Fundus Image Feature Extraction in Diabetic Retinopathy: A Bibliometric Analysis Approach

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Abstract. Diabetic retinopathy is the main cause of vision loss in diabetes patients. Eye fundus image analysis plays a critical role in identifying early signs of diabetic retinopathy. Rapid developments in the fields of digital image processing and artificial intelligence have brought about a revolution in fundus image feature extraction methods, enabling the identification of small details such as changes in blood vessels, the presence of microaneurysms, and exudates, all of which are important indicators of the progression of diabetic retinopathy. In this study, we used an analytical approach from Scopus and used bibliometrics with the Vosviewer application to map and assess research developments in fundus image feature extraction in the context of diabetic retinopathy. The results of the analysis of fundus image research on diabetic retinopathy show an increase in the number of publications every year, with India as the country with the most publications. Feature extraction techniques remain the focus of research, with several feature selection methods that can be used to detect diabetic retinopathy. In addition, the subject area of computer science is experiencing an increase in fundus image research of diabetic retinopathy, indicating the contribution of technology and related methods in the research of this disease.

Keywords: Diabetic retinopathy, fundus image feature extraction, bibliometric analysis, digital image processing, artificial intelligence

1 Introduction

Diabetic retinopathy, a common complication in diabetes patients, is the leading cause of vision loss among people with diabetes. This condition, characterized by damage to the retinal blood vessels, highlights the importance of early and accurate detection [1] , [2] , [3] . In this context, eye fundus image analysis plays a critical role, considering its ability to identify early signs of diabetic retinopathy [4] , [5] .

Rapid developments in the fields of digital image processing and artificial intelligence have brought a revolution in fundus image feature extraction methods [6] , [7] , [8] . These advanced techniques allow identifying small details such as changes in blood vessels, the presence of microaneurysms, and exudates, all of which are important indicators of the progression of diabetic retinopathy [9] , [10] , [11] . Despite increasing interest and progress in retinal image feature extraction for diabetic retinopathy, a systematic review of existing research is still needed. While these emerging trends open new avenues for more efficient

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diagnosis, challenges remain, particularly in understanding and integrating findings from scattered studies. [4] , [12] , [13] .

In this study, we used a bibliometric analysis approach to map and assess research developments in fundus image feature extraction in the context of diabetic retinopathy. This approach allows us to examine causality in the scientific literature, identifying research patterns, causal relationships between different feature extraction methods, and their impact on improving the diagnosis and management of diabetic retinopathy. Through this analysis, we seek to provide a comprehensive picture of the current status and future potential of this technology in the context of eye health.

The primary aim of this study is to highlight how innovations in fundus image feature extraction can have a significant impact on the detection and management of diabetic retinopathy [14] , [15] , as well as identify future research directions that may help in overcoming remaining challenges. To achieve this goal, we initially searched for and identified journals published on fundus image feature extraction in the last five years (2019 – 2023) that were indexed by the Scopus database. Where the Scopus database is one of the largest reference and citation databases for scientific, technical and medical literature. It provides access to a wide range of journal articles, conferences, and patents, making it a rich source for bibliometric analysis. VOSviewer software was then adapted to analyze the themes, keywords, authors, institutions, and co-itation and co-author networks of these papers, where the results of the analysis are explained and discussed further.

2 Research Methods and Data

In this study, we reviewed the current scientific literature on fundus image feature extraction in the context of diabetic retinopathy, using bibliometric analysis methods. We collected and analyzed data from the Scopus database from 2019 - 2023, relying on predefined keywords, to map the main trends, techniques and relationships between research in this field. This process not only reveals recent developments in fundus image feature extraction techniques but also highlights future directions of research in this area. The stages can be explained with the following picture;

From Figure 1 below, the bibliometric analysis process for extracting fundus image features for diabetic retinopathy can be explained. First, the initial stage and setup, namely accessing the Scopus database https://www-scopus-com. After successfully logging into Scopus, the next step is to use the search feature. The research focus was on the literature from 2019 to 2023, then set the search parameters to include only publications in that year range. This is done by selecting the 'Publication Date' option and entering '2019' as the start year and '2023' as the end year.

