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Visual Analysis of Digital Healthcare Based on CiteSpace

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Abstract

Objective: Digital healthcare is rapidly becoming a new model for medical development in the information society with its convenience, and personalization, and a research boom in digital healthcare has formed at home and abroad in recent years. The purpose of this study is to conduct a bibliometric analysis of the field of digital healthcare and to understand the research background and development trend in this field. Methods: A visual analysis of authors, institutions, journals and keywords was conducted using CiteSpace 5.8R3 software. **Results:** A total of 1646 digital healthcare-related retrieved from WoS and PubMed studies. There was an overall upward trend in the number of digital healthcare publications, with the highest number of publications in 2021 (290). The author AZIZ SHEIKH is ranked first in the number of published articles (13), while King Saud University (23) is the research institution with the most articles. Keyword clustering showed that the first cluster was data security; the common high frequency keywords that appeared were systems (85), artificial intelligence (82), mobile health (70), internet (61), and technology (57). Digital healthcare, artificial intelligence, healthcare services, machine learning and deep learning are the hotspot of current research. **Conclusion:** This paper summarises the state of the art in digital healthcare research. Using statistical analysis and network visualisation, it highlights the background, trends and hot topics in digital healthcare research. The paper finds that there is significant potential for artificial intelligence to help bridge the digital divide and reduce health inequalities. To understand the current state, hot trends and future directions of digital healthcare research, this paper can serve as a reference.

Keywords

Digital Healthcare, CiteSpace, Bibliometric, Visual Analysis

1. Introduction

With the development of digital technology, big data, the Internet of Things, artificial intelligence, cloud computing, wearable devices, and so on, digital technologies are constantly being applied to the medical and health fields, giving new vitality to the development of medical health [1]. Digital healthcare can provide important information about disease trends and risk factors, treatment outcomes or public health interventions, functional abilities, patterns of care, and healthcare costs and use [2]. Rojas *et al.* [3] highlighted the application of Internet-based procedures in curing depression. Henkenjohann [4] demonstrated that using patients' digital records increased the efficiency of healthcare services. Modern health records use blockchain technology to exchange electronic health records between patients and physicians [5]. Artificial intelligence-based robotic surgery helps doctors provide personalized patient treatment, eliminate repetitive activities, and prevent major diseases [6]. However, artificial intelligence poses dangerous privacy risks. Facial recognition technology can be used for passive, warrantless surveillance without the knowledge of the monitored person. In Russia, facial recognition has been used to spy on and arrest protesters supporting imprisoned opposition politician Alexei Navalny. Russians fear the Moscow subway's new facial recognition payment system will increase such arrests [7] [8] [9]. AI will also follow you around on your weekly errands. Target uses an algorithm to determine which shoppers are pregnant [10] [11]. In addition, AI can be a godsend for fraudsters. In 2020, 17 criminals used AI "deep voice" technology to defraud a bank in the United Arab Emirates of $35 million by posing as employees authorized to make money transfers [12]. In conclusion, digital healthcare is rapidly becoming a new healthcare development model in the information society with its convenience, speed, and individuality. Against this background, we analyse institutional collaboration, journal co-citation, keyword co-occurrence, author collaboration and bursting in digital healthcare using bibliometric analysis and knowledge network visualisation. In this way, we map the knowledge structure of research in this field. We also map research trends and trending topics. And for future research in this area, this study can provide essential support and direction.

2. Data and Methods

2.1. Data Collection

Web of Science and PubMed were used to search the databases, and "advanced search" was selected, "topic" was selected in Web of Science, and "title or abstract" was selected in PubMed. The search criteria were ("digital healthcare") OR ("the digitalization of healthcare") OR ("digitalization in healthcare") OR (e-healthcare) OR (m-healthcare) OR (mobile healthcare) OR (telehealthcare) OR ("artificial intelligence in healthcare") with data as of October 30, 2022. Finally, 1468 and 924 papers were retrieved from 2 databases, Web of Science and PubMed. The literature was exported in RefWorks NoteExpress and XLS formats. The following exclusion criteria further processed the literature: 1) removing news, conference announcements, call for papers, etc. 2) removal of non-digital healthcare-related literature, which mostly mentions digital healthcare-related concepts in the articles; 3) removing literature on digital healthcare applications in non-medical fields, which mostly mentions digital healthcare-related concepts in the content in medical fields. By merging the duplicate literature through Citespace, we finally obtained 1646 valid papers.

