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Original Article

Systematic Review on Methods for Detection and Diagnosis of Diabetic Retinopathy from the Year 2013 to 2023

Sebastian Ramos-cosi[1], Jacqueline Coquis-Flames[1], Michael Cieza-Terrones[2], David Llulluy-Nuñez[1], Alicia Alva-Mantari[*1]

[1]*Image Processing Research Laboratory (INTI-Lab) Universidad de Ciencias y Humanidades, Lima, Perú.*
[2]*Facultad de Medicina, Universidad Peruana Cayetano Heredia, Lima, Perú.*

[*]*Corresponding Author : aalva@uch.edu.pe*

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Abstract *- Diabetes is an illness that causes a multiple number of complications, Diabetic Retinopathy being one of them. The high level of glucose in the bloodstream eventually causes damage to the blood vessels and narrowing, including the small blood vessels in the eyes. If left unattended, this causes changes in the retina, and it can affect vision and lead to blindness. The present study was conducted to review the most predominant methods of detection and diagnosis of Diabetic Retinopathy from the years 2013 to 2023. The selection of the documents was done using the Scopus database, and the data gathered was then processed using RStudio and Google Collaborate. After processing the 9610 documents that were gathered, it was shown that with the technological advancements in recent years, new ideas and ways of detecting and diagnosing diabetic retinopathy have been developed. These include ways to get images of the fundus of the eye and process them more efficiently through methods like the use of artificial intelligence or neural networks and deep learning, the construction of hardware using microcontrollers and the use of smartphone cameras to capture the image in order to lower the costs. The use of artificial intelligence for image processing is most dominant in current trends, but the work on the development of new hardware built for image capture is not as numerous in comparison.*

Keywords *- Diabetic retinopathy, Scopus, Systematic review.*

1. Introduction

Diabetic patients can suffer from a number of different complications from the disease[1, 2]; high levels of sugar in the blood can cause the narrowing of the blood vessels which can lead to poor blood circulation and result in damage to the structures in the body including the eyes [3, 4] the condition in which the small blood vessels in the retina get occluded preventing correct blood flow to the eye that leads to vision problems and, if left unattended, to vision loss is known as Diabetic Retinopathy [5].

At present, Diabetic Retinopathy has caused blindness in more than 200 million people worldwide [6], and its global incidence was 103 million in 2020 and is anticipated to reach 161 million by 2045 [7]. 81% of adults with diabetes live in developing countries [5]. The research on this complication from the disease has continued to increase, and because of new technologies like artificial intelligence [8–12] and deep learning [13], there have been many more solutions that have been presented to prevent the development of this condition into something like vision loss.

These developments include the construction of different devices that intend to be lower in cost and easier to use to get the images of the fundus of the eye, advancements in software that uses deep learning[4, 12, 14, 15], artificial intelligence [8], [10], [11], machine learning [16] and convolutional neural networks [17–19] to sort the obtained images and give a more precise diagnosis in less time and also try to detect the abnormalities in the blood vessels at an earlier stage of the disease allowing the patient to get the necessary referrals and undergo treatment as soon as possible[20].

The main objective of this research is to know the reality of diabetic retinopathy over time by reviewing the most predominant methods for detection and diagnosis of the disease from the year 2013 to 2023, in the processing of fundus images and advancements in physical supports, like cases or stands, and the method for image capture.

All this will serve as a foundation for future research in different fields, such as healthcare and technological development.

Although the advances in artificial intelligence are increasing at a staggering speed[9], it is necessary for researchers to know the bibliometric price. Our contribution will focus on marking the additions necessary for optimal detection and diagnosis of diabetic retinopathy[21]. On the other hand, the advancements in hardware prototypes for image capture devices are also presented, and this research will mark the differentiators between the investigations.

Bibliometric reviews focus on processing the information and using tools to obtain easy-to-understand results and knowing the various topics and main variables in a research study. That is why the bibliometric analysis helps analyze trends and brings the researchers' attention to [22] future projects, which is why the authors plan to retrieve the articles from WOS by the end of the year 2022, where they analyze trends using VOSviewer and citeSpace to analyze a total of 10709 articles where they find as the main result that the topics with the highest incidence are AI, deep learning and image processing using various techniques. They conclude that the trend is focused on telemedicine and the use of AI as assistance to mitigate DR through prevention and treatment.

In [11], the authors indicate that diabetic retinopathy is the main cause of blindness in adults over 40 years of age. The main objective of their research is to summarise the applications of artificial intelligence in diabetic retinopathy through a bibliometric analysis, providing insights for future research in this field. They used the Web of Science database to carry out their search and analysis, collecting information until November 4 2022, articles in English and managing to gather 1770 references. CiteSpace 6.1.R2 software was used. They analyzed the conditions that cause vision changes to obtain information on the relationship between artificial intelligence and its application in diabetic retinopathy. They found that the analysis of publications and emerging trends is increasing and is a field of great interest today; they indicate that there was an increase in publications between the years 2011 and 2017 of an average of 100 articles per year. In 2018, 147 main articles were published, and the number continues to increase for the following years, 402 and 312 for 2021 and 2022, respectively. They conclude with a list of the countries, institutions and authors that produce the most publications and conclude, with the CiteSpace analysis, that research is increasing. This background research is important for the present investigation since it highlights the topic's importance and clarifies the countries in which the greatest scientific advances have been made in the field.

In [23], to prevent vision loss due to DR (Diabetic Retinopathy), the authors present the objective of conducting a review of current methods for convolutional network models such as Xception, Alexnet VGGNET- 16 and RESNET50. They propose a methodology where they test each one of these networks with classification systems. The main result is that the high performance of ResNet50 has a precision of 83.95%, and they point out a conclusion that the most precise networks in diabetic retinopathy detection must reach a high level of precision to use the visualization tools.

In [23] Given the recent development in artificial intelligence, it is important to know the reality of the advancements in diabetic retinopathy in recent investigations. For this reason, the authors carry out a bibliometric analysis review using the Web Of Science database in which they study the dates from January 2022 to December 2023 and process their data in Bibliometrix and VOSviewer finding from the total of the 931 articles that they analyzed that China is the country that does the most research, in addition to the fact that the journals that talk about DR in their articles come from the US and England.

For all these reasons, they conclude that these technological advancements have a high citation rate in research works and that the journals they studied support AI research as the solution to DR.

Next, the hybrid methodology that will be used for the present work will be presented; we have used the one recommended by the SCOPUS database and one of our own to process the data variables independently. The results will also be presented based on maps and graphs showing the authors, years, and publications. Lastly, the discussions made in the present study will be compared with those in previous articles.

2. Methodology

The methodology is based on a review of the articles in Scopus due to its bibliometric data provided by its platform and the metadata tools accessible to the Boolean search of its interface. Scopus is a database that comprises a rich number of scientific journals and encompasses a great variety of disciplines[25]; it possesses a search algorithm that allows the researcher to filter the information in an efficient way and analytical tools that enable it to manipulate the data straightforwardly.

2.1. Flowchart

The flowchart helps guide the research in terms of our methodology based on what is presented in Fig 1. When starting the information search process, emphasizing and defining the main objective is important, in addition to limiting the search with the use of appropriate keywords to improve the quality of the results[27]. The search criteria will be based on the Boolean logic that the Scopus interface uses to sort the various repositories in its database. All the above-mentioned refer to the information search stage.

