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REVIEW ARTICLE

A Structured Analysis to study the Role of Machine Learning and Deep Learning in The Healthcare Sector with Big Data Analytics

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Abstract

Machine and deep learning are used worldwide. Machine Learning (ML) and Deep Learning (DL) are playing an increasingly important role in the healthcare sector, particularly when combined with big data analytics. Some of the ways that ML and DL are being used in healthcare include Predictive Analytics, Medical Image Analysis, Drug Discovery, Personalized Medicine, and Electronic Health Records (EHR) Analysis. It has become one of the advanced and popular tool for computer science domain.' The advancement of ML and DL for various fields has opened new avenues for research and development. It could revolutionize prediction and decision-making capabilities. Due to increased awareness about the ML and DL in the healthcare, it has become one of the vital approaches for the sector. High-volume of unstructured, and complex medical imaging data from health monitoring devices, gadgets, sensors, etc. Is the biggest trouble for healthcare sector. The current study uses analysis to examine research trends in adoption of machine learning and deep learning approaches in the healthcare sector. The WoS database for SCI/SCI-E/ESCI journals are used as the datasets for the comprehensive analysis. Apart from these various search strategy are utilised for the requisite scientific analysis of the extracted research documents. Bibliometrics R statistical analysis is performed for year-wise, nation-wise, affiliation-wise, research area, sources, documents, and author based analysis. VOS viewer software is used to create author, source, country, institution, global cooperation, citation, co-citation, and trending term co-occurrence networks. ML and DL, combined with big data analytics, have the potential to revolutionize healthcare by improving patient outcomes, reducing costs, and accelerating the development of new treatments, so the current study will help academics, researchers, decision-makers, and healthcare professionals understand and direct research.

1 Introduction

Nowadays, machine learning (ML), and deep learning (DL), are leading topics and centres of interest in the industry, academia, and popular culture all over the world [1, 1]. Machine learning has emerged as a popular field of study and cutting-edge tool in recent years. Multiple areas of prediction and decision-making benefit from its suite of algorithms and statistical techniques. The fact that it can use a variety of learning approaches means it can process large amounts of unstructured and complex data in ways that lead to revolutionary shifts in perspective based on the data experience.

Different machine learning-based model has been applied in two ways: (1) Supervised learning, and (2) Unsupervised learning. The data are input into the supervised learning-based model, and then the model is used to perform classification, regression, and prediction on the labelled dataset [3–5]. In contrast, an unsupervised learning-based model is applied to unlabeled datasets to perform tasks such as

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clustering, dimensionality reduction of a dataset, detection, etc. Also, the concepts of machine learning are being applied in various industries; it is largely responsible for the revolutionary changes occurring in the healthcare industry. The majority of the time, it is utilized for the prediction of early-stage disease, the identification of disease, and the monitoring of the patient's status based on clinical datasets. Detecting automatic object features in medical images can also be accomplished by the use of machine learning techniques to datasets related to medical imaging. To manage picture collections and larger datasets, the deep neural network-based technique has emerged as the model of choice among the various machine learning models [6, 7]. Because it uses the three-layer perceptron for analyzing the dataset. Deep Neural Network-based approaches are a great solution in larger-scale datasets with different structures in fields of data mining, Image processing, Natural Language Processing, Expert Systems and Prediction, etc. [8, 9].

The subfield of machine learning known as "deep learning" employs iterative methods for learning new features. It offers several neural network algorithm variants that can learn features in a variety of ways [10–13]. It is used on a huge scale and processed via numerous layers of filters. As a result of its use of multi-layer filtering techniques, it can deliver increasingly precise results compared to conventional machine learning while efficiently organizing massive datasets.

Healthcare is the fastest expanding sector, drawing in more scientists, professors, and medical experts who are all eager to make important contributions to the discipline and the healthcare system as a whole. Hospitals, medical equipment, clinical trials, telemedicine, medical tourism, health insurance, and other related services are all examples of healthcare facilities. It presents a tremendous chance to enhance healthcare facilities with the use of cutting-edge technologies. Therefore, the development of more sophisticated technology has allowed for massive amounts of data and proven to be a massive transformation in healthcare fields, in terms of providing easy access to the best diagnostic tools, the most cutting-edge treatments, and a variety of minimally invasive procedures that result in less pain and quicker healing. Drug development, tailored treatment, robotic surgery, illness monitoring, etc. all rely heavily on healthcare in various capacities. A field's research dynamics and behaviours can be gleaned from scientific articles using bibliometric analysis, making it the most reliable tool for spotting patterns in the research landscape. Mathematical and statistical methods are used to research articles, books, and other forms of scholarly communication, and the results are used to analyze patterns in the scientific publishing world. Systematics examination of published sources is commonly used to gauge advancements in science across a range of disciplines using a variety of criteria.

In this research, bibliometric analysis has been applied to analyze the most significant and crucial research pattern in machine learning (ML), deep learning (DL), and the healthcare field, as well as the most relevant research areas of machine learning (ML) and deep learning (DL) application applying in the healthcare field. Also, explored the most related research areas of healthcare like disease detection, diagnosis, and prediction [14–16]. For this, Thomson Reuters' Web of Science (WoS) (Clarivate analytics, 2020) database has been used to collect the bibliometric information in topic-wise and title-wise categories and "Machine learning", "Deep Learning" and "Healthcare OR health*" used as query keywords. The web of science (WoS) database is a well-structured and differently indexed database, that selected only the most relevant top publication, it includes many significant scientific articles. Out of all relevant significant-top publication document types, only article, review, and early access articles have been selected for descriptive analysis. Another aspect of the bibliometric study is the following: number of published papers from 2010–2021; the number of authors; the number of papers per author and contribution; authors' collaboration; country-wise numbers of publications: country-wise paper impact factors; year-wise paper publication; top-most institution etc. Finally, we elected top categories to show the research dynamic, trends, hot topics, and research directions and variations on this related type of strategy have been successfully applied by the recent literature [14, 17, 18].

Therefore, the purpose of this study is to give depth insight and a clear understanding of the research pattern of machine learning and deep learning application in the healthcare sector and compare the application of both techniques in the advancement of healthcare treatment. Hence, this study will be more beneficial for academia, and researchers' health professionals to determine the relevant area of research in Machine Learning, Deep Learning, and Healthcare that has been broadly focused on along with the gaps that should be addressed. The paper is organized as (1) the "*Introduction*" section deals with the introduction of the topic. (2) *"Methodology"* section discusses the proposed methodology. (3) *"Results and discussion"* section provides the results and follows them with discussions. The "Summary" section deals with the summary of the whole work. *(4) "Conclusion and prospect"* section concludes and future scope of this work. (Fig. 1).

2 Material and Methods

2.1 Data Collection

For this study, all bibliometric information has been collected using the text keyword search strategies in topical

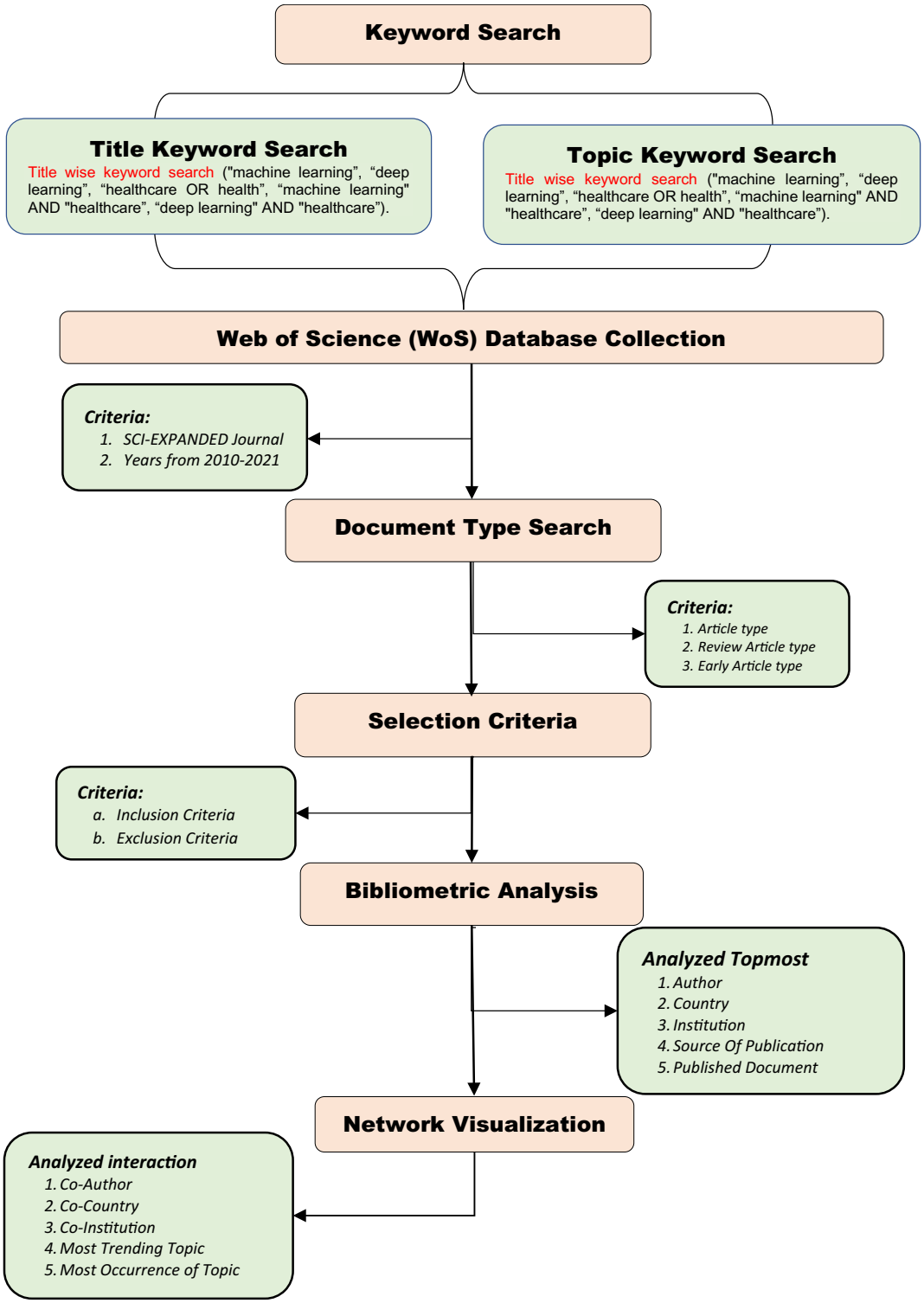

Fig. 1 Workflow diagrams

and title wise search from the Web of Science (WoS) database in machine learning and deep learning application in healthcare. The bibliometric information was searched only from Science Index-Expanded (SCI-Expanded) journal categories and retrieved complete data in plain text and BibTex data format, at global respect published

Table 1 Total bibliometric data retrieved in categories

Categories	Topic	Title
Machine learning	98,169	29,653
Deep learning	51,559	19,493
Healthcare	1,67,326	38,109
Machine Learning AND Healthcare	2014	119
Deep Learning AND Healthcare	922	58

literature during timespan 2010–2021(data accessed:31 august 2021). Then, filter the bibliometric information from Research articles, review articles, and early access articles from literature publication categories. Further, the bibliometric analysis method and network visualization methods were used to show the deep research trends and different levels of collaboration among scholars. In this context, the latest version of RStudio4.1.0 software was installed and then established the bibliometrics package [19] with R environment to perform descriptive bibliometric analysis and map the data. Then, the VOS viewer [20] open-source graphical user interface was used to demonstrate the show of different collaboration networks and bibliometric coupling based on retrieved bibliometric data.

2.2 Finding From Bibliometric Data Analysis

Table 1 shows the data retrieved from the database with searched keywords such as: *"machine learning", "deep learning", "healthcare", "machine learning" AND "healthcare", and "deep learning" AND "healthcare"* in topical and title-wise categories. This table data shows that, in both the categories such title wise and topical wise categories, the highest literature published with the keyword healthcare (1,67,326), followed by machine learning (98,169) and deep learning (51,559). Likewise, in the application field respect, machine learning techniques have largely contributed to the healthcare domain more than deep learning techniques, which is shown by the literature data.

Figure 2 represented the bibliometric information between the numbers of publications vs categories. It also shows that topic-wise literature is more than title-wise, which is shown by the blue and orange colours.

