Scientific Visualization, 2023, volume 15, number 5, pages 35 - 49, DOI: 10.26583/sv.15.5.04

Explorative Bibliometric Study of Medical Image Analysis: Unveiling Trends and Advancements

BinuThomas[1,A], JeenaJoseph[2,A], JobinJose[3,B]

[A] Department of Computer Applications, Marian College Kuttikkanam Autonomous, Idukki, Kerala, India

[B] Marian College Kuttikkanam Autonomous, Idukki, Kerala, India

[1] ORCID: 0000-0003-1594-2159, binu.thomas@mariancollege.org
[2] ORCID: 0000-0003-4070-5868, jeena.joseph@mariancollege.org
[3] ORCID: 0000-0003-1596-733X, jobin.jose@mariancollege.org

Abstract

Medical image analysis has quickly advanced, with several advantages for research, diagnosis, and healthcare planning. We must have enough knowledge of current trends and developments in this field due to improvements in medical imaging technology and the accessibility of a wide range of medical image databases. This work covers the research environment for bibliometric analysis of academic articles as part of medical image analysis, utilizing the tools VOSviewer and Biblioshiny. The Scopus database contains 1,973 articles submitted between 1988 and 2023; all have been gathered and examined. The study has focused on the key bibliometric elements, such as authorship patterns, highly cited papers, prestigious journals, and collaborative networks. The outcomes of our inquiry demonstrate its interdisciplinary nature. This bibliometric analysis is a valuable resource for researchers, practitioners, and decision-makers, allowing them to identify significant trends, identify knowledge gaps, and explore prospects for further advancements in this critical field by providing a comprehensive overview of the literature on medical image analysis.

Keywords: Bibliometric analysis, Medical Image Analysis, Machine Learning, Deep Learning, Artificial Intelligence, VOSviewer, Biblioshiny.

1. Introduction

Deep learning applications and artificial intelligence, medical data, and image analysis have the most robust capability of generating a positive, long-term impact on human lives in a relatively short period [1]. Image acquisition, image creation, analysis of imagery, and imaging-based visualizationare all part of the computerized processing and evaluation of healthcare images [2]. In numerous dimensions, medical image analysis has evolved to encompass computer vision, detection of patterns, image mining, deep learning, artificial intelligence, and machine learning [3]. The necessity for medical imagery services, such as radiological imaging, genomic sequences, endoscopy, computed tomography (CT), mammography images (MG), ultrasound images, magnetic resonance imaging (MRI), magnetic resonance angiography (MRA), nuclear medicine imaging, Positron Emission Tomography (PET), and pathological tests, has skyrocketed in the health-care system [4]. Machine Learning is an application for artificial intelligence that can acquire knowledge from data and make predictions. Itemploys supervised learning, unsupervised learning, and semi-supervised learning. The extraction and the selection of optimal features for a specific problem are part of the Machine Learning approach. Deep learning algorithms tackle the feature selection challenge. It is a subset of Machine Learning that can automatically extract significant characteristics from unstructured input data [5]. Deep Learning Algorithms can be used to discover abnormalities and characterizediseases in general. Convolutional Neural Networks (CNN) are appropriate for classification, segmentation, object recognition,and other tasks when Deep Learning Algorithms are applied to medical images [6, 7].

Bibliometric analysis is a statistical tool that uses mathematical methods to quantitatively analyze articles on particular subjects [8]. It might also assessthe study's excellence, analyze the major research topics, and forecast future research directions [9]. It is a research method that examines many aspects of academic literature to get perceptions on research progress in a specific field [10,11]. It analyses publishing data using multiple quantitative approaches to uncover emerging patterns and trends, including citation counts, co-authorship, keyword distribution, and more [12]. The bibliometric analysis considers the total quantity of articles, the relative indicators, how they fluctuate over time, and the amount spent on research is determined [13, 14].

The use of the Visualization of Similarities (VOS) viewer is becoming increasingly popular in the field of bibliometric research. Created by van Eck and Waltman in 2010, this software facilitates the simple generation and visualization of bibliometric maps that are easily understandable. It effectively gathers relevant literature, identifies the similarities between selected publications based on given criteria, and identifies the main themes present in these publications [15]. The bibliometrix R-package is afreely available software that provides tools for performing quantitative studies on bibliometric data. It includes algorithms for statistical and scientific mapping analysis. This package includes a web interface tool called Biblioshiny to help users who do not have coding skills conduct bibliometric analysis. The Biblioshiny interface accepts data from the Scopus or Web of Science databases in BibTex, CSV, or Plain Text format [16].

2. Materials and Methods

The scientific publications for the investigation were obtained from the Scopus database's core collection. On May 29, 2023, a search was performed using the keywords "medical image analysis", "artificial intelligence", "deep learning", and "machine learning". There were no language constraints, and the data was limited to articles from peer-reviewed journals and conference papers, excluding book chapters, meetings, editorials, notes,and books. Only articles in the final publication stage were included. The keywords "convolutional neural network", "convolutional neural networks" and "CNN" are treated as “deep learning” techniques in the query. As a result, we gathered 1973 articles from 697 sources between 1988 and 2023. The Scopus records havebeen screened for duplicates for maximum accuracy. The results obtained were stored as "CSV" files, and bibliometric analysis was performed on the data using VOSviewer version 1.6.19 and Bibloshiny software. The essential aspects of this investigation are shown in Table 1.

Table 1. Essential aspects of the investigation.