For the second section, the information process will be described in terms of the Boolean search given by Scopus. The data will be filtered according to the type of document

and year of publication. The data classification will be transferred in a . CSV storage format for further processing. Finally, the data will be shown in the form of easy-to-understand tables and graphs with highlighted characteristics in terms of novelty, citation, year, and impact[28–32] to finally provide a conclusion on the current status of the research and what we recommend for future investigation on diabetic retinopathy.

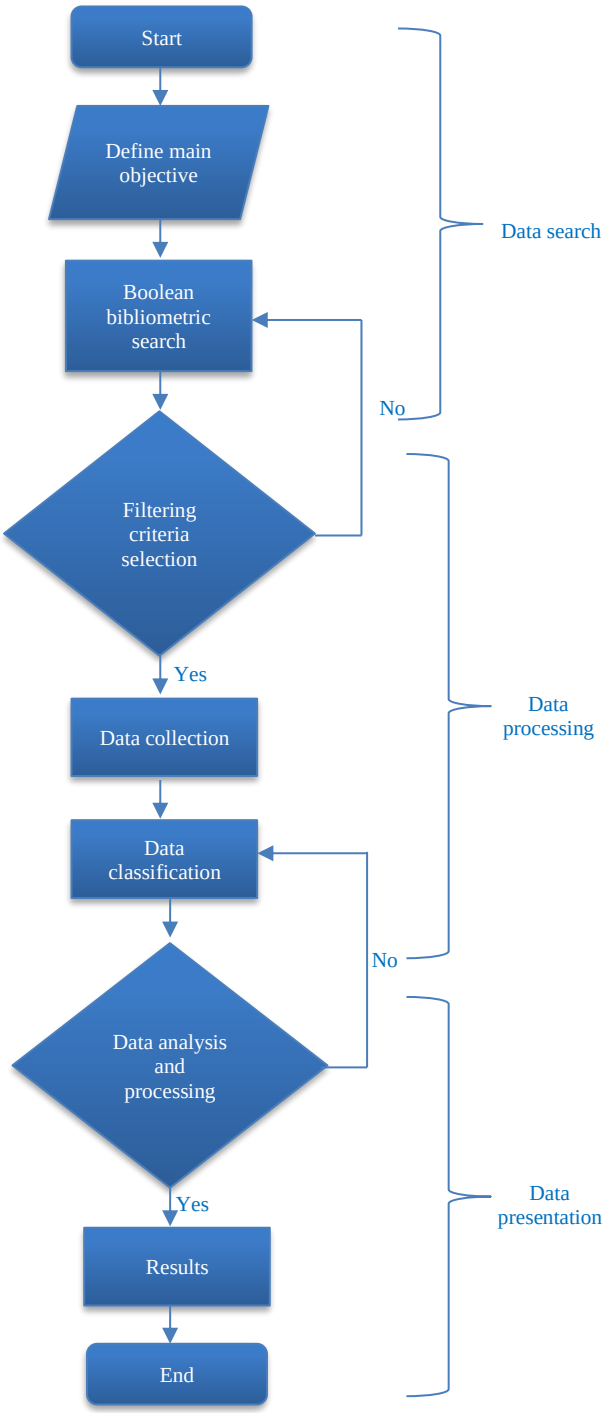

Fig. 1 Methodology flowchart

2.1.1. Data Search

Defining the main objective is a fundamental part of the beginning of any research study. Therefore, the search for the data in the Scopus database must be limited to Diabetic Retinopathy. In addition, this search should not be limited to a single discipline and should include areas such as medical sciences, image processing, and engineering.

2.1.2. Data Processing

For the second section, information processing will be described, starting with the specialized Boolean search in the settings section in Scopus[32–36]. This stage provides information according to the filters that are set; however, manually selecting the documents from the ones that comply with the parameters that we want to study and excluding the ones that do not is necessary, and also limiting the documents to Conference Paper, Review, Conference Review, Book Chapter, Editorial, Letter, Note Short Survey and Book, and discard the ones that do not follow the chosen discipline of study indicated in our main objective.

The documents taken for the data processing phase were of different types, but all of them are focused on DR and present solutions and ways for diagnosing the disease. The search for documents did not have a limitation on the language and were chosen from different fields of study and different disciplines [37], provided that they would present solutions and ways of diagnosing DR.

The time period taken for the present work is the years from 1950 to May 2023; from that interval, the number of documents per year was analyzed along with the data on most cited authors, countries that do the most research, number of documents by country or territory, number of publications by author, the journals with the most publications and their number of publications per year.

When previewing an incomplete result in Scopus, a Boolean criterion will be added or excluded in the Boolean formula described. On the other hand, a part of the information may be lost, so it is necessary to save some investigations manually. Finally, the .CSV and .BIB files are extracted to classify them in order of priority, year, journal, citations, and other information required for processing.

2.1.3. Data Presentation

The data processing for the present investigation will be carried out based on the R and Python languages with the Rstudio and Google Collaborate programs simultaneously.

Bibliometry with Rstudio

Rstudio is a free and open-source software tool that works with the R programming language for statistical computations and numerical analysis; it uses machine learning[36] to make predictions on the data that it is given and does data analysis to explore, model data and plot

graphs[39, 40]. RStudio Desktop is a desktop application, while RStudio Server can be accessed on a web browser. Biblioshiny is a web interface for bibliometrix that is installed as a package in RStudio, and it allows the conversion of the data to R programming language[25]. Bibliometrix works with data extracted from the main bibliographic databases, including Scopus. It allows a complete bibliometric analysis and the creation of different types of graphics.

Bibliometry with Google Colaborate

Python is a high-level object-oriented programming language. Since it is a general-purpose language, it can be used to perform a variety of different tasks, including conducting data analysis[41]. It is also the programming language used in Google Colaboratory, which is a tool based on machine learning that allows the user to edit and execute code for data analysis and graphs and combine it with images[42–44], HTML and LaTeX. Matplotlib is a library that can be added to Python via the package manager and can be used for plotting histograms, scatter plots and other graphs and interactive figures. Pandas is also a library in Python used for data analysis and numerical computing[45], [46]; it is free software a, one of the most popular Python libraries and can operate in a large dataset efficiently.

The years in the chosen period, the amount of scientific production during those years, authors and scientific journals from the bibliometric data were compared. The results will be presented in.SVG files or image formats as part of the results of this research.

3. Results

During the execution of the methodology, technical support from Scopus was needed to obtain bibliometrics.

3.1. Data Search

The data collection is based on the information of the main objective, which is based on the analysis of the most recent investigations of diabetic retinopathy, and the selection criteria are based on the different techniques for image processing in diabetic retinopathy, in addition to knowing what hardware [27] can be used to capture these images. The objective of the search was based on Diabetic Retinopathy, and all the emerging technologies in detecting this disease were reviewed, such as machine learning big data, among others. On the initial search, the total number of documents found was 3086773.

