Optic Disc Detection in Fundus Eye Images – A Detailed Survey

Prakash. J[1], Vinoth Kumar. B[2]
{[1]jpk.cse@psgtech.ac.in, [2] bvk.it@psgtech.ac.in}

[1] *Department of Computer Science & Engineering, PSG College of Technology,* [2]Department of Information Technology, PSG College of Technology, india.

Abstract. Detection of Optic Disc is an important task in the automatic retinal disease screening system. From the literature, it is identified that diabetic retinopathy is the main reason for blindness among working people especially aged people. Identifying and curing diabetic retinopathy at the earlier stages may prevent the cause of blindness among people. In this paper, a detailed survey involving the various techniques in optic disc detection like Morphological Operation Technique, Hough transform Technique, Evolutionary computing technique, and Machine learning technique are made from various literature works. This paper also discusses the various publicly available dataset that could be useful in assessing the performance of the various techniques. It also discusses the result obtained from the various methods proposed by different scholars in this domain and emphasize the enhancement obtained by them.

Keywords: Optic disc, Morphological operation, Hough transform, Evolutionary computing technique, Machine learning, soft exudates, hard exudates.

1 Introduction

The international diabetic federation shows that with around 422 million population (World Health Organization Global Report on Diabetic, 2016), where One out of Eleven has diabetic retinopathy. People who have diabetes will have diabetic retinopathy. The southern part of India has around 12.2 % to 18.03 % of the population already has diabetes. It's estimated that in Chennai 28.2 % of the people have diabetes. Diabetes mellitus is a term used by doctors to describe a set of metabolic disorders in which a person has excessive blood sugar levels due to insufficient insulin production or a failure of the body's cells in responding effectively to insulin. The rates of diabetes mellitus were found to be higher in males (53.4%) than females (46.6%) in the Coimbatore zone, according to the research (Scholars Research Library).

Diabetes retinopathy is because of the side-effect of prolonging diabetes, which is related to the human eye. The launch point for ganglion cell axons leaving the eye is called the optic nerve head or optic disc as shown in figure 1.1. The dampening of blood vessels is because of an increase in sugar level which results in blood leakage or fluid substance deposited under macular edema termed as exudates. Exudates are divided into two major types: Soft exudates and Hard exudates as shown in figures 1.2 and 1.3 respectively.

Diabetic retinopathy is due to the formation of exudates. Diabetic retinopathy is classified into two types as Proliferative Diabetic retinopathy and non-Proliferative diabetic retinopathy,

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where the Non-Proliferative diabetic retinopathy is known as the phase without any abnormal vessel growth which directs to the blood vessel swelling termed as a microaneurysm. Therefore, the blood vessels give away the fluids which will deposit under the macular edema to form hard exudates.

Based on the retina findings, the retina is classified as early stage (which has only one or two microaneurysms), moderate stage (multiple microaneurysms and venous bleeding), and severe stage (venous bleeding and intra-retinal microvascular abnormalities). Around 75 % of people are affected by Proliferative Diabetic Retinopathy.

Hard exudates are appearing similar to optic disc which looks in bright yellowish color. In order to detect hard exudates, the optic disc must be removed from the retinal image. As a result, one of the most essential procedures in the identification of exudates is the removal of the optic disc [1][5][6]. The major stages in the automatic detection method of optic disc [21] are pre-processing, feature extraction, segmentation of optic disc, and elimination of optic disc. The main goal of the paper is to review popularly used algorithm for detecting optic disc in an eye fundus image. Literature discloses that the various soft computing methods are applied in many scenarios as image processing application and prediction [24-27].

The remainder of this work is arranged as follows: the following section discusses retinal image processing for optic disc removal. Various dataset available in literature in Section 3, A survey on Optic disc Detection on Morphological operation, Hough Transform, Machine Learning, Evolutionary computing technique and classification are given in section 4. followed by the section 5 on performance analysis and the final thought and future works is summarized at Conclusion part 6.