Table 2 illustrates the total literature published research documents in various types, then three types of documents i.e., research article, review, and early access article were selected in both topical and title-wise categories. In a topic-wise published scientific article, the highest numbers of published scientific articles with keywords healthcare (article:1,28,247, review:22,071, early access article:3,540),

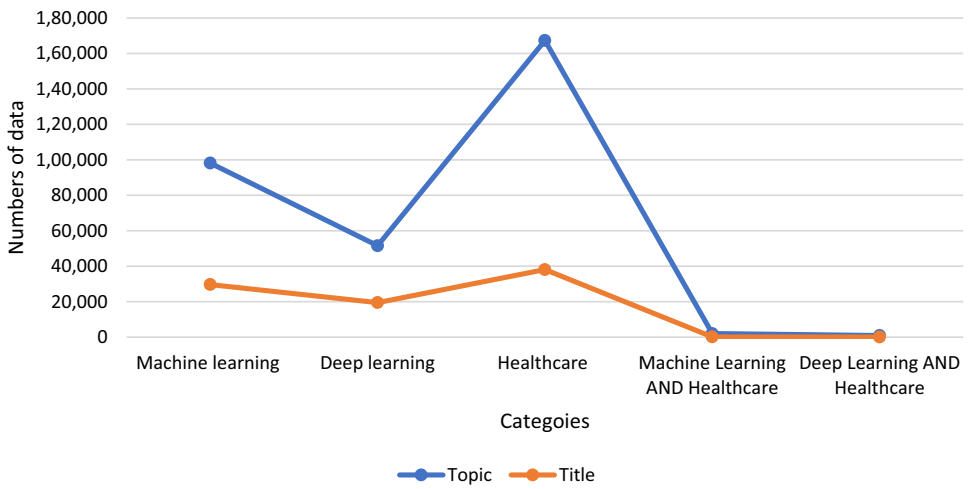

Fig. 2 Statistics Of Categories Wise Data Pattern

Table 2 Total literature publication under different categories type

categories	Topical keywords			Title keywords		
	Article	Review	Early Access	Article	Review	Early Access
Machine learning	86,292	5794	2854	22,935	1449	924
Deep learning	46,217	2412	2130	16,055	730	788
Healthcare	1,28,247	22,071	3540	21,545	2730	694
Machine learning AND healthcare	1625	316	98	74	11	10
Deep learning AND healthcare	750	149	74	42	5	9

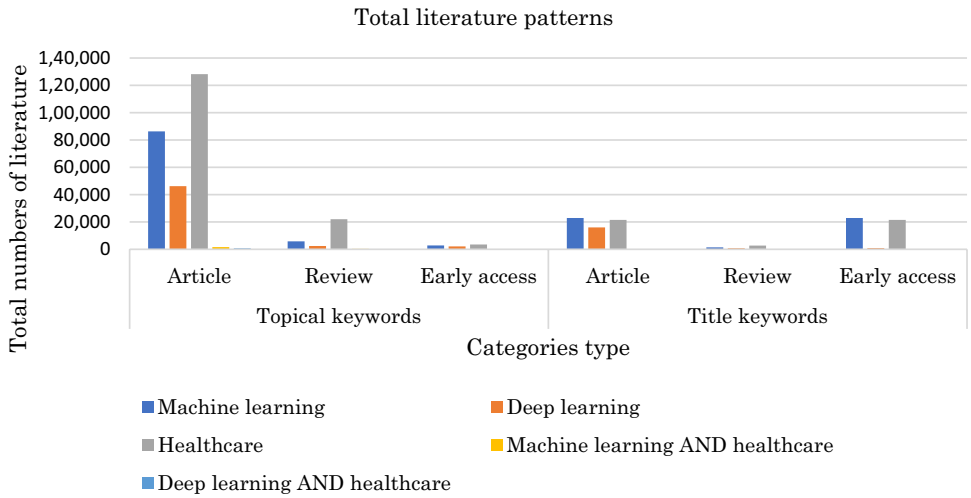

Fig. 3 Total literature publication under different categories type

followed by machine learning (articles:86,292, review:5,794, early access:2,854), deep learning (articles:46,217, review:2,412, early access:2,130), machine learning in healthcare (articles:1,625, review:316), early access:98) and deep learning in healthcare articles (750), review (149), early access (74).

Whereas, in title-wise published literature, the maximum number of research published with the keyword machine learning (article:22,935; review article:1,449; early access:22,935) followed by healthcare (articles:21,545; review article:2,730; early access:694), deep learning (articles:16,055; review article:730; early access:788), also machine learning in healthcare (articles:74; review article:11; early access:10) and deep learning in healthcare (articles:42; review article:5; early access:9). Figure 3 presents the statistical diagram, which demonstrates the published literature under different categories.

2.3 Data Searching Strategies

Then, data searching strategies were used to systematically search bibliometric information in topical and title categories. For performing these tasks single and combinational text keywords were used "machine learning"," deep learning", "healthcare", "machine learning" AND "healthcare" and "deep learning" AND "healthcare". The task was executed to gather statistical facts, research patterns, and trends regarding machine learning, healthcare, also, the uses of machine learning methods related to the healthcare domain based on bibliometric information.

Further, Inclusion parameters were set to include only peer-review literature from SCI-Extended journals available in the WoS database and described the machine learning, healthcare research area. From different categories of published articles in the WoS database, only three publication categories like research article, review article and early access article were included for this study in global respect. As ***Exclusion criteria***, Social Sciences Citation Index (SSCI) and Arts & Humanities Citation Index (A&HCI), and literature published before the year 2010 were excluded. all country-specific selections were discarded from the parameters. Furthermore, an article published in Proceedings Paper, Book Chapter, editorial material, letter, correction, re-print, etc. were excluded.

Furthermore, to understand the statistical research pattern in the application of machine learning and deep learning related to healthcare, bibliometric data were retrieved from the WoS database in a bibliography file (.bib) and plain text format (.txt). Both files included information like (i) Authors, (ii) Abstract, (iii) Addresses, (iv) ISSNs/ISBNs, (v) IDS numbers, (vi) Funding Information, (vii) PubMed IDs (viii) Titles (ix)Cited References, (x) Times Cited (xi) Cited Reference Counts, (xii) Language (xiii) Sources, (xiv) Documents Type, (xv) Keywords, (xvi) Source Abbreviations, (xvii) Author Identifiers, (xviii) Article Information, (xix) Publisher Information, (xx) Research Areas, (xxi) Usage Counts, and (xxii) Highly Cited.

2.4 Methods Used

The bibliometric analysis and Visualization method has gained immense popularity in research at present time. Because it provides the right direction to the research community, academia, and health professional based on depth knowledge of scientific publication patterns. This study included the top 20 latest publication patterns, domains, journals, authors, countries, organization research activities, and recent trending topics.

For this, the Bibliometrix R package [19] is used for mathematical and statistical calculation of publication frequency, percentage, and citations of each author, journal, country, etc. A global collaboration map and other

visualizations were done by open-source (corresponding information, author cooperation) VOS viewer [20] graphical user interface-based software, the tool was used for mapping of literature and analysis of author collaboration, country collaboration, etc. network visualization.

3 Result and Discussion

Bibliometric analysis has been conducted on the retrieved bibliometric data from all fields i.e., topic, title, abstract, affiliation, journal, etc. categorized by WoS core collection database in the research area of machine learning and deep learning application in the healthcare domain. To understand the various statistics of research trends in this research area, the latest relevant 1000 records have been selected among all available records from document-type research articles, review articles, and early access articles in SCI-Extended journals among globally available records. In this, the total number of research articles is 808, the total number of review articles is 120, and the total number of early access research articles is 45 in machine learning in healthcare, likewise, the total number of research articles is 806, the total numbers of review articles 106, and total numbers of early access research articles 71 in use of deep learning in the healthcare research field at worldwide level. At the Indian level, the total number of research articles is 213, the total number of review articles is 55, and the total number of early access research articles is 37, in the area of machine learning application in healthcare and the area of deep learning in healthcare, total numbers of research articles, total numbers of review articles and total numbers of early access articles are 157, 24, 38. Furthermore, the total number of research articles published in the field of computer science is 1057 articles, 611 articles at the worldwide level, and 137 articles, 104 articles in the research area of machine learning and deep learning in healthcare respectively.

3.1 Year-Wise Published Literature

Table 3 illustrates the year-wise scientific literature production at the worldwide level under peer-reviewed journals. So, the use of machine learning techniques in the healthcare domain has started in 2010, and the growth of implementation was very less till 2014 and after 2015 continuously increased till now. whereas the use of deep learning in the healthcare domain has started in 2015, and rapidly increased up to the highest peak in the machine learning field.

Hence, the higher scientific production rate shows the higher uses of deep learning techniques in the healthcare domain, compared to machine learning. Currently, deep learning technology is a more heavily used technology to handle more complex and unstructured data. The average year from publication is 1.5 and 1.2 around machine learning and deep learning used in the healthcare domain.

Figure 4 exhibits the year-wise publication or literature on the application of machine learning and deep learning

Table 3 Year-wise scientific literature production

Year	Machine learning in healthcare	Deep learning in healthcare
2010	1	0
2011	6	0
2012	2	0
2013	7	0
2014	6	0
2015	17	3
2016	18	4
2017	33	15
2018	99	71
2019	157	163
2020	297	302
2021	302	367

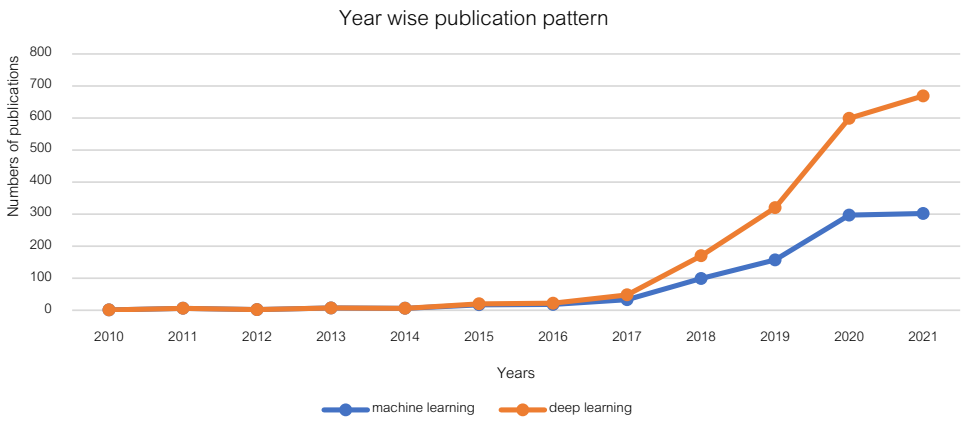

Fig. 4 Year-wise publication pattern

Table 4 Top 20 most relevant sources of publication

Machine-learning and healthcare		Deep-learning and healthcare	
Sources	Articles	Sources	Articles
IEEE Access	52	IEEE Access	78
Sensors	29	Journal of healthcare engineering	35
Journal of healthcare engineering	22	Sensors	27
Journal of biomedical informatics	20	IEEE Journal of biomedical and health informatics	22
PLOS One	20	Scientific reports	20
BMC medical informatics and decision making	19	CMC-computers materials \& continua	15
Journal of the American medical informatics association	19	Journal of biomedical informatics	15
Applied sciences-Basel	15	Multimedia tools and applications	13
International journal of environmental research and public health	14	Computer methods and programs in biomedicine	12
International journal of medical informatics	14	Magnetic resonance in medicine	12
Healthcare	13	Medical Physics	12
NPJ digital medicine	13	BMC medical informatics and decision making	11
Scientific reports	13	Electronics	10
CMC-computers materials \& continua	11	Healthcare	10
Journal of medical internet research	11	IEEE transactions on medical imaging	10
Journal of medical systems	11	NPJ digital medicine	10
JMIR medical informatics	10	Radiology	10
IEEE Journal of biomedical and health informatics	9	Applied sciences-Basel	9
Artificial intelligence in medicine	8	Artificial intelligence in medicine	9
Computers in biology and medicine	8	Computers in biology and medicine	9

in the healthcare domain. In this diagram, blue and orange colour sticks represent the area of research i.e., machine learning, and deep learning. So according to the graph, the research around machine learning application in the healthcare domain has been studied from the year 2010, so from years 2010 to 2021 the uses of machine learning techniques has continuously increased, similarly, research in the area of deep learning application in healthcare has started from 2015, so implementation of deep learning techniques in healthcare domains has rapidly increased. The diagram also reveals that deep learning techniques are highly used in healthcare to provide a better quality of medical treatment.

3.2 Top 20 Most Relevant Sources of Publication

Table 4 demonstrated the top 20 most relevant sources of publication in machine learning and deep learning application in the healthcare domain. hence top 5 journals' literature publications in IEEE Access(articles:52), Sensors (articles:29), Journal of healthcare engineering(articles:22), Journal of biomedical informatics(articles:20), PLOS One(articles:20) in machine learning application in the healthcare domain. similarly, for deep learning applications in healthcare, the topmost 5 publication sources are IEEE Access(articles:78), journal of healthcare engineering(articles:35), sensors(articles:27), IEEE Journal of biomedical and health informatics(articles:22), scientific reports(articles:20).

In both areas of research, IEEE Access and the journal of healthcare engineering produces a higher rate of literature on the application of deep learning in healthcare.

