REVIEW ARTICLE

Bibliometric exploration of artificial intelligence applications in healthcare: trends and future directions

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ABSTRACT

This research employs the PRISMA framework to conduct an extensive bibliometric analysis, delving into the dynamic realm of Artificial Intelligence (AI) within the healthcare domain. Spanning the years 2010 to 2023, the study systematically gathers and examines scholarly works to delineate the trends, patterns, and emerging topics about AI's integration into healthcare. A thorough initial screening yields substantial academic articles, conference papers, and reviews, forming the basis for analysis. The examination primarily focuses on quantifying publication patterns, identifying influential authors, institutions, and countries, and mapping the thematic landscape of AI in healthcare. Employing various bibliometric metrics such as publication trends, prolific authors, influential journals, and co-occurrence networks of keywords, the study uncovers the remarkable surge in research centred on AI-driven healthcare. This surge signifies a notable paradigm shift towards harnessing technology for predictive analytics, personalized medicine, and enhanced patient care. Additionally, by leveraging visualization tools like VOSviewer, the study presents informative graphical representations elucidating clusters and associations among keywords, thereby providing deeper insights into the interdisciplinary dimensions of AI in healthcare. This study provides a structured overview of the evolving landscape of AI in healthcare, providing valuable perspectives for researchers, practitioners, and policymakers aiming to harness the potential of AI for advancing healthcare delivery and outcomes. The implications of these findings underscore the transformative potential of AI technologies in revolutionizing healthcare delivery, promoting sustainable healthcare practices, and fostering innovative solutions for future challenges.

Keywords:
artificial intelligence, machine learning, healthcare technology, sustainable healthcare, health informatics, predictive analytics

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INTRODUCTION

Artificial Intelligence (AI) has revolutionized healthcare, presenting a transformative force in the industry's landscape.[1] Its integration has propelled healthcare systems into a new era, offering innovative solutions that enhance diagnostics, treatment plans, patient care, and operational efficiency. Leveraging AI in healthcare not only streamlines processes but also augments the capabilities of medical professionals, enabling them to make data-driven decisions, personalize treatments, predict outcomes, and ultimately, improve patient outcomes.[2] The collaboration of technology and healthcare holds the promise of reshaping the benchmark of medical treatment, rendering it more accurate, available, and tailored to individual patient requirements.[3]

Artificial Intelligence (AI) stands at the forefront of a profound transformation within the healthcare sector.[4] Its integration has sparked a revolution, fundamentally reshaping the way medical professionals diagnose illnesses, design treatment plans, manage patient data, and optimize healthcare operations.[5] Through the amalgamation of sophisticated algorithms, machine learning models, and vast data resources, artificial intelligence has surfaced as a potent tool, propelling healthcare systems into a new era of innovation and efficiency.[6] In the realm of diagnostics, AI showcases remarkable potential. It has shown unmatched proficiency in analyzing medical images like X-rays, MRIs, and CT scans, performing with accuracy and efficiency that matches or surpasses human abilities.[7] By leveraging deep learning algorithms, AI can swiftly analyze these images; detect abnormalities, and aid radiologists and clinicians in making timely and precise diagnoses.[8] This not only expedites the diagnostic process but also reduces the margin of error, thereby enhancing patient care and treatment outcomes.[9] Moreover, AI has proven instrumental in predictive analytics, facilitating proactive and preventive healthcare strategies.[10] By analyzing vast datasets encompassing patient history, genetic information, lifestyle factors, and more, AI models can forecast potential health risks and diseases. These predictive insights empower healthcare professionals to intervene early, offering personalized preventive measures and interventions tailored to an individual's specific health profile.[11] Consequently, this proactive strategy not only enhances patient results but also mitigates the burden on healthcare systems by potentially reducing the prevalence of certain conditions.

Treatment customization represents another significant area where AI makes substantial contributions.[12] By analyzing patient data such as genetic information, medical history, and treatment responses, algorithms powered by artificial intelligence can suggest tailored treatment plans. This personalized medicine approach holds immense promise, as it allows healthcare providers to deliver targeted therapies that are more effective while minimizing adverse side effects.[13] Furthermore, AI enables the continuous monitoring and adaptation of treatment plans, ensuring that they remain aligned with the evolving needs of each patient.[14]

Additionally, the utilization of AI-powered chatbots and virtual assistants has revolutionized patient engagement and support.[15] These intelligent systems offer round-the-clock assistance, answering queries, providing basic medical advice, scheduling appointments, and even offering medication reminders.[16] They not only improve patient convenience and access to healthcare information but also reduce the workload on healthcare providers by managing routine inquiries, enabling them to concentrate on more intricate and essential responsibilities. Beyond the realm of patient care, AI streamlines healthcare operations and administrative tasks. From optimizing resource allocation to

automating administrative workflows, AI-driven solutions enhance the efficiency of healthcare facilities.[17] Machine learning algorithms analyze historical data to forecast patient admissions, enabling hospitals to allocate staff and resources more effectively.[18] Moreover, AI facilitates the automation of routine administrative duties such as billing, arranging appointments and maintaining records, leading to a decrease in human error and freeing up valuable time for healthcare professionals to concentrate on delivering quality patient care.[19]

However, the integration of AI in healthcare is not without its challenges and considerations.[20] Data privacy and security emerge as paramount concerns, especially considering the sensitive nature of medical information.[21] Ensuring compliance with stringent regulations and safeguarding patient confidentiality are critical aspects that require constant attention and innovative solutions.[22] Furthermore, the need for seamless interoperability among different healthcare systems and technologies remains a significant hurdle.[23] Efforts to standardize data formats, protocols, and communication channels are essential to enable the seamless exchange of information across various platforms and healthcare providers.[24]

Ethical considerations also loom large in the development and deployment of AI in healthcare.[25] Questions regarding the accountability of AI systems, transparency in decision-making processes, and the potential biases embedded within algorithms demand scrutiny and regulatory frameworks to ensure the responsible and ethical use of these technologies.[26] Despite these challenges, the promise of AI in healthcare remains undeniable. As technology continues to advance and AI algorithms evolve, the potential for groundbreaking discoveries, enhanced patient care, and more efficient healthcare systems continues to expand.[27] In this landscape of constant innovation and evolution, collaboration among technology experts, healthcare professionals, policymakers, and ethicists is crucial.[28] By fostering interdisciplinary collaboration and embracing a shared vision for the responsible and ethical implementation of AI in healthcare, we can unlock its full potential to revolutionize healthcare delivery, enhance patient results, and shape a healthier future for all.[29]

Artificial intelligence (AI) is transforming the healthcare sector in unprecedented ways, wielding the potential to reshape diagnosis, treatment, patient care, and operational efficiency.[30] Harnessing its capacity to scrutinize large datasets, recognize patterns, and predict outcomes, AI is reshaping the healthcare industry, offering both opportunities and challenges.[31] AI's profound influence on healthcare primarily manifests in its ability to improve diagnostic capabilities. Sophisticated AI algorithms excel in analyzing medical imaging, such as X-rays, MRIs, and CT scans, exhibiting remarkable accuracy and often surpassing human radiologists in detecting anomalies and diseases.[32] For example, AI-driven technology can rapidly identify initial indications of illnesses such as cancer, facilitating prompt action and potentially preserving lives. Moreover, AI-driven decision support systems aid healthcare professionals in making informed decisions.[33] Through the examination of patient data, medical histories, and existing research, AI can suggest personalized treatment plans, predict potential complications, and recommend suitable medications or therapies.[34] This enhances patient results and assists physicians in delivering more precise and tailored care.