Second, a data search was carried out by entering keywords that were relevant to my research topic. I typed "feature AND extraction AND image AND fundus AND diabetic AND retinopathy" in the search field provided. Using the "AND" operator is important to ensure that all results that appear contain all of these keywords, so that they focus more on a specific topic. Filtering Based on Number of Citations is carried out using filters to see the number of citations available in Scopus to prioritize articles that have significant influence or references. Through four steps, namely identification, screening, eligibility, and inclusion, a total of 459 articles were obtained as research data with a time span of 2019–2023.

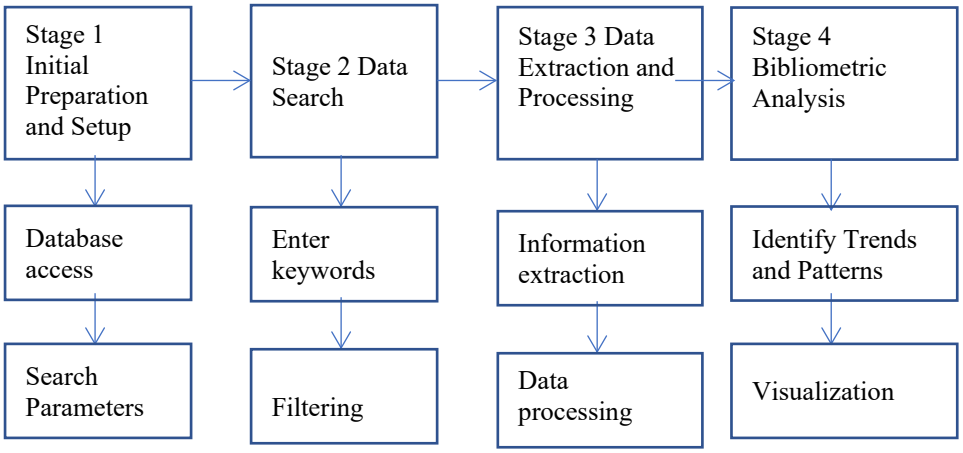

Figure 1. Bibliometric Analysis Stages in Fundus Image Feature Extraction

Third, carry out information extraction and data processing, select and filter search results, start the process of extracting information from relevant articles by opening each selected article one by one. Collect important information such as article title, author name, abstract, year of publication, and number of citations. This information is important to understand the context and significance of any research in the field of fundus image feature extraction in diabetic retinopathy. Then ensure that all data is organized in a way that facilitates analysis such as sorting data by year of publication, grouping articles by topic or methodology, or creating formulas to calculate certain metrics. Data processing for bibliometric analysis VOSviewer, this application is software for creating scientific network maps based on publication data. This is very useful for visualizing the relationships between different studies, authors, and topics in a scientific field.

Fourth, carry out bibliometric analysis by reviewing the data that has been collected and processed. The primary aim here is to identify key emerging trends in the literature on fundus image feature extraction in diabetic retinopathy. One important aspect of this analysis is examining the various feature extraction techniques used in the studies under review. Looking to find out which techniques are most frequently adopted and whether there are any new developments or innovations in this area. Then evaluate the main focus of the research being analyzed.

To assist in analyzing using VOSviewer data visualization, the visualization technique I use for creating quote maps. This map helps in illustrating the relationships between different studies, showing how one work influences another. Created various graphs and diagrams to depict the distribution of studies based on time, frequency of feature extraction techniques used, and other patterns I discovered in the data.

3 Bibliometric Analysis Results

3.1 Research Results

In the study "Fundus Image Feature Extraction in Diabetic Retinopathy: A Bibliometric Analysis Approach", we have succeeded in collecting and analyzing a large amount of data

from articles published between 2019 and 2023. The aim of this bibliometric analysis reveals several research trends in the field of fundus image feature extraction in diabetes retinopathy. Apart from that, this analysis aims to find out whether there is a significant increase in the use of machine learning techniques and artificial intelligence for extracting fundus image features.