2.2. Data Analysis and Visualization

A research hotspot is a topic that is commonly studied by most researchers at a specific time and is represented by keywords that appear many times in the relevant literature. CiteSpace software is an information visualization software developed by Chen [13] to measure the literature in a specific field based on co-citation analysis theory and path findiner network algorithm, which can analyze the hotspots of research in the industry field. Use CiteSpace software to convert the literature data and set its parameters in CiteSpace software. The time slicing was one year per slice from January 2000 to October 2022. The selection criteria were g-index, and the scale factor was k = 25. Default values are used for other parameters, and the total literature issuance, annual issuance, countrry, major research institutions, the distribution of research authors, distribution of research institutions, and research hotspots and trends are analyzed.

3. Results

3.1. Annual Publications

From 2000 to 2016, the literature related to "digital healthcare" was in a slow development period, and from 2017 to 2022, the annual number of publications showed a rapid growth, especially in 2021, when the number of publications was the first with 355. Since only 10 months of papers were searched in 2022, not all papers were included yet, so the number of "digital healthcare" papers showed a decreasing trend in 2022. See **Figure 1** for details.

3.2. Author Co-Occurrence Analysis

Default values are used for other parameters, authors with several literature publications of 4 or more were selected for visualization and analysis to obtain the author co-occurrence mapping, as shown in **Figure 2**. The number of nodes (N) is 675, the number of links (E) is 758, and the network density (Density) is 0.0033. The thicker the link, the higher the frequency of co-occurrence and the closer the research relationship between the two authors. In terms of the total number of publications, the top authors are AZIZ SHEIKH (13), NEERAJ KUMAR (13), PARTHA PRATIM RAY (12), DINESH DASH (12), CLAUDIA PAGLIARI (10), etc. In terms of the time of publication of the literature, the earlier scholars who carried out in-depth studies on digital healthcare were TL WILLIAMS (2001), A MACFARLANE (2003), T FINCH (2003), JAVIER

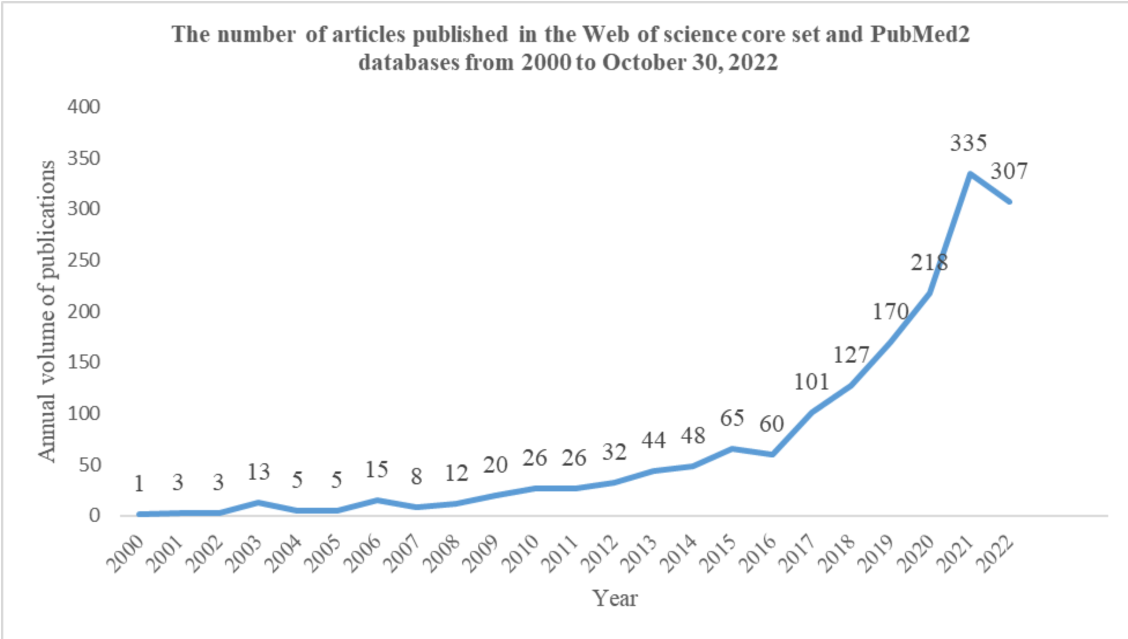

Figure 1. The number of articles published in the Web of science core set and PubMed2 databases from 2000 to October 30, 2022.