AI's impact extends beyond diagnostics and treatment; it significantly influences patient engagement and

experience.[35] Chatbots and virtual assistants powered by AI technology are increasingly used in healthcare settings to interact with patients, answer queries, schedule appointments, and guide basic health concerns.[36] These tools offer round-the-clock assistance, improving accessibility to healthcare services and reducing the burden on medical staff. Furthermore, the amalgamation of AI and wearable devices has led to the rise of remote patient monitoring.[37] Devices containing AI algorithms can monitor vital signs continuously, identify anomalies, and promptly notify healthcare professionals.[38] This proactive method facilitates early intervention and better management of chronic conditions, empowering patients to take charge of their health while minimizing hospital visits.[39]

Despite these advancements, integrating AI into healthcare comes with challenges and ethical considerations.[40] Data privacy and security remain paramount, as AI systems rely heavily on confidential patient data.[41] Maintaining trust among patients, healthcare providers, and technology developers hinges on guaranteeing the confidentiality and integrity of healthcare data.[42] Furthermore, the dependence on AI gives rise to worries regarding the possibility of bias within decision-making algorithms.[43] If not carefully monitored and regulated, these biases could exacerbate existing disparities in healthcare, affecting the quality of care provided to certain demographic groups. Ensuring fairness and transparency in AI algorithms is imperative to mitigate these risks and promote equitable healthcare outcomes for all.[44] Moreover, the integration of artificial intelligence into the healthcare sector necessitates robust regulations and standards to govern its implementation.[45] It's essential to find an equilibrium between promoting innovation and ensuring patient welfare. Regulatory frameworks need to adapt to tackle the ethical, legal, and societal impacts of AI in healthcare, promoting the conscientious advancement and utilization of such technologies.[46]

The financial implications of implementing AI in healthcare also warrant consideration.[47] While AI has the potential to optimize operational processes, reduce errors, and improve efficiency, the initial investments in technology infrastructure and staff training can be substantial.[48] Institutions must weigh the long-term benefits against the upfront costs to ensure a sustainable and effective integration of AI in healthcare systems.[49] In the foreseeable future, the potential of AI in healthcare is vast. Progress in machine learning, natural language processing, and predictive analytics persistently enhances AI's capacities, enabling more intricate utilization in disease prognosis, drug exploration, and tailored medical solutions.[50] Collaborations between providers of healthcare, technology developers, and regulating authorities are crucial to harnessing AI's full potential while addressing its associated challenges.[51]

Despite of extensive studies in the field of artificial intelligence in healthcare over the past several years, there is a need for a comprehensive study to map the AI landscape in this field. It is necessary to identify which topics are most studied each year and how many studies have been contributed by the authors, institutions and countries. A detailed review of previous literature is crucial to pin down the research trends, important contributors and geographical distribution of the studies, thereby highlighting potential areas of future research and collaboration.

Below research questions (RQs) were developed to assess the bibliometric analysis (review procedure) in this study.

RQ1: What are the most important emerging developments in the use of artificial intelligence (AI) in healthcare and which authors, organizations, papers, and journals in the literature on AIH (AI in

Healthcare) have had the biggest influence on citations during the past 13 years?

RQ2: Which important themes about AI in Healthcare have been studied, and how do they relate to one another?

RQ3: Which topics in AI in Healthcare have drawn the greatest interest and have been examined the most often?

METHODS

This research utilized bibliometric analysis to examine the application of artificial intelligence in healthcare. Data was extracted from the Scopus database with certain keywords and further analysis was conducted with the VOSviewer software.

Structure for analyzing data

The study's review procedure is depicted in Fig. 1. Keywords such as "artificial intelligence", "artificial intelligence in healthcare", "AI in healthcare", "health informatics", "machine learning in healthcare", "ml in healthcare", "healthcare predictive analytics" and "health informatics" were utilized to search for the published papers indexed in Scopus. The search targeted titles, abstracts, and keywords of papers published between 2010 and 2023. The decision to focus on the 2010–2023 period was based on the rapid growth and application of Artificial Intelligence (AI) technologies, particularly in healthcare, during this time. The adoption of AI in healthcare saw a significant surge post-2010, largely driven by advancements in machine learning, deep learning, big data analytics, and improvements in computational power. Many landmark studies, clinical applications, and real-world implementations of AI began to take shape after 2010, making this period especially relevant for capturing the most impactful and contemporary developments in the field. A longer timeframe could potentially offer broader insights, however, extending the study to include earlier years would likely introduce a period where AI applications in healthcare were in a nascent stage, with limited publications and practical use cases. Including earlier data may have diluted the focus on more recent, meaningful trends and could lead to an overrepresentation of non-AI healthcare studies, given that AI applications in healthcare were minimal before 2010. The keywords were chosen to provide a comprehensive framework for analyzing how technology supports sustainable practices within the healthcare industry. The keywords were combined into compound search phrases using the Boolean operators AND and OR. The selection, screening, determination of the papers' eligibility, and finalization of the list of articles to be included in this review study were conducted using the three phases of Preferred Reporting Items for Systematic Reviews and Meta-Analyze (PRISMA).[52] Since this study is a bibliometric study using the PRISMA framework, the search string was selected based on an extensive review of the literature. Using the selected keywords, data was extracted from the Scopus database, and the PRISMA framework was applied for further analysis. The search string was**:** ((TITLE ("artificial intelligence" "healthcare*") OR TITLE ("AI in healthcare") OR TITLE ("health informatics*") OR TITLE ("machine learning" "healthcare") OR TITLE (ml in healthcare) OR TITLE ("healthcare predictive analytics") OR TITLE ("health informatics") OR TITLE ("healthcare technology"))). The Scopus database is the largest database of articles, covering more than 45,000 journals with 1.7 billion citations. This comprehensive coverage has greatly facilitated the achievement of the

research objectives and the subsequent analysis in this study.[53]

The first set of metadata, bibliometric data (N = 6,480) included papers categorized as articles, conference papers, reviews, book chapters, book reviews, and books. To get the first search results, we went through a three-stage screening procedure. In the stage 1 cleaning process, 1095 articles were excluded for not being published in English and an additional 862 papers were removed, leaving a total of 1,957 papers (N=4,523) removed. During the second stage screening, we eliminated 185 more papers that were in press and 160 papers that were not related to healthcare, leaving us with 4,187 documents (N=4,178). During the second stage of cleaning, 1,488 papers with the publication status "in press" were removed. In the third stage of screening, we eliminated 189 papers that had no author names, and we were left with 3,989 eligible papers (N = 3,989).