In this research, you can see the feature extraction techniques used , including the use of artificial neural networks and deep learning algorithms, which have shown effectiveness in identifying signs of diabetic retinopathy. Primarily focused on improving accuracy and efficiency in early detection of diabetic retinopathy. We are also seeing an increase in research examining the influence of demographic and clinical factors on feature extraction accuracy. Citation map analysis shows an increase in collaboration between researchers from various disciplines, including ophthalmology, artificial intelligence, and image processing. Search results with Scopus can be seen in table 1:

Table 1. Document Data by Year

No	Year	Documents
1	2023	121
2	2022	116
3	2021	86
4	2020	66
5	2019	70

Table 1 above represents the number of research documents published each year from 2019 to 2023. Based on the data presented, we can see the increase and dynamics of publications regarding feature extraction of fundus images in diabetic retinopathy, where in 2019 there were 70 publications, in 2020 there were 66 publications, in 2021 there will be 86 publications, in 2022 there will be 116 publications and in 2023 there will be 121 publications. In graphic form we can see in Figure 2 below;

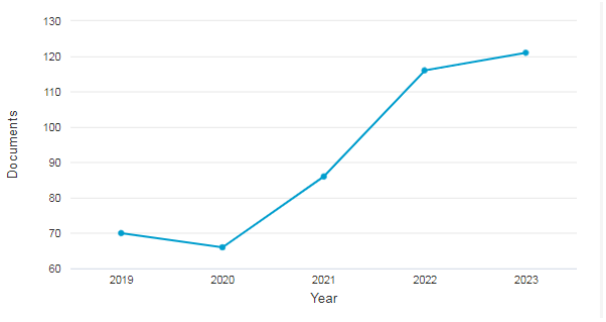

Figure 2. Linear Graph of Publications by Year

Figure 2 above shows a linear graph depicting the trend in the number of research publications on fundus image feature extraction in diabetic retinopathy from 2019 to 2023. Based on this graph, the following analysis can be presented. 2019 : Beginning with approximately 70 documents, this year may mark consistent interest in fundus image feature extraction research in diabetic retinopathy. 2020: There was a slight decrease in the number of publications to around 66 documents. This decline could be caused by various factors, including the influence of global situations such as the COVID-19 pandemic which has

affected research and publication activities. 2021: A significant increase is seen with the number of documents increasing to around 86. This indicates a recovery and/or increase in research activity after the previous year, perhaps due to adaptation to new conditions or technological and methodological advances in this field. 2022: The upward trend continues with the number of publications reaching almost 116 documents, indicating that there is a steady increase in research in this area, perhaps a result of the increasing number of research initiatives and increased funding. Year 2023: This year shows the highest number of publications in the chart, with around 121 documents. This indicates that the field of fundus image feature extraction in diabetic retinopathy continues to experience great growth and research interest, which can be attributed to the increasing need for early detection and more effective management of diabetic retinopathy.

3.2 Research Visualization Information

In the last decade, diabetic retinopathy has emerged as one of the most significant complications of diabetes, causing visual impairment and even blindness. Recent research in the field of fundus image feature extraction has provided new hope in the early detection and management of this condition. We can display some visual information below.

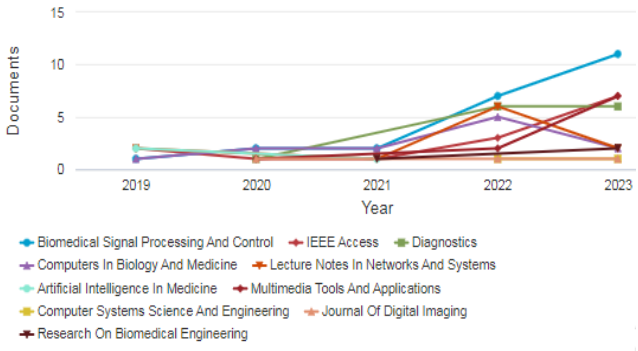

Figure 3. Line graph of documents per year per source

Figure 3 above displays a line graph illustrating the number of research publication documents on retinal image feature extraction in diabetic retinopathy per year, based on various sources or scientific journals from 2019 to 2023. The graph shows the distribution of research publications in various scientific sources over a five year period. Each line represents a different source, with varying colors to differentiate each source. General trends show fluctuations in the number of publications per source from year to year. Biomedical Signal Processing and Control, There is a consistent upward trend from year to year, indicating growing interest and continued development in this topic. IEEE Access , It shows significant growth, especially in 2023, which suggests that publications in this journal may become increasingly relevant to the research community. Computers in Biology and Medicine, has experienced an increase in the number of publications, although not as consistent as other sources, indicating that there is variation in interest in this topic within the scientific community. Artificial Intelligence in Medicine: The number of publications is relatively stable, with a slight increase in recent years, which could indicate stability in AI-related

research in medicine. Lecture Notes in Networks and Systems: Shows improvement in 2023, indicating possible increased relevance of network systems topics in the context of fundus image feature extraction. Multimedia Tools and Applications and Journal Of Digital Imaging: Both show fluctuations but tend to increase, indicating increasing applications of multimedia and digital imaging in medical research. Computer Systems Science and Engineering and Research On Biomedical Engineering: Both have a lower number of publications compared to other sources, perhaps indicating more limited topic specialization in the context of diabetic retinopathy.