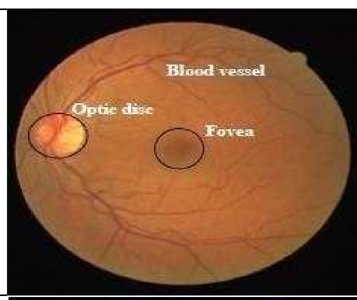

Fig 1.1- Eye fundus image with optic disc and fovea

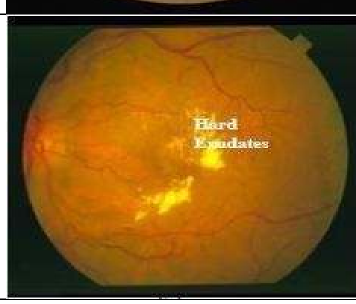

Fig 1.2- Eye fundus image with Hard Exudates

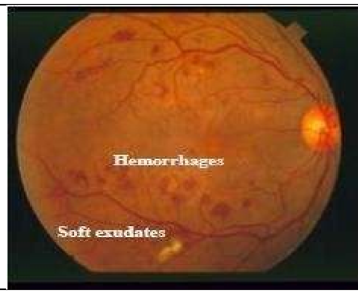

Fig:1.3- Eye Fundus image with soft exudates

Retinal Image Processing For Optic Disc Elimination

Retinal image processing is done to spot the eye fundus images optic disc, as shown in figure 2.1. At first input image is taken from retinal datasets. Here different datasets such as Stare dataset, Drive dataset, Roc dataset, ImageRet Dataset, Messidor dataset, etc., shall be used for retinal image processing. After the image is taken from Dataset, then retinal image processing is done by filtering the eye fundus image and resizing the eye fundus image. Different kinds of filters like Median filter, Green filter, Matched Filter, Gaussian filter, Gabor Filter can be used for image enhancement. Then the edges are Detected by using Edge Detect. Some of the edge detectors that are commonly used in Optic Disc Detection are Simple, Canny, and Prewitt edge detectors. The next process is Retinal Feature Extraction through morphological operation and Hough transform. future Optimization of Optic Disc Detection is done to detect optic disc in less computational time by Particle Swarm Optimization (PSO), Genetic Algorithm (GA), and Differential Evolution (DE). Finally, performance evaluation is done by determining the accuracy of the correctly detected optic disc of the fundus eye image. As a result, the optic disc will be obtained by retinal image processing.

Pre-processing is done to improve the image details. The images are improved by suppressing unwanted distortion or by enhancing their features. The objective of the preprocessing is to remove noise, equalization, and enhancement of image contrast. The noise removal can be done using filtering methods such as median, Wiener, and Gaussian. Image illumination and contrast can be improved by using the Contrast stretching technique. In the mean filtering method, the pixel value is exchanged with the average of the pixels in a processing window, whereas in the median filtering method, the median value of the adjacent pixels is replaced instead of the pixel value in a processing window. However, the median filter is preferred more over the mean filter [15].

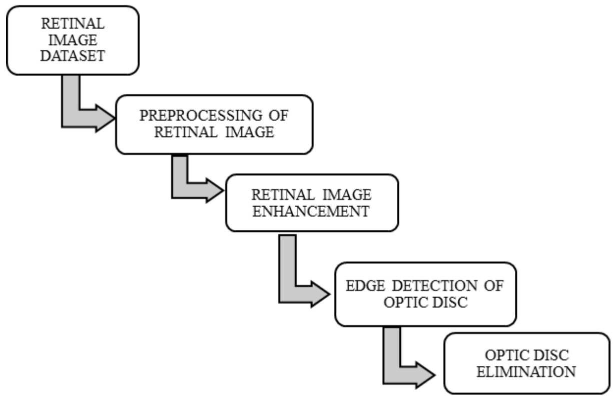

Fig. 2.1 Retinal Image Processing for Optic Disc Detection

Publicly Available Dataset

The description of the publicly available eye image databases is described in this section.

A. DRIVE Dataset

The Digital Retinal Images for Vessel Extraction (DRIVE) dataset [14] [1] [7] has around 40 images, out of which 7 images have pathologies such as exudates and hemorrhages. The size of the images is 768 × 584 pixels with all images are compressed to the JPEG format. Each image has taken by the Canon CR5 camera which is placed at an angle of 45-degree view with a diameter of 540 pixels. Among 40 images present in the dataset, 20 of the images shall be used for training purposes while the remaining 20 images can be used for the process of testing.

B. STARE Dataset

The STARE database [4] consists of 20 images, in which 10 images have pathologies such as exudates and hemorrhages. The size of the images is 605 × 700 pixels. Every image has taken at the 35-degree field of view with 650 × 500 pixels. Ground truth is available with this database.