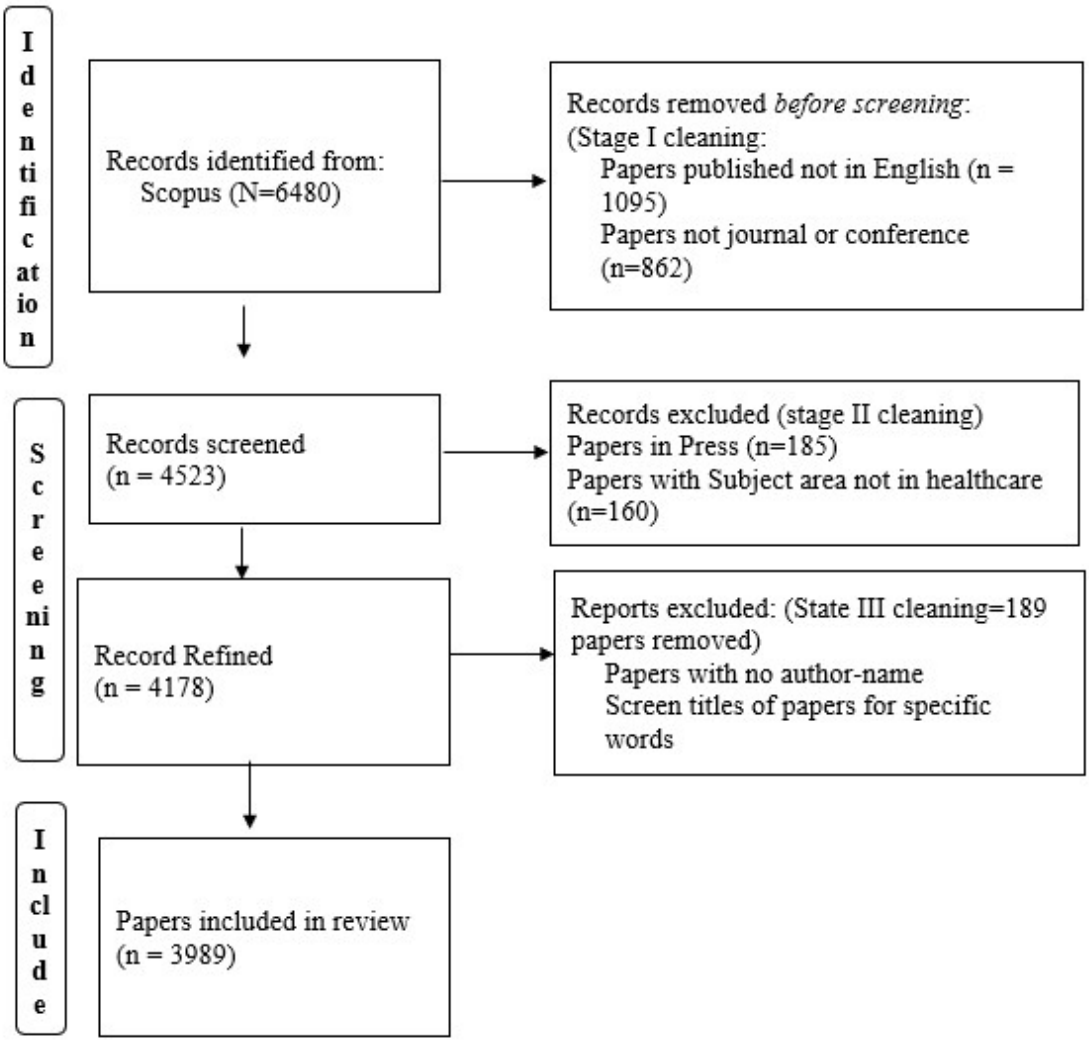

Figure1. PRISMA

RESULTS:

Analysis of 3,989 documents yielded 1426 (35.75%) journal publications classed as articles, 1057 (26.50%) conference papers, 528 (13.23%) book chapters, 408 (10.23%) review papers and 570 (14.29%) other documents. Fig. 2 displays the summary findings. The numerous articles that were looked at show how technology is increasingly being used and sought after in the healthcare sector.

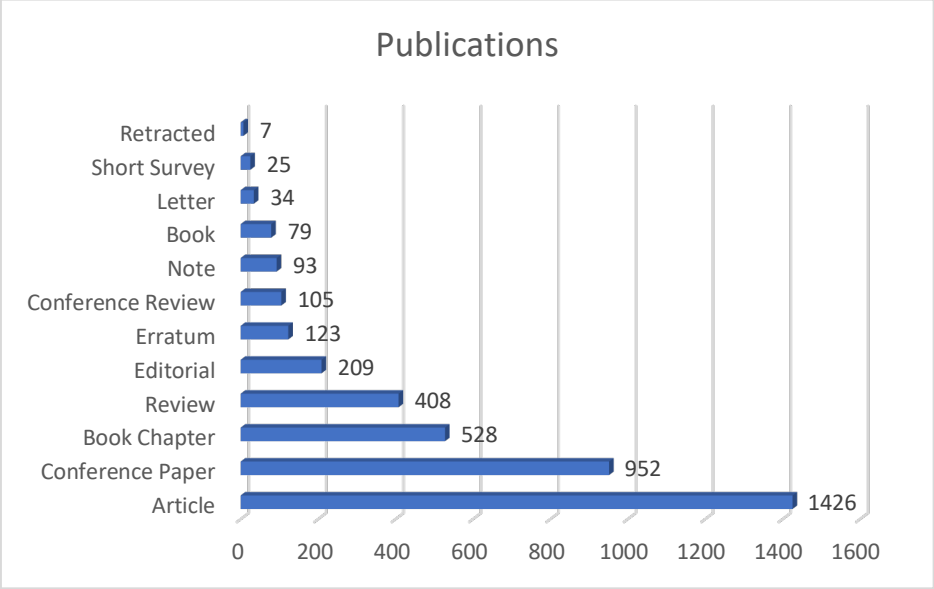

Figure 2. Publications

Trends in Publication, citation, and authors

It is possible to forecast the evolution of a study topic by looking at the number of publications and citations. The publication patterns from 2010 to 2023 are shown in Fig. 3. There are a few important things to note. 61.89% of the 2,469 documents that were examined were released between 2019 and 2023. The chart shows a steady increase in the research on technology for sustainable healthcare.