The graph above shows a trend of increasing interest and research in fundus image feature extraction in diabetic retinopathy in various fields related to technology and medicine. This shows a broad cross-discipline in research, from biomedical signal processing to the application of AI technologies, further emphasizing the importance of technology integration in medical research. These trends indicate the importance of various technological aspects in understanding and overcoming the challenges faced in the diagnosis and management of diabetic retinopathy

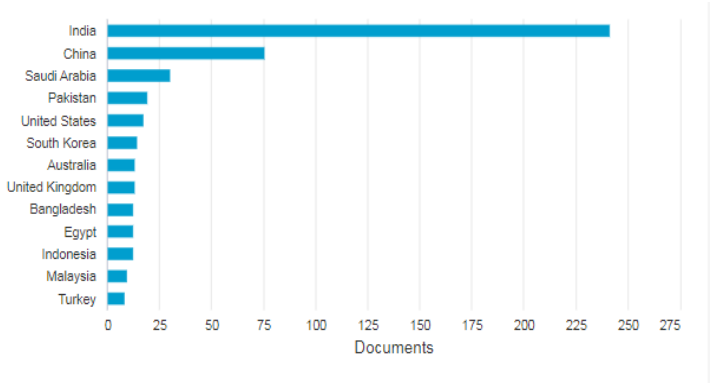

Figure 4. Document Bar Graph by country

Figure 4 above displays a horizontal bar graph illustrating the distribution of the number of research documents on retinal image feature extraction in diabetic retinopathy by country. The graph shows a comparison of the number of research documents published by various countries. India dominates with 241 documents out of a total of 459, which means India's contribution is around 52.5% of the total publications. This suggests that India has a central and active role in research in this area, which may be influenced by the country's high prevalence of diabetes and strong focus on medical research. China contributed 75 documents, about 16.3% of the total. This reflects the country's commitment to developing medical and technology-related research, as well as efforts to lead in the Asian region in these research topics. Saudi Arabia with 30 documents, Saudi Arabia contributed about 6.5%, confirming the country's interest and investment in health and science research. Pakistan produced 19 documents, constituting 4.1% of the total, indicating that the country is also active in this research although on a smaller scale compared to its neighbor, India. United States with 17 documents (3.7%), the United States indicated involvement in this research, which may reflect more distributed research across various medical fields. Other countries such as South Korea and Australia with 14 and 13 documents respectively (3.0% and 2.8%), as well as the UK with 13 documents (2.8%), all show solid engagement in this global research. Then the countries of Bangladesh, Egypt, and Indonesia, each with 12 documents (2.6%), together with Malaysia 9

documents (2.0%), and Turkey 8 documents (1.7%), provide contributions that indicate the existence and interest of research in various regions. world.

From the above percentage that India has a very significant contribution to the total number of research documents, reflecting the large focus on this issue in the country. Meanwhile, active participation from countries such as China and Saudi Arabia shows the existence of strong research centers in Asia and the Middle East. The existence of Western countries with more moderate contributions reflects a more even distribution of research in various fields. Countries with fewer publications remain important because they demonstrate geographic diversity and interest in research on diabetic retinopathy, which is a significant global health problem.