3.3 Year-Wise Production of the Source of Publication

The year-wise scientific production of the source of publication has shown in the figure. It revealed the frequency of published articles in different journals. Hence, IEEE Access journal production started slowly from 2010, and after the year 2015, it rises continuously in literature production and has maximum in the year 2020 in the application area of machine learning in healthcare. The Journal of healthcare engineering articles' production rate was slow from 2010–2017, and after 2017 its publishing rate increased and in the year 2021, it has a maximum of 10 articles. Similarly, in the present scenario total publication of the source journals are the journal of the American medical informatics(articles:5), PLOS One(articles:6), BMC medical informatics and decision making(articles:7), an international journal of medical informatics (articles:3) (fig. 5)

Figure 6 demonstrated the year-wise publication rate of journals/sources in the application of deep

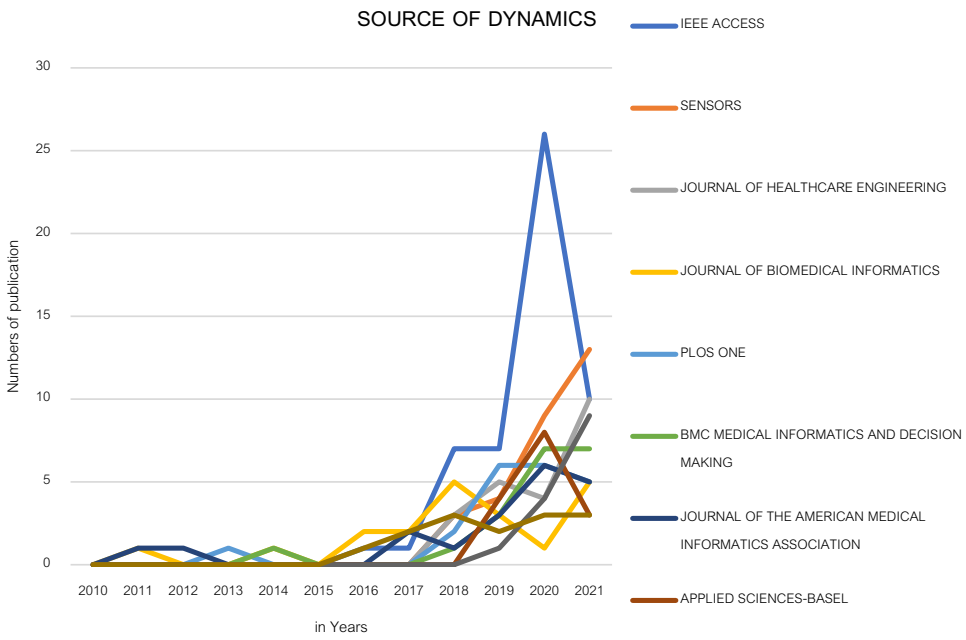

Fig. 5 Year-wise production of a source of publication in machine learning in healthcare

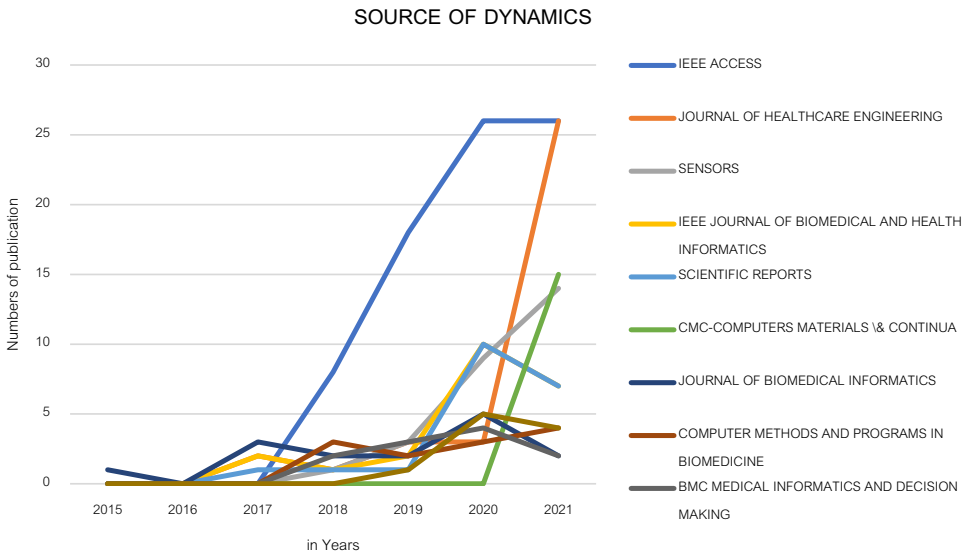

Fig. 6 Year-wise production of the source of publication in Deep learning in healthcare

learning in healthcare. The production of articles by top journals is IEEE Access(articles:26), journal of healthcare engineering(articles:26), journal of biomedical informatics(articles:2), IEEE journal of biomedical and health informatics(articles:10), scientific reports(articles:7), etc. among all top 10 journals IEEE Access production rate is sharply raised after the year 2017–2019 and maintained till the year 2021. Also, the journal of healthcare engineering started raising from the year 2017–2020 and after 2020 reached its highest peak. And rest of the journal production ranging (articles:2–15) from the year 2017–2021.

3.4 Top 20 Most Globally Cited Document

Table 5 represented the top 20 most published documents in the area of machine learning and deep learning application in healthcare. thus, the total citation and total citation per year citation of the top 5 documents in the application area of machine learning are Jiang F, 2017, Stroke Vasc Neurol (Total citation:467; TC per year:93.4), Rudin C, 2019, Nature of Mechanical Intelligence(Total citation:432; TC per year:144), Lundervold As, 2019, Journal of Medical Physics (Total citation:302; TC per year:101.6), Yu Kh, 2018, Nature of Biomedical Engineering (Total citation:268; TC per

Table 5 Top 20 most globally cited document

Paper	Total Citations	TC per Year	Normalized TC
Most cited document in machine learning in healthcare			
[21]	467	93.4	9.31
[22]	432	144	26.52
[2]	305	101.66	18.72
[23]	268	67	9.30
[24]	255	51	5.08
[25]	188	31.33	4.009
[26]	180	45	6.24
[27]	178	14.83	1
[28]	170	42.5	5.90
[29]	167	27.833	3.56
[30]	127	21.167	2.70
Trang Pham, 2017, J Biomed Inform	119	23.8	2.37
[31]	114	19	2.43
[32]	110	27.5	3.81
[33]	103	25.75	3.57
[34]	94	47	15.32
[35]	93	23.25	3.22
[36]	84	12	3.15
[37]	83	20.75	2.88
[38]	73	24.33	4.48
Most cited document in deep learning in healthcare			
[39]	862	215.5	10.26
[40]	542	135.5	6.45
[41]	481	120.25	5.73
[21]	470	94	4.69
[42]	461	153.66	19.33
[43]	433	108.25	5.15
[2]	311	103.66	13.04
[44]	311	62.2	3.10
[45]	285	71.25	3.39
[46]	231	57.75	2.75
[47]	216	72	9.05
[48]	191	47.75	2.27
[49]	165	41.25	1.96
[50]	161	32.2	1.60
[51]	149	37.25	1.77
[52]	138	23	1.78
[53]	129	32.25	1.53
[54]	126	63	13.09
Zhu J, 2018, IEEE Internet Things J	122	30.5	1.45

year:67), Chen M, 2017, IEEE Access(Total citation:255; TC per year:51). Similarly, in the area of deep learning application, the top most highly cited documents are Kermany DS, 2018, Cell (Total citation:862; TC per year:215.5), Coudray N, 2018, Nat Med (Total citation:542; TC per year:135.5), Rajkumar A, 2018, Npj Digit Med (Total citation:481; TC per year:120.25), Jiang F, 2017, Stroke Vasc Neurol (Total citation:470; TC per year:74), Esteva A, 2019, Nat Med (Total citation:461; TC per year:153.66). Apart from this, the total number of the cited document is highest Jiang F, 2017, Stroke Vasc Neurol (Total citation:467; TC per citation:101.6), while the maximum citation per year is Rudin C, 2019, Nat Mach Intell (total citation:432; TC per year:144) in machine learning in healthcare. Whereas, the maximum total citation and TC per year are Kermany DS, 2018, Cell(Total citation:862; TC per year:215.5) in the area of the deep learning application.

Table 6 Top 20 most relevant authors and their production

Machine learning in healthcare			Deep learning in healthcare		
Authors	Articles	Articles Fractionalized	Authors	Articles	Articles Fractionalized
Zhang Y	14	2.02	Li H	17	2.12
Li X	11	1.29	Li J	17	2.34
Li J	10	1.63	Wang H	14	2.81
Li Y	9	1.49	Yang J	14	2.15
Wang Z	8	1.39	Liu Y	13	2.21
Hussain A	7	1.27	Muhammad G	13	4.32
Khan A	7	1.25	Sun J	13	1.94
Wang L	7	0.9	Zhang Y	12	2.02
Chen X	6	0.95	Hossain MS	11	3.54
Chen Y	6	1.08	Li L	11	1.26
Gupta S	6	0.86	Wang Y	11	1.63
HU YH	6	1.83	Li Y	10	1.1
Lee J	6	1.97	Wang L	10	2.91
Wang W	6	0.64	Xu Y	10	1.1
Zhang J	6	1.06	Yi PH	10	2.09
Abedi V	5	0.64	Zhang H	10	1.52
Chen M	5	0.94	Zhang X	10	1.31
Chen S	5	0.81	Lee J	9	1.21
Huang Y	5	0.5	Li C	9	1.1
Kim YH	5	0.36	Li M	9	1.33

3.5 Top 20 Most Relevant Authors and their Production

The overall statistics of relevant authors state the numbers of authors significantly contributing to research areas. Thus, the total numbers of (5101/5916 authors) and (4871/6280 authors) authors are well contributing in the research field of application of machine learning and deep learning in the healthcare domain respectively. Likewise, out of the 5016 authors, single-authored documents are 16 and

multi-authored documents are 5085, as well single-authored documents are 17 and multi-authored documents are 4854 in the application of deep learning and deep learning in the healthcare domain respectively. The analysis also reveals, larger groups of authors are contributing to the implementation of machine learning techniques in healthcare and producing more articles than deep learning application research area.

Table 6 demonstrated the top author's production and its fractional, thus, the top 5 authors Zhang Y(articles:14; article fractional:2.02), Li X(articles:11; article fractional:1.29), Li J(articles:10; article fractional:1.63), Li Y(articles:9; article fractional:1.49), Wang Z(articles:8; article fractional:1.39), similarly, Li H(articles:17; article fractional:2.12), Li J(articles:17; article fractional:2.34), Wang H(articles:14; article fractional:2.81), Yang J(articles:14; article fractional:2.15), Liu Y(articles:13; article fractional:2.21) in machine learning and deep learning in healthcare.

3.6 Top 20 Most Author Production Over Time

Figure 6 shows the year-wise top authors' production in the application of machine learning in healthcare. The diagram shows Zhang J is continuously working from the years 2011 -2021 and produced several articles more in the years 2020–2021. Authors Hussain A and Gupta S were involved in this research area from 2013 to, 2015 respectively. Rest authors Zhang Y, Li Y, Li X, Li J, Wang L, Chen Y, Hu YH, Chen M, etc. been involved in this area from the year 2015 and produced articles after the year 2020 on towards (Fig. 7)

Figure 8 shows the year-wise top authors' production in the application of deep learning in healthcare. Deep learning techniques mostly came in research scenarios after the year 2015 and uses of its technique in healthcare mostly appeared after 2017.

The diagram shows Zhang J is continuously working from the years 2011 -2021 and produced several articles more in the years 2020–2021. Authors Hussain A and Gupta S were involved in this research area from 2013 to, 2015 respectively. Rest authors Zhang Y, Li Y, Li X, Li J, Wang L, Chen Y, Hu YH, Chen M, etc. been involved in this area from the year 2015 and produced articles after the year 2020 on towards.

Li H, Wang H, Zhang Y, Li L, Wang Y, and Lee J has started contributing to research from the years 2017–2021.

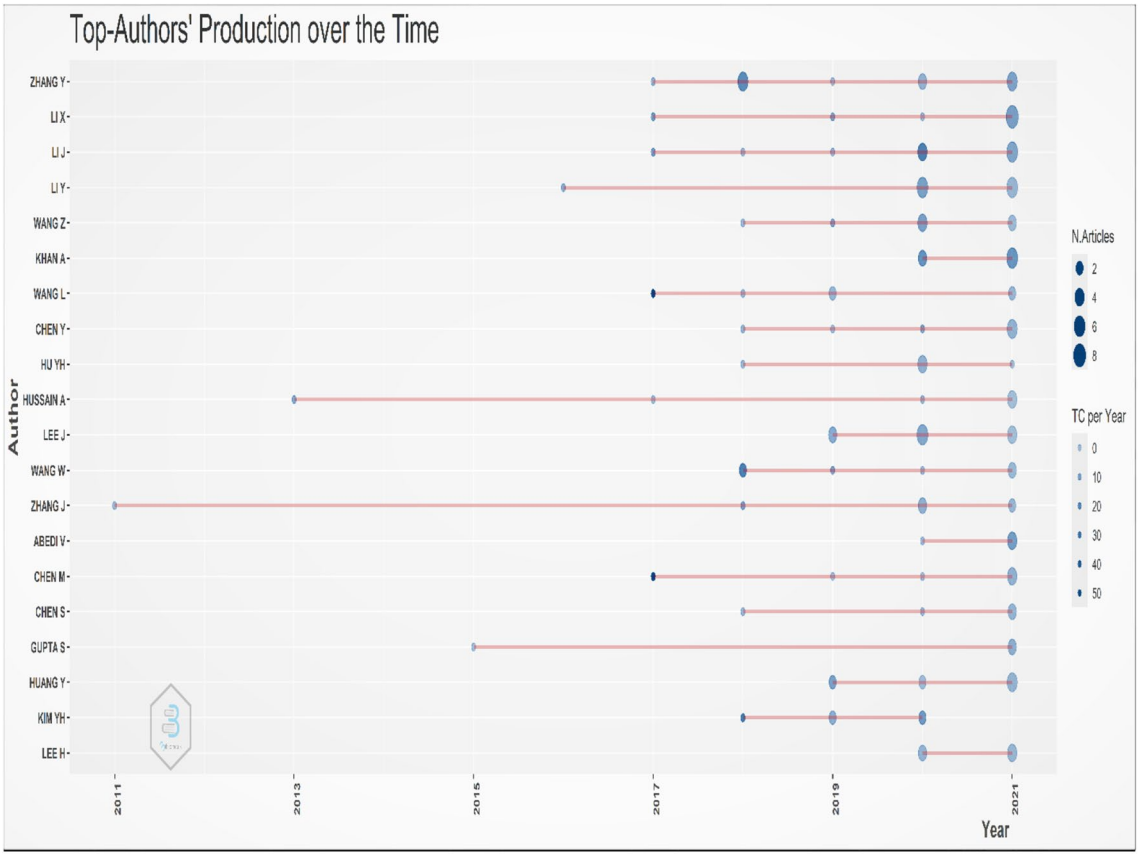

Fig. 7 Top author production over time in machine learning in healthcare

Fig. 8 Top author production over time in deep learning in healthcare

Table 7 Top 20 most country production

Machine learning in healthcare		Deep learning in healthcare	
Region	Freq	Region	Freq
USA	2043	USA	1327
China	589	China	1103
UK	375	South Korea	398
South Korea	274	India	330
Canada	264	UK	329
India	231	Germany	214
Germany	168	Saudi Arabia	203
Spain	140	Italy	136
Italy	136	Pakistan	116
Saudi Arabia	129	Spain	105
Pakistan	104	Netherlands	103
Netherlands	102	Singapore	103
Australia	96	Canada	99
Japan	95	France	99
Brazil	67	Australia	95
France	58	Egypt	82
Singapore	53	Switzerland	80
Switzerland	51	Japan	78
Iran	48	Malaysia	64
Sweden	42	Israel	51

After the year 2018 Li J, Yang J, Liu Y, Muhammad G, Sun J, Hossain MS, Wang L, Xu Y, Zhang H, etc. started the application of deep learning in the area of the healthcare domain.