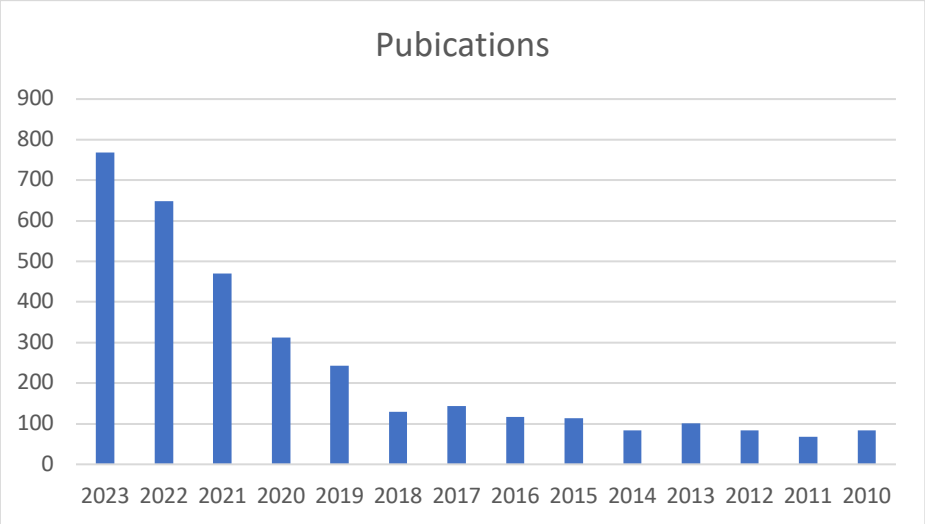

Figure 3. Trends in Publications

Co-occurrence of keywords

The most frequently occurring keywords in technology for research on sustainable healthcare are machine learning, healthcare, medical informatics, health informatics, and artificial intelligence (Fig 4). Using informatics technologies to enhance healthcare procedures, analyze data, and support decision-making is the emphasis of the keywords "health informatics" and "medical informatics." When sophisticated algorithms are integrated into healthcare systems to perform activities such as clinical decision assistance and image analysis, this is referred to as "artificial intelligence."

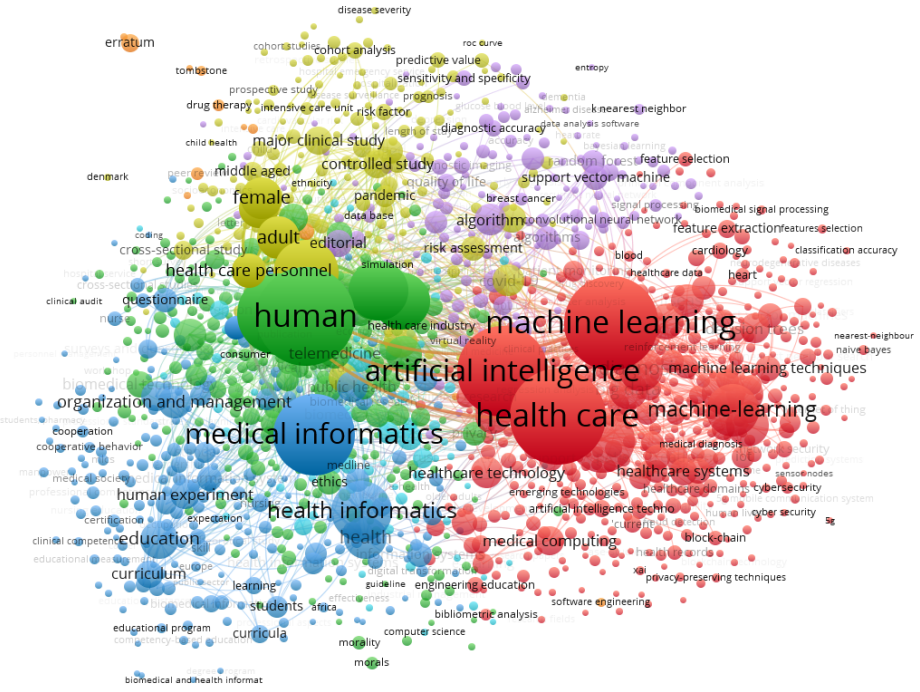

Figure 4. Co-occurrence of Keywords

The most focused countries and organizations

The top twenty countries with the highest research output in healthcare are shown in Fig. 5. By highlighting the most inventive and active areas within a field, we can shape upcoming research collaborations throughout the globe. The US has the most papers (970) in the healthcare technology area, followed by the UK (2174), India (784), United Kingdom (419), Australia (227), Canada (218), China (157), Saudi Arabia (137), Germany (123), and other countries that also contribute.

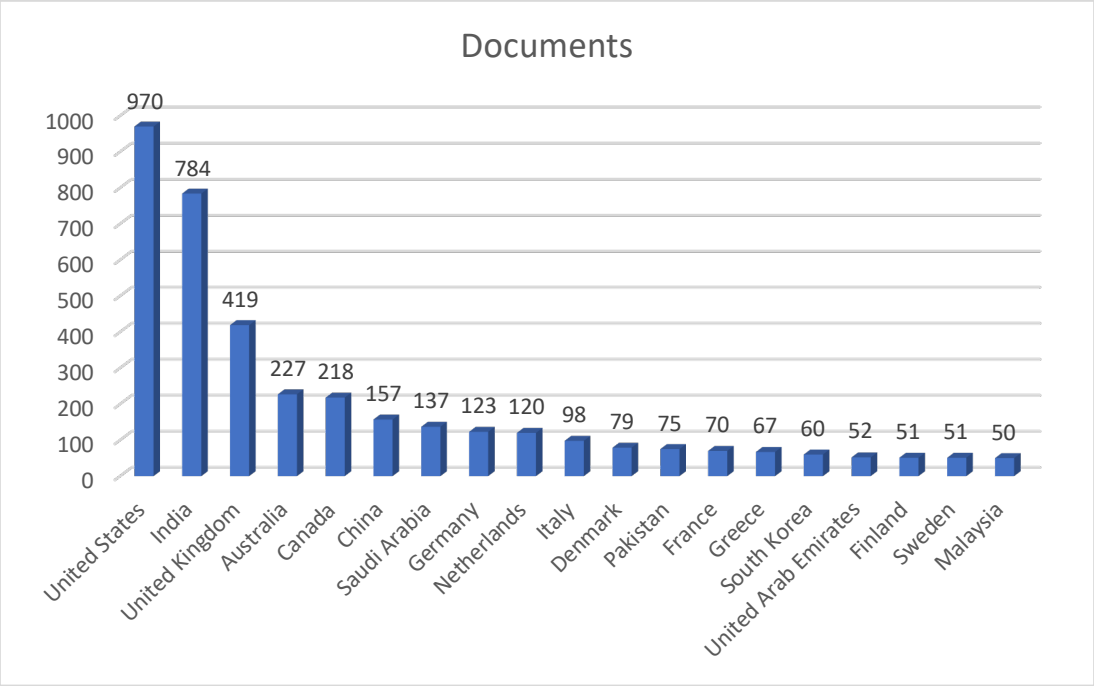

Figure 5. Top Countries

The top twenty institutions are shown in Fig. 6, which ranks them according to production (number of documents published). Among the 3,989 documents examined for analysis, 48 were connected to the University of Victoria, making it the top organization for AIH (AI in Healthcare) research. The University of Toronto and the National and Kapodistrian University of Athens both came in second with 40 papers, followed by Aalborg University and University College London with 38 publications. It's essential to note that many of the organizations or institutions are based in the United States (US). The US has made a significant contribution to this field of study; in addition, most institutions with a high publishing rate are US universities.