3.2. Data Processing

The selection criteria for the documents was based on the following algorithm:

(TITLE-ABS-KEY (diabetic and retinopathy) Y TITLE-ABS-KEY (diagnostic) O TITLE-ABS-KEY (machine and learning) O TITLE-ABS-KEY (machine and intelligent) O TITLE-ABS-KEY (neuronal and network) O TITLE-ABS-KEY (supervised and learning) O TITLE-ABS-KEY (deep and network) O TITLE-ABS-KEY (neural and networks And model) O TITLE-ABS-KEY (convolution) O TITLE-ABS-KEY (automat) O TITLE-ABS-KEY (unsupervised and clustering) O TITLE-ABS-KEY (big And data) O TITLE-ABS-KEY (natural and speech and process) O TITLE-ABS-KEY (robot) O TITLE-ABS-KEY (expert and system) O TITLE-ABS-KEY (hybrid and intelligent and system) O TITLE-ABS-KEY (diffuse and logic) O TITLE-ABS-KEY (random and forest) O TITLE-ABS-KEY (decision and making and tree) O TITLE-ABS-KEY (bayes) O TITLE-ABS-KEY (artificial and intelligence) O TITLE-ABS-KEY (thinking and computer and system) O TITLE-ABS-KEY (recursive and learning)).

It is important to mention that when selecting the keywords and getting the results of the search, it was necessary to discard some of the articles retrieved since they did not comply with the kind of information being looked for based on the objective of the present work. For example, when filtering the information with the names of electronic devices like Arduino or raspberry pi or with other keywords like phone cases, some of the results obtained were not taken for the number of articles studied since they did not include the topic of diabetic retinopathy in the information within the article.

It is for this reason that when selecting these systems, the following Boolean algorithm was considered: (TITLE-ABS-KEY (retinopathy AND diabetic) OR ABS (raspberry) OR ABS (arduino) OR ABS (design) OR ABS (pic) OR ABS (atmega) OR AUTHOR-NAME (esp32) AND TITLE-ABS-KEY (diagnostic) AND KEY(smartphone)).

All of this metadata was useful for the collection of the filtered information through manual selection and through the use of the tools provided by the Scopus interface. This metadata was stored in .CSV format and was processed using the software mentioned in the methodology section.

3.3. Data Presentation

With this segmented search, a total of 9610 articles were obtained. These articles were processed using Python and its libraries like pandas.lib and matplotlib on the Google Collaboratory platform. After processing, highly valuable information was obtained using that clean data as a base.

As part of the methodology, the processing of the 9610 scientific documents focused on finding the historical production of journals associated with diabetic retinopathy and their evolution through the years. It is important also to mention that the journals that were analyzed have a variation in their frequency of publication since some of them are published bimonthly, every six months or annually, something that favors other magazines.

Analyzing the data from articles on solutions and ways of diagnosing diabetic retinopathy allowed us to locate the moments during the chosen period of time in which the amount of scientific production (Fig. 2) on this topic was the lowest and when it was at its peak. The most prominent journals during this time were also compared. The years from 1950 to 1992 had the least scientific production during this period, with the British Journal of Ophthalmology being the leading journal during those years. From 1992, the number of publications started to increase, and by the year 2000, the investigations on the topic became more numerous.

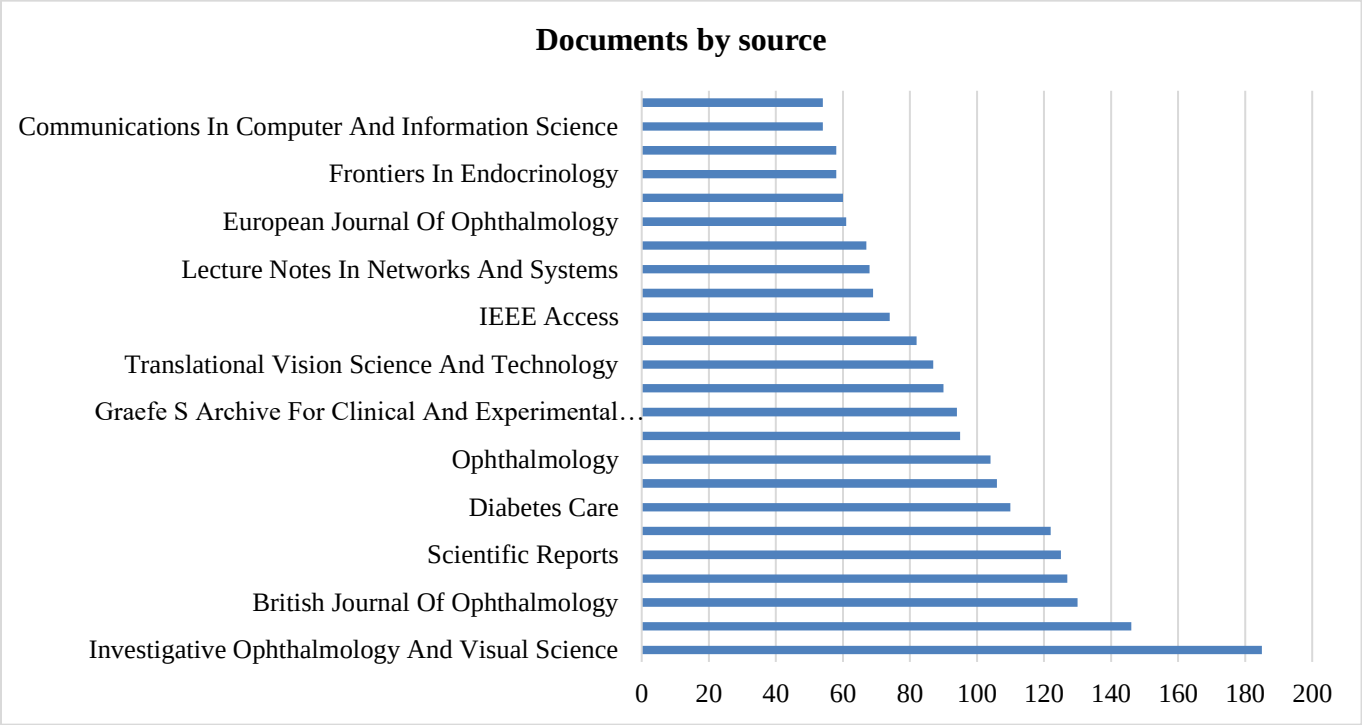

Fig. 2 Documents regarding methods of detection and diagnosis for diabetic retinopathy per year from 1950 to 2023 by source

However, in the year 2013, the number of publications and scientific production had a small decrease, being a year with fewer investigations on the topic than in previous years. Following this small decrease, the number of publications started to increase once more and reached an all-time high. From 2000, the number of journals researching solutions and ways of diagnosing diabetic retinopathy started to increase steadily, and the curve had an exponential rise. The sudden fall on the graph in the last year (Fig. 3) references the fact that the last year that was taken in the study is the current year 2023 until the month of May; in this current year, the production of scientific documents related to the topic of the present study has only reached 522, a remarkable number for the first part of the year.

The peak on the graph shows the production by the end of the previous year, 2022, with a total of 1451 scientific documents, nearly 98% of which cover the use of AI and other methods to detect diabetic retinopathy. On the other hand, the most significant coefficient of variation was seen on the graph in the years from 2013 to 2022, with a coefficient of variation of 0.6182684.

Taking all this into consideration, a low production was observed in 2013, which served as a starting point for bibliometric analyses regarding authors and keyword searches. Therefore, by contrasting the scientific production from 2013 to 2023 (Fig. 3), the image shows the scientific journal PLOSONE had a consistent growth in the field of diabetic retinopathy compared to other journals that exhibit some points in which the production decreases at some points over time. It is worth mentioning that in 2019, with the advancements in artificial intelligence, significant ideas for detection emerged, and these journals adopted these research studies for subsequent dissemination.