C. ARIA Dataset

The ARIA ONLINE database [16] consists of the 3 groups; the first group consists of 92 images which are taken from aged people; the second group consists of 59 images that have pathologies such as exudates and hemorrhages, and the third group consists of 61 images which have pathologies such as exudates and hemorrhages. Ground truths given by experts are available with this database.

D. IMAGERET Dataset

The IMAGERET database consists of two sub-databases, DIARETDB0[2][6] and DIARETDB1[1][6][23]. DIARETDB0 has 130 images of which 20 are normal images and the remaining have pathologies such as exudates and hemorrhages. DIARETDB1has 89 images, in which 5 images are normal and the remaining have pathologies such as exudates. The size of the DIARETDB1 images is 1500 × 1152 pixels with all images are compressed to PNG format. Every image has taken by Canon CR5 camera at a 45-degree field of view.

E. ROC Dataset

The ROC MICRO ANEURYSM dataset comprises 100 images, out of which 50 images can be taken for training purposes and the other 50 images can be used for testing. The image size of the images in the dataset are 768 × 576, 1058 × 1061, and 1389 × 1381 pixels with all images are compressed to JPEG format. Every image has taken by Canon CR5 camera with a 45-degree field of view.

F. VICAVR Dataset

The VICAVR database contains 58 images, each of size of 768 × 584taken by Topcon camera NW-100 model. This database has its ground truth given by three experts.

G. MESSIDOR Dataset

The MESSIDOR DATABASE [10] [3] contains 1200 images in the dataset, out of which around 800 images are taken from the dilated eye. The database images are taken by a 3CCD camera at an angle of 45-degree view with the size of 2304 × 1536, 2240 × 1488, or 1440 × 960 pixels, and all images are compressed in TIFF format.

TABLE I DATA SET DESCRIPTION

S.NO	Dataset	No of Images	Description
1	DRIVE	40	The size of the images is 768 × 584 pixels with all images in the dataset are compressed to JPEG format.
2	STARE	20	The size of the images is 605 × 700 pixels with every image has taken at the 35-degree field of view with 650 × 500 pixels.
3	ARIA	212	The dataset consists of the 3 groups with ground truths given by experts
4	IMAGERET DATASET	219	The images of this dataset have taken by Canon CR5 camera at a 45-degree field of view
5	ROC MICROANEURYSM	100	The sizes of the images are 768 × 576, 1058 × 1061, and 1389 × 1381 pixels with all images are compressed to JPEG format.
6	VICAVR	58	The image size is 768 × 584 taken by the Topcon camera NW-100 model.
7	MESSIDOR	1200	The image size is 2304 × 1536 with the images are taken using the 3CCD camera at a field view of 45-degree.

Optic Disc Detection

H. The optic disc elimination shall be performed using the following four ways, which include morphological operation, Hough transform, Machine learning, and Evolutionary computing techniques.

I. Morphological Operation

J. The morphological operation helps to discover the new relationship or configuration which may not be so evident or which extracts the image component based on binary object value using the logical operation. Morphology is the wide group of operations for image processing, which are being processed based on shapes. Morphological operation is the extraction of features from the image. Dilation adds the pixel to the boundaries of the image. Erosion removes the pixel on the object boundaries of images and the number of pixels added or removed is based on size and structuring.

K. The below Table.II shows the various study on morphological operation in optic disc detection. It is inferred that most of the researchers find the optic disc using the morphological operation that uses erosion and dilation. Dilation expands the desired object and finds a local maximum operator. Erosion shrinks the desired object and finds the local Minimum Operator. Thus, we can use both the local Maximum Operator and Local Minimum Operator to find Morphological gradient from this gradient we can find the optic disc.

L. *Hough Transform*

M. Hough transform is a universally used technique nowadays. In an automated analysis of image due to the imperfection either in image data or either edge detection, the Hough transform method is efficient in finding an optic disc in an imperfect eye fundus image. The technique is used in the extraction of features for the image application. Generally, this technique is used in identifying the lines that are there in an image and to identify the arbitrary shapes and their positions in an image.

N. The below Table.III shows the various study on Hough transforms in optic disc detection. From these studies, it is concluded that by applying the circular Hough transform on an imperfect image input eye fundus image, we may locate the optic disc.