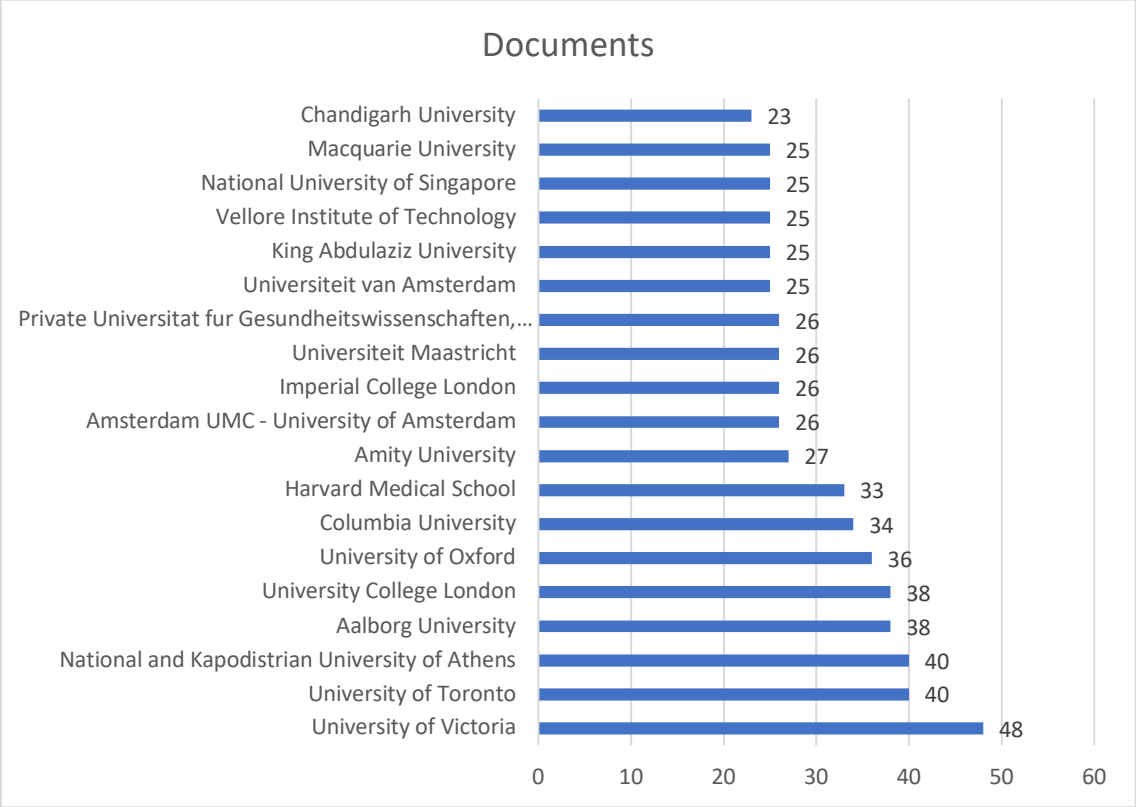

Figure 6. Top Institutions

It is observed that there is an interdisciplinary character to technology for long-term medical research sustainability, with advances in this area being fueled by partnerships between computer science and medicine. There is a great focus on using technological breakthroughs to enhance patient care, medical procedures, and the general provision of healthcare, as seen by the wealth of research in healthcare technology undertaken within medical disciplines.

Co-authorship analysis

The co-authorship evaluation of the examined manuscript using VOSviewer is displayed in Fig. 7. The plot was limited to writers who had at least 500 citations across five co-authored works. The co-authorship connections between them are shown by the arrows. The size of each node in the dataset corresponds to the number of publications a researcher has co-authored. It is found that a high dynamic of information exchange, cross-disciplinary teamwork, and idea flow in the field of using technology in research is sustainable. The result confirms the preliminary findings.

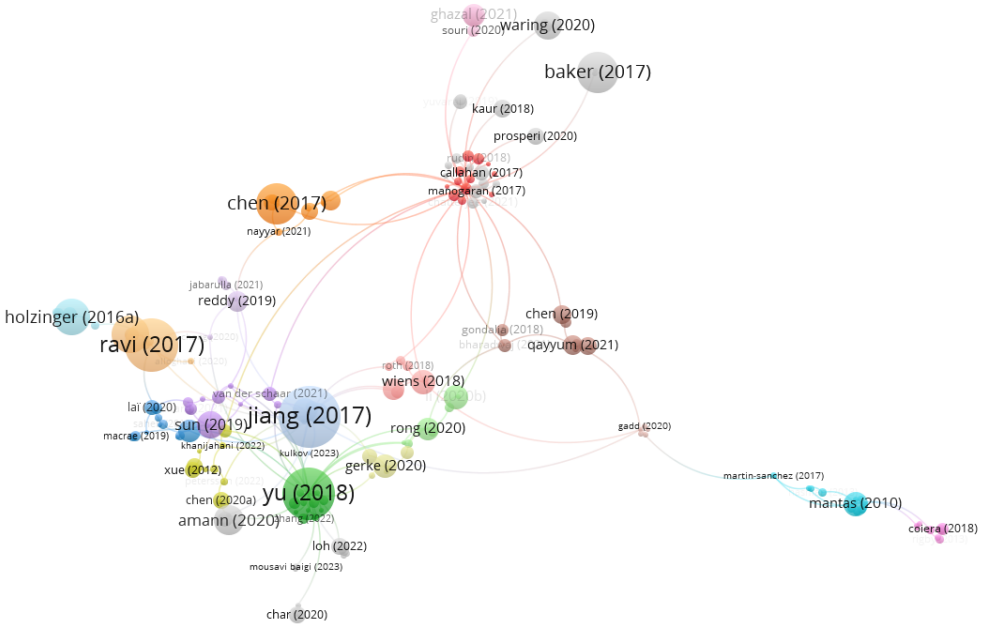

Figure 7. Co-authorship Analysis

DISCUSSION

The current study's findings provide a complete evaluation of AIH, which may be compared to earlier studies to identify trends and insights in this quickly growing subject. This study identifies machine learning, deep learning, and predictive analytics as significant upcoming AIH trends. This is consistent with prior research by Jiang et al.,[54] who found that machine learning algorithms have transformative potential in disease diagnosis and treatment personalisation. Both studies emphasize the importance of these technologies in advancing healthcare, indicating a steady trend towards the incorporation of complex algorithms in clinical settings. The current study's use of "machine learning" and "deep learning" as top keywords is consistent with earlier findings, indicating the continued importance of these technologies in developing healthcare. This analysis of influential authors, organizations, and journals reveals that authors like Mantas, J., as well as institutions like the University of Victoria and the University of Toronto, make important contributions to AIH research. These research findings are consistent with previous research by Meskó et al. and Topol,[55-56] who also recognised the significance of these factors. The identification of these prominent entities emphasises their critical role in developing AIH research, suggesting a concerted effort by leading scientists and institutions to push progress in the field. Healthcare informatics, medical informatics, and AI applications in clinical settings are the most common themes identified in this study. This is supported by Bizzo et al.,[57] who emphasised the use of AI in electronic health records (EHR) and clinical decision support systems. The co-occurrence of keywords like "Covid-19" suggests a recent spike in research motivated by the pandemic, which has been a focal point in multiple modern studies.[58] This thematic analysis emphasises the field's adaptive response to growing health concerns and the ongoing evolution of research

objectives. According to the study, AI algorithms for patient monitoring, medication development, and disease diagnosis are areas of great interest in research. Similar observations, emphasising the promise of AI in imaging, pathology, and genomics have been reported in a study.[59] The persistent emphasis on these applications demonstrates a concerted research effort to leverage AI to improve many elements of patient care and medical practice. The co-authorship study reveals a high level of collaboration among scholars, suggesting a dynamic interchange of ideas and interdisciplinary teamwork. This pattern of cooperation is established in studies by Luo et al.,[60] who emphasise the importance of interdisciplinary research in AIH. The frequent co-authorship among top experts highlights the collaborative nature of AIH research, which is critical for innovation and successful problem-solving in complicated healthcare systems.