Fig. 2 and Fig. 4 show that they have multidisciplinary production since they have diverse research fields for detecting diabetic retinopathy. The comparison of the five selected journals with the highest publications historically and the number of scientific documents published according to the Boolean algorithm shows a prevalence in the year 2013. Therefore, this year will be considered a milestone for sampling authors and citations.

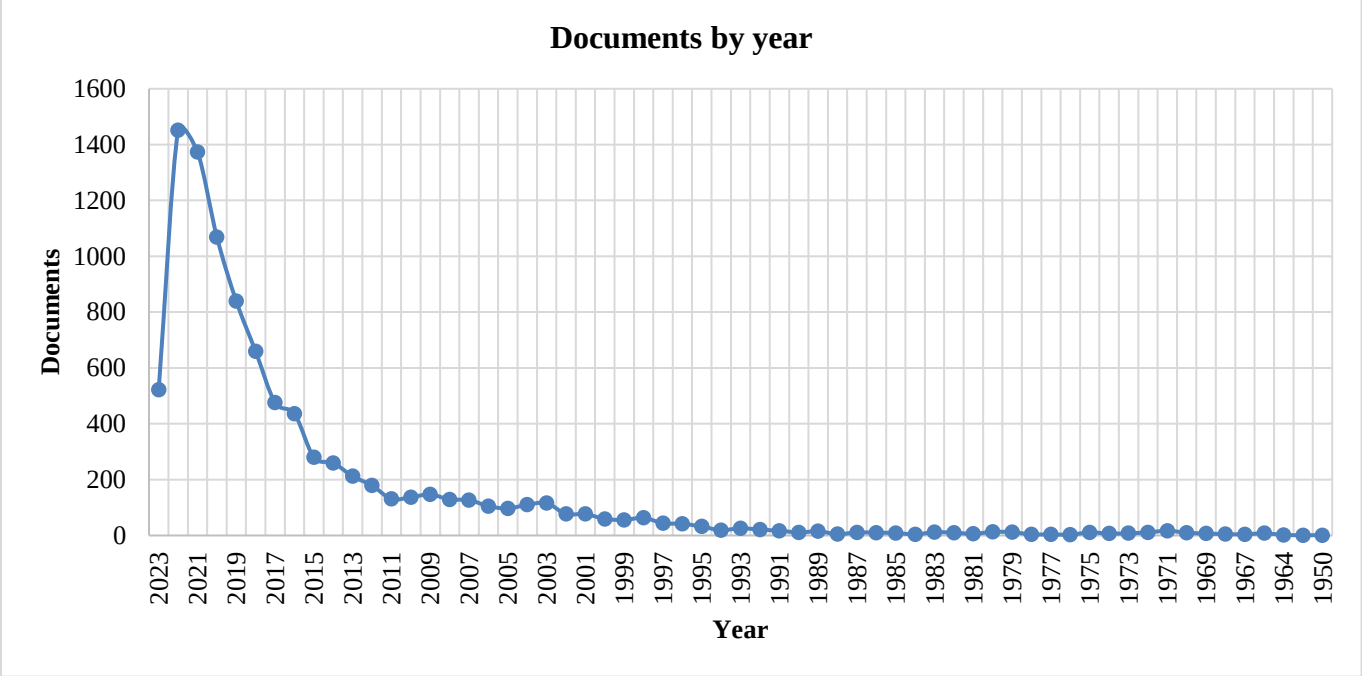

Fig. 3 Documents regarding methods of detection and diagnosis for diabetic retinopathy by year from 1950 to 2023

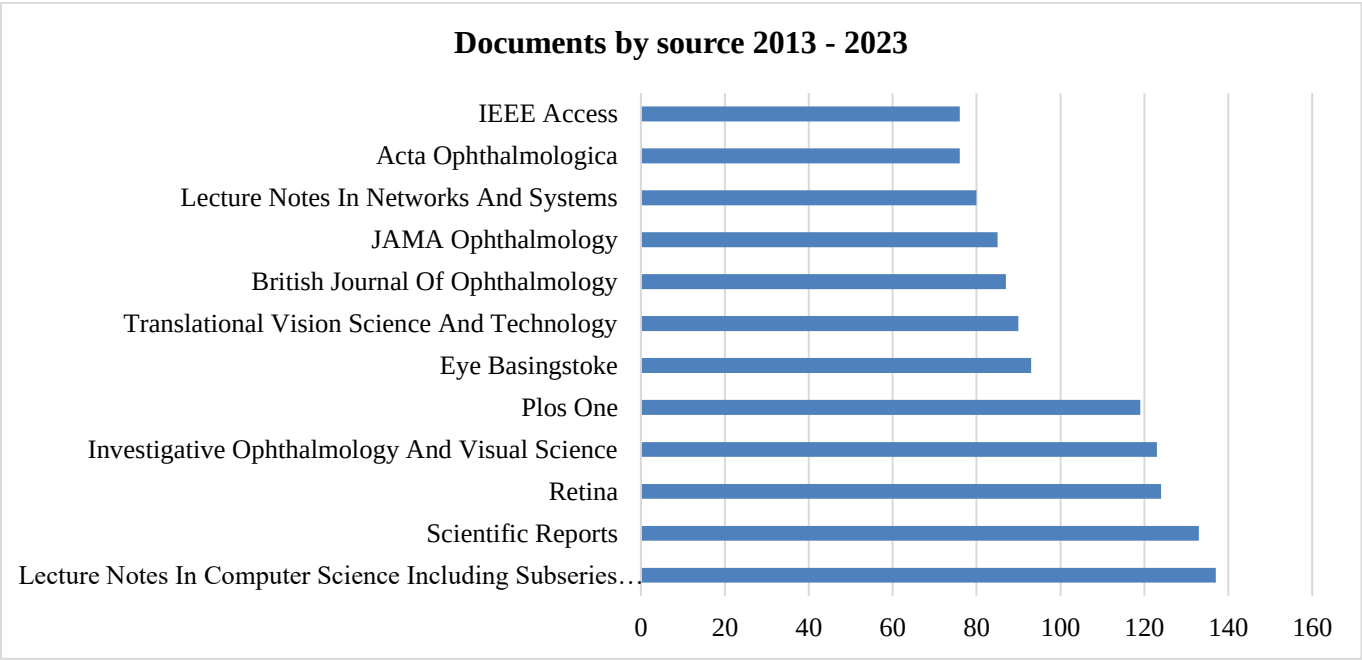

Fig. 4 Documents regarding methods of detection and diagnosis for diabetic retinopathy per year from 2013 to 2023 by source

Regarding TABLE1, which shows the DOCTYPES, although important scientific documents were considered, it should be noted that 0.2% consists of errata, retractions, and data papers, which are not of significant importance in the proposed review. In the field of research, conference papers are considered to have a lower level of depth on a topic. However, in the case of this research, as it involves image processing topics, researchers have a prevalence of presenting their advancements in the form of conferences. Presenting a conference paper as a precursor and following it with a scientific article indicates that the research follows a continuous line over time as an important topic within different affiliations, thus popularizing the dissemination of various diagnostic methods for diabetic retinopathy. The same applies to editorials and editor's notes.