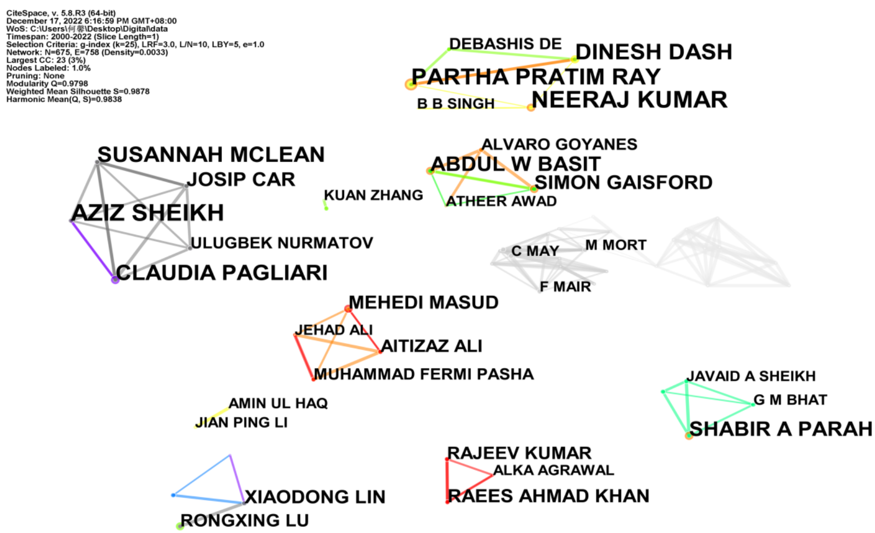

Figure 2. Co-presentation of authorship collaborations.

REINATOSINA (2003), FRANCES MAIR (2003), etc. These studies have laid an essential foundation for relevant research in the field. According to Price Law, half of the literature on the same research topic comes from a group of core authors. The formula for calculating the core authors is: where Npmax is the number of literature published by the most productive authors in the field during the statistical period, and Mp is the number of literature that should be posted by the core authors in the area at least during the statistical period. According to the co-occurrence results, the source authors with the highest number of publications in the Web of Science core set and PubMed database from 2000 to 2022 published 13 articles, *i.e.*, Npmax = 13, and the derived Mp value is 2.7. According to the principle of rounding, *i.e.*, the authors who published three or more articles can be considered the core authors in the field. Thus, there are 73 core authors in the field of digital healthcare research, and 344 core authors have published literature, accounting for only 20.90% of the total relevant literature, which is far from Price's target of 50% of the entire literature by the sum of core authors. The core authors in the field of digital healthcare research have not yet formed.

3.3. Institutional Co-Occurrence Analysis

Other parameters are kept constant, and the node type is set to the institution, *i.e.*, the node of the publishing institution is used for visual analysis. By counting the institution where the first author of the literature is located, we analyze the inter-institutional cooperation and influence in digital healthcare research. As shown in **Figure 3**, the co-occurrence mapping of institutions with seven or more publications, 466 nodes, 387 links, and 0.0036 network density was selected. In addition, the links between research institutions show that digital healthcare-related research is mainly carried out by universities and in cooperation, and fewer institutions conduct independent research. The top five institutions in digital healthcare research are King Saud Univ (23 articles), UCL (14