Description	**Results**
Search Query	(TITLE-ABS-KEY ("Medical Image Analysis")AND(TITLE-ABS-KEY ("artificial intelligence")ORTITLE-ABS-KEY ("Deep learning")ORTITLE-ABS-KEY ("Machine Learning")))AND(LIMIT-TO(DOCTYPE,"ar")ORLIMIT-TO(DOCTYPE,"cp"))AND(LIMIT-TO(PUBSTAGE,"final"))
Timespan	1988:2023
Sources	697
Documents	1973
Annual Growth Rate %	16.05
Document Average Age	3.18
Average citations per doc	27.17
References	69144
DOCUMENT CONTENTS	
Keywords Plus (ID)	8758
Author's Keywords (DE)	3639
AUTHORS	
Authors	6173

Authors of single-authored docs	44
AUTHORS COLLABORATION	
Single-authored docs	48
Co-Authors per Doc	4.77
International co-authorships %	27.77
DOCUMENT TYPES	
Article	1027
conference paper	946

3.Results

3.1. Annual Scientific Production

Between 2004 and 2015, there was a slight rise in the quantity of publications in medical image analysis. However, starting from 2015, there was a significant acceleration in the growth of published works, which continued until 2022. Figure 1 illustrates the correlation between the number of publications and their corresponding publication years using Biblioshiny for visual representation.

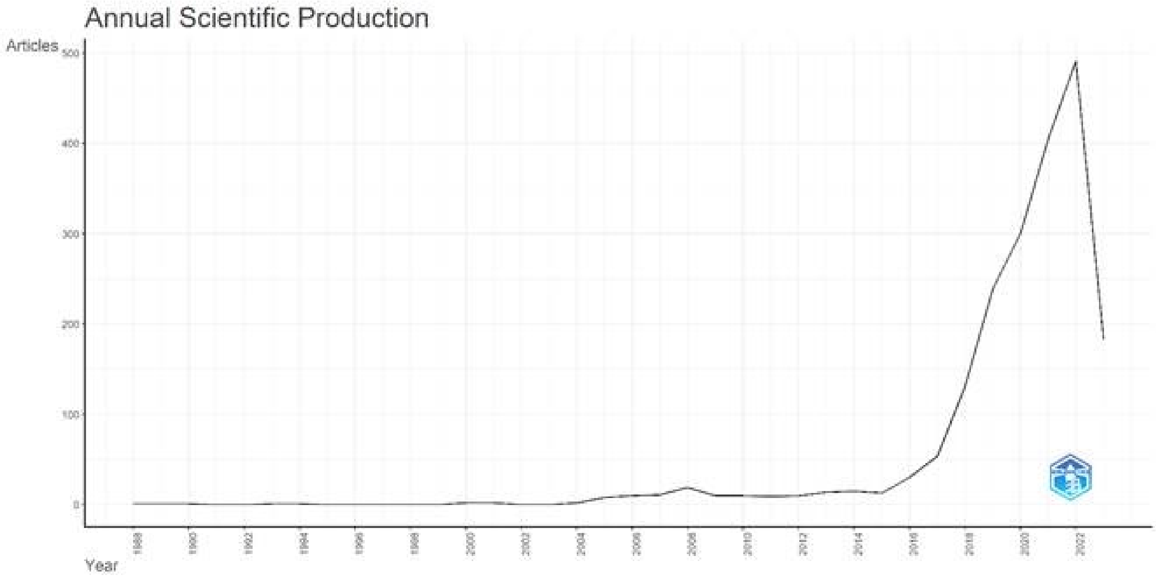

Figure 1. The annual scientific production from 1988 to 2023 visualized using the tool Biblioshiny.

3.2. Average Citations per Year

Average Citations per Year refers to the average number of citations received by a particular entity (such as a research paper, author, or journal) in a given year. It is a statistic frequently used to assess the significance or acceptance of academic publications in academic and scientific environments. The average number of citations per year sheds light on how frequently a specific entity's work is mentioned or referenced in other academic works, demonstrating its importance in the field. The annual average of citations is shown in Figure 2, which shows a cyclical trend between increase and collapse from 1989 to 2015. Then, from 2015 to 2016, there was a notable increase in citations, followed by a fall. The peak value of 41.5% occurred in 2016. Following the usual cyclic trend of decline after a peak value in 2016, the annual average number of citations sharply decreased to 6.2% in 2018. Then it showed an upward trend to reach the next peak value of 10.6% in 2019 and fell to 4.7% in 2021. The declining trend is continuing in recent years.

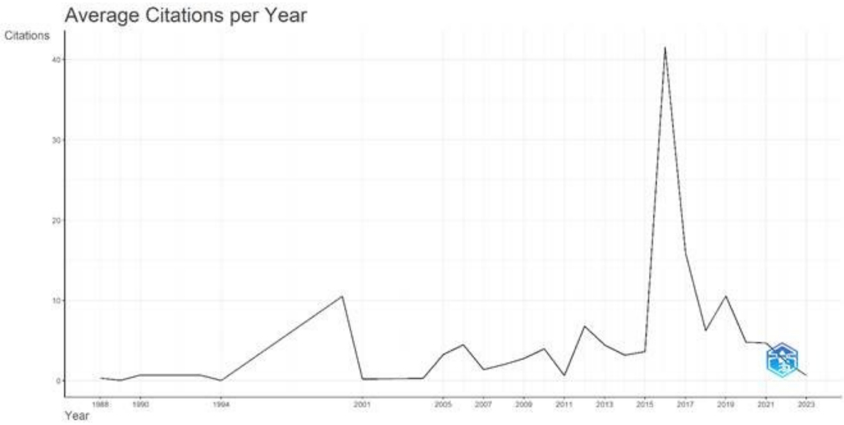

Figure 2. The average citations per year from 1988 to 2023 represented using the tool Biblioshiny.

3.3. Most Significant Authors

By publishing articles, a total of 6173 authors have contributed to the study of medical image analysis. The number of publications published was utilizedas a parameter to determine the most significant authors, taking into account authors who had written at least twenty articles. Wang Y stands out with 40 published articles, followed by Zhang Y with 35, and Li Y and Wang X with 27 each. Table 1 provides an overview of the number of publications by these prominent authors, who have consistently produced more than twenty articles over a period of time. They have established a strong presence in their respective fields through extensive experience and expertise, making them highly influential. Figure 3 depicts the authors' productivity from 1988 to 2023, showing the number of articles they have produced over time. The authors' productivity was determined based on the volume of articles they wrote within specific time frames.