Table 1. Number of each type of document used for the systematic review

Document Type	Number of results	Percentage
Article	6073	63.1%
Conference Paper	1658	17.3%
Review	1029	10.7%
Conference Review	172	1.8%
Book Chapter	169	1.8%
Editorial	163	1.7%
Letter	153	1.6%
Note	118	1.2%
Short Survey	40	0.4%
Book	14	0.2%

The information processing allowed the categorization of the surnames and pseudonyms of the authors in terms of publications on diabetic retinopathy. The most significant authors and their citation indices were analyzed.

The analysis reveals the territories that conducted the most research on diabetic retinopathy from 2013 to 2023. The diagram in Fig. 5 shows the top 15 countries, with India leading the list with 1643 documents, followed by the United States with 1459 documents, and China in third place with 1296 documents. In terms of countries with the highest number of publications since 1950, the United States takes the lead with 2005 documents, followed by India with 1709 documents. Unlike previous years, India has shown a significant increase in research density over the past 10 years, indicating progress and concern for the topic.

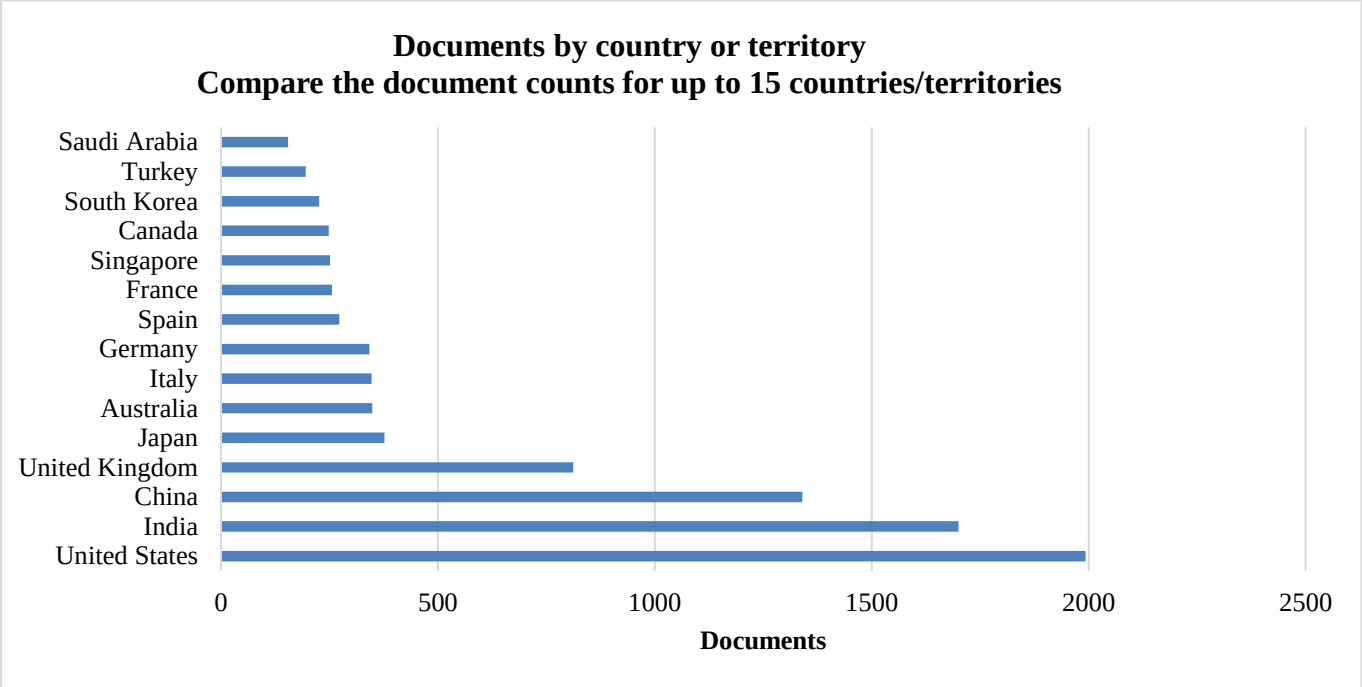

Fig. 5 Number of documents regarding methods of detection and diagnosis for diabetic retinopathy by country or territory

The authors with the most contributions were also analyzed (Fig. 6) during the time period from 2013 to 2023, taking the first 15 authors with the most documents published during that time. Most publications were done by Prof. Wong Tien Yin, Founding Head and Chair Professor at Tsinghua Medicine, who received clinical residency training in ophthalmology at the Singapore National Eye Center; his contribution in this time period adds up to 65 documents. In second place in the number of contributions is Prof. Sobha Sivaprasad, Honorary Professor at the Institute of Ophthalmology of University College London, since her documents published during this time add up to 54.

Regarding the keywords, the analysis of this information was approached using a co-occurrence analysis map (Fig. 7) that relates the occurrences of keywords with the titles composed of nodes and links representing their relationships. A more significant map emerges by combining the keywords with the titles and their occurrences, focusing on diabetic retinopathy, diagnosis, automatic detection, machine learning, and artificial intelligence.

Based on the merged stage of developing themes for capturing diabetic retinopathy and detection methods between 2013 and 2022, the co-occurrence analysis reveals a central node with 275 links, followed by deep learning with 197 nodal links. The density of the co-occurrence result is calculated to be 0.019 using a network layout called Fruchterman & Reingold, along with clustering using the walktrap method.