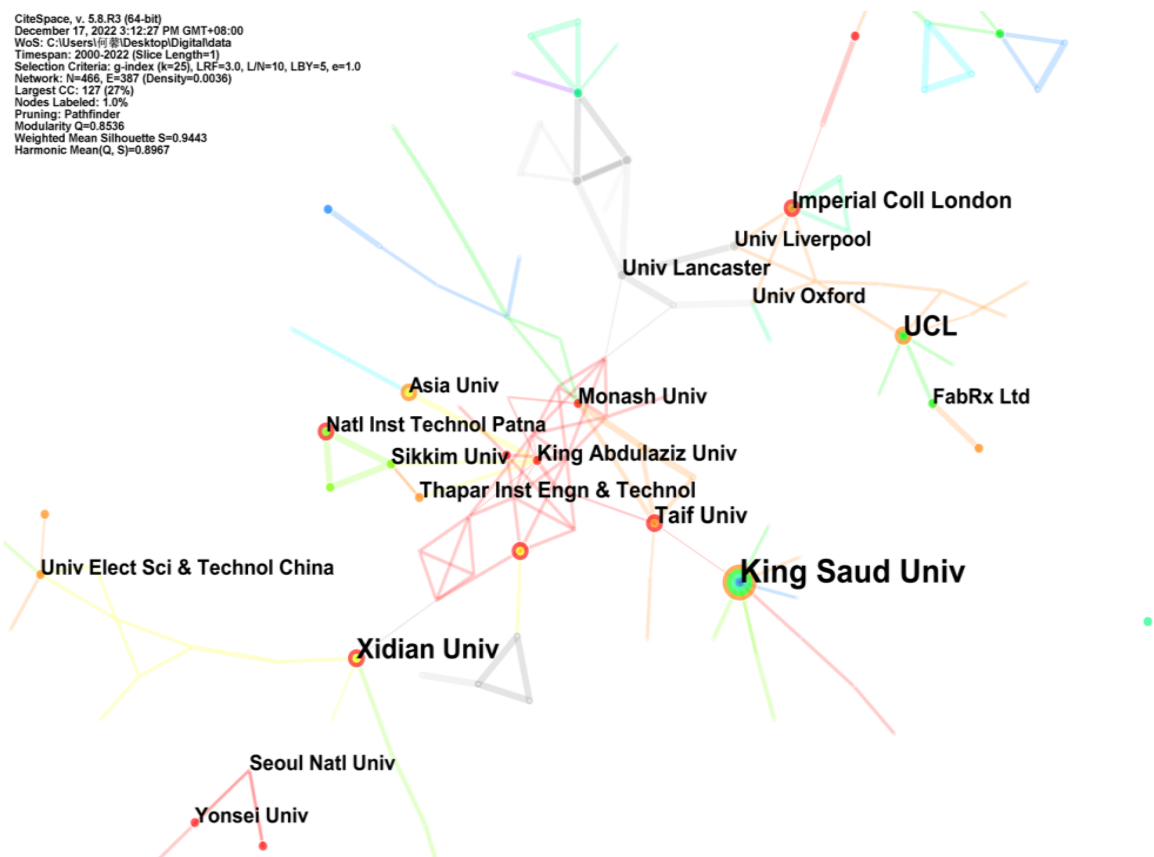

Figure 3. Co-presentation map of Institution collaboration.

pieces), Xidian Univ (14 articles), Imperial Coll London (9 articles), and Taif Univ (9 papers). Notably, two of the top five universities are from the UK. Regarding the total number of publications, the institutions mentioned above take the lead in the total number of publications compared with other institutions. To some extent, they represent the main strength of the current digital healthcare research field. The research power still needs to be more cohesive.

3.4. Country Co-Occurrence Analysis

Figure 4 shows the country co-occurrence mapping of publications, with 228 nodes, 315 connections, and a network density of 0.0122. It is observed that among the top 10 major countries in terms of digital healthcare research publications, the United States tops the list, followed by China, India, and the United Kingdom, with 217, 170, 153, and 104 articles published, respectively.

3.5. Co-Occurring Keywords Analysis

Keywords with a high frequency of occurrence and high mediated centrality in CiteSpace can deeply reflect a specific research mediated centrality of keywords can deeply reflect particular research. Keeping other parameters unchanged, the node type is set to keyword, and the pathfinding algorithm (PathFinder) is selected to generate the keyword co-occurrence mapping (**Figure 5**). As shown in **Figure 5**, there are 557 nodes, 1714 links, and a network density of 0.0111. The keyword system occupies a central position on the map, appearing 85 times. In addition, keywords such as artificial intelligence, mobile healthcare, Internet, technology, and digital healthcare, which represent the specific application methods and combined fields of digital healthcare, appear more frequently and