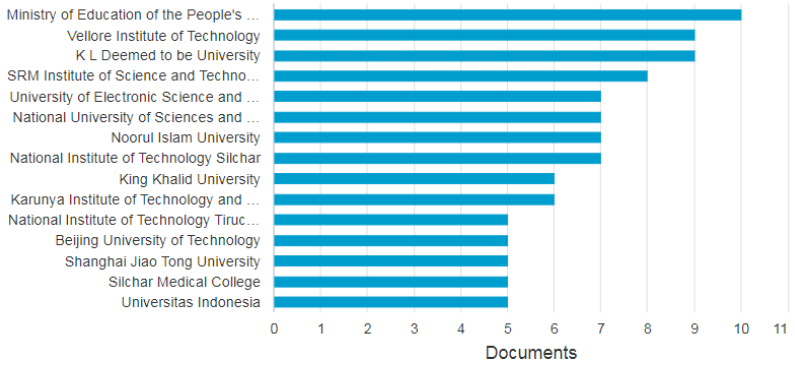

Figure 5. Document Bar Graph by affiliation

Graph 5 above shows the distribution of the number of research documents published by various affiliates or educational and research institutions from around the world. The Ministry of Education of the People's Republic of China is the affiliate with the highest number of publications at 2.18% with 10 publications, indicating that this institution plays an important role in research and development in the field of diabetic retinopathy. This may reflect the large investment of the Chinese government in scientific research and medical development, followed by Vellore Institute of Technology and KL Deemed to be University. These two institutions from India show a significant contribution in the number of publications at 1.96% with a total of 9 publications, which affirms India's commitment to research in the fields of health and technology. Third from SRM Institute of Science and Technology, University of Electronic Science and Technology of China, National University of Sciences and Technology Pakistan, Noorul Islam University, National Institute of Technology Silcha,: These institutions also show active research activities with a large number of publications respectively 1.96%, 1.74%, 1.53%, 1.53%, 1.53%. Other affiliates such as King Khalid University 1.31%, Karunya Institute of Technology and Sciences 1.31%, National Institute of Technology Tiruchirappalli 1.09%, Beijing University of Technology 1.09%, Shanghai Jiao Tong University 1.09%, Silchar Medical College 1.09% and University of Indonesia 1.09% where these affiliates also demonstrate involvement in diabetic retinopathy research with a number of publications reflecting ongoing research efforts. We can observe that educational and research institutions from China and India have contributed the largest number of publications in this field.

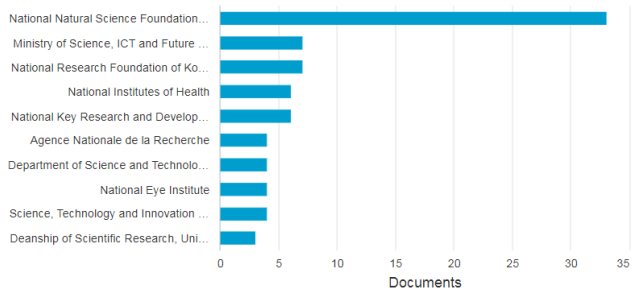

Figure 6. Document Bar Graph by Sponsor

Figure 6 above displays a bar graph illustrating the number of research documents on retinal image feature extraction in diabetic retinopathy funded by various sponsors. We can see a graphic analysis of research documents based on funding sponsors, firstly the National Natural Science Foundation of China (NSFC). This sponsor is seen as the largest funding contributor with a significant number of documents of 33 publications, showing its important role in supporting research in China, especially in fields of natural and medical sciences. The two Ministry of Science, ICT and Future Planning (MSIP) from Korea also showed a large contribution to research funding with 7 publications, which confirms Korea's commitment to investing in research and technology development. National Research Foundation of Korea (NRF): In line with MSIP, NRF also provides strong support for research with 7 publications, reflecting Korea's national strategy to promote scientific innovation. National Institutes of Health (NIH) and National Eye Institute (NEI) from the United States, these two institutions appear to have almost the same number of documents and show their involvement in research funding in the United States as 6 and 4, with NEI focusing on related research with eyes. National Key Research and Development Program of China, this program also makes a significant contribution, indicating China's priority in funding strategic and high-impact research projects with 6 publications. Agence Nationale de la Recherche (ANR) from France and Department of Science and Technology (DST) from India: These two bodies show the involvement of their respective countries in supporting research with 4 publications, with ANR funding research in France and DST supporting research in India. Science, Technology and Innovation Policy Research Organization (STIPO) and the Deanship of Scientific Research University of Jordan with 4 and 3 publications respectively, although the number of documents is less compared to other sponsors, these two organizations still show their commitment to research funding.