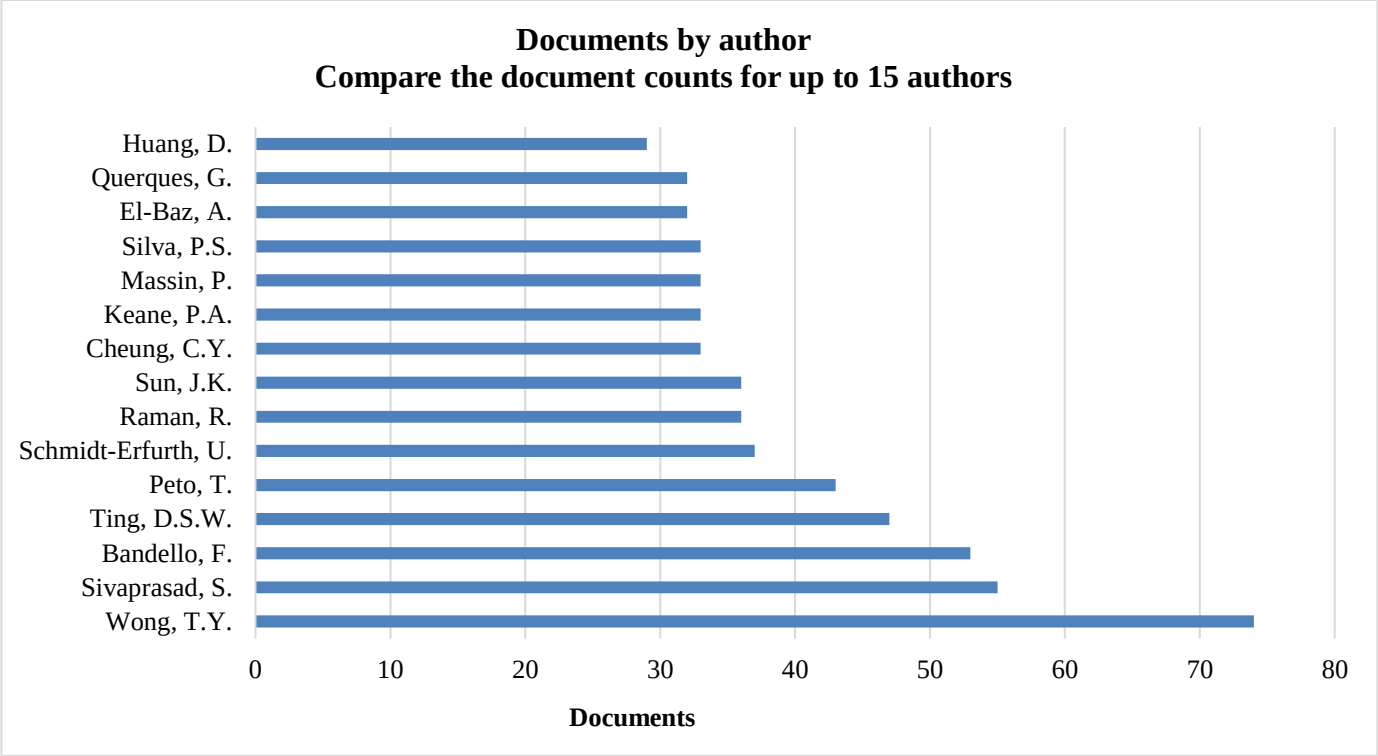

Fig. 6 Number of documents regarding methods of detection and diagnosis for diabetic retinopathy by author

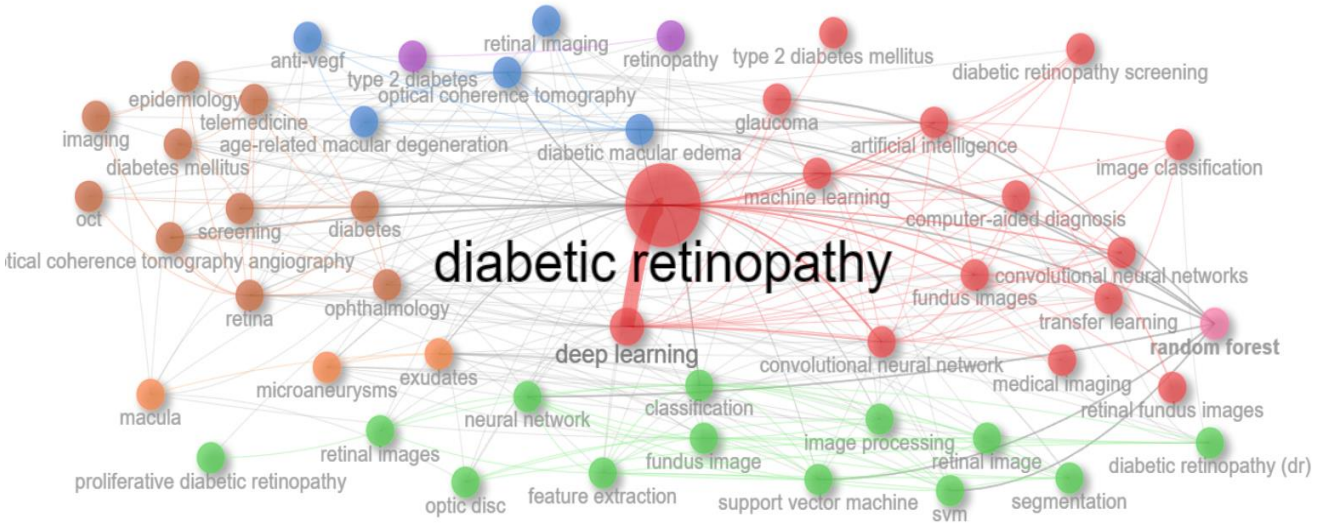

Fig. 7 Co-occurrence clustering network map of most used keyworks in documents regarding methods of detection and diagnosis for diabetic retinopathy

The co-occurrence clustering of titles and keywords allows us to analyze trends in the areas of diagnosis. For example, the 98 nodes of "type 2 diabetes" show a strong relationship with the detection of diabetic retinopathy, indicating that research related to diabetic retinopathy deals with current methods like neural networks for diagnosis.

It is worth mentioning that the overall co-occurrence pair of the initially extracted data showed a high density of keywords and relationships between the years 2015 and 2022. Therefore, considering this map with data from 1950 to 2022 would not provide visible and significant information for the present study's analysis.

In the figure, purple matching words such as "type 2 diabetes," "retinopathy," and "random forest" stand out. These words have diversified links with other areas, such as methods for diagnosing diabetic retinopathy, epidemiology, or telemedicine. However, words like "low cost," "prototype," or "hardware development", such as the use of microcontrollers, Raspberry Pi, or webcams, are not observed.

Lastly, the journals and trends in subject areas were processed (figure: subject area) and classified. The areas of medicine, computer science, and engineering stand out, accounting for over 63% of the documents related to diabetic retinopathy, its diagnosis, and methods of capturing fundus images. It is worth mentioning that these values are significant as they are evaluated by Scopus and include updated quartile information according to Scimago. However, many journals have the multidisciplinary category, and the information is increased in terms of the percentage by research area. The documents also receive a label from Scopus indicating the corresponding area, which is the basis for the development of Table 2.

Table 2. Number of documents used for the present systematic review by subject area

Subject Area	Number of Documents	Percentage
Medicine	6151	31.6%
Computer science	2735	18.4%
Engineering	1975	13.0%
Biochemistry, Genetics and Molecular Biology	1291	7.1%
Neuroscience	869	4.4%
Mathematics	715	4.8%
Physics and Astronomy	534	3.5%
Health Professions	426	2.4%
Decision Sciences	393	2.8%
Materials Science	361	2.3%
Other	932	9.7%

A random selection of 50 documents was read to ensure the search focused on the methodology's main objective. The reading of 50 articles out of a total of 9610 provides a margin of error according to EQUATION 1 of 11.6012%, considering a confidence level of 90%. This is due to the inclusion of some studies in languages such as Chinese and Korean, which can make understanding their results somewhat challenging when translated.

$$EM = Z\gamma * \sqrt{\frac{p(1-p)}{n}} * \sqrt{\frac{N-n}{N-1}}$$

Where:

- $Z\gamma =$ Score standard
- $p =$ Proporción de observaciones positivas.
- $N =$ Tamaño de la población.
- $n =$ Tamaño de la muestra.

As a result of the reading phase, the use of machine learning and artificial intelligence for the detection and classification of Diabetic Retinopathy (DR) stands out. Among the methods found, image processing was used to detect microinfarctions in the retinal [26] veins, and the search for abnormalities based on diagnosed images was one of the most prominent ones. Regarding methods for obtaining fundus images, only a few prototypes that utilize smartphones or digital cameras for capturing fundus images were found.

4. Discussion

The number of documents published on RD, as provided by the Scopus database, allowed for the analysis of the chosen documents. However, the research should be based solely on articles for future work. The decision to include a significant portion of manuscripts was to gain an understanding of the general idea of diabetic retinopathy detection methods and image capture techniques of the fundus of the eye for the same purpose. Examining the historical production of published documents over the years provides an overview of the evolution in the field of research on diabetic retinopathy. However, the latest findings offer greater resolution and significant advancements.