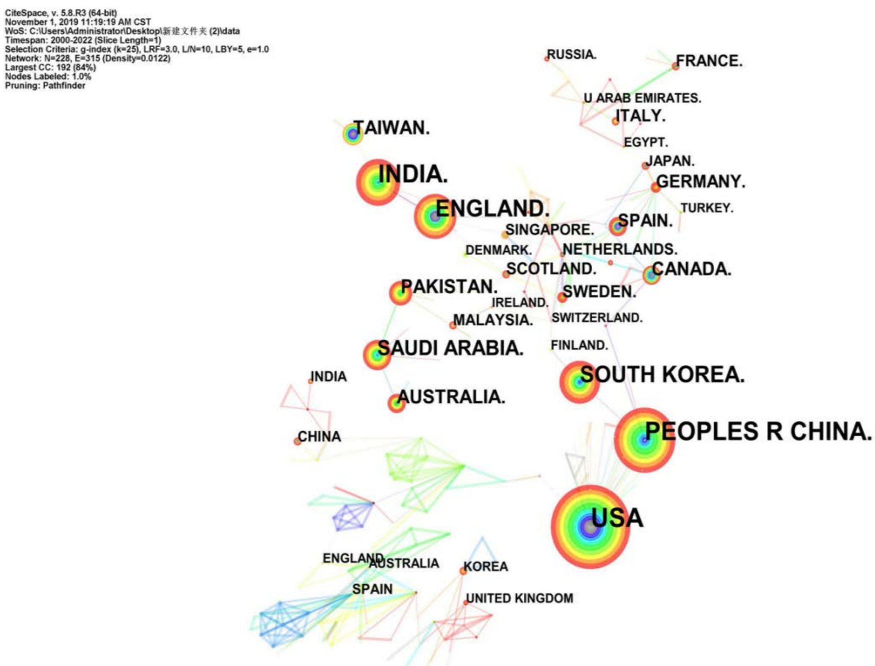

Figure 4. Country distribution map.

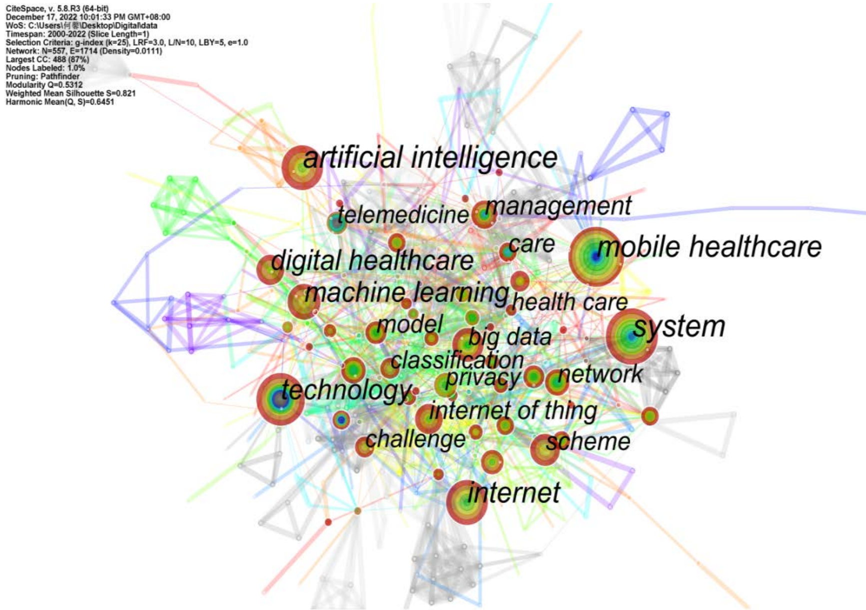

Figure 5. Co-presentation of digital healthcare keywords.

describe the research hotspots in digital healthcare. As another significant result of keyword co-occurrence analysis, mediated centrality (Centrality) is an indicator to measure the importance of nodes in the co-occurrence network, and keyword centrality reflects its repetitiveness in the whole keyword co-occurrence network. Nodes with high mediator centrality are usually key hubs connecting different hotspots and can be regarded as critical points, turning points, and trigger points in the research field [14]. The keyword with the highest mediated centrality in the keyword co-occurrence map is care (0.29). Other keywords with high mediated centrality are authentication (0.28), mobile healthcare (0.27), healthcare (0.27), diagnosis (0.22), children (0.19), innovation (0.15), classification (0.14), telemedicine (0.14), management (0.13), acceptance (0.13), cancer (0.12), diffusion (0.12), digital health (0.11). The above keywords significantly influence the co-occurrence network and can be regarded as significant "intermediary" terms connecting high-frequency keywords in digital research.

