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Artificial intelligence in diabetic retinopathy: Bibliometric analysis

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ABSTRACT

Background: The use of artificial intelligence in diabetic retinopathy has become a popular research focus in the past decade. However, no scientometric report has provided a systematic overview of this scientific area.
Aims: We utilized a bibliometric approach to identify and analyse the academic literature on artificial intelligence in diabetic retinopathy and explore emerging research trends, key authors, co-authorship networks, institutions, countries, and journals. We further captured the diabetic retinopathy conditions and technology commonly used within this area.
Methods: Web of Science was used to collect relevant articles on artificial intelligence use in diabetic retinopathy published between January 1, 2012, and December 31, 2022 . All the retrieved titles were screened for eligibility, with one criterion that they must be in English. All the bibliographic information was extracted and used to perform a descriptive analysis. Bibliometrix (R tool) and VOSviewer (Leiden University) were used to construct and visualize the annual numbers of publications, journals, authors, countries, institutions, collaboration networks, keywords, and references.
Results: In total, 931 articles that met the criteria were collected. The number of annual publications showed an increasing trend over the last ten years. *Investigative Ophthalmology & Visual Science* (58/931), *IEEE Access* (54/931), and *Computers in Biology and Medicine* (23/931) were the most journals with most publications. China (211/931), India (143/931, USA (133/931), and South Korea (44/931) were the most productive countries of origin. The National University of Singapore (40/931), Singapore Eye Research Institute (35/931), and Johns Hopkins University (34/931) were the most productive institutions. Ting D. (34/931), Wong T. (28/931), and Tan G. (17/931) were the most productive researchers.
Conclusion: This study summarizes the recent advances in artificial intelligence technology on diabetic retinopathy research and sheds light on the emerging trends, sources, leading institutions, and hot topics through bibliometric analysis and network visualization. Although this field has already shown great potential in health care, our findings will provide valuable clues relevant to future research directions and clinical practice.

1. Introduction

Diabetic retinopathy (DR) is a growing public health concern [1]. The proportion of diabetes patients is projected to increase notably in the coming decades [2]; the world population with diabetes mellitus (DM) will be approximately 700 million by 2045 [3]. DR is the most common and specific complication of DM [4,5], and the leading cause of preventable blindness amongst adults aged between 20 and 70 years [6]. The global prevalence of DR-related blindness has increased up to 19% in the past two decades [7]. Therefore, it is imperative to develop public health approaches to reduce the incidence and burden of vision-related illness.

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The guidelines from the International Diabetes Federation recommend yearly screening; however, patient awareness, access issues, and shortage of experienced/trained ophthalmologists are the main barriers to yearly screenings [8]. Telemedicine has been showing immense potential as a cost-effective solution and has reduced the distance barrier [9,10]. Implementing telemedicine in remote/ limited setting areas is nevertheless difficult because there is a lack of trained graders who efficiently grade fundas image and send it to clinicians for better treatment [11–13]. The question then arises first about how to get proper access and lower the risk of DR-related blindness with a limited amount of resources. Thus, automated grading of DR shows immense promise for increasing productivity, efficiency, and screening coverage [12,14,15]. Indeed, automated tools based on AI are reducing the barrier to accessing remote areas and improving patient outcomes through early treatment.

AI techniques allow computers to learn the most predictive features from a large amount of data (e.g., clinical, images, and lab) without explicitly applying specific rules or features [16,17]. Over the last decade, AI algorithms have attracted attention due to their excellent diagnostic performance in classifying various eye diseases, including DR [18–20]. The performance of AI tools in screening for DR may vary in different population settings. However, implementing AI-based screening tools can offer significant benefits by reducing dependency on manual work and providing savings in healthcare costs and resources. AI tools can be considered to be incorporated in DR screening programmes in low-resource settings where there is a scarcity of ophthalmologists to diagnose DR.

Although these studies summarized essential aspects of the AI research field related to DR, to our best knowledge, no study has so far been conducted to map out the entire field in a systematic manner. Therefore, we used bibliometric analysis to achieve an integral view of this emerging field whereby we utilized a quantitative evaluation of publishing metrics of scientific literature [21,22]. A bibliometric study takes publication-related information such as authors, journals, countries, institutions, and collaboration networks to provide a bird's eye view of a field [23]. Bibliometric analysis is a statistical analysis approach which generates valuable insights by exploring the trends of particular topics, who and where the most active researchers are who drive the specific field, which journals are the most prominent, which organizations are mainly contributing, what kind of research is being conducted, and what types of tools are being used in this domain. Bibliometric analysis is useful because it allows researchers to understand this field better and provides insights for future directions.