Table 2. The authors having more than twenty articles

Authors	Articles
Wang Y	40
Zhang Y	35
Li Y	27
Wang X	27
Li J	26
Li X	24
Wang S	24
Chen X	23
Zhang J	23
Liu Y	22
Wang J	22
Liu J	20

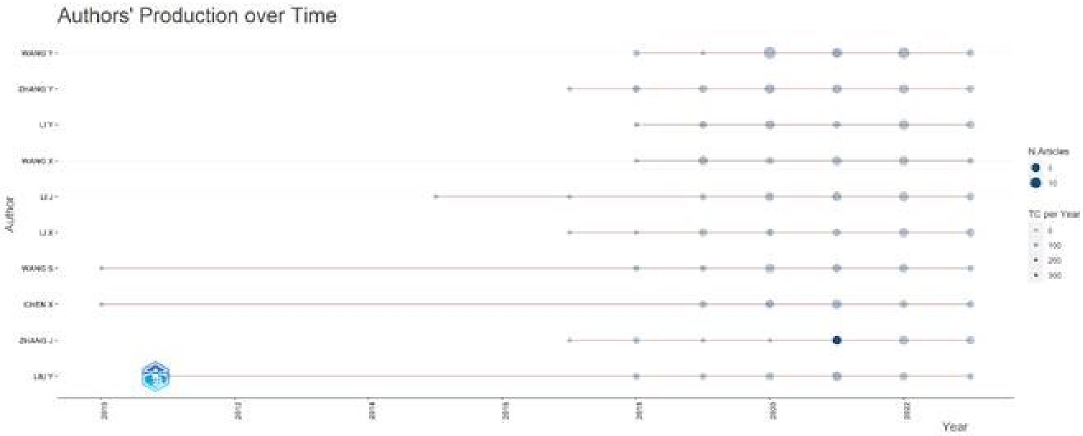

Figure 3. Authors' Production over Time

3.4. Most relevant sources and affiliations

The 1973 collected publications from a total of 697 journal sources. Among these, Lecture Notes in Computer Science (which includes subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) stood out as the most productive journal we analyzed, with a maximum of 249 articles. The journal Medical Image Analysis followed closely behind with 73 publications. Figure 4 lists the top 15 journals that produced the most medical image analysis research papers.

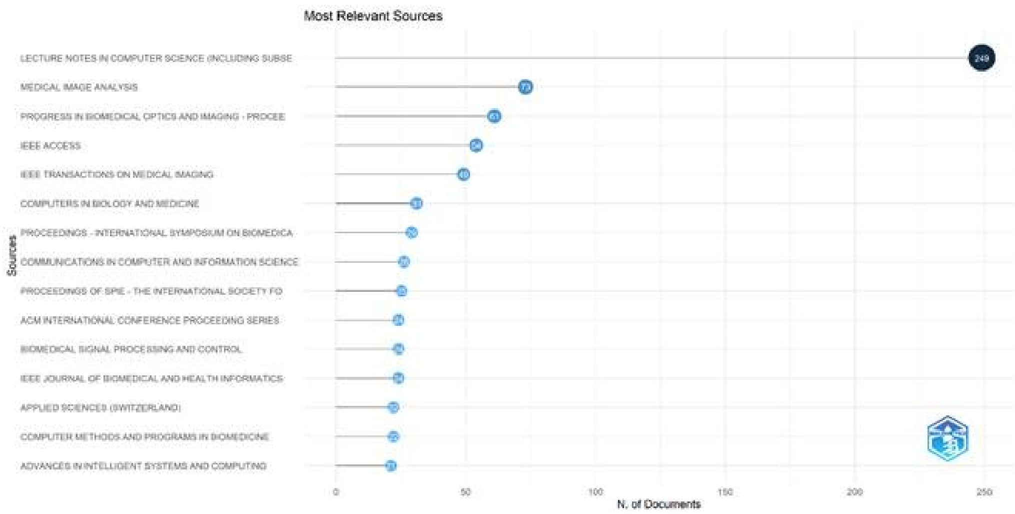

Figure 4. The top 15 relevant sources in terms of the number of publications

Figure 5 showcases the primary institutions involved in medical image analysis research publications generated using Biblioshiny. The leading positions on the list are held by Imperial College London and the University of Oxford, with a maximum of 69 publications each. Following closely is Shanghai Jiao Tong University, with 61 publications. Sichuan University, Graz University of Technology, Beihang University, and Vanderbilt University are the subsequent institutions where noteworthy research has been conducted in this field.