3.7 Top 20 Most Country Production

Table 7 presented the topmost country production, countries USA and China are heavily contributing to machine learning and deep learning application field research. In the USA the highest number of published articles is 2043 in the machine learning application field, while China is the maximum publication of 1103 articles in deep learning application research in the healthcare domain. Indian research heavily contributes to deep learning application(articles:330) implementation than machine learning(articles:231). The top 5 most country having maximum publications are the USA (Articles:2043), China (articles:589), the UK (articles:375), South Korea (articles:274), Canada(articles:264) and the USA (Articles:1327), China (articles:1103), South Korea(articles:389), India(articles:330), UK (articles:329) in machine learning and deep learning application in healthcare research respectively.

Table 8 Top 20 most cited country

Machine learning in healthcare			Deep learning in healthcare		
Country	Total Citations	Average Article Citations	Country	Total Citations	Average Article Citations
USA	5072	14.7	USA	5625	26.41
China	1434	14.2	China	2686	13.57
United Kingdom	847	12.28	United Kingdom	1176	19.93
India	434	7.23	Korea	904	12.05
Norway	316	63.2	Saudi Arabia	601	13.07
Australia	286	15.05	Singapore	441	27.56
Canada	286	6.98	Australia	414	19.71
Germany	235	9.04	Switzerland	357	39.67
Korea	233	4.48	India	354	4.27
Italy	227	9.08	Norway	319	79.75
Saudi Arabia	226	8.69	Spain	286	14.3
Netherlands	141	10.85	Canada	260	16.25
Pakistan	140	8.75	Turkey	227	22.7
Spain	121	4.84	Netherlands	213	15.21
Greece	104	17.33	Italy	198	7.92
Japan	104	6.93	Germany	180	5.62
Malaysia	99	9	Austria	165	82.5
New Zealand	91	15.17	Pakistan	165	8.68
Egypt	79	13.17	France	123	9.46
Finland	77	15.4	Belgium	77	15.4

Table 9 Top 20 most affiliation production

Machine learning		Deep learning	
Affiliations	Articles	Affiliations	Articles
Icahn Sch Med Mt Sinai	100	Stanford Univ	109
Harvard Med Sch	78	King Saud Univ	89
Stanford Univ	68	Johns Hopkins Univ	84
Univ Toronto	46	Imperial Coll London	47
Penn State Univ	34	Fudan Univ	40
Univ Calif San Diego	34	Taipei Med Univ	38
Univ Michigan	34	Natl Univ Singapore	36
Washington Univ	32	Yonsei Univ	36
Seoul Natl Univ	30	Univ Calif San Diego	35
Univ Calif San Francisco	30	Korea Adv Inst Sci and Technol	32
Univ Oxford	30	Seoul Natl Univ	32
Univ Pittsburgh	29	Icahn Sch Med Mt Sinai	31
Vanderbilt Univ	29	Harvard Med Sch	30
King Saud Univ	28	Emory Univ	28
Columbia Univ	27	Univ Ulsan	28
Taipei Med Univ	27	Tech Univ Munich	25
Cincinnati Children's Hosp Med Ctr	26	Zhejiang Univ	24
Univ Penn	26	Nanjing Univ	23
Boston Univ	25	Sichuan Univ	23
Imperial Coll London	25	Univ Malaya	23

3.8 Top 20 Most Cited Country

The table demonstrates the top 20 most cited countries in the field of usages of machine learning and deep learning technique in the healthcare domain. And the citation of the country states the contribution to significant quality of research. hence, the top 5 country citation in the field of machine learning uses in the healthcare domain are the USA (citation:5072), China (citation:1434), United Kingdom (citation:847), India (citation:434), Norway (citation:316) and likewise in the field of deep learning uses in healthcare domain are USA (citation:5,625), China (citation:2,686), United Kingdom (citation:1,176), Korea (citation:904), Saudi Arabia (citation:601).

So, also tables indicate that countries the USA, China, and the UK contribute much to the application of machine learning and deep learning techniques in healthcare fields. But this three-country contribute the highest area of deep learning implementation in healthcare (Table 8).

3.9 Top 20 Most Affiliation Production

Here, Table 9 Shows the worldwide topmost 20 institutes, which have contributed more to research and published the highest article. Among all most 5 affiliations are Icahn School of Medicine at Mount Sinai, New York (articles:100), Harvard Medical School, Massachusetts (articles:78), Stanford University, California (articles:68), University of Toronto, Canada (articles:46), Pennsylvania State University (articles:34) and Stanford University, California (articles:109), King Saud University, Saudi Arabia (articles:89), Johns Hopkins University, Maryland (articles:84), Imperial College London, London (articles:47), Fudan University, Shanghai, China (articles:40) in uses of machine learning and deep learning technique in healthcare. Among all the top 20 affiliations, the highest articles produced by Stanford University, California in deep learning applications in healthcare also reveal the larger research in this research field.

3.10 Network Visualization

For visualization and network analysis of existing bibliometric information in the research area of machine learning, deep learning and healthcare VOS viewer software were used. This tool is applied for creating and representing a bibliometric science map of the author's collaboration, country collaboration, institute collaboration, citation analysis, co-citation analysis, bibliographic coupling, co-word analysis, and co-authorship analysis as well as an article published by corresponding countries, etc. science map analysis pertains to the intellectual interaction and structural connection among research constituents [20]. Furthermore, text mining can be performed to construct and visualize co-occurrence networks of the most significant term extracted from the scientific literature by VOS viewer software.

Table10 Top 20 most corresponding authors' countries in the application of machine learning and deep learning in the healthcare domain

Country	Articles	Freq	SCP	MCP	MCP_Ratio
Machine learning					
USA	345	0.34535	263	82	0.238
China	101	0.1011	70	31	0.307
United Kingdom	69	0.06907	40	29	0.42
India	60	0.06006	50	10	0.167
Korea	52	0.05205	38	14	0.269
Canada	41	0.04104	29	12	0.293
Germany	26	0.02603	14	12	0.462
Saudi Arabia	26	0.02603	11	15	0.577
Italy	25	0.02503	16	9	0.36
Spain	25	0.02503	17	8	0.32
Australia	19	0.01902	13	6	0.316
Pakistan	16	0.01602	1	15	0.938
Japan	15	0.01502	10	5	0.333
Netherlands	13	0.01301	10	3	0.231
Brazil	11	0.01101	5	6	0.545
Malaysia	11	0.01101	1	10	0.909
Singapore	11	0.01101	4	7	0.636
France	9	0.00901	4	5	0.556
Iran	8	0.00801	5	3	0.375
Mexico	8	0.00801	5	3	0.375
Deep learning					
China	365	0.36537	255	110	0.3014
USA	168	0.16817	120	48	0.2857
Korea	89	0.08909	68	21	0.236
India	42	0.04204	36	6	0.1429
United Kingdom	38	0.03804	21	17	0.4474
Japan	26	0.02603	23	3	0.1154
Australia	24	0.02402	15	9	0.375
Canada	21	0.02102	9	12	0.5714
Turkey	18	0.01802	17	1	0.0556
Netherlands	17	0.01702	11	6	0.3529
Spain	17	0.01702	11	6	0.3529
Germany	15	0.01502	10	5	0.3333
France	13	0.01301	9	4	0.3077
Saudi Arabia	13	0.01301	9	4	0.3077
Singapore	13	0.01301	7	6	0.4615
Italy	11	0.01101	7	4	0.3636
Greece	8	0.00801	6	2	0.25
Pakistan	8	0.00801	2	6	0.75
Switzerland	7	0.00701	3	4	0.5714
Brazil	5	0.00501	5	0	0

SCP Single country publications, *MCP* Multiple country publications

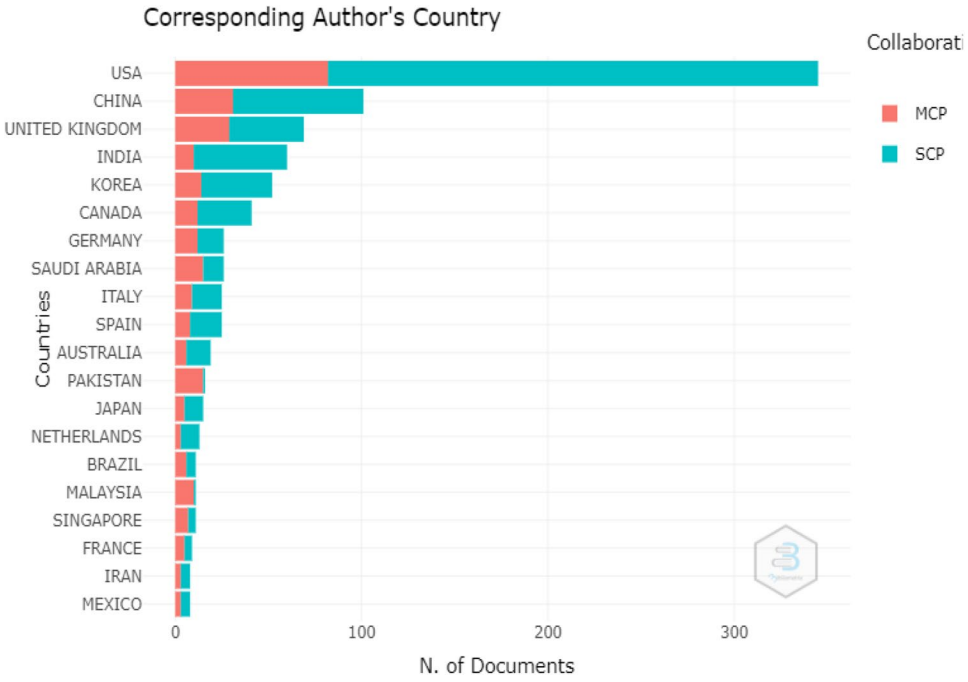

Fig. 9 Top 20 most Corresponding author's country in the application of machine learning in the healthcare domain

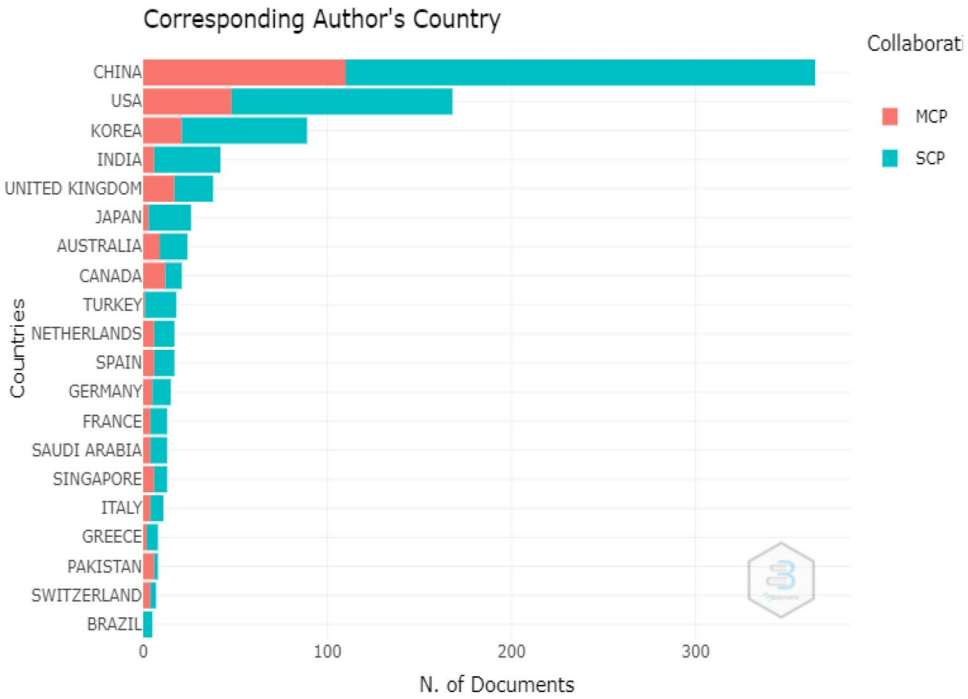

Fig. 10 Top 20 most Corresponding author's country in the application of deep learning in the healthcare domain

Out of all bibliometric literature data downloaded from the WoS database in the research area of machine learning, deep learning, and healthcare, only 1000 literature records were selected for analyzing and visualization of the network from applying machine learning and deep learning in healthcare query keywords, that were extracted, and bibliometric analysis presented in this study. Article from this database was collected because this database contains only peer-reviewed articles [55].

3.11 Most Relevant Countries by Corresponding Author

Table 10**,** Fig. 9 and Fig. 10 represent the top 20 countries by corresponding author's articles production. The top 5 countries USA, China, United Kingdom, India, and Korea have produced maximum and greatly contributed to the research area of the application of machine learning and deep learning technique in the advancement of the healthcare field.