We used bibliometric analysis to conduct a systematic overview of AI use in DR between 2012 and 2022, and thus provide an overview of current trends, topics, and bibliometric characteristics within this body of literature. The findings of our study give valuable information and future research directions about this rapidly developing field.

2. Methods

2.1. Search strategy

We searched for relevant articles in the Web of Science (WoS) Core Collection (Clarivate Analytics, USA), considered one of the most comprehensive international databases of scientific literature. WoS covers over 9000 research journals, offering various bibliometric indicators (e.g., titles, institutions, country/region, publication year, categories, and keywords) and includes articles from all disciplines. The following keywords were used to find relevant publications: "artificial intelligence" OR "AI" OR "machine learning" OR "deep learning", OR "Support vector machine" OR" random forest" or "logistic regression" OR "supervised machine learning" OR "unsupervised machine learning" OR "transfer learning" OR "neural network" AND "diabetic retinopathy". We considered only full-length articles published in English. Afterwards, two experts (≥ 5 years of experience conducting systematic reviews and scientometric analysis) validated our search strategy by manually checking all titles of the retrieved articles. They selected all relevant articles, and any disagreement in this stage was resolved by discussion with a third author. Finally, all retrieved articles were saved in TXT formats.

2.2. Screening the publications

In this study, all articles about AI in DR were included for screening. The articles for bibliometric analysis were restricted to those that (1) were published in English, (2) focused on DR as an outcome, and (3) used AI technologies. Articles published in peer-reviewed journals as research papers, conference proceedings, and reviews were included, but articles published as letters, editorials, and book chapters were excluded. The prediction/classification of DR was booming after 2012 due to the introduction of the convolution neural network model; therefore, articles published before 2012 were also excluded. Two authors who are trained bibliometric analysis specialists screened the retrieved articles by using predefined criteria and bibliometric analysis guidelines [24, 25].

2.3. Bibliometric analysis

Bibliometric analysis was first proposed by Mulchenko [26], which is the quantitative evaluation of scientific research, and used to measure and analyse the current research trends within a specific area to obtain quantifiable and reproducible information relevant to policy management [27]. Bibliometric analysis can provide a broad overview of a knowledge domain and identify research questions that researchers may attempt to answer, as well as methods that authors have developed to achieve their goal [28]. Visualizing the entire field of AI in DR will help readers to get a global perspective of AI research patterns and trends in the field of DR.

The growth rate of publications over the ten years was calculated by checking the rate of the number of publications in 2022 over the number of publications in 2012 to the power of 1/10, as presented below. The publication trends for each year were also calculated.

$$Growth\ rate = \left(\left(\frac{Number\ of\ publications\ in\ 2022}{Number\ of\ publication\ in\ 2012} \right)^{1/n} - 1 \right) \times 100$$

Here, n = number of year.

Publications trends of the top 10 countries, top 10 journals, top 10 institutes, and top 10 authors were also calculated. Frequency, percentages, and categories of each journal was provided. Frequency, percentage, and single and multiple countries' corresponding author ratios were calculated for each country. Moreover, frequency and citation rate were provided for each institution and author. The rank of research impact of each country, journal, institution, and author was provided based on the number of publications.

3. Results

3.1. Publication output

The electronic database search resulted in 3572 articles. After screening the titles and abstracts, 2641 were excluded. Finally, 931

Table 1
The distribution of articles by year between 2012 and 2022.

Year	Articles, n	Annual growth, n	Average growth rate
2012	6	N/A[a]	N/A
2013	20	14	233.33
2014	14	−6	−42.85
2015	25	9	64
2016	24	−1	−4
2017	37	13	54.16
2018	84	47	127.02
2019	167	83	98.80
2020	210	43	25.74
2021	262	52	24.76
2022	82	N/A	N/A

articles were included in the final bibliometric analysis. Table 1 shows that the number of articles on AI use in DR increased over the past ten years.

Overall, the articles were published in 270 international peer-reviewed journals. As Table 2 exhibits, the *Investigative Ophthalmology & Visual Science* published the most articles with 58, followed by *IEEE Access* with 54, and *Computers in Biology and Medicine* with 23.

931 articles were published from 74 countries/regions. Table 3 shows the location of the top 10 countries that were publishing AI-related research on DR. The People's Republic of China had the highest number of publications with 211, and India ranked second with 143, followed by USA and South Korea with 133 each. However, the ratio of multiple country publications (MCP) was higher in Australia (15/22, 0.68), followed by Singapore (29/44, 0.65) and South Korea (22/44, 0.50).

1609 research institutions contributed to AI in DR. Table 4 shows the top 10 most productive institutions in AI research. The National University of Singapore (40 articles) ranked first amongst all institutions, followed by the Singapore Eye Research Institute (35 articles) and Johns Hopkins University (34 articles).