The study's findings indicate key trends and insights that contribute to a more comprehensive understanding of AIH. When these findings are compared to earlier research, many major points emerge:

- **Consistent Technological Focus**: Both the current study and earlier research emphasise machine learning and predictive analytics as critical components of AIH. This persistent focus emphasises the relevance of these technologies in driving healthcare innovations, as well as ongoing efforts to harness their potential for improving patient outcomes.

- **Influential Contributors**: The identification of leading authors and institutions highlights the focused efforts of significant actors in the subject. This shows that improvements in AIH are driven by a small but powerful group of academics and institutions, emphasising the significance of focused support and funding for these key players.

- **Adaptive Research Priorities**: Thematic analysis shows that AIH research objectives are adaptable and responsive to new health issues, like as the Covid-19 outbreak. This versatility is critical for responding to urgent healthcare needs and efficiently managing health crises using AI.

- **Interdisciplinary Collaboration**: The high level of cooperation among researchers emphasises the interdisciplinary nature of AIH research. This partnership is critical for integrating varied skills and promoting innovation, resulting in the creation of complete solutions for complicated healthcare challenges.

The findings have important implications for SDG 3: Good Health and Well-being, which seeks to ensure healthy lifestyles and promote well-being for everyone. AIH research helps achieve this goal in a variety of ways:

- **Improved Patient Outcomes**: AI applications for disease diagnosis, treatment personalisation, and patient health monitoring directly improve patient outcomes, which aligns with SDG objectives.

- **Efficiency in Healthcare Delivery**: AI technologies automate healthcare operations and optimise resource allocation, making quality care more accessible and efficient. AI technologies improve healthcare processes by reducing diagnostic mistakes and optimising resource allocation. This can result in more efficient healthcare delivery systems, allowing more people to receive high-quality care.

- **Innovation and Research**: AIH's continual research and development,

which is driven by interdisciplinary collaboration, promotes healthcare innovation. This encourages the development of novel solutions to existing health concerns, hence improving population well-being.

- **Response to Health Emergencies**: The study's findings on the increased research attention on "Covid-19" highlights AI's importance in reacting to health emergencies. AI tools have proved critical in managing the pandemic by modelling, tracking, and predicting outbreak trends, which aligns with SDG 3's aims for health disaster planning and response.

The study's findings are compared to earlier research, revealing major trends and insights into AIH (Artificial Intelligence). AIH research is dynamic and changing, as seen by its consistent focus on essential technologies, recognition of influential contributors, adaptable research goals, and interdisciplinary collaboration. The findings of the other studies support the current research's outcomes. These findings further illustrate AIH's vital role in reaching UNSDG (United Nation's Sustainable Development Goals), emphasising its ability to improve patient outcomes, increase healthcare efficiency, stimulate innovation, and efficiently respond to health emergencies. This bibliometric analysis provides a comprehensive overview of the AI environment in healthcare, emphasizing significant trends, influential contributors, and topic focuses. When compared to other research, the findings demonstrate consistency in the identification of important technologies and collaborative activities that propel the area ahead. The study's findings also highlight AIH's critical role in attaining SDG-3 by improving patient outcomes, increasing healthcare efficiency, encouraging innovation, and responding effectively to health emergencies. This convergence with global health goals demonstrates AI's transformative potential in creating a healthier, more egalitarian world.

The goal of utilizing technology analytics to promote sustainable healthcare is to increase the application of analytics methods to support decision-making processes, improve patient outcomes, allocate resources as efficiently as possible, and handle ethical issues in healthcare environments.

- **Creating decision-supporting infrastructure:** This entails building complex instruments that make use of analytics methods like optimization and machine learning to help medical practitioners make well-informed choices. Risk assessment, treatment planning, and resource allocation are a few examples of applications.
- **Real-time data analysis:** To facilitate prompt decision-making and proactive treatments, several sources of real-time data streams, including wearable technology and digital health documentation, must be harnessed. To help guide healthcare decisions, patterns, trends, and abnormalities in the data are identified using predictive analytics.
- **Ethical considerations:** The storyline indicates that decision analytics' ethical ramifications for privacy, prejudice, accountability, and openness have drawn attention. Ensuring fair, egalitarian, and morally good decision-making procedures is the main goal of this field's research.
- **Human-computer interaction:** Research is being done to better understand how decision analytics tools and healthcare professionals interact to improve usability, user experience, and trust. Researchers focus on creating user-friendly interfaces, making analytics results comprehensible, and encouraging

productive interaction between humans and algorithms. On the other hand, less attention has been paid to decision-making in intricate settings, which comprises researching decision analytics techniques for resolving issues in environments with multiple stakeholders or resource constraints as well as creating models and algorithms that can manage uncertainty, variability, and competing goals.

Future technological developments for sustainable healthcare

One of the main areas of study and a hot topic in recent years is sustainable healthcare technology. The parts that came before this one covered both historical and modern technology advancements and how they have affected the healthcare industry. This section outlines the most recent developments, issues, and opportunities in the study for sustainable healthcare applications of future technologies. The findings of this study provide researchers with new avenues for investigation, growth, and contribution in the domain of medical technology. Specifically:

Comprehensive investigation of high-frequency keywords

The investigation finds terms like "machine learning," "health informatics," "medical informatics," "artificial intelligence," and "disease detection" that have been used frequently by academics in the subject. Subsequent research endeavours may explore these subjects in greater detail, highlighting their potential uses, difficulties, and prospects for growth. Examining less often researched keywords; It was discovered that phrases about medical applications, such as "quality," "implication," "study protocol," and others, occurred less frequently. To learn more about these understudied topics' importance, ramifications, and prospective contributions to healthcare technology, future research can concentrate on them.

Emerging themes and trends

The analysis identifies the most common keywords in the field as "COVID," "health information technology," "information," "challenges," "trial," and "intervention." A more thorough investigation of these hot-button issues is necessary to examine how they affect medical technology, tackle problems and come up with creative solutions. Co-occurrence study of keywords: The strong correlations between concepts that are seen such as ‘approach’, ‘machine’, ‘detection’, ‘COVID’, ‘quality’, ‘trial’, and ‘informatics’ show substantial links as well as the connections among these ideas. Recognizing the relationships and synergies between these terms, investigation is essential for understanding how they progress in healthcare technology.

Examining less-studied issues

It was discovered that terms such as "diabetes," "communication technology," "Internet of Things," "pandemic," "architecture," "validation," "telemedicine," "randomized controlled trial," and "meaningful use" had independent occurrences, suggesting possible areas that have not gotten much research attention. A closer examination of these issues is needed, including their potential effects on healthcare technology as well as its uses and difficulties.