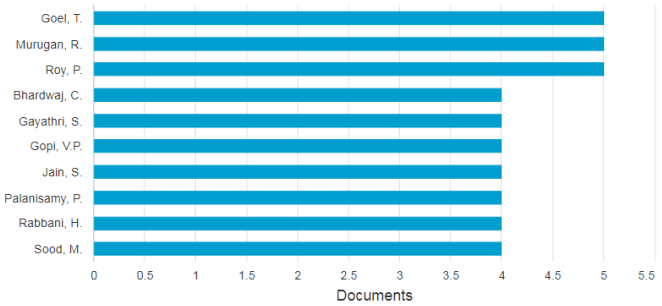

Figure 7. Document Bar Graph by Author

Graph 7 above displays the distribution of the number of research publication documents on retinal image feature extraction in diabetic retinopathy based on author. Authors named Goel, T, Murugan, R., Roy, P., are seen as the authors with the largest number of publications, with more than 5 documents each, which indicates a significant contribution to research in this field. This may indicate that Goel, T, Murugan, R., Roy, P. is a researcher or academic who focuses on diabetic retinopathy and fundus image feature extraction. Then other authors such as Bhardwaj, C., Gayathri, S., Gopi, VP, Jain, S., Palanisamy, P., Rabbani, H., and Sood, M., each have the number of publications from 3 to almost 4 document. Their involvement indicates a group of researchers who consistently contribute to this field.

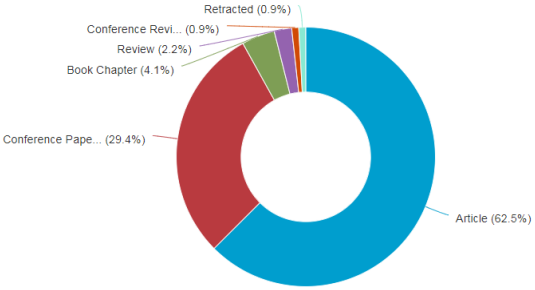

Figure 8. Document Pie Chart Based on Type

Figure 8 above is a pie chart which displays the distribution of types of research publications on retinal image feature extraction in diabetic retinopathy. The following is an explanation of the image. Pie chart analysis of types of research publications where the contribution of documents is Article type (62.5%), Most of the publications are journal articles, which shows that research results are most often communicated through peer-reviewed scientific journals. This indicates that journal articles remain the main medium for dissemination of scientific knowledge in this field. Second place is Conference Papers (29.4%) , a large number of publications are also conference papers, which indicates that the exchange of information and the latest findings in scientific conferences is significant. This shows the importance of scientific forums and academic meetings as platforms for sharing research. In third place are Book Chapters (4.1%), a small number of publications are chapters in books, which may include in-depth reviews or theoretical studies of research topics. Ranking third in the Review type (2.2%), review articles, which summarize and discuss current literature, indicate that there is an attempt to synthesize existing research and provide a comprehensive perspective on the topic. Final Conference Reviews (0.9%) and Retracted (0.9%) where these publications are fewer, with conference reviews which may include summaries of various presentations or discussions at a conference, and retracted publications which demonstrate the proofreading process and scientific integrity underway in the research community.

This diagram effectively illustrates the diversity of formats in the dissemination of research results in the field of retinal image feature extraction in diabetic retinopathy. With journal articles as the largest contributor, this diagram emphasizes the important role of peer-reviewed publications in the academic field. Meanwhile, the significance of the conference paper underscores the importance of scientific dialogue and collaboration in research development and validation.

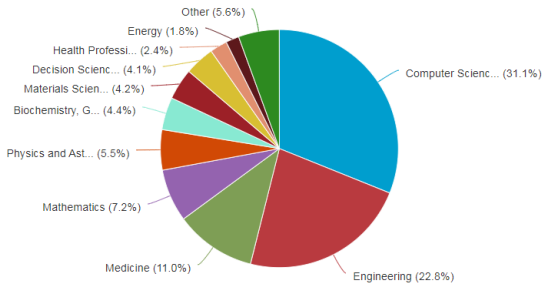

Figure 9. Pie Chart of Documents by Subject Area

Figure 9 above is a bar chart which depicts the number of documents based on the subject area regarding retinal image feature extraction in diabetic retinopathy based on the subject area of the publication. The following is an explanation of the graphic image, the Computer Science field has the largest number of subjects, namely 330 documents around 31.1%, followed by the Engineering subject with 242 documents around 22.8%, then the Medicine subject with 117 documents around 11.0%, research subjects with an increase in Mathematics with 76 documents around 7.2% and Physics and Astronomy with 58 documents around 5.5% and average subjects including Biochemistry, Genetics and Molecular Biology with 4.4%, Materials Science 4.2%, Decision Sciences 4.1%, Health Professions 2.4% documents, Energy 1.8%, while subjects that are rarely used are 10 subjects around 5.6%.