Machine learning has become one of the main tools for diagnosis due to the continuous specialization and further research on the topic, as evidenced by the analysis of the 9610 documents. In reference [11], which examined 1770 scientific articles to explore the relationship between artificial intelligence and DR, a significant interest in detecting and diagnosing DR using new trends and models was found, similar to the present study. However, quantifying other types of documents supports the development of future research. Artificial intelligence facilitates detection, classification, and diagnosis, but it is also important to consider methods for capturing images of the fundus of the eye.

Similarly, in reference [23], Bibliometrix is used to analyze 931 articles, highlighting Chinese research on diabetic retinopathy, where the trend is to use artificial intelligence to diagnose and classify the disease. However, since it does not include other types of documents, it emphasizes that the countries with the highest production are the United States and England. Our results, on the other hand, show that India and the United States are the leading countries. This suggests that India may be publishing initial scientific documents in the form of conferences and books to utilize AI to support the development in the field of research on diabetic retinopathy.

Furthermore, Artificial Intelligence (AI) faces the challenging task of capturing and processing images of the fundus of the eye. Therefore, in reference[24], they switch to the use of convolutional networks to combine Xception and ResNet-50 models with an accuracy of 83%. These classifications are highly relevant due to the results and the interest they generate in classifying the different levels of diabetic retinopathy.

While bibliometric reviews are expected to maintain a neutral character in terms of document search, this study conducted a reading to understand not only the trends in DR research through co-occurrence analysis but also to gain insights into future research directions. The predominant trend in DR research is using image processing methods for classification. However, very few studies focused on low-cost methods for image acquisition. The lack of technical feasibility in capturing fundus images or the absence of new methods for

detecting diabetic retinopathy without using ophthalmoscopy limits the classification and detection methods to process the same set of images or employ data augmentation techniques to train their models.

Promoting the use of smartphones for capturing fundus images significantly reduces costs compared to high-cost equipment such as digital ophthalmoscopes or pupil dilation methods for DR screening. However, a noteworthy aspect regarding image capture is the trend of holding the capturing device, often a smartphone, with bare hands. This introduces a potential source of error due to hand vibrations, leading to blurry images. The presence of disturbances such as natural hand vibrations or dirty smartphone lenses are variables that should be considered in future research, as they were not addressed in the documents collected for this study.

5. Conclusion

The trends of using artificial intelligence and machine learning are evident in current research. Improving healthcare through robust image processing tools and technology capable of automatically diagnosing diabetic retinopathy has gained significant attention. There has been a notable increase in high-impact research publications related to bibliometric reviews and systematic reviews. This study aimed to add value by including other types of documents, such as initial projects and preliminary studies, to provide a deeper understanding of methods and techniques for diabetic retinopathy. A quantitative approach was used to evaluate 9610 articles, identifying countries, document types, authors, and co-occurrences, which yielded relevant documents and valuable insights into research technologies. Despite the significant research advancements in diabetic retinopathy, low- and middle-income countries are prevalent with limited scientific output, indicating potential challenges and opportunities for applying new diagnostic methods for DR in these regions, which are currently experiencing rapid development. It is worth noting that document production has increased in countries like India and China. Using Scopus as a data collection database provided easy access and quick response time when retrieving information. Python and RStudio, on the other hand, possess the necessary robustness to analyze trends and process bibliometric information in the current research. Few results were found regarding methods for capturing images of the fundus of the eye and DR. The use of smartphones for image capture is the most common technique in support of this research. Countries like India and other Latin American countries stand out regarding their research contributions in DR and the use of tools such as microcontrollers or cameras. There is a need for more research in developing countries to evaluate the impact of tools such as AI, machine learning, and the use of cameras or techniques for efficient image capture and processing. Issues such as the lack of fundus images for training new methods and the direct relationship between prototypes and validation of devices, such as ophthalmoscopes, in DR research are also highlighted.

The present research serves as a starting point to understand the reality of detecting and diagnosing diabetic retinopathy. It proposes the use of machine learning methods for DR classification and the creation of prototypes of a device for capturing images of the fundus of the eye. This includes considering variables such as luminosity, stability for the physical support for the head and image capture device, as well as methods and techniques for capturing sharp images. Future work also includes creating physical support that allows the physician to place the patient in front of a lens through which the image of the fundus of the eye will be taken using a device like a smartphone to capture the image. This support will ensure that the image capture has stability, resulting in a good image quality with the least amount of movement or shaking that could cause distortion.

References

[1] George L. Bakris et al., "Effect of Finerenone on Chronic Kidney Disease Outcomes in Type 2 Diabetes," *The New England Journal of Medicine*, vol. 383, no. 23, pp. 2219–2229, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[2] Thippa Reddy Gadekallu et al., "Early Detection of Diabetic Retinopathy using PCA-Firefly based Deep Learning Model," *Electronics*, vol. 9, no. 2, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[3] Alan W. Stitt et al., "The Progress in Understanding and Treatment of Diabetic Retinopathy," *Progress in Retinal and Eye Research*, vol. 51, pp. 156–186, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[4] Feng Li et al., "Deep Learning-Based Automated Detection for Diabetic Retinopathy and Diabetic Macular Oedema in Retinal Fundus Photographs," *Eye*, vol. 36, no. 7, pp. 1433–1441, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[5] N. Gundluru et al., "Enhancement of Detection of Diabetic Retinopathy using Harris Hawks Optimization with Deep Learning Model," *Computational Intelligence and Neuroscience*, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[6] Prawej Ansari et al., "Diabetic Retinopathy: An Overview on Mechanisms, Pathophysiology and Pharmacotherapy," *Diabetology*, vol. 3, no. 1, pp. 159–175, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[7] M. Kropp et al., "Diabetic Retinopathy as the Leading Cause of Blindness and Early Predictor of Cascading Complications-Risks and Mitigation," *EPMA Journal*, vol. 14, pp. 21–42, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[8] Srikanta Kumar Padhy et al., "Artificial Intelligence in Diabetic Retinopathy: A Natural Step to the Future," *Indian Journal of Ophthalmology*, vol. 67, no. 7, pp. 1004-1009, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[9] Tahmina Nasrin Poly et al., "Artificial Intelligence in Diabetic Retinopathy: Bibliometric Analysis," *Computer Methods and Programs in Biomedicine*, vol. 231, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[10] Andrzej Grzybowski et al., “Artificial Intelligence for Diabetic Retinopathy Screening: A Review,” *Eye*, vol. 34, no. 3, pp. 451–460, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[11] Liu Chun, Jian Wenyuan, and Duan Junguo, "Bibliometric Analysis of Artificial Intelligence in Diabetic Retinopathy," *Chinese General Practice*, vol. 26, no. 15, pp. 1847-1856, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[12] R. R. A. Bourne et al., "Causes of Blindness and Vision Impairment in 2020 and Trends Over 30 Years, and Prevalence of Avoidable Blindness in Relation to VISION 2020: The Right to Sight: An Analysis for the Global Burden of Disease Study," *The Lancet Global Health*, vol. 9, no. 2, pp. e144–e160, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[13] Mohammad Z. Atwany, Abdulwahab H. Sahyoun, and Mohammad Yaqub, "Deep Learning Techniques for Diabetic Retinopathy Classification: A Survey," *IEEE Access*, vol. 10, pp. 28642–28655, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[14] Zengqiang Yan, Xin Yang, and Kwang-Ting Cheng, "Joint Segment-Level and Pixel-Wise Losses for Deep Learning based Retinal Vessel Segmentation," *IEEE Trans Biomed Eng*, vol. 65, no. 9, pp. 1912–1923, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[15] V. Banupriya, and S. Anusuya, "Improving Classification of Retinal Fundus Image using Flow Dynamics Optimized Deep Learning Methods," *SSRG International Journal of Electrical and Electronics Engineering*, vol. 9, no. 12, pp. 39-48, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[16] G. U. Parthasharathi et al., "Diabetic Retinopathy Detection using Machine Learning," *Journal of Innovative Image Processing*, vol. 4, no. 1, pp. 26–33, 2022. [CrossRef] [Publisher Link]