Big data processing in real-time

Infrastructure and data processing of the enormous amounts generated by the health industry need to be efficient and real-time to achieve SDG. On the other side, real-time analytics, and processing of large data through apps have grown to be both intriguing and difficult. It is almost impossible to avoid managing such large volumes of data in the healthcare sector. Big data contains a great deal of noise; therefore, it requires a lot of time and money to clean and extract important

information from such a large data set. Moreover, machine learning is essential for converting data into understandable and relevant information. Owing to the vast amount of data that is available, sophisticated machine learning and deep learning techniques and algorithms are needed. One issue is that the process needs to take place in a dispersed context. Among the challenges posed by big healthcare data on software design are those of scale, parallelism, security, integrity, performance, concurrency, and dependability. To meet the demands of volume, diversity, and velocity both functional and non-functional architects must reconsider their architectural solutions.

Security and Ethical Concerns (Privacy)

While the development of new technologies for sustainable healthcare has made it possible for businesses to automate more and better processes, including pandemic treatment and disease diagnosis (such as with the novel COVID-19 virus), certain safety and confidentiality risks need to be carefully considered and addressed immediately. Increased personal data collection made possible by technological advancements in the healthcare industry raises grave privacy problems that need to be addressed right away. Infrastructure connected to the Internet and public data must also be safeguarded, in addition to confidential data. Therefore, appropriate techniques need to be developed and put into action to reduce the danger of security and privacy breaches. It is still problematic to use machinery, technology, and patient health data securely and safely.

Hazards Associated with Cyber-attacks

Cyberattacks in the healthcare industry have increased due to the rapid growth of the Internet of Medical Things (IoMT), which includes medical devices and apps, as well as an increase in the volume and accessibility of healthcare data. IoMT ecosystem devices might not have the bare minimum security measures, leaving them open to hacker attacks. To ensure high security in this regard, current research may examine low-weight integrated encryption and security solutions.

Potential Risks associated with a dynamic workforce

To enhance patient care, contemporary healthcare professionals utilize technologies, devices, and data. Consequently, the traditional model has shifted to a more dynamic one due to both technological advancements and the impact of the pandemic, enabling healthcare providers to remotely attend to patients. Nevertheless, organizations face issues related to inaccurate worker authentication and authorization, making it increasingly difficult to monitor employee activities.

THEMATIC MAP

The thematic map for the current study was analyzed using the Scopus data, which was examined through the Biblimatrix package in R. It comprises four quadrants: basic themes, emerging or decreasing themes, specialty themes, and motor themes.

The thematic map (Figure 8) is a graph that plots the development of different themes in a field. The Y axis shows the development degree (density), while the X axis shows the relevance degree (centrality). On the top left corner are "Niche Themes" while on the top right corner are "Motor Themes". Themes are represented by bubbles of different colors. "Human, Medical Informatics, Humans" is a niche theme, while "Health care, Machine

Learning, Artificial Intelligence" is a basic theme.

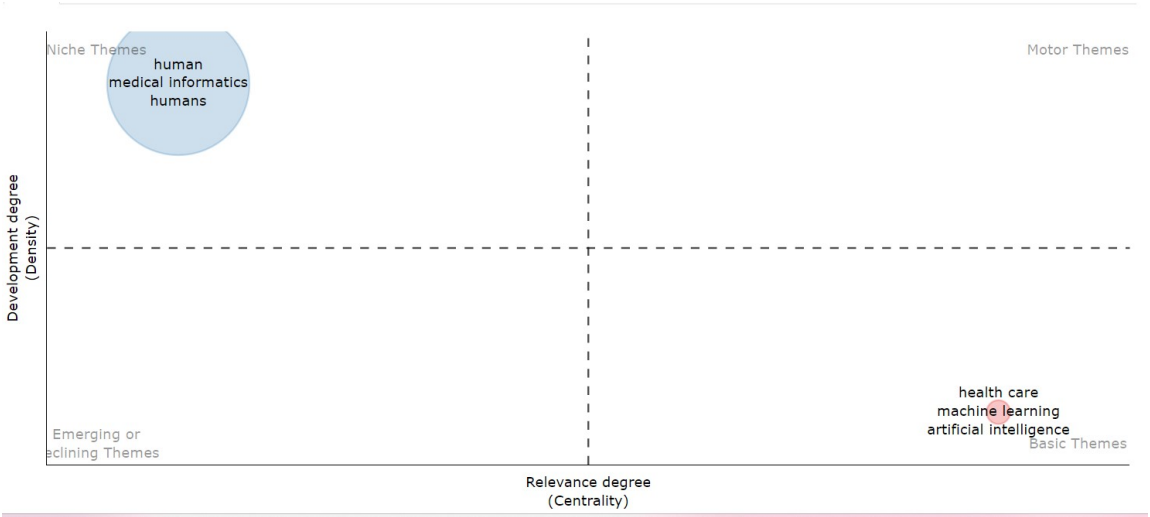

Figure 8. Thematic Map

Quadrant Analysis:

Motor Themes (High Centrality, High Density): The study field revolves around highly developed motor themes. These topics indicate that they are important and active fields of research since they not only show significant linkages with other themes (high centrality) but also show internal cohesiveness (high density). Motor themes would probably center on the fundamentals of AI in healthcare, including healthcare, health informatics, and machine learning (ML) techniques. These are the core ideas guiding the field's conversation and have numerous applications in a variety of fields, including business and healthcare. This quadrant contains articles about artificial intelligence in healthcare, like the one titled "Artificial intelligence in Healthcare" in this study. Given the plethora of research and technology developments in this field, the issue of applying AI to healthcare has both broad relevance (centrality) and active development (density). A further possible motor theme would be AI frameworks for business applications, as seen in the "AI in Healthcare" article.

Niche Themes (Low Centrality, High Density): Niche themes are highly specialized and developed but have limited connections with the broader research field. These themes don't have broad effect or application, but they are frequently significant for a particular subfield or industry. Healthcare predictive analysis in this study might fit within this quadrant. These themes could center on issues that are important to tiny groups but not as important to the larger conversation around AI. They might be investigated further, but their influence across disciplines might not be as great.

Emerging or Declining Themes (Low Centrality, Low Density): Themes in this quadrant are underdeveloped and have limited relevance to the field. These themes may be in decline (becoming less relevant with time) or developing (representing new research areas). Their trajectory in the future is contingent upon their level of acceptance or rejection by the academic community. This quadrant may include healthcare technology.

Basic Themes (High Centrality, Low Density): Basic themes are critical to the field's structure, meaning they have

strong connections with other research themes, but they are underdeveloped. These are frequently fundamental subjects or approaches that underpin other subfields but need further study and investigation. Healthcare that is sustainable may fit into this area. They could be shallow in terms of in-depth analyses and specialized study, even if they are crucial and related to numerous academic fields. These themes offer significant avenues for further investigation. By dedicating more effort and resources to these areas, it may be possible to fill up knowledge gaps and create a more thorough understanding of these fundamental subjects.

Centrality vs. Density:

Centrality (Relevance): The theme's significance within the thematic network is shown by the vertical axis. A theme with high centrality is one that is important for the general direction of research since it is a major topic that is connected to many other themes. This could include wide-ranging uses in AI research, such as AI-driven decision-making systems or AI in healthcare.