TABLE III SURVEY OF OPTIC DISC DETECTION USING MORPHOLOGICAL OPERATORS

Author	Year	Description	Merits	Demerits
Akyol et al.,	2016	The author proposed a method for an accurate and efficient optic disc segmentation of retinal images which have lesions and noise.	Automatic optic disc segmentation is Robust and effective, fairly reliable	Due to the number of key points presents in the analysis region it takes a long computational time
Karunanayake et al.,	2015	A method has been proposed for partitioning of the optic disc using mathematical morphological operations and histogram specification, which includes dilation and erosion with appropriate thresholding and circles detection using the Hough Transform technique.	This method is Reliable	Takes longer computational Time
Marin et al.,	2014	An approach for providing higher accuracy of optic disc center location is proposed.	Better overall performance in searching the optic disc	-
Wisaeng et al.,	2014	An approach is proposed to detect the optic disc in eye images which have poor quality.	Though the optic disc boundary are not blurred and continuous the OD connected have Good performance for poor quality image.	Not fully succeeded in detecting the optic disc due to fuzzy boundaries

Prasath et al.,	2000	A technique for automatic optic disc elimination is discussed in this work.	This system can be very useful for poor computing system.	Huge time variance for different iteration with same Data

TABLE IIII SURVEY OF OPTIC DISC DETECTION USING HOUGH TRANSFORM

Author	Year	Description	Merits	Demerits
Sinha et al.,	2010	Proposed a method to detect and localize the optic disc using an Embedded, Dictionary-based method. The Hough transform finds the curve of the optic disc detection. Gaussian and matched Filters are used to filter the unwanted noise and removing noise.	It yields robust localization of Optic Disc.	Long processing time because of the image of different resolution
Karunanayake et al.,	2015	Proposed a method for the optic disc partitioning of the optic disc using mathematical morphological operations and histogram specification. The histogram definition is derived from the intensity of RGB pictures, and mathematical Morphology extracts an image's feature.	Reliable	Takes longer computational Time
Marin et al.,	2014	In this, the author proposed a method and used morphological operation for the extraction of the feature of image Erosion and dilation to fill the breaks and holes.	Better overall performance	-
Dehghani et al.,	2012	This work uses Histogram matching to finds the histogram of images in RGB and Template matching to find the match of RGB value from the template.	Tolerate the vast variety of image characteristic	-

O. Machine Learning

The machine learning Technique provides an effective way for finding the optic disc even when the object size is resized. Machine learning effectively maps the old coordinates to the new coordinates by scaling factors.

The below Table.IV shows the study of various machine learning methods in optic disc detection. This review work was conducted based on the image processing technique on basis of machine learning techniques used in optic disc detection. It is inferred that the usage of machine learning techniques can able to detect optic disc through a supervised machine learning algorithm. The most widely used supervised algorithms are Support vector machines, Neural networks, K-NN Regressor, which are effective in finding the optic disc when the image size is resized.

P. Evolutionary Computing Technique

The evolutionary computing technique is an optimization technique that uses Darwinian's natural evolution process to determine the optic disc location from the randomly chosen coordinates in an image.

Table. V shows the study on various Evolutionary computing techniques in optic disc detection. From the study, it is inferred that by using the Evolutionary computing technique, we can able to find the optic disc through the optimized technique such as Particle Swarm Optimization (PSO), Genetic Algorithm (GA), and Differential Evolution (DE). Evolutionary computing techniques can able to find an optic disc in both brighter and darker intensity regions whereas the traditional method failed to detect the optic disc at brighter images.

TABLE IV SURVEY OF OPTIC DISC DETECTION USING MACHINE LEARNING

Author	Year	Description	Merits	Demerits
Niemeijer et al.,	2009	In this work, a kNN regressor is used to estimate the distance between pixels in an image and the item of interest,	It gives Good performance	-
Gupta et al.,	2015	An Automatic retinal screening is done to detect retinal microaneurysms, exudates and the optic disc is proposed.	Efficient for low-quality images.	Computation time too long
Lakshman et al.,	2013	This work deals with the analysis of retinal image analysis for the effective detection of optic disc and exudates.	It Avoids false Edge pixel detection	The problem of the presence of a severe lesion in Retinal fundus images
Abirami et al.,	2015	The Optic cup and optic disc segmentation were determined and segmented is done using grow cut algorithm.	Efficient Results can be detected using optic cup &disc in texture based retinal Image	A region is presently given manually, which may be made automatically
Farooq et al.,	2015	They proposed a method to detect and eliminate optic disc using SVM	Identification of the optic disc is done in lesser time.	Size and density of optic disc difficult to find.
Jeffery et al.,	2016	They proposed a method to locate the optic disc in eye fundus images using the shortest path approach	The optic disc can be easily identified where there is less lesion	Difficult in finding highly variable appearance in Retinal images