3.6. Keyword Clustering Analysis

Using the co-word analysis method, the researcher can directly analyze the topics of a specific research domain. The lookup clustering function was run, keeping all other parameters constant, and the log-likelihood ratio algorithm was chosen to cluster keywords in digital healthcare research. Based on the network structure and cluster clarity, Modularity Q (Q) can be used to measure the stability of the generated clustering network, and a Q value greater than 0.3 is generally considered to indicate a significant clustering structure and a sound effect; MeanSilhouette (S) can be used to measure the degree of similarity of nodes within a cluster, and an S value greater than 0.5 is generally considered to indicate a high degree of matching within the clusters and good clustering. The clustering results are shown in **Figure 6**, and the Q value is 0.8536, more significant than the critical value of 0.3, and the S value is 0.9443, more important than the critical value of 0.5. Overall, the clustering results have a high confidence level. According to the clustering, the high-frequency keywords in digital healthcare research within the Web of Science core set and PubMed database were mainly concentrated in eight clusters.

3.7. Keyword Burst Analysis

The research frontier trend refers to the frontier hotspot that best represents the future development direction in a specific research field; through the mutation rate detection, we can understand the more active related literature in a certain period and track the future direction of the research according to the trend of the literature. While keeping other parameters constant, the "Citation/Frequency Burst History" function was run to generate a list of mutability keywords in the field of digital medicine research in the Web of Science core library and PubMed database from 2000-2022, to analyze the Chinese digital medicine research field in different periods frontier trends. The frontier trends in the research field of digital healthcare in different periods were analyzed. The terminology that represents the frontier of the research field was obtained by the "Find Burst Phrases" algorithm of Citespace, which is shown in **Figure 7**. By eliminating the burst words that do not fit the research theme, the keywords with the burst time until 2022 are "machine learning," "artificial intelligence,"

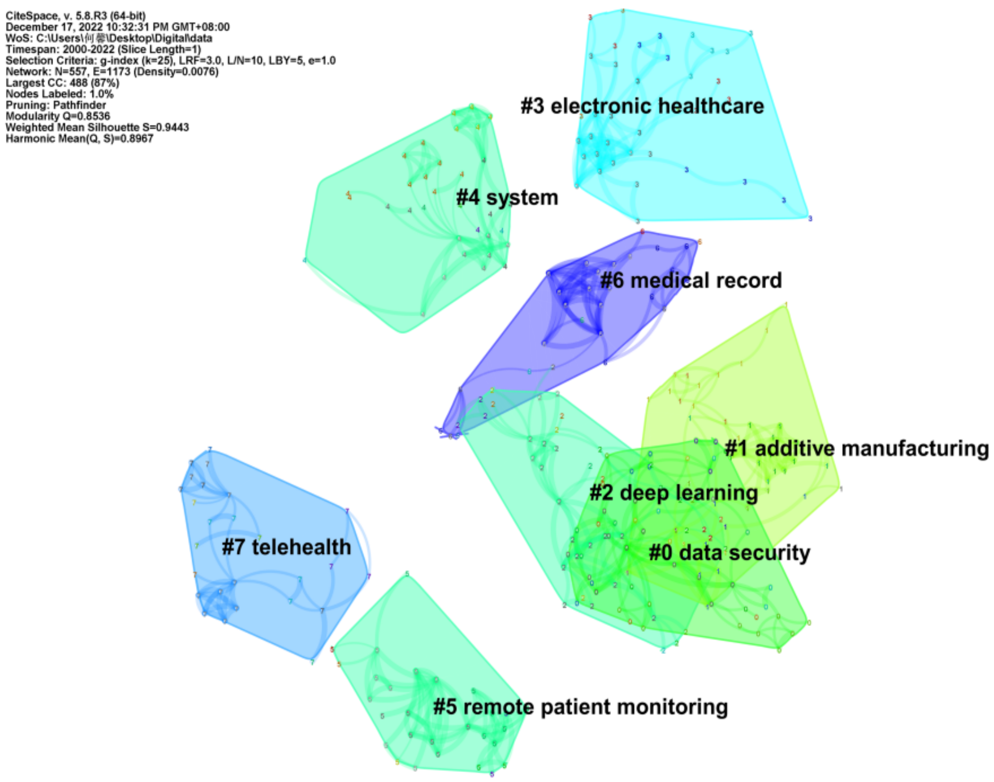

Figure 6. Cluster mapping of keywords.