VOSviewer tool was used to conduct co-authorship analysis and to present the broad picture of the institutional network in AI research for DR. The link between institutions is calculated by the number of articles co-authored between them. The authorship analysis of institutions forms a total of 103 institutions, each of which published at least 5 articles, which generated 11 clusters. These clusters are presented in Fig. 1.

931 articles on AI for DR were conducted by 4164 authors. Table 5 shows the top 10 most productive authors in AI research for DR. Ting D. (34 articles) ranked first amongst all authors, followed by Wong T. (28 articles), and Tan G. (17 articles).

Co-authorship analysis of authors presents that 95 out of 4164 authors had published at least five papers, and the highest set of associated authors consisted of 58 authors in eight clusters (Fig. 2).

3.2. Co-occurrence analysis of top 100 keywords

There were 1649 keywords used in the 931 articles. Table 6 presents the top 20 keywords used in the retrieved articles. Notably, clinical keywords like diabetic retinopathy, retina, diabetes, retinopathy, glaucoma, and macular oedema were on the top lists. However, deep learning, artificial intelligence, machine learning and convolutional neural network were the top technical keywords. The research hot spots of AI research for DR were found via co-occurrence analysis of the top 100 keywords.

3.3. Reference co-citation analysis

We further explored the knowledge base for AI research in the DR domain. We found 931 AI-related articles, which were cited by 20,152 references, averaging 21.66 references per article. The top 10 high cited articles are presented in Table 7. The publication that received the most citations, Gulshan V. and colleagues' "Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs," was published in JAMA in 2016 and received a total of 2490 citations as of April 10, 2022. We

We further chose the top 173 articles, which were cited at least 25 times and presented them in a visualization network map with VOSviewer of co-cited references in AI for DR. Fig. 4 shows 18 main clusters differentiated by various colors.

4. Discussion

The purpose of this study was to assess the emerging research field of artificial intelligence-related research for diabetic retinopathy. The substantial growth of research output was seen in the AI related field for DR, with most articles being published in recent years after introducing convolution neural network models. Recent trends in publication numbers indicate that this field will continue to grow. Hence, the ophthalmology field, including DR, will be one of the attractive research areas of the future, driven by the increasing number of diabetes patients. This study not only found research trends but research hot spots, productive researchers, regions, institutes, and collaboration networks.

Exponential growth was seen in the field of DR, reaching over 900 publications since 2012. If this trend continues, we can expect the number of publications in DR to AI research field to be triple in the next 5 years. The trends of research output also reflect progress, visibility, usability, and the importance of technology to improve the healthcare system. Over the past ten years, AI related research has achieved excellent diagnosis performance in DR [18,20,29–31]. The clinical performance of AI tools in classifying DR has been shown to be comparable to expert ophthalmologists. Moreover, AI tools offer immense benefits by reducing manual classification tasks and contributing to saving in costs. The research in AI for DR was often cited compared with the research within the same WoS subject categories. This shows an overall trend and interest in DR.

For journal sources, the top 5 journals publishing AI research for DR belong to the area of ophthalmology and computer science, accounting for 18.68% (174/931) of the total publications. Journals publishing AI models for DR were widely distributed across health informatics, biomedical engineering, computer science, and ophthalmology. Most scientific research articles (80%) are hardly cited, while 20% of papers get more than 80% of citations [32]. Previous studies investigated why some research papers are cited more than others [33] and reported several factors such as quality of the paper, journal impact factor, number of authors, visibility and international cooperation are the main factors for citations. Our study showed that top cited articles were published in high impact factor journals such as *JAMA*, *JAMA Ophthalmology*, and *Nature Medicine* (Table 7). Therefore, researchers who are working in this fields may be able to enjoy more opportunities to receive higher number of citations if they publish paper in high impact factor journals.

While AI research related to DR has been rapidly increasing in high-income countries; however, the research output of middle and low-income countries is still scanty. It is because the governments of developing countries are investing more money in non-

Table 2
Top 10 journals that published articles on artificial intelligence in diabetic retinopathy, 2012–2022.