Thus, the total number of published articles is USA (345articles), China(101articles), United Kingdom (69 articles), India (60 articles), and Korea (52articles) and China (365 articles), USA (168 articles), Korea (68 articles), India (42 articles), United Kingdom (38 articles) in the application of machine learning and deep learning research fields.

Among all enlisted top 20 countries, the USA has significantly contributed with (263/345 articles) of SCP and (82/345 articles) of MCP, China with (70/101 articles) of SCP and (31/101 articles) of MCP, United Kingdom with (40/69 articles) of SCP and (29/69 articles) MCP, India with (50/60 articles) SCP and (10/60 articles) MCP, Korea with (38/52articles) SCP and (14/52articles) MCP. Similarly, China with (255/365 articles) in SCP and (110/365 articles) in MCP, USA has significantly contributed with (120/168 articles) in SCP and (48/168 articles) in MCP, Korea with (68/89articles) in SCP and (21/89 articles) MCP, India with (36/42 articles) SCP and (6/42 articles) MCP, United Kingdom with (21/38 articles) SCP and (17/38 articles) MCP. Overall, the USA, China, United Kingdom, Korea, and India have done huge research in this area and published maximum numbers of SCP, which shows that these countries have greatly contributed to the application area of machine learning in healthcare. While more numbers of MCP show worthy research collaboration with other countries.

3.12 Co-Authorship and Collaboration Analysis

Co-authorship collaboration analysis is a formal way of interaction among scholars. It is a most decent way to know, how scholars interact among themselves, including affiliation and countries associated with authors. Due to improving methodological and theoretical complexity in research, collaborations among scholars have become common, and collaborations among scholars contribute to showing greater clarity and richer insights between different scholars.

In Fig. 11, for building the co-authorship collaboration network between the authors the minimum number of documents of an author is 4 and the minimum number of citations of an author is 5, and out of 5528 authors, 17 meet the thresholds parameter were set. Then, a total of 17 authors were selected and associated in two clusters 1 and cluster 2. In this network, cluster1 represented in red colour has 3 group authors (de cecco, carlo n), (tesche, christian), (schoef, joseph) and green colour having 2 group authors (kim, young-hak), (lee, June-go). Among both cluster1 and cluster2, 4 group authors (tesche, christian), (schoepf, u. joseph), (de cecco, carlo n.) and (kim, young-hak) have equal numbers of link strength, and authors (lee, June-goo) have only one link connection in machine learning application areas.

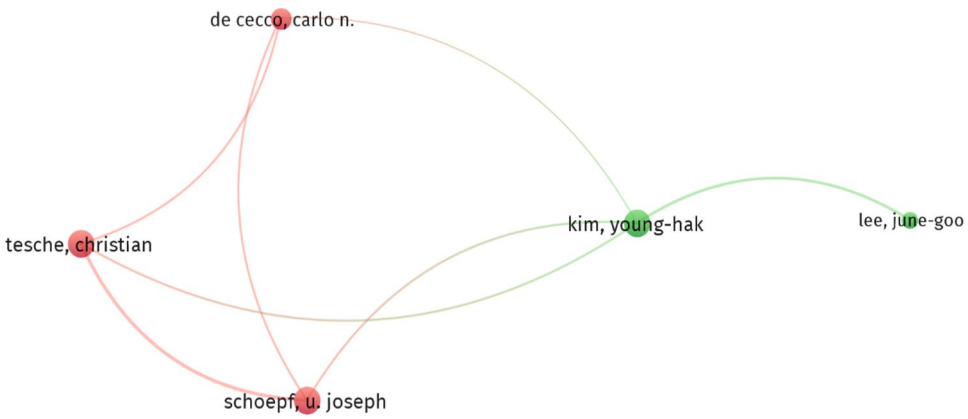

Fig. 11 Co-authorship visualization in machine learning application in healthcare

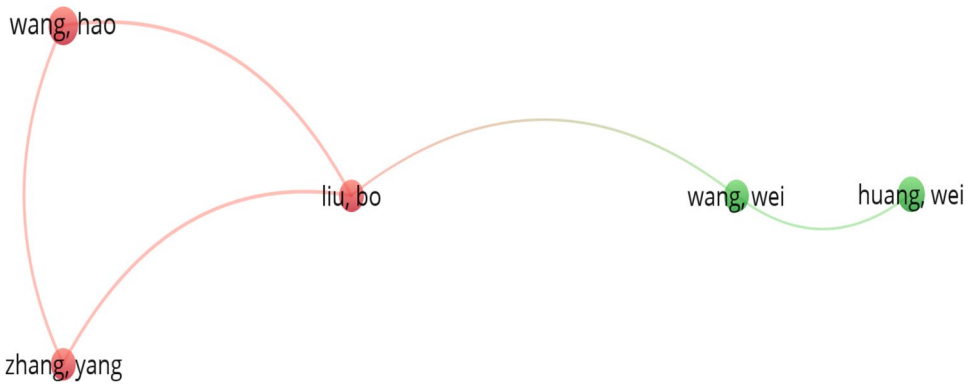

Fig. 12 Co-authorship visualization in deep learning application in healthcare

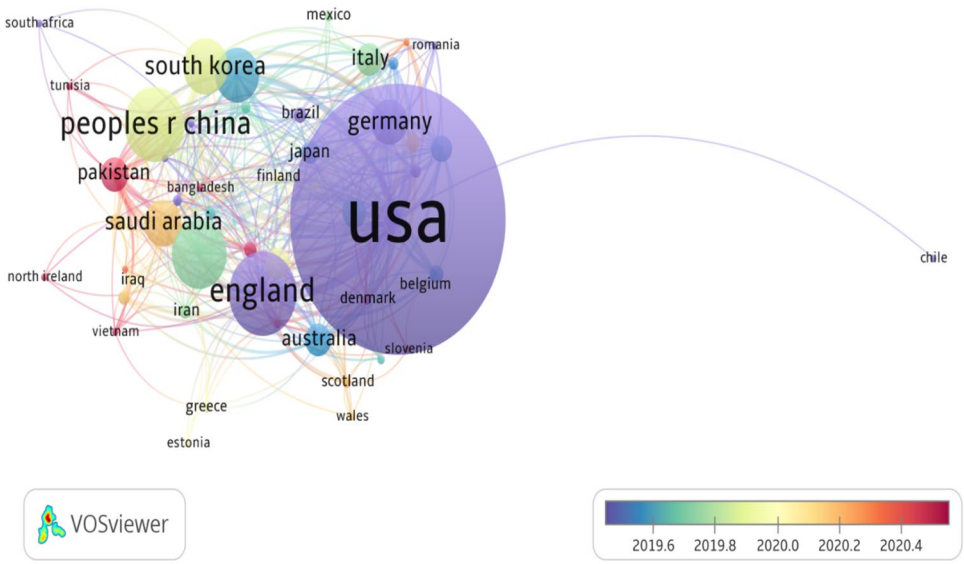

Fig. 13 Co-authors-Country collaboration visualization in machine learning application

While, in Fig. 12**,** in deep learning application areas the most productive author was selected to meet threshold 8, out of 4220 authors, and it was associated with two clusters cluster1 and cluster2. In cluster1, the group authors are (Wang, Hao), (Zang, Yang), (Liu, Bo) and in cluster2 group, the authors are (Wang, Wei), (Huang, Wei). In this network, cluster1 is bigger than cluster2.

3.13 Co-Authors-Country Collaboration Visualization

Figure 13 **and** Table 11 exhibited, the co-authors-country collaboration in the field of application of machines in the healthcare domain. For building the collaboration network, the parameter such as the minimum number of documents of a country 3 and the minimum number of citations of a country 5, and out of 85 countries, 51 meet the thresholds were taken. Based on the parameter 52 countries were selected and different colour size bubbles and link strength thickness of line, which shows the association among the co-authors-country interaction. Further, a total of 51 selected countries were associated in 7 clusters with 51 items.

Table 11 enlisted the top 20 countries having the highest number of published articles. Out of the 20 most countries, the top 5 countries, USA, England, peoples from China, India, and South Korea have a total of 410, 110, 97, 87, 69 articles, followed by a total citation of 6093, 1287, 1474, 686, 531 respectively. In this, the highest numbers of publications, citations and more numbers of strength shown by the USA, England, people from China, India, and South Korea have significantly contributed and a larger group of collaboration in this research field.

The Network (Fig. 14) has generated the minimum number of documents for country 5, and the minimum number of citations for country 10, to meet threshold 36. Out of the 77 countries, which meet the set-up parameter and most top 20 countries listed in Table 11 have the highest collaboration with each other. The maximum collaboration shown by countries are People from China (Article:358; Citation: 10,962), the USA (Article:249; Citation:11,291), South Korea (Article: 101; Citation: 2664), England (Article:66; Citation: 4015), India (Article:50; Citation: 579), Australia (Article:49; Citation: 2074), Canada (Article:43; Citation: 1937), have maximum numbers of collaboration with others countries and contributing most in deep learning application in the healthcare research area.

3.14 Co-Authors-Institute Collaboration Visualization

Table 12 **and** Fig. 15, show the top 20 most institute affiliation collaborations with the highest numbers of documents, citations, and total link strength.

For creating institute network collaboration, the minimum number of documents of an organization of 5, the minimum number of citations of an organization, and meet the threshold of 105 were set. Out of 1887 organizations, 105 institutes were selected. Therefore, the top 5 organizations, Harvard Medical School, Stanford University, Icahn School of Medicine at Mount Sinai, MIT, and King Saud University have the highest numbers of publications 42, 24, 19, 18, and 16 respectively. Although, the top 5 organizations Harvard Medical School, Stanford University, University of Oxford, University of Pennsylvania, and University Calif

Table 11 Co-authors-Country collaboration visualization

Machine learning			
Country	Documents	Citations	Total Link Strength
USA	421	6093	265
England	110	1287	129
Peoples r China	97	1474	80
India	87	686	79
South Korea	69	531	74
Canada	67	510	66
Saudi Arabia	56	471	74
Germany	55	682	94
Pakistan	41	233	90
Australia	39	456	60
Italy	39	385	46
Taiwan	37	257	45
Spain	35	287	29
Netherlands	31	392	50
Japan	24	294	36
France	19	178	22
Switzerland	18	117	42
Brazil	17	135	24
Malaysia	16	148	32
Singapore	16	33	31
Deep learning			
Peoples r China	398	10,962	183
USA	249	11,291	168
England	66	4015	67
Australia	49	2074	51
Canada	43	1937	51
South Korea	101	2664	42
Germany	29	1334	34
Singapore	25	3060	31
Saudi Arabia	31	381	30
France	22	589	26
Taiwan	29	191	25
India	50	579	24
Pakistan	17	186	24
Italy	18	329	21
Netherlands	23	4265	21
Spain	26	1342	20
Switzerland	13	739	20
Japan	32	691	17
Denmark	6	149	16
Portugal	9	58	16

San Francisco have maximum citations 800, 573, 422, 371, 353, followed by link strengths 63, 27, 34, 23, 25 respectively. The more numbers of citations of organizations show the quality of research publication and the numbers of link strength show the numbers of collaboration. Therefore, selected organization publications and citations show that Harvard Medical School and Stanford University contribute to the better quality of research in the field of application of machine learning in the healthcare domain.

In Fig. 16, out of 1374 countries, the top 70 countries were selected to meet threshold 70 and countries having a minimum number of documents of an institute 5, minimum number of citations of an institute 10. Listed 20 countries, most published article and significant of research, top 5 countries Chinese Academy of Science, China (article:31; citation:896), Tsinghua University (article:18; citation:901), University Chinese Academy of Science (article:18; citation:539), Tsinghua University (article:18; citation:901), Stanford University (article:15; citation:546), National University of Defense Technology (article:14; citation: 1219), Harbin Institute of Technology (article:10; citation: 1607) in area of deep learning application in the healthcare domain.