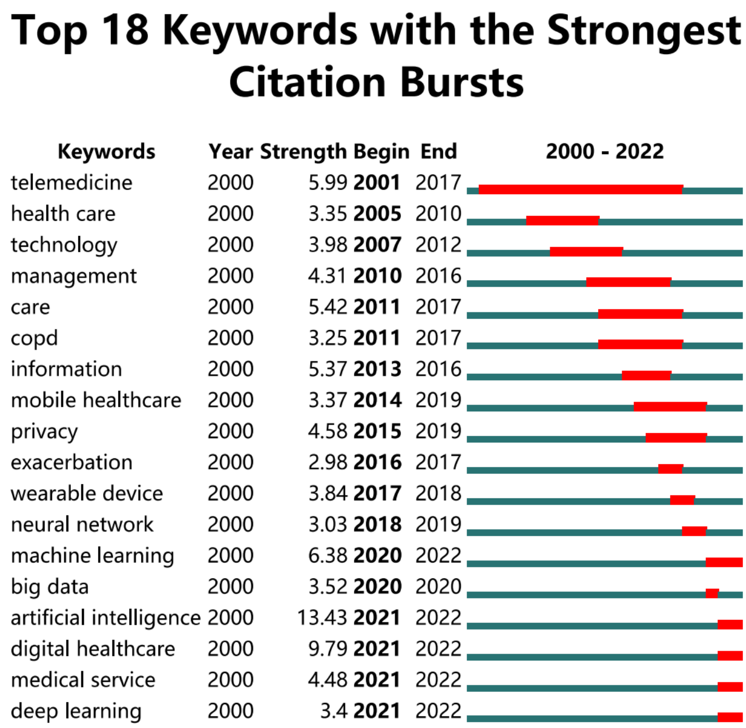

Figure 7. Top 18 terms with the strongest citation bursts.

"digital healthcare, "medical service," "deep learning," etc., of which the emergent duration is one year, and the emergent intensity is greater for " artificial intelligence" (13.43), "digital healthcare" (9.79)..

4. Discussion

4.1. Current Status of Digital Healthcare Research

Annual publication volume is an essential indicator of a research field's research heat and development trend. The research hotspots and development trends of industries and specialties can be reflected, to a certain extent, by the volume of paper output in a period [15]. The trend graph of publications shows that the volume of digital healthcare literature is on an upward trend, suggesting that research related to digital healthcare is gaining importance. 2021 has the highest number of scientific publications. One of the reasons behind this is the shift in existing medical practices due to the new coronary pneumonia pandemic, forcing healthcare organizations and professionals to adopt digital technologies to deal with the current situation. This is in line with the findings of Alhamzah F. Abbas [16]. Our survey shows that most of the research related to digital healthcare is conducted in the United States, consistent with previous findings, reflecting the leading position of the United States in digital healthcare research. The number of publications from China, India, and Korea has also gradually increased recently. It may be related to following the trend of globalization and the promotion of the new crown epidemic. During the prevention and control of the new crown pneumonia epidemic, China has actively applied digital technologies in healthcare and accelerated digital healthcare innovation, which has provided the world, especially developing countries, with solutions to learn from. Regarding authors and institutions, the total number of literary publications, the top authors are AZIZ SHEIKH (13) and NEERAJ KUMAR (13). There are 73 core authors in digital healthcare research, and 344 core authors have published literature. The core group of authors in digital healthcare research has yet to be formed, and there are fewer connections between authors and the lack of continuity in analysis. The core group of authors in a research field is a microcosm of the continuity and depth of research practice in that field [17], and a research group that continues to focus on a particular research direction can keep abreast of the latest frontiers in that direction and gain more in-depth insights. The results of this study show that in the research field of "digital healthcare," most of the research teams are small collaborative teams, and the number of authors with one publication is high, indicating that most researchers have not chosen "digital healthcare" as a long-term and fixed research direction. This shows that most researchers have not selected "digital healthcare" as a long-term and fixed research direction, and the authors have little communication and cooperation. Therefore, in the following research, it is necessary to strengthen the collaboration among the authors and focus on the continuous attention to this topic to promote the development of "digital healthcare further." The linkage between research institutions shows that the research on digital healthcare is mainly carried out by universities and in the form of cooperation. There are few independent research institutions. This shows that universities are a vital research force in digital healthcare. They can build systematically on the talents and resources of universities, medical schools, and affiliated hospitals and integrate multidisciplinary clusters such as public health, medicine, computer, and artificial intelligence.