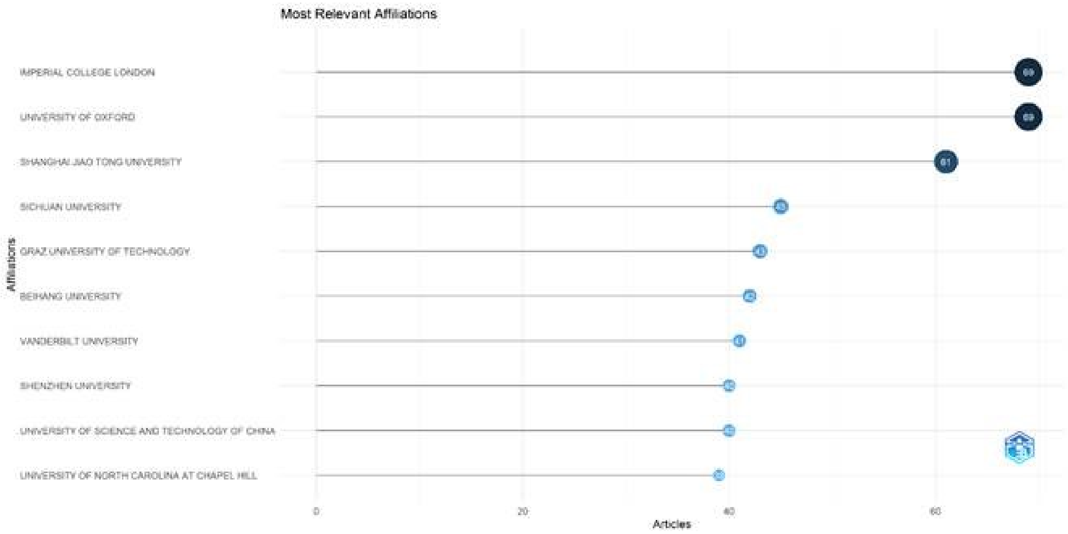

Figure 5. Most relevant affiliations in terms of the number of publications

3.5. Three Field Plot of keyword, author and source

Biblioshiny utilizes a three-field plot to display the connections between various elements and the critical components are represented by colored rectangles, with the height of each rectangle indicating the level of association between components like countries, organizations, sources, authors, keywords, and so on. The width of the rectangle reflects the complexity of interactions between different components [17].

Figure 5 presents an illustration that explores the connection between keywords (on the left), authors (in the middle), and sources (on the right) in the field of medical image analysis literature. The investigation aimed to identify the frequently used keywords in the literature by different authors and published journals. The analysis of the top keywords, authors, and sources revealed several key phrases such as "deep learning," "medical image analysis," "machine learning," and "convolutional neural networks." It was observed that most of the authors like Wang Y, Wang X, Li X, commonly employed these keywords and published their work in sources such as Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) and the journal Medical Image Analysis.

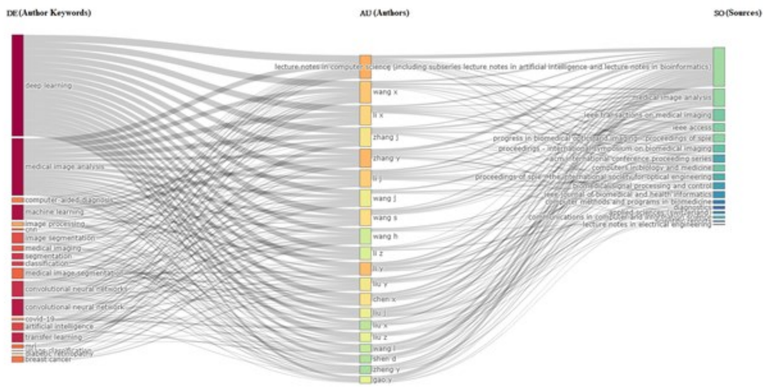

Figure 6. Three Field Plot representing the relationship between author keyword (DE), author (AU) and source (SO) using Biblioshiny.

3.6. Co-Occurrence of Keywords and Content Analysis

A word network constructed using the co-occurrence of keywords to identify meaningful connections and research themes is given in Figure 7. Each node in the diagram represents a specific keyword, and the edges connecting pairs of nodes illustrate the occurrence of these keywords together. The thickness of an edge reflects the frequency of co-occurrence between keywords, while the size of a node and its label indicate the frequency of occurrence of a particular keyword. A thicker edge signifies a stronger relationship between the keywords. Additionally, the color of a node represents the cluster to which the keyword belongs, suggesting its association with a specific research area. The keywords and their connections imply that each cluster is associated with a distinct research domain. The figure presents two separate clusters identified by the Biblioshiny system. The larger cluster, depicted in red, highlights prominent terms like "deep learning," "medical imaging," "image analysis," and "image segmentation," which are closely related to one another. The second cluster, shown in blue, includes keywords such as "human," "humans," "article," and "diagnostic imaging," among others.

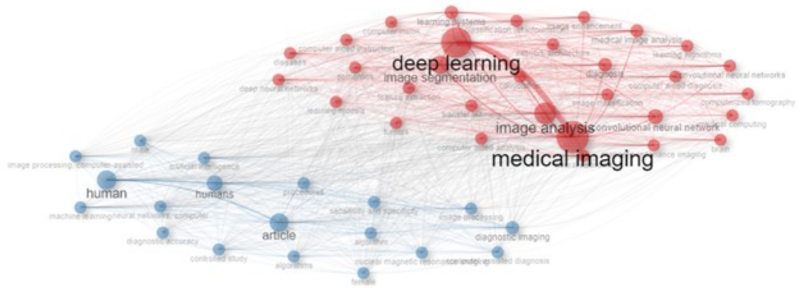

Figure 7. Co-occurrence network generated by Biblioshiny

3.7. Most Frequent Words and Word Cloud of the authors' keywords

The visual representation in Figure 8 illustrates the key phrases that are commonly used and their respective frequencies. The ten most popular keywords are "deep learning (807)", "medical image analysis (465)", "machine learning (155)", "convolutional neural network (128)", "transfer learning (126)", "convolutional neural networks (110)", "segmentation (109)", "classification (94)", "artificial intelligence (76)", and "image segmentation (72)".

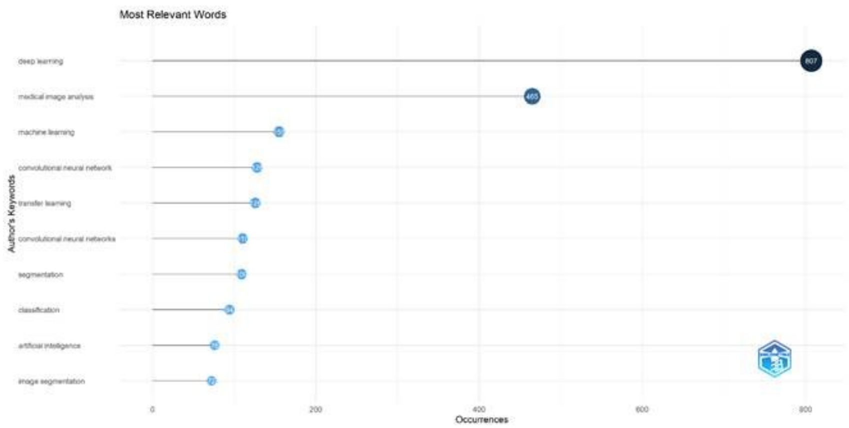

Figure 8. The most frequently used author keywords

Figure 9 and Figure 10 contain word clouds that represent the authors' keywords and keywords plus. Author Keywords are chosen by authors and serve as a representation of the phrases they have chosen, whereas Keywords Plus are assigned automatically by the indexing system to provide more context and related ideas. These word clouds are utilized to investigate the frequently occurring phrases in the articles being examined, indicating that the majority of the analysis focuses on those specific areas. A word cloud transforms text input into identifiers, typically shorter terms, and their size in the resulting cloud reflects their relative importance.