Rank	Journal	Country	Categories	Article (N = 931)	Ranked based on citation	Citation count (N = 20,152)	Impact factor in 2020	5-year impact factor
1	Investigative Ophthalmology & Visual Science	USA	Ophthalmology	58	3	849	4.79	4.84
2	IEEE Access	USA	Computer Science, Information System	54	7	661	3.36	3.67
3	Computers in Biology and Medicine	USA	Computer Science, Interdisciplinary Applications	23	6	677	4.58	3.90
4	Translational Vision Science & Technology	USA	Ophthalmology	22	28	180	3.28	3.39
5	Eye	England	Ophthalmology	17	20	273	3.77	3.89
6	Scientific Reports	England	Multidisciplinary Sciences	17	24	240	4.38	5.13
7	CMC–Computers Materials & Continua	USA	Computer Science, Interdisciplinary Applications	15	54	73	3.77	3.27
8	PLOS One	USA	Multidisciplinary Sciences	15	18	325	2.24	3.78
9	Sensors	Switzerland	Engineering, Electrical and electronics	14	68	55	3.57	3.73
10	Computer Methods and Programs in Biomedicine	Netherlands	Medical informatics, computer science & interdisciplinary applications, biomedical engineering	13	8	603	5.42	5.03

Table 3
Top 10 countries that published articles on artificial intelligence in diabetic retinopathy, 2012–2022.

Rank	**Country**	**Articles**	**Freq.**	**SCP**	**MCP**	**MCP Ratio**
1	People's Republic of China	211	0.24	147	64	0.30
2	India	143	0.16	117	26	0.18
3	USA	133	0.15	79	54	0.40
4	South Korea	44	0.05	22	22	0.50
5	Singapore	44	0.05	15	29	0.65
6	Spain	23	0.02	18	5	0.21
7	United Kingdom	23	0.02	14	9	0.39
8	Australia	22	0.02	7	15	0.68
9	Pakistan	21	0.02	12	9	0.42
10	Japan	16	0.01	15	1	0.06

Abbreviations: Freq. = Frequency; SCP = single country publication, MCP = multiple country publication *(Note: The countries were identified by the affiliations of the listed authors).*

Table 4
Top 10 institutions that published papers on artificial intelligence in diabetic retinopathy, 2012–2022.

Rank	Affiliations	Country	Articles, n	Citations, n
1	National University of Singapore	Singapore	40	1853
2	Singapore Eye Research Institute	Singapore	35	1435
3	Johns Hopkins University	USA	34	734
4	Sun Yat-sen University	People's Republic of China	33	604
5	Oregon Health & Science University	USA	30	792
6	Shanghai Jiao Tong University	People's Republic of China	30	139
7	Capital Medical University	People's Republic of China	26	335
8	Nanyang Technological University	Singapore	23	1067
9	Stanford University	USA	22	967
10	University of Iowa	USA	22	1706

Table 5
Top 10 authors that published papers on artificial intelligence in diabetic retinopathy, 2012–2022.

Rank	Authors	Articles, n	Citations, n (rank)	h-index [a] (rank)	g-index [a] (rank)
1	Ting D.	34	1665 (17)	14 (2)	29 (1)
2	Wong T.	28	1825 (16)	15 (1)	25 (2)
3	Tan G.	17	1300 (20)	10 (6)	13 (5)
4	Raman R.	16	2962 (2)	8 (15)	10 (15)
5	Acharya Ur.	14	807 (35)	13 (3)	14 (3)
6	He Mg.	14	1263 (21)	9 (8)	11 (9)
7	Laude A.	13	603 (83)	11 (4)	13 (4)
8	Lim G.	13	1004 (23)	8 (13)	11 (10)
9	Peng L.	12	3400 (1)	10 (5)	12 (6)
10	Abramoff M.	12	883 (26)	6 (20)	9 (16)

a = Web of Science database only.

Table 6
Top 20 author keywords for artificial intelligence in diabetic retinopathy.

Rank	Author keyword	n (%)
1	Diabetic retinopathy	389 (20)
2	Deep learning	225 (12)
3	Artificial intelligence	108 (6)
4	Machine learning	94 (5)
5	Retina	60 (3)
6	Convolutional neural networks	51 (3)
7	Feature extraction	50 (3)
8	Diabetes	49 (3)
9	Classification	37 (2)
10	Retinopathy	37 (2)
11	Glaucoma	35 (2)
12	Optical coherence tomography	35 (2)
13	Computer-aided diagnosis	34 (2)
14	Transfer learning	33 (2)
15	Support vector machine	31 (2)
16	Fundus images	28 (1)
17	Diabetic macular oedema	24 (1)
18	Exudates	24 (1)
19	Screening	23 (1)
20	Age-related macular degeneration	22 (1)

classified AI research, and private sectors are also spending billions of dollars in many domains, including healthcare, which is transforming their research outputs and economy [34]. Moreover, with the rapid development of technologies in developed countries, AI research has been produced faster compared in developing countries. The management of DR depends on three fundamental strategies- a) preventing the onset of diabetes, b) developing public awareness, evidence-based clinical guidelines, and screening programs, and c) implementing automated tools to provide timely treatment both in rural and urban areas [35]. Our study shows that developed countries and highly reputed institutes are developing AI models for DR; these are helping to stratify DR patients early and improving the treatment outcomes of patients with DR [36]. Although AI research for DR in developed counties is crucial, the prevalence and burden of DR are always high in low-income and middle-income countries [37]. The findings of this study have highlighted the urgency of AI research in the DR domain for ensuring the benefits from the development of intelligent healthcare in low and middle-income countries. The barriers related to investments, novel technologies, workforces, infrastructures, and languages must overcome.