[17] Nasmin Jiwani, Ketan Gupta, and Neda Afreen, "A Convolutional Neural Network Approach for Diabetic Retinopathy Classification," *Proceedings IEEE 11th International Conference on Communication Systems and Network Technologies*, pp. 357–361, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[18] Alva Mantari Alicia et al., "Abnormal Pulmonary Sounds Classification Algorithm using Convolutional Networks," *International Journal of Advanced Computer Science and Applications*, vol. 12, no. 6, pp. 408–415, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[19] Shaohua Wan, Yan Liang, and Yin Zhang, "Deep Convolutional Neural Networks for Diabetic Retinopathy Detection by Image Classification," *Computers and Electrical Engineering*, vol. 72, pp. 274–282, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[20] Sweta Bhattacharya et al., "Deep Learning and Medical Image Processing for Coronavirus (COVID-19) Pandemic: A Survey," *Sustainable Cities and Society*, vol. 65, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[21] Sehrish Qummar et al., "A Deep Learning Ensemble Approach for Diabetic Retinopathy Detection," *IEEE Access*, vol. 7, pp. 150530–150539, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[22] H. Xiao et al., "Global Trends and Performances in Diabetic Retinopathy Studies: A Bibliometric Analysis," *Front Public Health*, vol. 11, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[23] Chun-Ling Lin, and Kun-Chi Wu, "Development of Revised ResNet-50 for Diabetic Retinopathy Detection," *Research Square*, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[24] Tahmina Nasrin Poly et al., “Artificial Intelligence in Diabetic Retinopathy: Bibliometric Analysis,” *Computer Methods and Programs in Biomedicine*, vol. 231, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[25] Wasi Yazdani, Mohd Shamim Ansari, and Lamaan Sami, "A Bibliometric Analysis of Mandatory Corporate Social Responsibility using Rstudio: Based on Scopus Database," *International Journal of Professional Business Review*, vol. 7, no. 6, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[26] S. Deepa, and S. Vijayprasath, "Certain Investigation of the Retinal Hemorrhage Detection in Fundus Images," *SSRG International Journal of Electronics and Communication Engineering*, vol. 2, no. 2, pp. 24-34, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[27] Sebastian Ramos-Cosi, and Natalia I. Vargas-Cuentas, "Prototype of a System for Quail Farming with Arduino Nano Platform, DHT11 And LM35 Sensors, in Arequipa, Peru," *International Journal of Emerging Technology and Advanced Engineering*, vol. 11, no. 11, pp. 140–146, 2021. [CrossRef] [Publisher Link]

[28] Jia-Heng Zhang et al., "A Bibliometric Analysis of Apoptosis in Glaucoma," *Front Neuroscience*, vol. 17, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[29] Ning Zhu, Bingwu Huang, and Liuyan Zhu, "Bibliometric Analysis of the Inflammation in Diabetic Cardiomyopathy," *Front Cardiovascular Medicine*, vol. 9, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[30] Dmytro Pavlenko, "Analysis of Scientific Literature on Teleophthalmology using a Bibliometric Approach," *European Journal of Ophthalmology*, vol. 33, no. 3, pp. 141-142, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[31] Hafizah Omar Zaki et al., "Virtual Reality in Digital Marketing: Research Agenda based on Bibliometric Reflection," *Marketing Intelligence and Planning*, vol. 41, no. 4, pp. 505-524, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[32] Parul Datta, Abhishek Kumar, and Prasenjit Das, "A Bibliometric Survey of Diabetic Retinopathy Research in the Last Decade," *International Conference on Artificial Intelligence and Smart Communication*, pp. 146–150, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[33] An Shao et al., "Overview of Global Publications on Machine Learning in Diabetic Retinopathy from 2011 to 2021: Bibliometric Analysis," *Front Endocrinol*, vol. 13, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[34] Khaled Elubous et al., "Teleophthalmology Research: Where do we Stand?," *European Journal of Ophthalmology*, vol. 33, no. 1, pp. 74–82, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[35] S. Fowjiya, M. Karnan, and R. Sivakumar, "An Automatic Detection and Assessment of Diabetic Macular Edema Along with Fovea Detection from Color Retinal Images," *International Journal of Computer & Organization Trends*, vol. 3, no. 1, pp. 49-53, 2013. [Google Scholar] [Publisher Link]

[36] Huan Xiao et al., "Global Trends and Performances in Diabetic Retinopathy Studies: A Bibliometric Analysis," *Front Public Health*, vol. 11, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[37] Abidin Kemeç, and Ayşenur Tarakcıoglu Altınay, "Sustainable Energy Research Trend: A Bibliometric Analysis Using VOSviewer, RStudio Bibliometrix, and CiteSpace Software Tools," *Sustainability*, vol. 15, no. 4, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[38] Zaid Sanchez et al., "An Algorithm for Characterizing Skin Moles using Image Processing and Machine Learning," *International Journal of Electrical and Computer Engineering*, vol. 11, no. 4, pp. 3539–3550, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[39] G. Thippa Reddy et al., "Analysis of Dimensionality Reduction Techniques on Big Data," *IEEE Access*, vol. 8, pp. 54776–54788, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[40] Muneer M. Alshater et al., "Influential and Intellectual Structure of Islamic Finance: A Bibliometric Review," *International Journal of Islamic and Middle Eastern Finance and Management*, vol. 14, no. 2, pp. 339–365, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[41] Valentin Heimhuber et al., "InletTracker: An Open-Source Python Toolkit for Historic and Near Real-Time Monitoring of Coastal Inlets from Landsat and Sentinel-2," *Geomorphology*, vol. 389, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[42] Masanori Kuroki, "Using Python and Google Colab to Teach Undergraduate Microeconomic Theory," *International Review of Economics Education*, vol. 38, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[43] Joe Llerena-Izquierdo, and Loqui-Larroza Sherry, "Combining Escape Rooms and Google Forms to Reinforce Python Programming Learning," *Smart Innovation, Systems and Technologies*, vol. 252, pp. 107–116, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[44] William Vallejo, Carlos Díaz-Uribe, and Catalina Fajardo, "Google Colab and Virtual Simulations: Practical e-Learning Tools to Support the Teaching of Thermodynamics and to Introduce Coding to Students," *ACS Omega*, vol. 7, no. 8, pp. 7421–7429, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[45] G. Thippa Reddy et al., "Analysis of Dimensionality Reduction Techniques on Big Data," *IEEE Access*, vol. 8, pp. 54776–54788, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[46] Ashwin Pajankar, "Visualizing Data with Pandas and Matplotlib," *Hands-on Matplotlib*, Apress, pp. 211–241, 2022. [CrossRef] [Google Scholar] [Publisher Link]