Figure 9 represents the word cloud of author keywords in the area of medical image analysis. It is evident from the figure that, the keywords "deep learning," and "medical image analysis," are the most prominent keywords chosen by the authors followed by the keywords “machine learning”, “convolutional neural network”, and few more. Figure 10 is the word cloud representation of keyword plus which indicates that “deep learning”, “medical imaging”, “image analysis”, and “image segmentation” are the most recurring keywords automatically assigned to the documents by the indexing systems. This analysis reveals that “deep learning” and “medical imaging” are the most significant keywords. The extensive range of keywords iscovered by the keyword plus analysis.

Figure 9. A Visualized Word-cloud of Authors Keywords

Figure 10. A Visualized Word-cloud of Keywords Plus

3.8. Conceptual Structure Map using Multiple Correspondence Analysis

Multiple Correspondence Analysis (MCA) is utilized to illustrate the conceptual arrangement of the subject area, enabling the identification of document clusters that share similar ideas. The outcomes are then displayed on a two-dimensional map [18]. The conceptual structure map, generated through multiple correspondence analysis, consolidates relevant keywords while considering their cohesion within the network.

When conducting multiple correspondence analysis on the Keywords Plus field, the resulting factorial network revealed two clusters (Figure 11). These clusters had a minimum of 50 terms, cluster number 2, a label size of 10, and a minimum of five documents for graphic parameters. One cluster consisted of keywords such as "medical imaging," "computer vision," "image enhancement," and "image analysis," while the other cluster included keywords like "diagnostic imaging," "computer-assisted diagnosis," and "image processing."

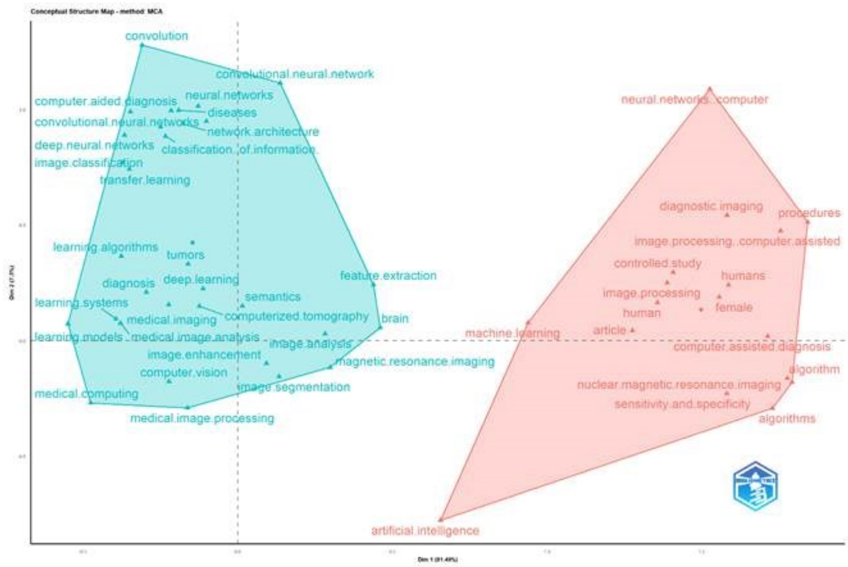

Figure 11. Structure map developed from the multiple correspondence analysis.

3.9. Country Co-Authorship Analysis

The analysis of country co-authorship involves examining the influence and communication between countries in a particular field of investigation. In the case of medical image analysis, Figure 12 displays the country's co-authorship network visualization. The size of the nodes represents the countries with the greatest influence, while the links indicate cooperative relationships between institutions across different countries. The thickness and distance between nodes reflect the level of cooperation between countries. The map also reveals the diversification of research directions through various colors. In terms of publication output, China (492), the United States (398), and India (306) have the highest number of publications. The United States (20438) and China (7804) receive the most citations, and they have the highest total link strength value (United States (285) and China (277)).

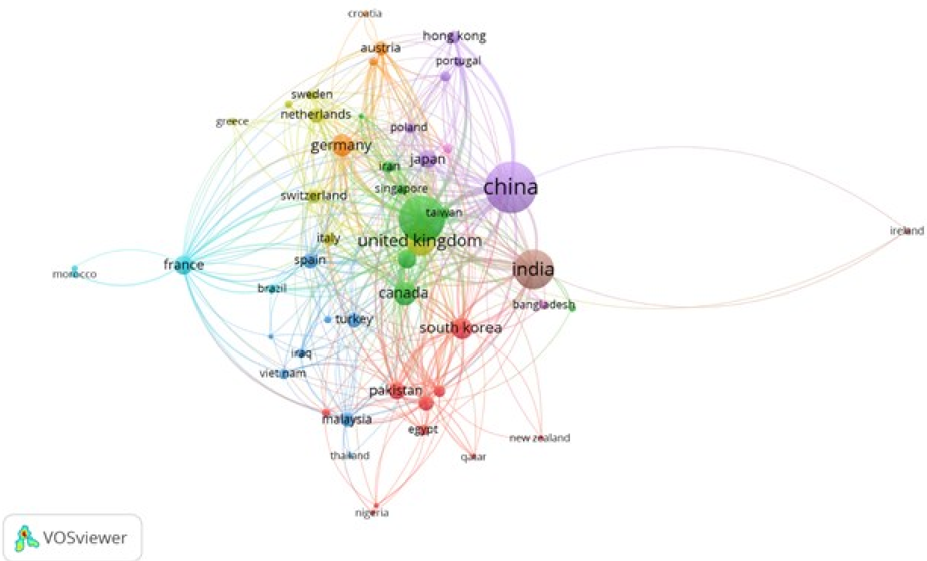

Figure 12. The network visualization of country co-authorship analysis using VOSviewer