Table 7
Top 10 high cited articles in AI for DR research, 2012–2022.

Rank	Author	Title	Journal	Citations, n	Citation per year, n
1	Gulshan V. et al. 2016	Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs	JAMA	2490	355.71
2	De Fauw J. et al. 2018	Clinically Applicable Deep Learning for Diagnosis and Referral in Retinal Disease	Nature Medicine	795	159
3	Ting D. et al. 2017	Development and Validation of a Deep Learning System for Diabetic Retinopathy and Related Eye Diseases Using Retinal Images from Multiethnic Populations with Diabetes	JAMA	738	123
4	Gargeya R. et al. 2017	Automated Identification of Diabetic Retinopathy Using Deep Learning	Ophthalmology	461	76.83
5	Abramoff M. D. et al. 2016	Improved Automated Detection of Diabetic Retinopathy on a Publicly Available Dataset Through Integration of Deep Learning	Investigative Ophthalmology & Visual Science	393	56.14
6	Abramoff M. D. et al. 2018	Pivotal Trial of an Autonomous AI-based Diagnostic System for Detection of Diabetic Retinopathy in Primary Care Offices	Digital Medicine	351	70.2
7	Ting D.S.W. et al. 2018	Artificial Intelligence and Deep Learning in Ophthalmology	British Journal of Ophthalmology	281	70.25
8	Li Z. et al. 2018	Efficacy of a Deep Learning System for Detecting Glaucomatous Optic Neuropathy Based on colour Fundus Photographs	Ophthalmology	261	52.2
9	Burlina P.M. et al. 2017	Automated Grading of Age-Related Macular Degeneration from colour Fundus Images Using Deep Convolutional Neural Networks	JAMA Ophthalmology	233	38.83
10	Mookiah M.R. K. et al. 2013	Computer-aided Diagnosis of Diabetic Retinopathy: A review	Computers in Biology and Medicine	226	22.6

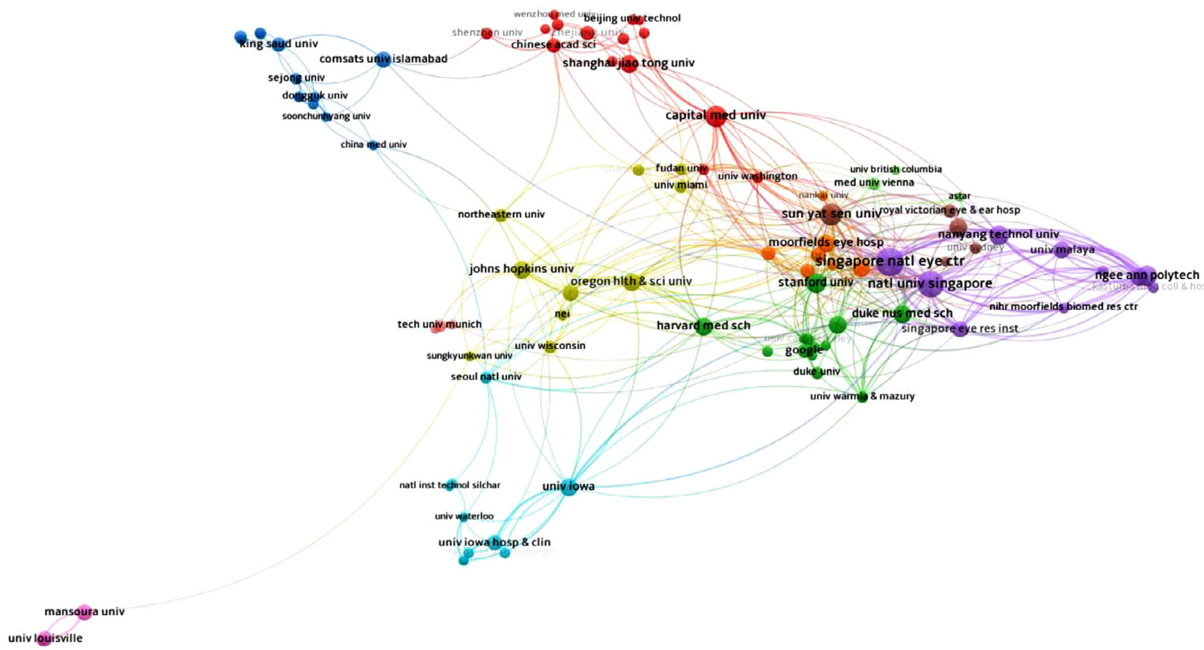

Fig. 1. The co-authorship network of institutes that contributed to artificial intelligence research in diabetic retinopathy, 2012–2022.