Density (Development): The horizontal axis gauges a theme's maturity or internal strength. A theme with a high density of study has a more established and organized body of work. A theme pertaining to a certain AI technology or use case that has been thoroughly investigated and is backed by multiple in-depth studies would be regarded as highly developed.

The artificial intelligence in healthcare thematic map analysis is a methodical way to comprehend how different subjects in the field develop and connect to one another. Researchers can guarantee that AI keeps growing in relevance and progress by concentrating on fundamental and basic issues while also keeping a look out for emergent subjects that can spur future innovation.

FACTORIAL ANALYSIS

Factorial analysis for the current study was conducted by utilizing the bibliometrics in R. Figure 9 depicts a scatter plot graph for the factorial analysis. There are two axes, labeled "Dim 1 (59.95%)" and "Dim 2 (24.8%)". There are many points on the graph, each representing a word. The words, written in red, are all related to healthcare and technology. The position of each word on the graph is determined by its relation to other words, and its placement can signify commonality or discrepancy with other words. Words like "machine learning", "deep learning", and "diagnosis" are closely clustered together on the left-hand side of the graph. "Health informatics" and "information science" are clustered together on the top of the graph. "Health care" and "health care personnel" are clustered together on the right-hand side of the graph.

Many words associated with "health care" are positioned close to the center of the graph. This type of scatter plot graph can be used to visualize and analyze the relationships between different concepts, such as words in a corpus of text or healthcare topics.

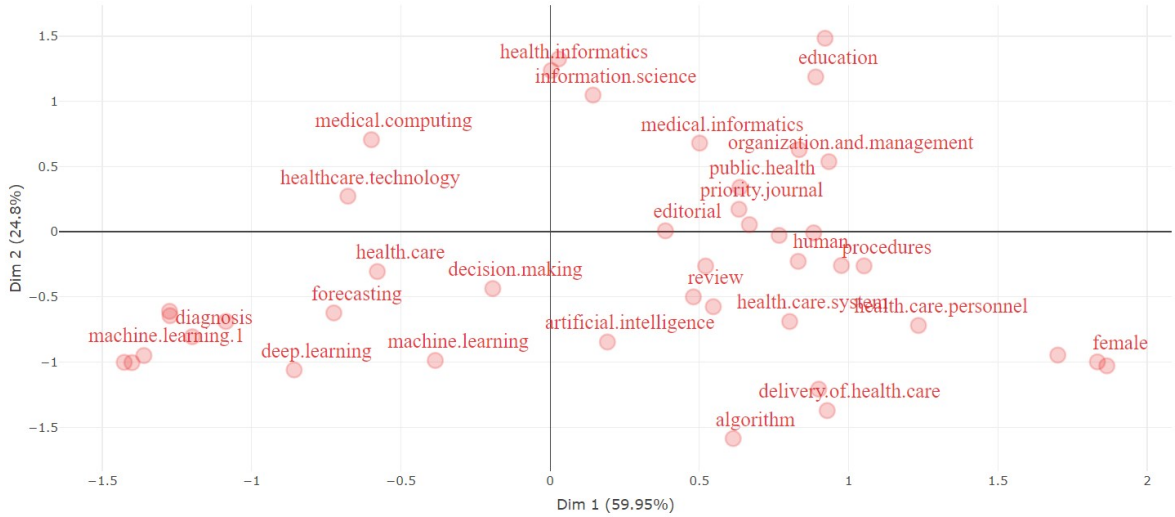

Figure 9. Factorial Analysis

RECOMMENDATIONS

AI has a wide range of effects on healthcare, including improved patient engagement, treatment, diagnosis, and operational effectiveness. AI raises ethical, legal, and financial issues in addition to offering previously unheard-of capacity to improve patient outcomes and revolutionize the delivery of healthcare. To ensure responsible AI integration, prioritize patient welfare, and promote equal access to high-quality healthcare services enabled by artificial intelligence, stakeholders must work together to navigate these issues. But even with these encouraging developments, there remain obstacles associated with implementing AI in healthcare that need to be recognized and addressed. It is crucial to take moral dilemmas about patient confidentiality and data safety, and the proper application of AI algorithms into account. Moreover, healthcare organizations and legislators have a formidable obstacle in negotiating the regulatory environment to maintain adherence to current standards while adjusting to the quick development of AI technologies. Additionally, it's important to consider the financial effects of implementing AI in healthcare. The initial expenditure needed for deployment and maintenance may provide obstacles, especially for smaller healthcare facilities and areas with limited resources, even if AI has the potential to optimize procedures and reduce costs over time.

Theoretical implications include the need for integrated information from many fields to improve AI in healthcare by promoting collaboration and knowledge exchange across disciplines. Potential future routes for research and development are implied by the study's identification of developing themes and links within the field of AI healthcare research. Theoretical implications encompass the need for visual analytics in understanding transdisciplinary relationships and promoting more lucid stakeholder communication. Researching patterns in AI applications leads to the creation of moral standards and laws that guarantee patient privacy, preserve algorithmic openness, and establish responsible AI use in healthcare. The requirement for ongoing education and training for healthcare personnel to effectively use and adapt to new technologies is highlighted by an understanding of the growing trends in AI within the healthcare industry. Through cost-effective problem-solving, resource optimization, and the elimination of unnecessary tests and procedures, artificial

intelligence (AI) applications hold the promise of lowering healthcare expenditures. Understanding the role AI plays in managing sensitive healthcare data highlights the necessity for strong cybersecurity measures to protect patient data from hacks and other online threats.

This study offers insights for the healthcare sectors' practitioners and policy makers both. This study suggests the need for practitioners to adopt machine learning (ML) and deep learning (DL) technologies to improve clinical outcomes, patient monitoring, disease diagnosis, and medication development and improve patient care. The healthcare sector can also connect to the top leading contributing institutions identified in this study to ask for their expertise and collaborate with them. This study suggests practitioners to integrate AI applications in the areas of the health sector to make the healthcare system more responsive, adaptable, accessible and efficient. This study also provides insights for policy makers to make supportive policies that uplift the use of ML and DL and provide training programs to develop the required skills of healthcare professionals; to support initiatives that promote the deployment of artificial intelligence in operations. The policymakers of the healthcare sector must consider the allocation of resources and get grants to make innovation and maintain a leadership position in artificial intelligence in healthcare's research and application. This study also provide policy to integrate the AI into public health polices to make sure the preparedness and rapid action during health crises, aligning with the sustainable goal of united nations i.e. healthcare and wellbeing.

The present research study utilizes the Scopus database. Future research endeavours may explore alternative research databases such as Web of Science, Google Scholar, and EBSCO. It is imperative to recognize that the results of this investigation could be constrained by the availability and accessibility of data concerning artificial intelligence applications in healthcare. Furthermore, the current study may be susceptible to publication bias, wherein certain types of research studies or outcomes are more likely to be published or indexed, potentially leading to an overrepresentation or underrepresentation of specific trends or perspectives in the analysis. Subsequent research could undertake comparative analyses of different bibliometric methodologies or databases to evaluate the robustness and reliability of the findings.

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CONFLICTS OF INTEREST

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