3.10. Co-authorship visualization of authors

In Figure 13, there is a visual representation of the collaboration among researchers who have published on medical image analysis from 1988 to 2023. During this period, a total of

1,973 articles were written by 6,173 authors. The number of authors per article varied from 5 to 25. Out of the 6,173 authors, only 216 met the criteria using the full counting method. These 216 authors were examined for their co-authorship connections with other authors, and the strongest connections were selected. A researcher's overall co-authorship relationships with other researchers are represented by their total link strength. Consequently, 2,031 link strengths were identified and categorized into 17 clusters of 197 items. To be more precise, the initial cluster consisted of 32 items, the next cluster had 23 items, and the third, fourth, and fifth clusters contained 16 items each. The sixth cluster comprised 14 items, the seventh cluster included 12 items, and the eighth, ninth, and tenth clusters consisted of 11 items each. The eleventh cluster contains 8 items, while the twelfth and thirteenth clusters contain 6 items each. The fourteenth, fifteenth, and sixteenth clusters each have 4 items, and the final cluster has only 3 items.

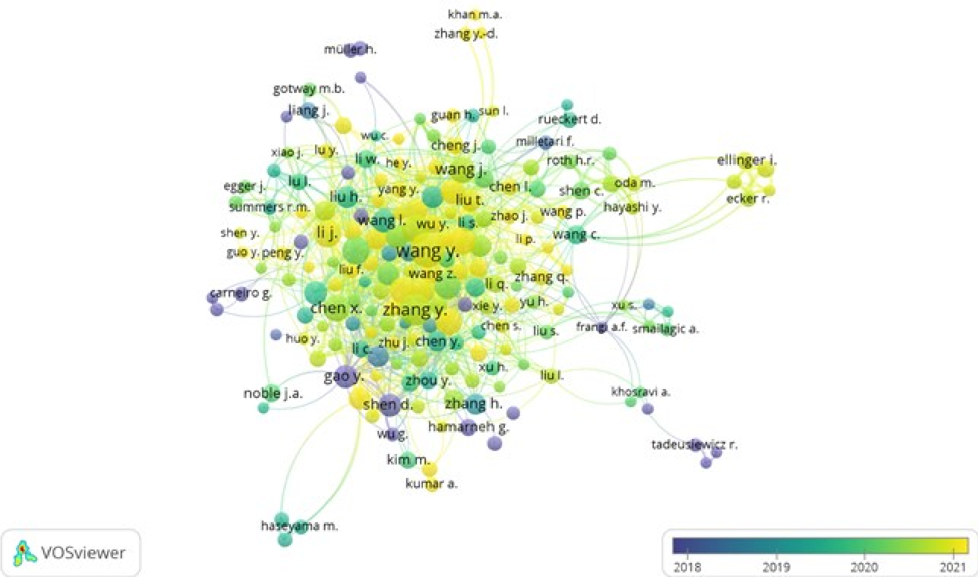

Figure 13. The overlay visualization of Co-authorship of authors using VOSviewer

3.11. Bibliographic Coupling with Sources

The visualization depicts bibliographic connections among research articles focused on medical image analysis. Out of the 697 sources that published such articles, only 64 sources met the specified criteria. These criteria involved selecting sources that had published at least five articles and using a full counting method to assess their relevance. This network mapping aims to showcase the connections and relationships between the research articles and their respective sources. The total strength of the bibliographic coupling links among the 64 sources was calculated. The total link strength indicates the strength of the connection between any two network nodes. By determining the most significant total link strength (TLS) from their sources, a value of 98159 TLS was obtained. This value was then used to classify the sources into seven clusters of 64 items. Specifically, the first cluster included 16 items, the second cluster had 14 items, the third cluster contained 12 items, the fourth cluster comprised seven items, and the fifth and sixth clusters consisted of six items each. The seventh cluster consisted of 3 items. The data presented indicates that the highest combined link strength achieved was 22249, which involved 249 articles receiving 3698 citations from the journal "Lecture Notes in Computer Science (includes subseries Lecture Notes in Artificial Intelligence and Bioinformatics)." This high ranking suggests that this journal played a prominent role in publishing academic papers within this field. In the second position, the journal "Medical Image Analysis" had 19742 combined link strengths from 73 research articles. This indicates significant collaboration between these two journals in the publication of academic papers, as illustrated in Figure 14.