4.2. Hot Topics and Frontiers of Digital Healthcare Research

Telemedicine has been emphasized in the research of "digital healthcare," but the research topics need to be expanded. The centrality and node size of keywords in a particular field visually reflect the research hotspots in that field [18]. According to the content of the literature in the clusters and the structure of the disciplines, these 8 clusters can be divided into three digital healthcare research directions: first, digital healthcare technology research, including deep learning, information systems, 3 d printing, and other technology research; second, digital healthcare application research, including applied research in telemedicine, telemedicine monitoring, electronic healthcare, electronic medical records, etc.; third, digital healthcare review research, including research on The third, is digital healthcare review research, including the analysis of the regulation of digital healthcare, data security, etc. In addition, the study of the keyword emergence chart reveals that "telemedicine" was the emergent theme word in the field of digital healthcare in 2001, and it has continued until 2017 with a high emergence intensity, indicating that telemedicine is an important research content in the area of digital healthcare applications. 2010-2016. With the rapid development of digital technology and the emphasis on healthcare, "care," "management," "COPD" information," and other subject terms with high emergent intensity emerged. This may be due to the gradual application of digital healthcare to manage chronic diseases. Simon Bourne [19] *et al.* applied digital healthcare to the management of COPD by conducting a 6-week randomized controlled trial study of a 6 MWT distance and symptom score in a 6-week online supported PR program and concluded that online supported PR was superior to the traditional model of face-to-face lectures and was safe and well-tolerated. From 2020 onwards, keywords such as "machine learning," "artificial intelligence," "digital healthcare," "medical service," and "deep learning" can be considered as emerging research hotspots in digital healthcare so far. Among them, "artificial intelligence," as an important research content in the field of information security, has the highest burst intensity (13.43) at this stage, which generally indicates that artificial intelligence is the focus of informationization in China's medical system. Also, with the development of the COVID-19 epidemic, the emergence of disruptive technologies such as artificial intelligence has leveraged a variety of healthcare applications [20] [21] emphasizing COVID-19 data analysis, data security, data privacy, authenticity, and data sharing at all levels. In this regard, Samuel *et al.* [22] reviewed the role of AI in the coronavirus and its related epidemics prediction, contact tracking, forecasting, screening, and drug development. Nguyen *et al.* [21] introduced a new conceptual architecture integrating blockchain and AI to combat the COVID-19 pandemic. Artificial intelligence is considered an emerging support technology with the potential to enable multidisciplinary innovation [23]. Artificial intelligence systems are more efficient and reliable and work for extended periods. This is an important area of innovation for many healthcare organizations currently suffering from staff shortages, increased demand pressures, and strict financial constraints. AI also has the potential to enhance medical devices, particularly by working in tandem with robotics to increase the speed and scope of their iterative improvements. However, extensive research on the use of AI in healthcare and abstract discussions of its potential has yet to find much research on how AI is integrated into the healthcare system and regulated and monitored upon market entry. As a digital innovation, AI presents several challenges to healthcare systems wishing to realize its potential, many of which have been mentioned in the broader innovation literature [24]. Reviewing previous studies, most suggested solutions have not yet been implemented, and many of the problems are only tentatively addressed. A future strategy will be to adopt some of the proposed solutions to overcome the shortcomings and open new doors for the healthcare industry.

5. Conclusion

This study analyzed the digital healthcare research literature published in Web of Science and PubMed journals from 2000 to October 2022 with the help of CiteSpace software and combed through the visual analysis of the volume of publications, research authors, and keywords in this field in the last 22 years. The number of research digital healthcare publications has been increasing year by year and is in a rapid upward trend in recent years. However, no larger research groups have been formed, and there needs to be more cooperation among teams. In the future, it is necessary to establish multidisciplinary and multicenter collaboration further to explore digital healthcare's advantages and application prospects. The current research hotspots in digital healthcare focus on the research of telehealth, mobile healthcare, and data security. Artificial intelligence has significant potential to bridge the digital divide and reduce health inequalities. Our work can serve as an important reference point and provide a direction for future research. There are some limitations to this study. Firstly, the literature included was all written in English, which means it was biased. In addition, some recently published high-quality literature may be infrequently cited due to the short time of publication, which may lead to certain inconsistencies between the research results and the reality. The visual analysis is based on the Web of Science Core Collection and PubMed, which may miss some important documents indexed by other databases, leading to biased results. To overcome the negative effects of language and time of publication, bibliometrics, and visual analysis in medical research require more comprehensive and up-to-date data.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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