We found that most of the studies in the field used deep learning algorithms such as convolutional neural networks and transfer learning. The convolutional neural network is more common in the research of image analysis. Traditionally, computer-aided detection (CAD) system is used to describe medical images automatically, offer an opportunity for DR diagnosis and assist ophthalmologists [38]. Unlike CAD, the convolutional neural network (CNN) can learn valuable features that minimize the limitations of DR detection using digital images [39,40]. Islam et al. [1] conducted a systematic review with a meta-analysis of relevant studies to quantify the performance of the CNN algorithm for detecting DR and mentioned that the sensitivity and specificity of CNN

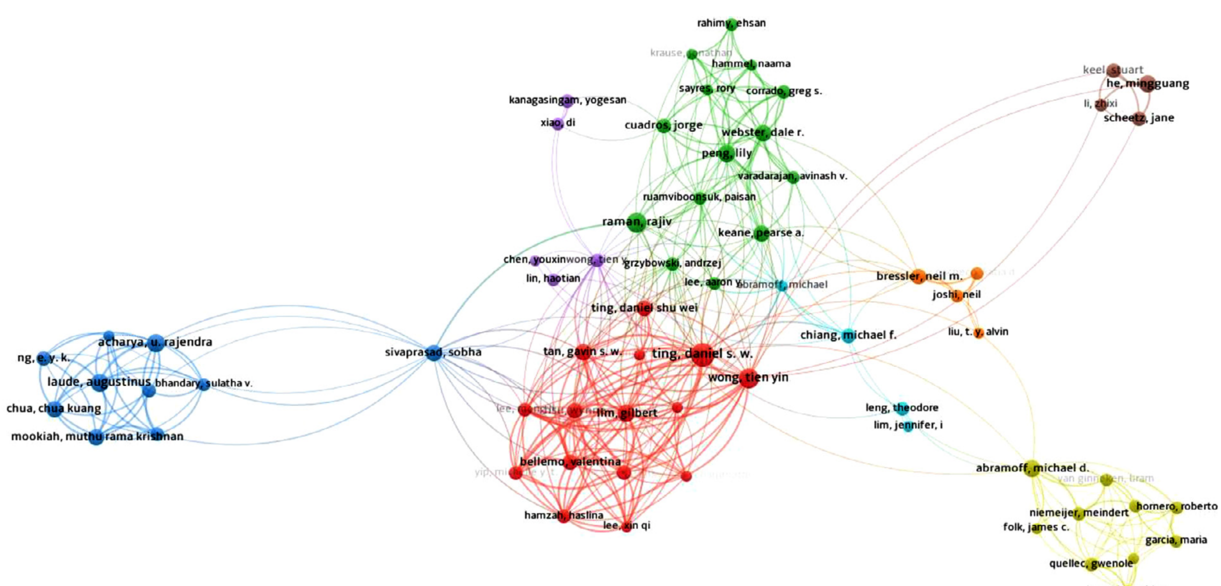

Fig. 2. The co-authorship network of authors who contributed to AI research for DR, 2012–2022. The node label presents the author's name, and the node size is the number of published articles. The link that connected two nodes presents co-authorship between the two authors. The thicker and thinner line shows that the number of documents shared between the two authors.