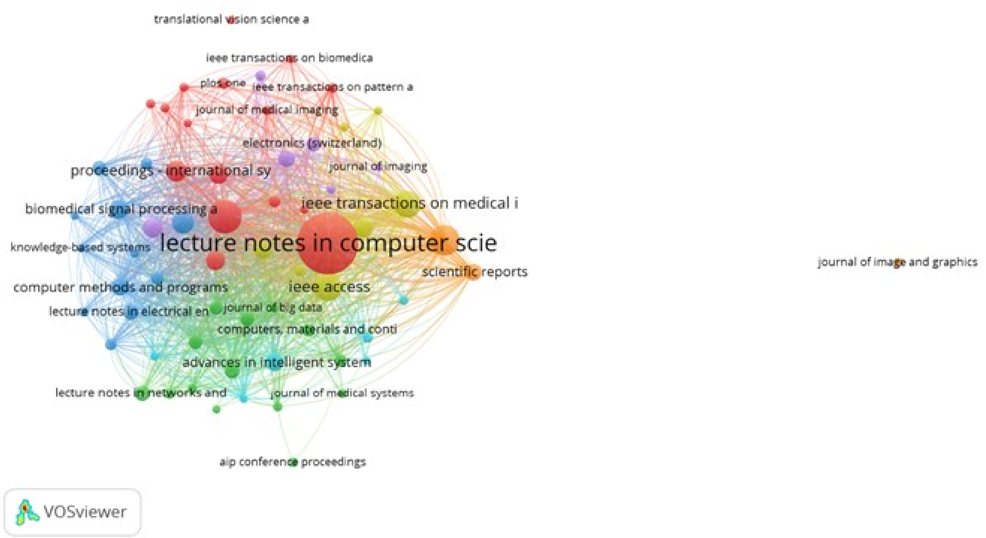

Figure 14. The network visualization of bibliographic coupling with sources using VOSviewer

3.12. Bibliographic Coupling with Countries

In Figure 15, the relationship between bibliographic coupling and various countries conducting medical image analysis research is depicted. A total of 114 countries participated in publishing academic papers, with 53 countries surpassing the threshold of five publications. Consequently, the figure illustrates eight clusters comprising a total of 53 items. Among these clusters, cluster 1 consists of 12 items, clusters 2 and 3 each contain ten items, clusters 4 and 5 consist of six items each, cluster 6 has five items, cluster 7 has three items, and cluster 8 has only one item. Additionally, the figure represents the overall strength of the bibliographic coupling links between the 53 countries and other nations, totaling 563,309 links. Total link strength is calculated based on the number of connections or the strength of connections between two nodes.

According to the figure, China has the highest number of bibliographic coupling links, amounting to 191,988 occurrences. China's publications include 492 documents with 7,804 citations. The United States follows closely with 159,455 bibliographic coupling links across 398 documents, accompanied by 20,438 citations. This indicates a significant reliance on each other's research in the field of medical image analysis by both countries.

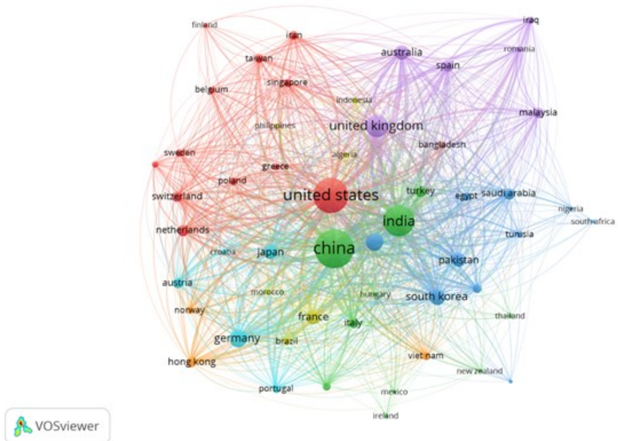

Figure 15. The network visualization of bibliographic coupling with countries using VOSviewer

4. Discussion

A total of 1973 articles were gathered from 697 different sources from 1988 to 2023. For collecting articles, the terms “Medical Image Analysis”, “Artificial Intelligence”, “Deep Learning,” and “Machine Learning” were included in the search query. The field of medical image analysis experienced a significant surge in research activity and publication output starting from 2015, which continued until 2022. This growth signifies the growing importance and interest in this field, potentially driven by technological advancements, increased funding, and the need for advanced medical imaging techniques for diagnosis, treatment, and research purposes. The average citations per year studied showed a fluctuating pattern between growth and decline from 1989 to 2015. However, there was a significant surge in citations in 2016, representing a peak value of 41.5%. This suggests that the entity's work gained considerable attention and influence within the academic community that year. Additionally, 2019 and 2000 also had relatively high average citations per year, with values of 10.6% and 10.5%, respectively, indicating a significant level of impact or popularity during those years.

With 40 articles written, Wang Y is the most prolific author among the aforementioned people. This suggests that Wang Y has actively engaged in research and substantially contributed to the field. The second most prolific author, Zhang Y, has 35 articles in the publication. Although Zhang Y has fewer publications published than Wang Y, their production is still significant, indicating a solid devotion to research. Li Y and Wang X has 27 articles to their names. Despite having slightly less impact than Wang Y and Zhang Y, Li Y and Wang X have made substantial contributions to the field.

The 697 journal sources examined produced 249 articles, with "Lecture Notes in Computer Science" being the most productive. The University of Oxford and Imperial College London were the top two institutions in the number of medical image analysis research publications, with each having 69 articles.

The study turned up several significant phrases that authors like Wang Y, Wang X, and Li X frequently used. They contain the terms "deep learning," "medical image analysis," "machine learning," and "convolutional neural networks." Additionally, the authors frequently published their work in journals like Medical Image Analysis and Lecture Notes in Computer Science (including subseries like Lecture Notes in Artificial Intelligence and Bioinformatics). This shows that certain subjects and resources, particularly those relating to artificial intelligence, bioinformatics, and medical image analysis, are very important and well-known in computer science.

The articles’ analysis focuses primarily on deep learning, medical image analysis, machine learning, convolutional neural networks, transfer learning, segmentation, classification, artificial intelligence, and image segmentation. These topics are indicated by the high frequencies of their respective keywords and their prominence in the word clouds. The correspondence analysis and co-occurrence network analysis of the Keywords Plus field revealed two distinct clusters of keywords. These clusters represent different topics or themes within the dataset, with Cluster 1 describing AI architectures and Cluster 2 describing medical image analysis and diagnostics.

China, the United States, and India produce the most publications in medical image analysis. The country with the most publications is China, with 492, followed by the US, with 398, and India, with 306. The co-authorship relationship among writers suggests that there has been an excellent level of collaboration in medical image analysis, with a core group of authors building solid relationships and substantially contributing to the research output in this area.