TABLE V
SURVEY OF OPTIC DISC DETECTION USING EVOLUTIONARY COMPUTING TECHNIQUES

Author	Year	Description	Merits	Demerits
Kar et al.,	2015	The author proposed work on the diagnosis of retinal disorders through the extraction of retinal blood vessel information through differential evolution,	The contrast of an image is reduced by 20% High detection accuracy than other methods.	This method fails to detect the thin and weak vessel
Dias et al.,	2012	In this work, Ant colony Optimization is used to detect edges and to localize the optic disc.	Simple and computationally efficient.	Theoretical analysis is difficult.
Carmona et al.,	2008	In this work Genetic algorithm is used to determine the optic disc and localize it.	Robustness can be seen in high performance in optic disc Detection	Additionally penalized since mat lab is an interpreted language
Burman et al.,	2013	In this work, Multilevel thresholding is achieved through Differential evolution	Real-time Image Segmentation and Reorganization problem.	Accuracy to be improved in finding the object.
Ponnaiah et al.,	2013	Proposed a method to improve the performance using weighted error rate.	Randomly choose the optic disc region so the optic disc region can be found very fast.	Not efficient for all types of images. Sometimes it can take a long time to converge.
Vinoth Kumar et al.,	2017	Localization of optic disc is made through Differential Evolution with Memetic search capability	The convergence rate is improved	Reliability has to be improved

3 Performance Evaluation

Performance analysis is done based on determining the accuracy obtained by optic disc detection in an eye fundus image. The formula for determining accuracy is given in equation (1). Result analysis is done for each technique separately, and the accuracy of optic disc detection is determined based on the number of optic discs detected correctly in eye fundus images.

$$Accuracy = \frac{(TP+TN)}{(TP+TN+FP+FN)} \dots\dots\dots\dots\dots\dots\dots\dots..(1)$$

Where,

TP - True Positive,
TN - True Negative,
FP - False Positive,
FN - False Negative.

Table. VI shows the performance of various study work that took place in the area of optic disc localization.

TABLE VI PERFORMANCE ANALYSIS ON VARIOUS DATASETS

Author	Year	Dataset	Accuracy
Akyol et al.,	2016	DIARETDB1	94.38%
		DRIVE	95%
		ROC	90%
Prasath et al.,	2000	ARAVIND EYE HOSPITAL-MADURAI, STARE AND DRIVE	93%
Karunanayake et al.,	2015	DIARET DB0	90.7%
		DIARET DB1	89.8%
Wisaeng et al.,	2014	LOCAL DATASET	97.61%
		STARE	97.61%
Sinha et al.,	2012	DIRETDB0	96.9%
		DIRETDB1	100%
		DRIVE	95%
Dehghani et al.,	2012	STARE	91.36%
		DRIVE	100%
		LOCAL DATASET	98.9%
Gupta et al.,	2015	MESSIDOR	86%
Lakshman et al.,	2013	LOCAL DATASET	98%
Farooq et al.,	2015	MESSIDOR	90%
		STARE	100%
Wigdahl et al.,	2017	DIARET DB1	98.88%
		DRIVE	100%
		MESSIDOR	99.42%
Kar et al.,	2015	DRIVE	97%
Dias et al.,	2012	DRIVE	100%

4 Conclusion

In this work, an extensive study has been accomplished on different approaches for optic disc localization in a human eye fundus image. This study also showcases the publicly available datasets for this application. The survey also shows the accuracy of optic disc localization achieved by different approaches such as traditional methods and evolutionary techniques. From this study, it has been found that evolutionary algorithms give better results when comparing them with other techniques. The future direction includes the usage of memetic techniques to improve the performance of the optic disc localization in an eye fundus image.

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