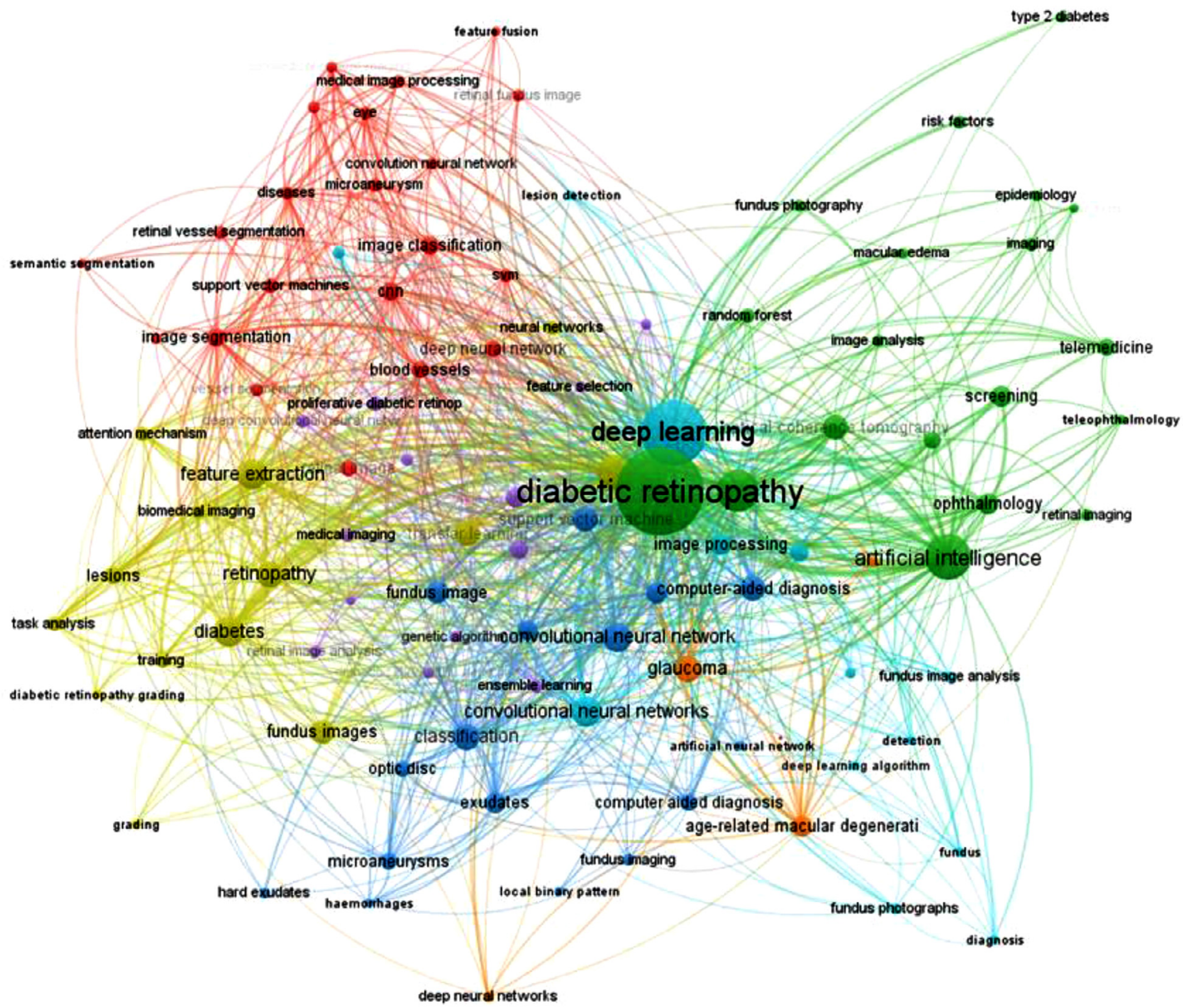

Fig. 3. The co-occurrence network of the top 100 keywords in AI research for DR, 2012–2022. The visualization tool, VOSviewer, was used to collect and generate clusters for the top 100 keywords. As depicted in Fig. 3, we utilized VOSviewer to illustrate a visualization network map of the top 100 keywords in 8 clusters with their co-occurrence. The eight clusters are represented by colors: red (cluster 1, 20 items), green (cluster 2, 18 items), blue (cluster 3, 18 items), yellow (cluster 4, 13 items), dark violet (cluster 5, 10 items), cyan (cluster 6, 10 items), dark orange (cluster 7, 6 items), and sienna (cluster 8, 5 items). The node label is the keyword, and the number of keywords decides the size of the label. The link connects two nodes which present the association between two keywords.

model were high for detecting referable DR from retinal fundus photographs. Wang et al. [41] also evaluated the performance of CNN algorithm in terms of sensitivity and specificity for DR grading. The pooled sensitivity and specificity of the AI model showed better performance in detecting DR and encouraged using real-world clinical settings. However, the performance of the AI model varies in various settings. For example, most of the studies used common datasets (MESSIDOR 2, EyePACS-1, and E-Ophtha.) to develop and test their model performance. In future, validation of the algorithms is warranted in different settings and various quality of images [42]. Moreover, we identified top producing researchers and highly cited articles in DR. These articles might be useful for researchers who are less familiar with the fields and can collaborate with those renowned researchers.