3.15 Occurrence of top 20 Most Author's Keywords and Keyword plus

Table 13**,** Fig. 17**, and** Fig. 18 demonstrated the top 20 most occurrences of the author's keywords and Keyword plus in the area application area of machine learning uses in the healthcare domain. For generating the network map, the parameter was used as the minimum number of occurrences of keyword 10 for all relevant keywords, and the threshold meets 38. Out of 2603 authors' keywords, the most occurrence of 38 keywords was selected. Then, the top 10 most relevant author's keywords in this field are "machine learning (Occurrence:650)"," artificial intelligence (Occurrence:99)"," healthcare (Occurrence:81)"," deep learning (Occurrence:63)"," big data (Occurrence:38)"," classification (Occurrence:38)"," covid-19(Occurrence:34)"," internet of things (Occurrence:34)"," natural language processing (Occurrence:34)"," prediction (Occurrence:33)". Among all 10 author's keywords "machine learning (link Strength:614)"," artificial intelligence (link Strength:157)"," healthcare (link Strength:150)"," deep learning (link Strength:115)". Authors, enlisted keywords show that machine learning is the most popular word, which is applied in several fields. Likewise, for building a network map of the total numbers of authors' keywords with higher numbers of occurrence frequency in deep learning applications in the healthcare domain, the threshold parameter 10, out of 2491 authors' keywords was set. Then, the top 10 highest generated authors' keywords are "deep learning (link Strength:762)", "machine learning (link Strength:198)", "artificial intelligence (link Strength:123)", "neural network (link Strength:98)", "training (link Strength:75)", "convolutional neural network (link Strength:74)", "classification (link Strength:67)", "feature extraction (link Strength:62)",

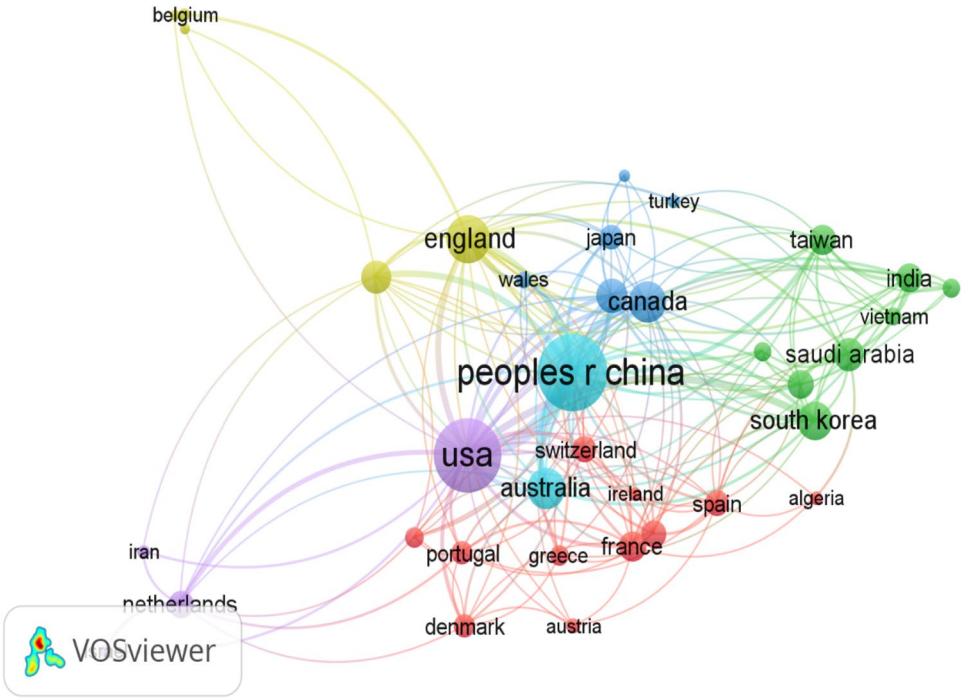

Fig. 14 Co-authors-Country collaboration visualization in deep learning application

"segmentation (link Strength:53)", "Big Data (link Strength:45)".

As well, Table 13**,** Fig. 19**, and** Fig. 20 revealed the top 20 most occurrences of the most relevant Keywords plus which are popular in machine learning uses in the healthcare domain. For generating the network map, out of 2063 keywords plus, only 63 keywords were selected, onset parameter such as a minimum number of occurrences of keyword 10 for all relevant keywords plus, and the threshold meet 63. Further, among 63 selected keywords, the 10 most popular keywords in this field are "classification (Occurrence:113)"," Prediction (Occurrence:82)"," Risk (Occurrence:58)"," diagnosis (Occurrence:57)"," model (Occurrence:54)"," validation (Occurrence:50)"," Mortality (Occurrence:46)"," Models (Occurrence:42)"," System (Occurrence:42)"," bigdata (Occurrence:40)". Among all author's keywords topmost popular keywords are "classification (link Strength:293)"," Prediction (link Strength:181)"," Risk (link Strength:112)"," diagnosis (link Strength:122)"," model (link Strength:126)"," validation (link Strength:126)"," Mortality (link Strength:105)". Authors, enlisted keywords show the highest link strength with other relevant words, which is about other fields.

Also, the selected total keywords plus, on the minimum number of occurrence frequency 10, meet thresholds 42, out of 1610 keywords were set up. Out of all generated 1610 keywords plus, the top 10 highest link strength keywords are" classification (link Strength:271)"," Model (link Strength:177)"," neural network (link Strength:176)"," segmentation (link Strength:150)"," algorithm (link Strength:123)"," prediction (link Strength:102)"," images (link Strength:95)"," recognition (link Strength:92)"," convolutional neural network (link Strength:81)"," features (link Strength:73)"," Diagnosis (link Strength:71)" (Figs. 21, 22, 23, 24)

3.16 Year-Wise Identification of the top 20 most Trending Author's KEYWORDS and Keywords in Machine Learning and Deep Learning uses in Healthcare.

The below table shows the top trending author's keywords and keywords plus keywords used in machine learning and deep learning application in the healthcare domain.

Table 14 represented the top 20 authors' keywords with years of frequency of machine learning techniques applied in the healthcare domain are "machine learning (freq.:617)","artificial intelligence (freq.:93)", "healthcare (freq.:91)", "deep learning (freq.:61)","prediction (freq.:43)" etc. likewise most trending authors keywords of deep learning techniques applying in healthcare domain are "deep learning (freq.:994)","machine learning (freq.:103)", "artificial intelligence (freq.:65)","neural network (freq.:49)"," Convolutional Neural Network (freq.:43)" etc. it also demonstrated the yearly most popular authors keyword are machine learning, artificial intelligence, healthcare, prediction model, data analytics, medical services, deep learning, diagnosis, Convolutional Neural Network, biomedical images, etc. in the application of machine learning and deep learning in healthcare fields during the year 2019–2021.

Table 12 Co-authors-Institute collaboration visualization

Machine Learning			
Organization	Documents	Citations	Total Link Strength
Harvard Med School	42	800	63
Stanford University	24	573	27
Icahn School of Medicine at Mount Sinai	19	262	13
MIT	18	263	28
King Saudi University	16	224	4
University of Oxford	16	422	34
University of California San Francisco	15	353	25
University of Toronto	15	50	4
Brigham & Women's Hospital	14	142	22
Columbia University	13	56	20
Massachusetts Gen Hosp	13	214	20
University of Pennsylvania	13	371	23
Imperial College of London	12	96	11
Pennsylvania State University	12	169	1
University of California San Diego	12	169	15
University of Washington	12	222	14
Emory University	11	237	17
Kings College of London	11	174	10
University of California Los Angeles	11	53	9
Boston Children's Hospital	10	339	18
Deep Learning			
Chinese Academy of Science	31	896	32
University Chinese Academy of Science	18	539	23
University of Electrical Science & Technology	10	588	13
National University of Defense Technology	14	1219	12
North-eastern University	9	329	12
Peng Cheng Laboratory	6	56	9
Tsinghua University	18	901	9
Harbin Institute of Technology	10	1607	8
Nanyang Technology University	11	2140	8
Chinese University Hong Kong	8	472	7
Guangdong University Technology	6	59	7
Tianjin University	9	234	7
UCL	11	491	7
Xidian University	5	113	7
Beihang University	10	168	6
Huazhong University of Science & Technology	11	99	6
Hunan University	6	466	6
Peking University	9	147	6
Stanford University	15	546	6
China Medical University	5	18	5

Table 15 exhibited yearly published numbers of the frequency with the popular keywords plus in the research area of machine learning and deep learning techniques applied healthcare domain. table enlisted the total numbers of an article with keywords plus classification(freq.:133), prediction (freq.:86), Risk (freq.:62), diagnosis (freq.:57), model (freq.:56), regression (freq.:26), segmentation (freq.:18) etc. and neural network(freq.:138), classification(freq.:123),

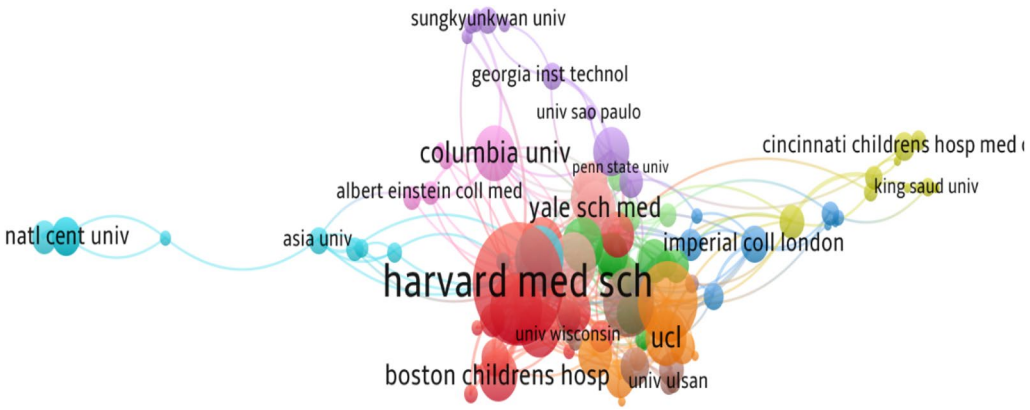

Fig. 15 Co-authors-Institute collaboration visualization in machine learning

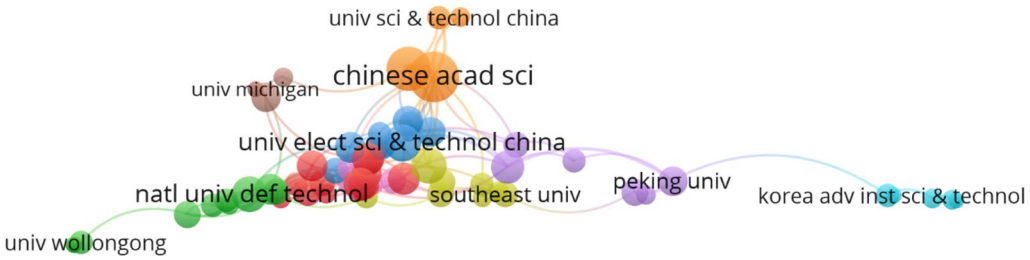

Fig. 16 Co-authors-Institute collaboration visualization in deep learning application

model (freq.:78), algorithms (freq.:59), prediction(freq.:54), segmentation(freq.:50) etc. in area of Machine learning and deep learning in the healthcare domain.

These tables also demonstrate the year-wise highly popular keywords plus are classification, prediction, diagnosis, model, segmentation, classifier, data analytics, network, convolutional neural network, architecture, etc. in both the area of machine learning and deep learning applied in the healthcare field during the year 2018–2021. Among all listed keywords in Table15 classification, segmentation, classifier, network, model, and regression, the convolutional neural network is heavily used in the application filed research areas.

4 Summary

As emerging techniques, Machine Learning (ML) and Deep Learning (DL) have shown incredible potential in tackling challenging problems in several fields. This study has focused on those problems in healthcare that have been addressed using machine learning (ML) and deep learning (DL) with promising results globally. Both techniques have been shown as powerful tools in dealing with disease detection in preprocessing, feature extraction, feature selection, classification, and clustering steps. All literature was published on machine learning (ML) and deep learning (DL) in the Healthcare sector, as well as the application of machine learning (ML) and deep learning (DL) related to the healthcare domain.

This study has established the bibliometric analysis technique in the research area of machine learning, deep learning, and the healthcare field. And it revealed the worldwide research trends and performance analysis of the subject area. Up to now, there is a substantial gap in current research about the bibliometric analysis of Machine Learning (ML), Deep Learning (DL), and the Healthcare field. In this study, selected topical, title, and all fields' keywords were used to extract the most relevant research paper from the Web of Science (WoS) core collection database, which included Science Citation Index Expanded (SCI) papers and articles, review article, early access document type paper from the period from 2010–30 June 2021.

Globally, in machine learning, deep learning, and healthcare, a total of 98,169, 51,559 and 1,67,326 articles with topical keywords search and 29,653, 19,493, and 38,109 articles with title-wise keywords search bibliometric information data were downloaded from the WoS database during 2010–2021(accessed 31 august 2021) respectively. Similarly, A total of 5,065, 2,755, and 4,588 articles from topic-wise

Table 13 Occurrence of top 20 most author's keywords and Keyword plus

Machine learning					
Author's Keywords			Keyword plus		
Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
Machine Learning	650	614	Classification	133	293
Artificial Intelligence	99	157	Prediction	82	181
Healthcare	81	150	Risk	58	112
Deep Learning	63	115	Diagnosis	57	122
Big Data	38	63	Model	54	126
Classification	38	61	Validation	50	126
Covid-19	34	65	Mortality	46	105
Internet Of Things	34	79	Models	42	75
Natural Language Processing	34	54	System	42	96
Prediction	33	49	Big Data	40	97
Electronic Health Records	24	30	Outcomes	38	109
Feature Selection	20	34	Internet	32	63
Random Forest	20	27	Management	32	67
Data Mining	19	31	Care	31	74
Feature Extraction	17	38	Disease	28	51
Medical Services	14	51	Healthcare	27	73
Predictive Models	14	39	Impact	27	58
Support Vector Machine	14	21	Regression	26	57
Electronic Health Record	13	26	Artificial-Intelligence	25	64
Predictive Analytics	13	18	Cancer	25	76
Deep learning					
Deep Learning	944	762	Neural-Networks	138	176
Machine Learning	103	198	Classification	123	271
Artificial Intelligence	65	123	Model	78	177
Neural Networks	48	89	Algorithm	59	123
Convolutional Neural Network	43	64	Prediction	54	120
Convolutional Neural Networks	40	74	Segmentation	50	150
Classification	34	67	Convolutional Neural-Networks	43	102
Neural Network	33	63	Networks	43	31
Feature Extraction	29	62	Neural-Network	42	62
Training	29	75	Recognition	38	92
CNN	28	47	Images	37	95
Segmentation	27	53	Convolutional Neural-Network	33	81
LSTM	21	41	Framework	32	73
Computer Vision	20	37	Network	31	42
Big Data	19	45	Diagnosis	27	68
Survey	17	36	Features	27	71
Bioinformatics	16	33	System	27	46
Medical Imaging	15	32	Models	26	28
Image Recognition	14	22	Cancer	24	55
Object Detection	14	26	Reconstruction	24	45
Sentiment Analysis	14	32	Performance	20	49

