphism, trust, chatbot, privacy, chatbots, machine learning, technology adoption, natural language processing, human-computer interaction, social presence, technology, amazon alexa, customer experience, amazon echo, conversational agent, deep learning, google assistant, human-machine communication, autonomy, older adults, voice shopping
Simulation	Basic theme	Simulation

Perceived Value	Niche theme	Perceived Value
Augmented Reality	Niche theme	augmented reality, intelligent virtual assistant, collaboration
Gender	Niche theme	Gender
VBA	Emerging theme	VBA

Country Collaboration Network

The map indicates which countries have made significant contributions to the texts related to Voice Assistants. The texts were primarily produced by scientists and researchers from the United States and the United Kingdom.

Figure 12: Country Collaboration Network



Co-Citation Network

Citation analysis is a quantitative technique used in bibliometric and scientometrics to evaluate scientific texts by counting the number of citations they receive. This method involves counting and reviewing references cited in the texts, and conducting various analyses based on the results. It aims to explore the correlation between citations and cited documents. By examining references to relevant works, citation analysis reveals that the more times a reference is cited, the more relevant it is considered to be in relation to the topic.

Based on Figure 7, Hoy M.B.(2018) is the most frequently cited reference. The primary aim of this study is to map the citation patterns of the prominent authors in the field of voice assistants using scientific articles indexed from 2002 to 2023. This research employs bibliometric methods, including citation analysis, and is science-based. By establishing citation links between authors in the field of voice assistants, the study illustrates the intellectual connections among these authors. However, not all writers in this field are necessarily considered influential authors.

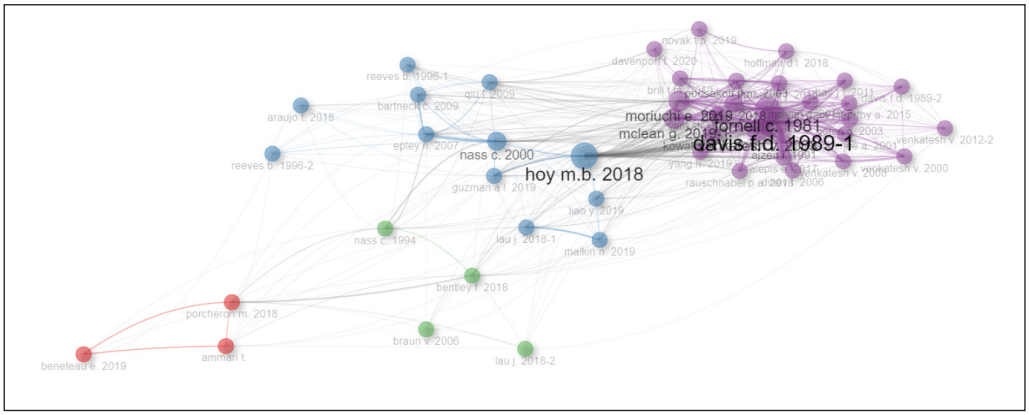


Figure 13: Co-Citation Network

Implications of the study

This study makes significant theoretical contributions in several ways. Firstly, it adds to the existing body of voice assistants research. Secondly, it analyses the trends in research production in this domain over more than two decades, providing insights into the contributions made by countries, organizations, authors, and journals. The study also employs an examination of top keywords which can help identify gaps in existing literature for future researchers.

The research study on voice assistants has significant business implications. Implementing its findings can improve customer experiences, enhance operational efficiency, and provide a competitive advantage. Optimizing voice assistants based on the study's insights leads to personalized interactions, streamlined processes, and increased customer satisfaction. Businesses can reach a larger audience through voice-enabled devices, tap into user data for data-driven insights, and explore partnerships and integrations. By leveraging the study's guidance, businesses can differentiate themselves, drive productivity, and capitalize on the growing voice assistant market.

Future research directions

Future research in voice assistants needs to focus on enhancing natural language understanding and context awareness to enable more accurate and contextually relevant responses. Additionally, advancements in machine learning and deep learning techniques can improve voice recognition accuracy and enable more complex interactions. Exploring the integration of voice assistants with emerging technologies like augmented reality and virtual reality can open up new possibilities for immersive and interactive user experiences. Lastly, addressing privacy and security concerns to ensure user trust and data protection will be crucial for future voice assistant research.

Conclusion

Summary of Research Findings

This research study examined the patterns of global research output in the field of voice assistants. The study utilized bibliometric techniques to analyse 563 research articles published from 2002 to 2023.

This bibliometric review also employs thematic concepts and knowledge structures to analyse core journals, articles, authors, institutions, countries, and thematic maps. The findings indicate a consistent and gradual growth of research in this domain over the past decade. The analysis also revealed that a significant portion of research output is concentrated in the top ten journals, accounting for 20% of the total research articles.

Ten core journals, including proceedings of the ACM on human-computer interaction" and the "computers in human behaviour" have shown substantial interest in this field.

The study identifies influential authors in voice assistants such as Lopatovska, Irene V. From Pratt Institute, United States, and Loureiro S.M.C. from Iscte – Instituto Universitário de Lisbo, Portugal. Collaboration among researchers is evident, as articles authored by multiple authors outnumber those by single authors. The US emerged as the leading contributor in terms of the number of research articles. The study maps out research topics and clusters, highlighting emerging directions of Intelligent personal assistants which include keywords like conversational agents, ai, Alexa, digital personal assistants, and e-commerce. Artificial intelligence, voice assistants, education, and simulation are essential topics.

Overall, this research provides comprehensive knowledge and insights for researchers and policymakers in the field of voice assistants. It offers a foundation for understanding the subject, extracting relevant documents, and guiding future exploration in theory and practice.

Limitations

Similar to any other research, our study has certain limitations that could be addressed through more detailed and comprehensive investigations in the future.

To begin with, relying solely on the Scopus database may not be sufficient to capture all scientific publications related to voice assistants. It would be beneficial to use additional sources like the Web of Science and Dimensions to avoid any gaps in the analysis. Secondly, the lack of standardization of author and organizational names in the Scopus database is a major source of error in the analysis, as authors may have multiple names presented in different orders, and manual adjustments are not possible. The accuracy of the results heavily depends on the quality of the input data extracted from the Scopus database.

In the future, it would be beneficial to conduct a replication study using the Web of Science database to compare the current findings with those obtained from a different database. This would help identify similarities and differences

between the results obtained from the two analyses. Thirdly, due to the limitation posed by language barriers, the authors have limited their analysis to articles published only in English. This suggests that future studies may need to consider literature available in other languages to obtain a more comprehensive understanding of the topic.

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