3.2 Mapping the Development of Feature Extraction Fundus Image Research for Diabetic Retinopathy

Mapping the research development using the Vosviewer application, the researcher used Create of map based on bibliographic data for the type of data, then selected Read data form bibliographic database file for Choose data source with support for the Scopus file type. Next, to analyze the Scopus dataset, the analysis type uses Co-occurrence and the unit of analysis selects the index keyword, while choose threshold minimum number of occurrences of keyword with a value of 5 so that of the 2182 keywords, 277 meet the threshold. The researcher then verified the data by not ticking several keywords that were deemed unnecessary for the research objectives, so that an image of the research cluster based on words that frequently appeared in the research could be seen as shown in Figure 10 below.

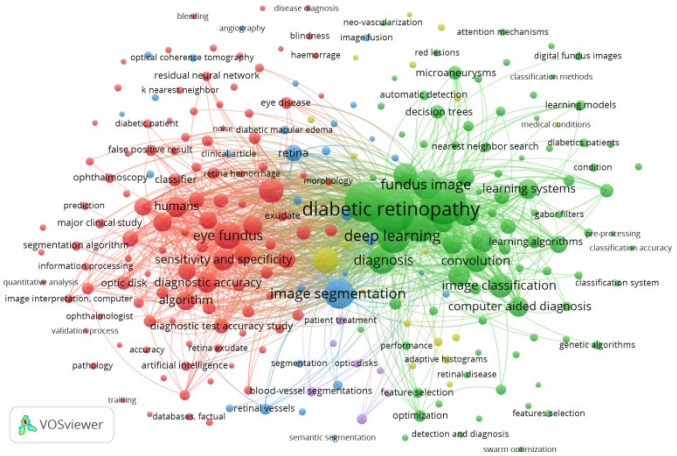

Figure 10. Feature Extraction Mapping With Network Visualization Mode

The mapping in Figure 10 above is a network visualization. It can be explained that there are 255 items and there are 5 clusters, where the first cluster has 107 items with red circles, the second cluster has 90 items with green circles, the third cluster has 31 items with blue circles, cluster four has 18 items with yellow circles and cluster five has 9 items with purple circles. From the color display above, it can be seen that the words diabetic retinopathy and fundus image are more dominant, this indicates that there has been a lot of research in the field of diabetic retinopathy using fundus images. Next we will display the Overly visualization form with the following image;

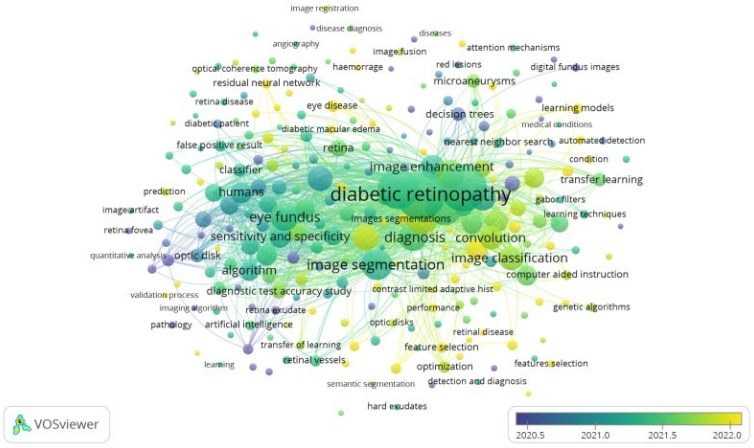

Figure 11. Feature Extraction Mapping With Overly Visualization Mode

In Figure 11 above you can map the circles from dark to light, where the darker the circles with purple and green colors means there has been a lot of research, the lighter the color, the less research is done. The following are important circles to describe in Figures 12, 13 and 14.