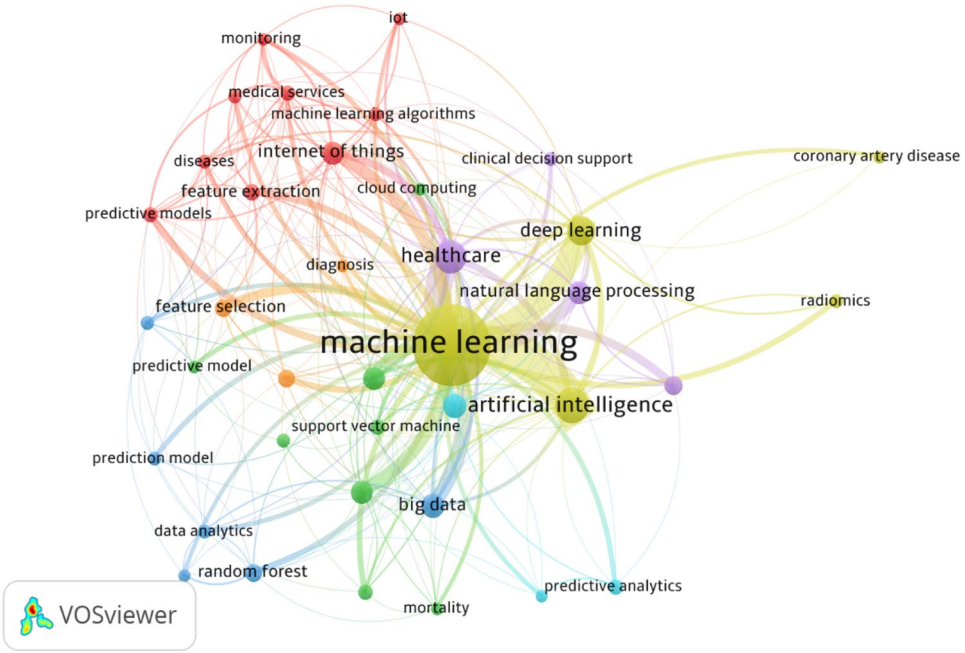

Fig. 17 Network visualization of occurrence of top 20 most authors' keywords in machine learning application

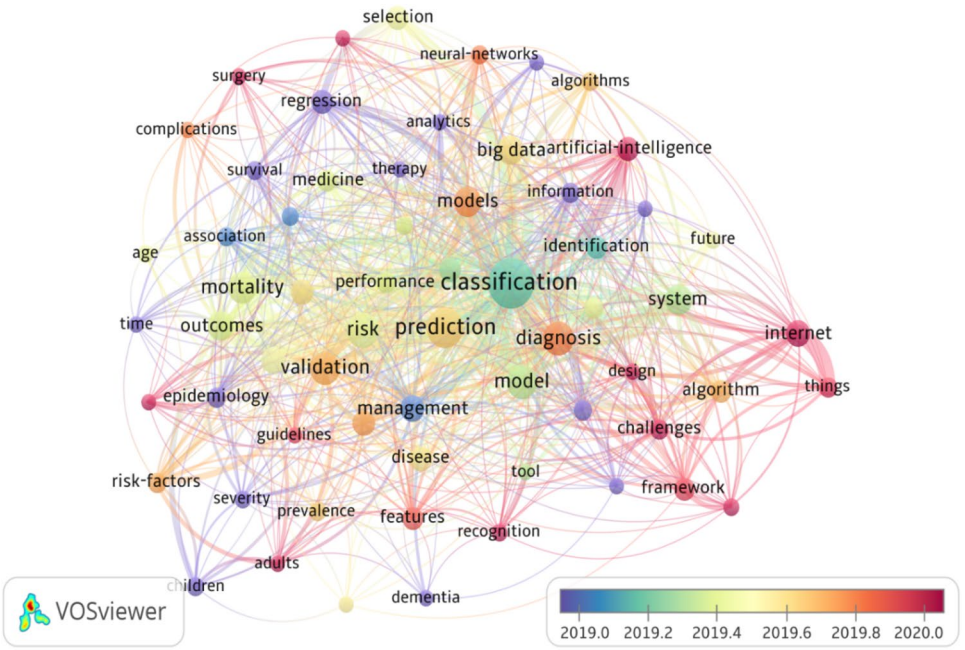

Fig. 18 Network visualization of occurrence of the top 20 keywords plus in the machine learning area

categories and 1,380, 992, and 894 from title-wise categories with searched keywords Machine learning, Deep Learning, and Healthcare has been used in Indian scientific research. Additionally, exploring the application of machine learning in the healthcare and deep learning in the healthcare domain has published a total of 2,014 topics wise and 119 title-wise articles and 922 and 58 respectively worldwide. Similarly, an Indian research prospect in the application of machine learning and deep learning in the healthcare domain has published a total of 218 topic-wise articles and 16 title-wise articles globally and 142 articles topics-wise and 13 articles titles-wise at the Indian level *(*Table 1).

The purpose of this bibliometric data collection is to perform a bibliometric analysis, and network visualization, then evaluate the latest followed by the Document Type and Language, Publication output, Top Country Contribution, Top WoS core Categories and Journals, Top Authors, Top Research Areas and Analysis of Author Keywords, Keyword Plus related and most trending topic in machine learning, Deep learning uses in Healthcare. also, this paper analyses

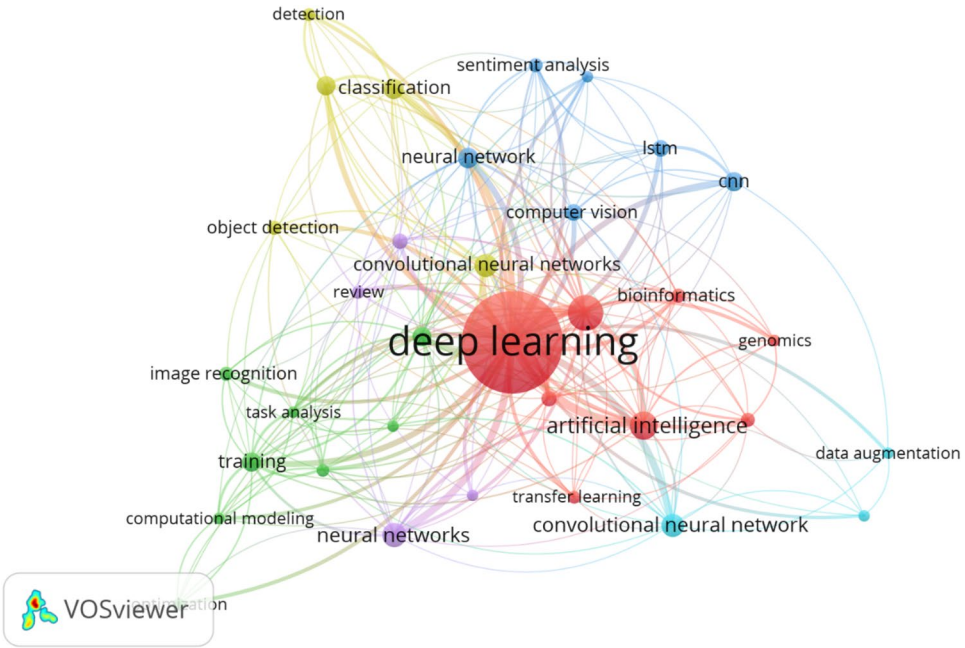

Fig. 19 Network visualization of occurrence of top 20 most authors' keywords in deep learning application

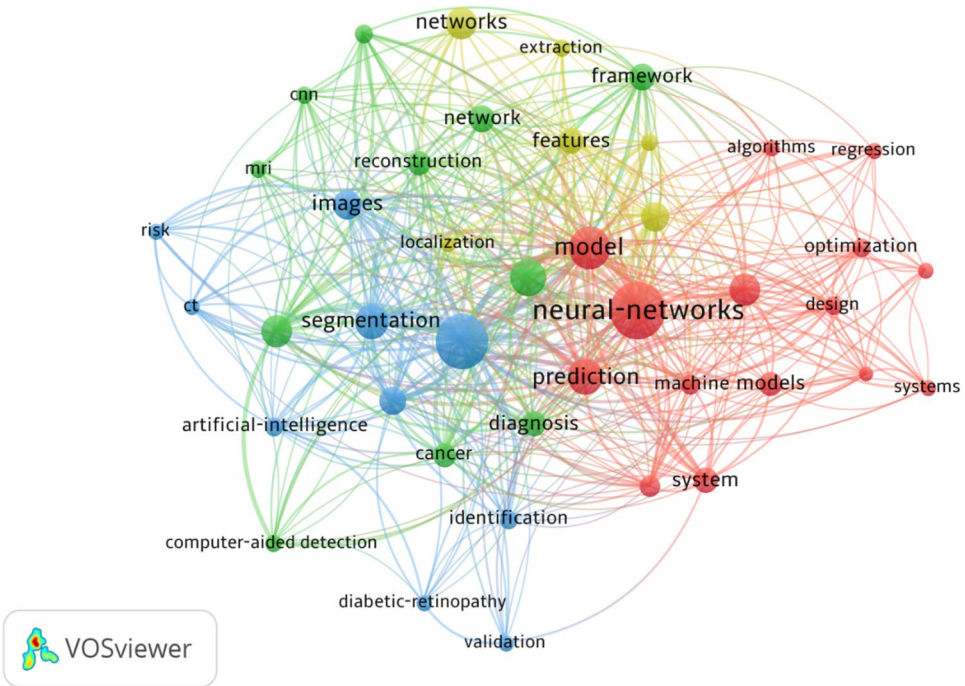

Fig. 20 Network visualization of occurrence of top 20 most keywords plus keywords in deep learning application

the number of citations based on the impact of multiple factors of the research paper as the number of authors, number of pages, and number of references. All bibliometric information data were downloaded by all relevant and latest literature published in ML, DL, and Healthcare research fields also implementation of machine learning and deep learning in healthcare fields, and all the source titles were included in web of science categories with three different document type article, review article, and early access article.

At the worldwide level, the total topical keywords-based article published is 86,292 research articles, 5,794 review articles, 2,854 early access articles with machine learning, 46,217 research article, 2,412 review article, 2,130 early access article in deep learning and 1,28,247 research articles, 22,071 review article, 3,540 early access article in the healthcare domain, also total numbers of research article 1,625, review articles 316, early access 98 in the application of machine learning in healthcare and total of 750 research

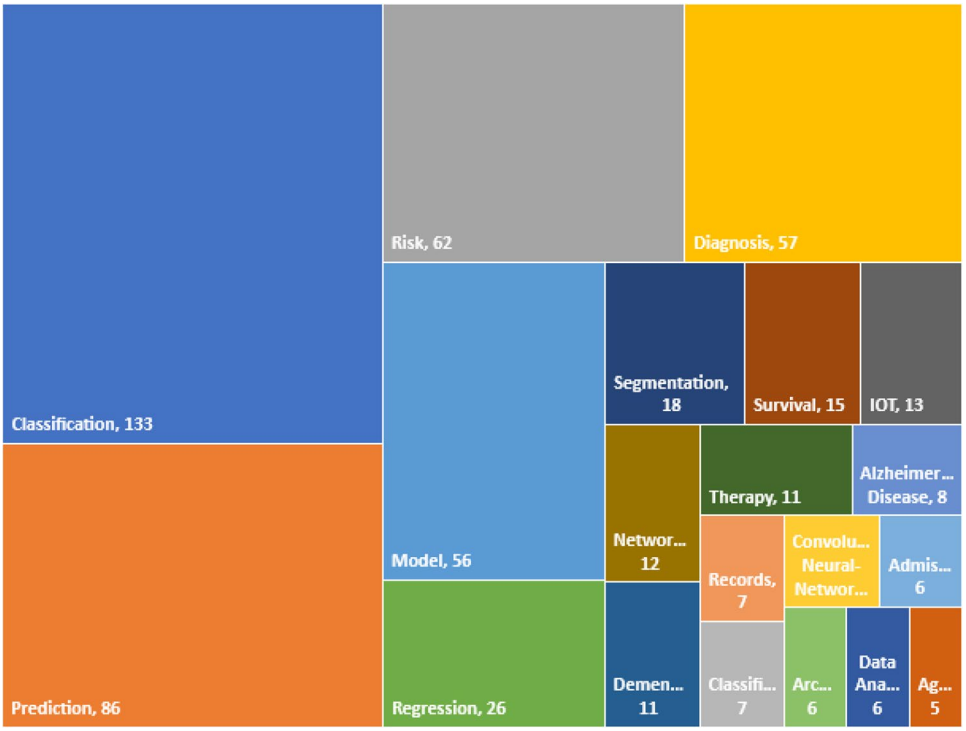

Fig. 21 Year-wise most trending authors' keyword tree map of application of Machine learning in the healthcare domain