The strength of this current bibliometric analysis is that it has provided a comprehensive overview of the AI research on DR. We discussed with experts, read previous bibliometric studies to obtain knowledge about search strategy, developing inclusion and exclusion criteria, and a screening process. We are confident that this bibliometric study has included all research papers related to DR with AI. We also have provided information regarding very productive regions, institutions, and authors. Although, it is, to our knowledge, the first bibliometric analysis of AI on DR. Still, there are some limitations that need to address. First, we only included studies that were published in English. Although, most WoS articles are in English. Second, we only included articles from one single database- WoS. Although, it is a comprehensive database, offering wide range of publications metrics that are appropriate for bibliometric analysis. And only good quality of peer-reviewed journals is indexed in the WoS and maintain high quality. Nevertheless, we may have missed some relevant studies published in the major conferences (e.g., MICCAI, MLHC, ISBI, etc.). Future studies will apply other databases, like Scopus and PubMed, to explore more potential articles. Third, the number of citations of any article does not give fully overview of the quality of an article. Some articles can have good quality but get less citations, and self-citations can cause bias (Figs. 1 and 4).

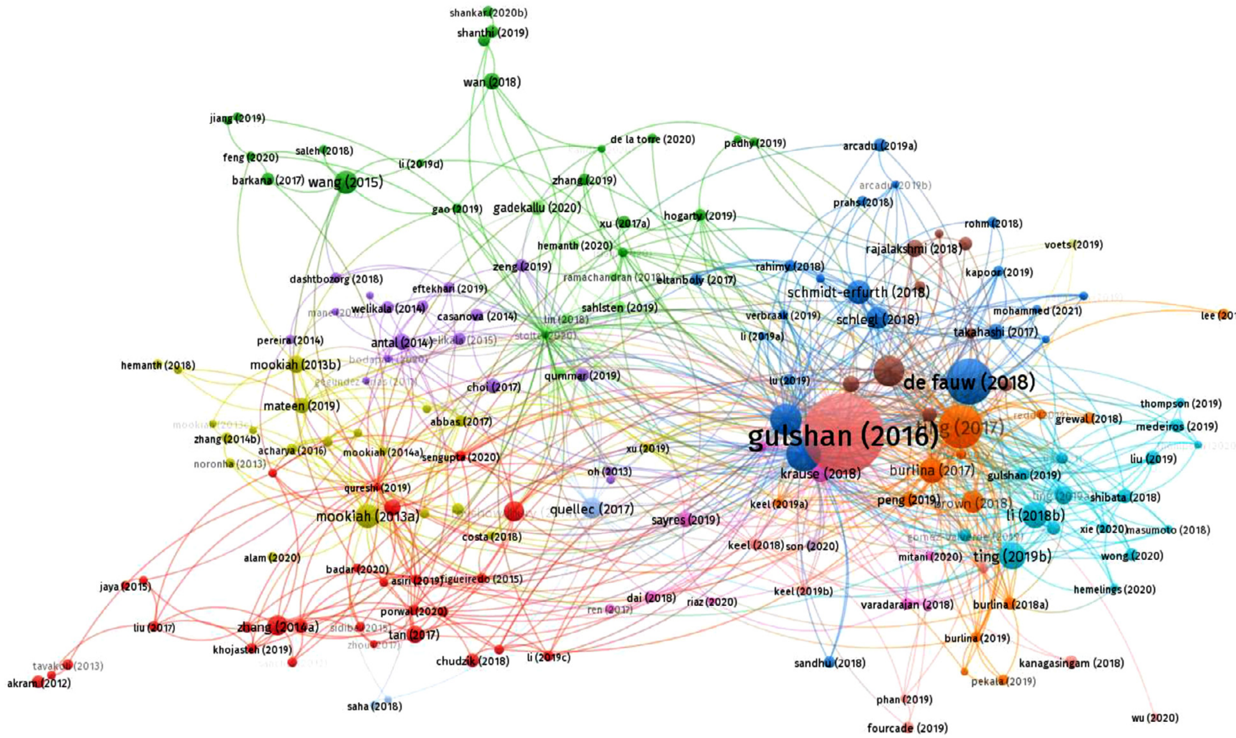

Fig. 4. The co-citation network of publications in AI for DR, 2012–2022.

5. Conclusion

Artificial intelligence has begun to transform certain critical aspects of healthcare sectors and has gained immense attention from researchers and practitioners. A bibliometric study was conducted to explore the status and global trends of AI research related to DR. Although a significant number of scoping reviews, systematic reviews and meta-analyses have already been published, this is the first bibliometric analysis of this field, in which 931 scientific research papers were examined using a "quantitative mapping" approach. The most productive countries, institutions, authors, the state of the research technologies, and relevant areas on DR were identified. Despite promising developments of AI research in developed countries, research in low-income and middle-income countries are still limited. More research in low-income and middle-income countries are needed to assess the impact of AI research in DR. Future studies should address potential challenges such as methodological implications, ethics, and clinical deployment of AI models in low and middle-come countries.

Declaration of Competing Interest

None.

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