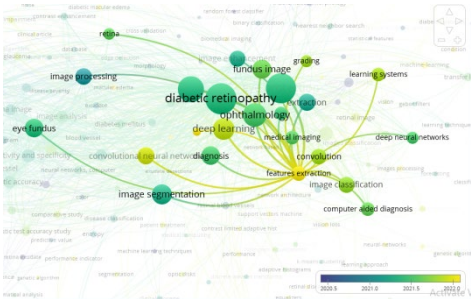

Figure 12. Overlay Mapping of the Word Feature Extraction

The word feature extraction in Figure 12 shows that research in the field of feature extraction is still rarely carried out, where the color of the circles is bright or yellow.

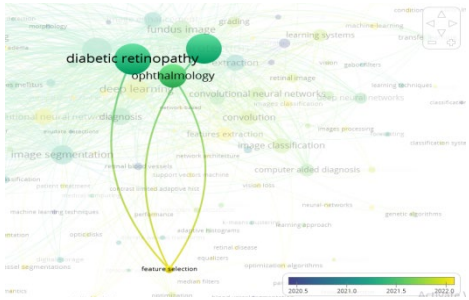

Figure 13. Overlay Mapping of the Word Feature Selection

There are also related circles such as feature selection in Figure 13 which shows that research in the field of feature selection is still rarely carried out, where the color of the circles is bright or yellow.

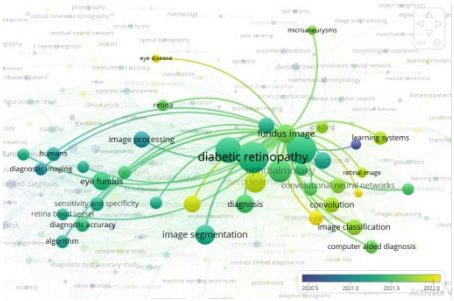

Figure 14. Overlay Mapping of the Word Fundus Image

In figure 14 above there are research fundus image circles for the detection of moderate category diabetic retinopathy because the color of the circles is still a stable green color which is close to the yellow line.

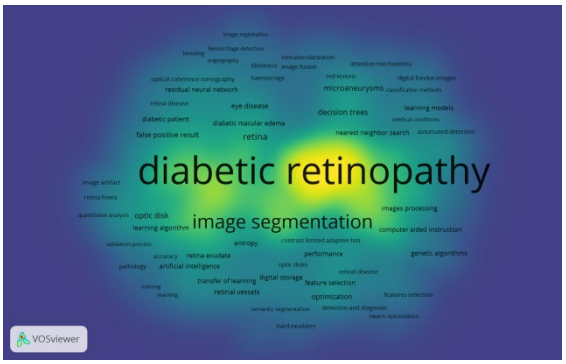

Figure 15. Feature Extraction Mapping With Density Mode

Density mode is a mapping that describes a pile of words in dark to light areas. Light colored keywords, in this case yellow, indicate that research in that area has been widely carried out, whereas if words are entered in dark colors such as green to blue, this indicates that research is still rarely carried out. It can be seen that the words diabetic retinopathy and image segmentation are in a bright area, which means that the object of this research is very important to carry out, however for the words fundus image, feature extraction and feature selection, they are still in a dark area which is an opportunity for further research to gain knowledge for medical purposes as well as in science to find the latest model or algorithm in detecting diabetic retinopathy. the field of Computer Science as the largest subject, namely 330 documents, around 31.1%.

4 Conclusion

Based on research that has been carried out previously with a research range of 2019 to 2023, it can be concluded, firstly, in terms of the number of studies on feature extraction fundus image diabetic retinopathy, the trend is increasing every year, where the highest number of publications in 2023 was 121 articles, India being the contributor of the most publications in 5 last year, namely 241 publications, 52.5%, the largest research affiliation was dominated by the Ministry of Education of the People's Republic of China with the highest number of publications, 2.18% with 10 publications, while the National Natural Science Foundation of China (NSFC) was the most research sponsor with 33 publications, Goel, T, Murugan, R., Roy, P each with 5 publications as popular names of publications in their field, based on the type of publication most in the form of articles, namely 62.5%, the largest subject area in the field of Computer Science as the most subjects, namely 330 documents around 31.1%. Secondly, based on research mapping where feature extraction techniques are still needed to contribute to extracting diabetic retinopathy, there is also a selection of features that can be used independently or in combination with techniques that can detect diabetic retinopathy.

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