China and the United States cooperate and rely heavily on one another's research. China has the most bibliographic coupling links, which shows that it has strong ties to other nations. The United States is close behind with a sizable number of links. The significant number of citations for their papers highlights the value of their scholarly contributions and the interdependence of the two nations.

5. Conclusion

By performing an extensive bibliometric analysis, the work offers valuable insights on medical image analysis. The report sheds light on the present status of research, significant contributors, well-liked research areas, and upcoming trends in medical image processing through an exhaustive evaluation of scholarly publications and citation patterns. The study emphasizes the expanding role of medical image analysis in healthcare and how it significantly impacts illness monitoring, treatment planning, and diagnosis. The study uses analysis of publication output, citation counts, and collaboration networks to pinpoint significant research institutes and nations that are actively advancing medical image analysis. It also demonstrates that well-known authors and important research journals are the primary hubs for information dissemination and area advancement.

The paper also lists several research areas and sub-disciplines in medical image analysis, such as feature extraction, image segmentation, machine learning algorithms, and deep learning methods. The research area of medical image analysis is showing an increasing application of Deep Learning and Artificial Intelligence (AI) through Deep learning techniques, particularly convolutional neural networks (CNNs). Promising research has been conducted in the areas of image segmentation, classification, and detection, aiding in the diagnosis and treatment of various diseases using AI. Recent advancements in Cloud computing and Telemedicine open new avenues for researchers in the field of medical image analysis.

References

1. LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. Nature, 521(7553), 436–444.https://doi.org/10.1038/nature14539

2. Razzak, M. I., Naz, Z. S., & Zaib, A. (2018). Deep learning for medical image processing: Overview, challenges and the future. Classification in BioApps: Automation of decision making (pp. 323–350). Springer. https://doi.org/10.1007/978-3-319-65981-7_12

3. Pang, S., & Yang, X. (2016). Deep Convolutional Extreme learning Machine and its application in Handwritten Digit Classification. Hindawi Publ Corp. Computational Intelligence and Neuroscience, 2016, 3049632.https://doi.org/10.1155/2016/3049632

4. Puttagunta, M., & Ravi, S. (2021). Medical image analysis based on deep learning approach. Multimedia Tools and Applications, 80(16), 24365–24398. https://doi.org/10.1007/s11042-021-10707-4

5. Liu, W., Wang, Z., Liu, X., Zeng, N., Liu, Y., & Alsaadi, F. E.(2017). A survey of deep neural network architectures and their applications.Neurocomputing, 234, 11–26. https://doi.org/10.1016/j.neucom.2016.12.038

6. Dhillon, A., & Verma, G. K. (2019). Convolutional neural network: A review of models, methodologies, and applications to object detection Prog Artif Intell, no. 0123456789. https://doi.org/10.1007/s13748-019-00203-0

7. Greenspan, H., Van Ginneken, B., & Summers, R. M.(2016). Guest editorial deep learning in medical imaging: Overview and future promise of an exciting new technique.IEEE Transactions on Medical Imaging, 35(5), 1153–1159. https://doi.org/10.1109/TMI.2016.2553401

8. Chen, C., Dubin, R., & Kim, M. C. (2014). Emerging trends and new developments in re-generative medicine: A scientometric update (2000–2014). Expert Opinion on Biological Therapy, 14(9), 1295–1317. https://doi.org/10.1517/14712598.2014.920813, PubMed: 25077605

9. Yu, Y., Li, Y., Zhang, Z., Gu, Z., Zhong, H., Zha, Q., Yang, L., Zhu, C., & Chen, E. (2020). A bibliometric analysis using VOSviewer of publications on COVID-19. Annals of Translational Medicine, 8(13), 816. https://doi.org/10.21037/atm-20-4235

10. Godin, B. (2006, July 1). On the origins of bibliometrics. Scientometrics, 68(1), 109–133. https://doi.org/10.1007/s11192-006-0086-0

11. Hood, W. W., & Wilson, C. S. (2001, October 1). The literature of bibliometrics, scientometrics, and informetrics. Scientometrics, 52(2), 291–314. https://doi.org/10.1023/A:1017919924342

12. Ellegaard, O., & Wallin, J. A. (2015, December 1). The bibliometric analysis of scholarly production: How great is the impact? Scientometrics, 105(3), 1809–1831. https://doi.org/10.1007/s11192-015-1645-z

13. Khakimova, A. Kh., Zolotarev, O. V., & Berberova, M. A. Coronavirus infection study: Bibliometric analysis of publications on COVID-19 using PubMed and Dimensions databases. Scientific Visualization, 12(5), 112–129. https://doi.org/10.26583/sv.12.5.10, PubMed: PubMed and Dimensions databases (2020)

14. Zhang, B., Rahmatullah, B., Wang, S. L., Zhang, G., Wang, H., & Ebrahim, N. A. (2021). A bibliometric of publication trends in medical image segmentation: Quantitative and qualitative analysis. Journal of Applied Clinical Medical Physics, 22(10), 45-65. https://doi.org/10.1002/acm2.13394

15. Nobanee, H., Al Hamadi, F. Y., Abdulaziz, F. A., Abukarsh, L. S., Alqahtani, A. F., AlSubaey, S. K., Alqahtani, S. M., & Almansoori, H. A. (2021). A bibliometric analysis of sustainability and risk management. Sustainability, 13(6), 3277. https://doi.org/10.3390/su13063277

16. Agbo, F. J., Oyelere, S. S., Suhonen, J., & Tukiainen, M. (2021). Scientific production and thematic breakthroughs in smart learning environments: A bibliometric analysis. Smart Learning Environments, 8(1), 1–25. https://doi.org/10.1186/s40561-020-00145-4

17. Kumar, R., Singh, S., Sidhu, A. S., & Pruncu, C. I.(2021). Bibliometric analysis of specific energy consumption (SEC) in machining operations: A sustainable response.Sustainability,13(10), 5617. https://doi.org/10.3390/su13105617

18. Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007