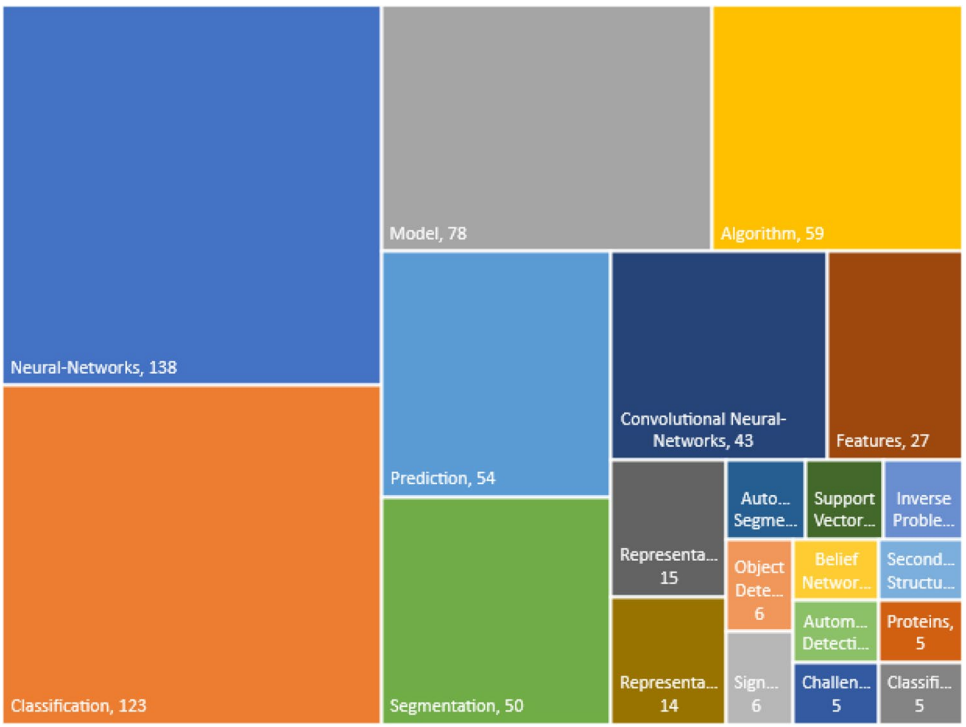

Fig. 22 Year-wise most trending authors' keyword tree map of application of Machine learning in the healthcare domain

articles, 149 review articles, 74 early access articles in deep learning application in healthcare. Comparatively, title wise query search was conducted and obtained a total of 22,935 research articles, 1,449 review articles and 924 with machine learning, followed by 16,055 research articles 730, review articles 788 early access articles in deep learning and 21, 545 research articles, 2,730 review article and 694 early access articles with healthcare, further, total research articles 74, review articles 11, early access articles 10 and 42 research articles, 5 review articles, 9 relay access articles in

Fig. 23 Year-wise most trending keyword is Plus word cloud in Machine learning applied in the healthcare domain

both machine learning and deep learning application in the healthcare sector (Table 2).

Also, worldwide five highest publication sources are IEEE Access, Journal of healthcare engineering, journal of biomedical informatics, PLOS One, BMC medical informatics, and decision-making publishing articles in machine learning and deep learning in healthcare fields. In the area of machine learning application these sources of publication total articles such as IEEE Access(articles:52), Journal of healthcare engineering(article:22), journal of biomedical informatics(article:20), PLOS One(article:20), BMC medical informatics, and decision making(article:19). Respectively, in deep learning in the healthcare area these sources of publication total articles like IEEE Access(articles:78), Journal of healthcare engineering(article:35), journal of biomedical informatics(article:15), BMC medical informatics and decision making(article:11).

From the global prospect, the top three countries that produced more research articles on the application of machine learning(ML) and deep learning(DL) in healthcare fields are the USA(articles frequency:2043), China(articles frequency:589), UK(articles frequency:375), South Korea (articles frequency:274), Canada(articles frequency:264), India (articles frequency:231) and USA(articles frequency:1327), China(articles frequency:1103), South Korea(articles frequency:398), India(articles frequency:330), UK (articles frequency:329). Among the top 10 most cited countries, the three topmost cited country having the USA (total citation:5072; avg articles citation:14.7), China (total citation:1434; avg articles citation:14.2), the UK (total citation:847; avg articles citation:12.28), India (total citation:434; avg articles citation:7.23), Norway (total citation:316; avg articles citation:63.2) in the area of machine learning use in healthcare. similarly, USA (total citation:5625; avg articles citation:26.41), China (total citation:2686; avg articles citation:13.57), UK (total citation:1176; avg articles citation:192.93), Korea (total citation:904; avg articles citation:12.05), Saudi Arabia (total citation:601; avg articles citation:13.07) in deep learning use in healthcare. Out of all the most cited and average cited countries USA has the highest total citations 1327 with an average article citation 26.41 in the use of deep learning in healthcare.

And top five authors are Zhang Y(articles:14), Li X(articles:11), Li J(articles:10), Li Y (article:9), Wang Z (article:8) and Li H(articles:17), Li J(articles:17), Wang H(aricles:14), Yang J(article:14), Liu Y(article:13) respectively.and the top five most affiliated Icahn School of Medicine at Mount Sinai, New York(articles:100), Harvard Medical School, Massachusetts(articles:78), Stanford University, California(articles:68) and Stanford University, California(articles:109), King Saud University, Saudi Arabia(articles:89), Johns Hopkins University(articles:84) are contributed greatly to both research fields.

Fig. 24 Year-wise most trending keyword Plus word cloud in Deep learning applied in the healthcare domain

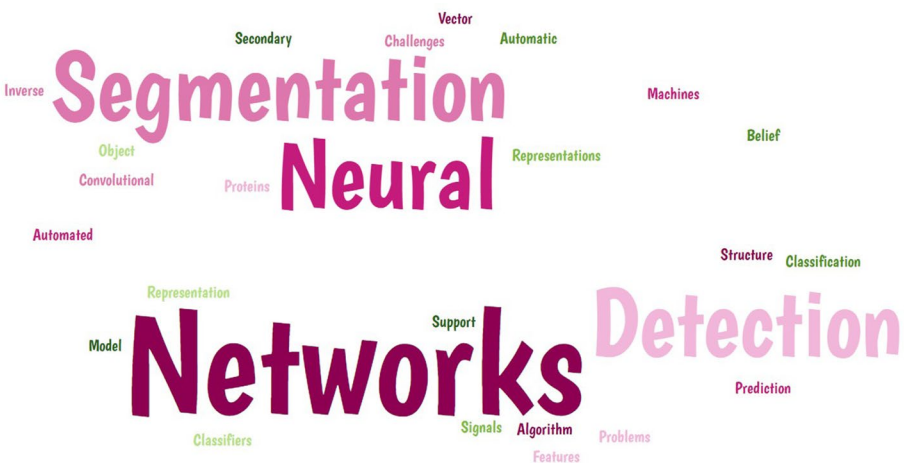

Table 14 Top 20 most trending author's keywords in the application of machine learning and deep learning in the healthcare sector

Machine Learning				
Item	Freq	Year_Q1	Year_Med	Year_Q3
Machine Learning	617	2019	2020	2021
Artificial Intelligence	93	2019	2020	2021
Healthcare	91	2019	2020	2021
Learning	68	2019	2020	2020
Deep Learning	61	2019	2020	2021
Prediction	43	2018	2019	2020
Big Data	39	2018	2019	2020
Covid-19	34	2020	2021	2021
Data Mining	18	2017	2018	2020
Medical Services	14	2020	2021	2021
Diabetes	13	2021	2021	2021
Prediction Model	11	2019	2019	2021
Data Analytics	11	2020	2021	2021
IOT	11	2020	2021	2021
Alzheimer's Disease	10	2018	2019	2020
Electronic Health	9	2018	2019	2020
Big Data Analytics	7	2016	2018	2019
Feature	7	2016	2018	2020
Clustering	5	2016	2018	2020
Critical Care	5	2018	2018	2019
Deep Learning				
Deep Learning	994	2019	2020	2021
Machine Learning	103	2018	2020	2020
Artificial Intelligence	65	2019	2020	2021
Neural Networks	49	2019	2020	2021
Convolutional Neural Network	43	2019	2020	2021
Neural Network	33	2018	2019	2020
Big Data	19	2018	2019	2020
Artificial Neural Network	11	2018	2019	2020
Data Mining	9	2017	2018	2020
Security	9	2019	2021	2021
Recurrent Neural Network	8	2019	2019	2020
Recurrent Neural Networks	7	2018	2019	2020
Wireless Communication	7	2020	2021	2021
Biomedical Imaging	6	2020	2021	2021
Hyperspectral Imaging	6	2020	2021	2021
Diagnosis	5	2019	2021	2021

Table 15 Top 20 most trending keywords Plus in the application of machine learning and deep learning in the healthcare sector

Machine learning				
Item	Freq	Year_Q1	Year_Med	Year_Q3
Classification	133	2018	2020	2020
Prediction	86	2019	2020	2021
Risk	62	2018	2020	2021
Diagnosis	57	2019	2020	2021
Model	56	2019	2020	2020
Regression	26	2019	2019	2020
Segmentation	18	2018	2019	2020
Survival	15	2018	2019	2020
IOT	13	2020	2021	2021
Networks	12	2017	2018	2020
Dementia	11	2018	2019	2020
Therapy	11	2018	2019	2020
Alzheimer's-Disease	8	2016	2017	2018
Records	7	2014	2017	2020
Classifiers	7	2017	2018	2020
Convolutional Neural-Network	7	2020	2021	2021
Admission	6	2017	2018	2020
Architecture	6	2021	2021	2021
Data Analytics	6	2021	2021	2021
Agreement	5	2018	2018	2020
Deep learning				
Neural-Networks	138	2018	2019	2020
Classification	123	2019	2020	2021
Model	78	2019	2020	2020
Algorithm	59	2018	2019	2020
Prediction	54	2019	2020	2021
Segmentation	50	2019	2020	2021
Convolutional Neural-Networks	43	2019	2020	2021
Features	27	2018	2019	2020
Representation	15	2018	2019	2020
Representations	14	2018	2019	2019
Automatic Segmentation	6	2017	2018	2019
Support Vector Machines	6	2018	2018	2019
Inverse Problems	6	2020	2021	2021
Object Detection	6	2020	2021	2021
Signals	6	2021	2021	2021
Belief Networks	5	2014	2017	2018
Secondary Structure	5	2017	2017	2018
Automated Detection	5	2018	2018	2021
Challenges	5	2018	2018	2020
Proteins	5	2017	2018	2020
Classifiers	5	2020	2021	2021

The network analysis of the top 5 relevant terms yielded classification, prediction, neural network, model(s), design in machine learning, deep learning, quality, management, impact, services, and prevalence in healthcare research. During 2010–2021, the top 5 authors' keywords were machine learning, artificial intelligence, deep learning, classification, and neural networks in machine learning and deep learning,

and healthcare, healthcare professionals, health policy, primary healthcare, patient safety, etc. in healthcare.

In addition, the top five trending keywords in the machine field are support vector machine, networks, algorithms, genetic algorithm approximation, neural network, classification, algorithm, architecture, dimensionality, sequence, mortality, attitudes, information, epidemiology, models, etc. The top authors' keywords in current research are classification, data mining, support vector machine(s), data analysis, unsupervised learning in machine learning, artificial intelligence, convolutional neural network, neural network, classification, object detection in deep learning, epidemiology, influenza, healthcare costs, healthcare service research, and e-health in healthcare.

5 Conclusion and Future Trends

When applied to any field of study, bibliometric analysis offers a fresh perspective on the study of research patterns. The purpose of this research was to apply bibliometric analysis techniques to uncover previously unknown relationships between machine learning, deep learning, and healthcare research areas, and to gain a deeper comprehension of how machine learning (ML) and deep learning (DL) methods are being used to improve healthcare delivery by minimizing human error in areas such as disease detection, diagnosis, prediction, drug discovery, precision medicine, robotic surgery, etc. This study provides a fresh perspective on the intersection of machine learning, deep learning, healthcare research, and the solutions they provide. In addition, the complete bibliometric information data on this topic has been analyzed using query keywords such as "machine learning," "deep learning," and "healthcare" from the web of science core collection from the period 2010 through August 30th, 2021, with a special emphasis on journals included in the SCI-Extended Index. In addition, this report discovers the extensive adoption of machine learning and deep learning techniques in healthcare and other domains by university researchers and industry practitioners. And it facilitates the application of these methods in other fields by researchers and practitioners.

From a global prospect, the top three countries that produced more research articles on the application of machine learning (ML), and deep learning (DL) in healthcare fields are the USA, China, and the UK. And top three authors are Zhang Y., Li X, Li J, Li H, Li J, Wang H and the top 3 most affiliated Icahn School of Medicine at Mount Sinai, New York(articles:100), Harvard Medical School, Massachusetts(articles:78), Stanford University, California (articles:68) and Stanford University, California(articles:109), King Saud University, Saudi Arabia(articles:89), Johns Hopkins University(articles:84) are contributed greatly in both research fields.

This study revealed that machine learning, and deep learning, in the healthcare field are some of the emerging areas of research that attract researchers to contribute to the future at a global level. Thus, the bibliometric study is a solution for detailed analysis of machine learning (ML) and deep learning (DL), and healthcare research areas and it helps to work in these areas special focusing on the healthcare domain. The key purpose of this endeavour is to raise awareness among academics and professionals about how machine learning (ML) and deep learning (DL) methods affect the medical field. More work needs to be done in this area, but it is expected to grow rapidly and have a greater effect on a structured dataset of greater size in the future. As a result, this ground-breaking study will assist scientists in maintaining a culture of constant innovation as they construct robust technologies tailored to the healthcare sector. We believe this research objective will encourage academics to keep exploring the potential of Machine learning and Deep learning in the medical field.

Author Contribution Dr. Ela Kumar (EK) conceived and designed the study, Ms. Juli Kumari (JK) performed the research, analyzed the data, and Dr. Deepak Kumar (DK) contributed to editorial input. Conceptualization, methodology and formal analysis: JK, DK; investigation: EK; visualization: JK, DK; writing—original draft: JK; writing—review and editing: DK, EK; All authors read and approved the final manuscript.

Data Availability The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Conflicts of interest The authors declare that there is no conflict of interests regarding the publication of this paper.

Ethical Approval Not applicable.

Consent for Publication All authors read and approved the final manuscript.

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