Landmark Detection in Retinal Fundus Images

A thesis submitted in partial fulfilment of the requirements for the award of degree of

Master of Engineering
in
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DECLARATION

I hereby certify that the work is being presented in this thesis work entitled **"Landmark Detection in Retinal Fundus Images"** in partial fulfilment of award of degree of Master of Engineering in Electronics Instrumentation & Control submitted in the Department of Electrical & Instrumentation Engineering, Thapar University, Patiala is an authentic record of my own work carried under the supervision of **Dr. Deepti Mittal**, Assistant Professor, Department of Electrical & Instrumentation Engineering, Thapar University, Patiala, Punjab.

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I certify that the above statement made by the student is correct to the best of my knowledge and belief.

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ABSTRACT

Fundus imaging is one of the most frequent used techniques for screening, diagnosis of eye diseases and abnormalities related to vessels. Optic disc, blood vessels are the main landmarks of the fundus retinal images. If the disease is detected prior then the visual loss can be prevented. Therefore automatic evaluation of fundus images is very necessary and can be used to support immediate diagnosis in ophthalmology as the shape and size of blood vessel and optic disc is an essential indicator of various eye diseases such as diabetic retinopathy and glaucoma. The basis of many automatic evaluations or diagnosis is the segmentation of retina remarkably the detection of optic disc and segmentation of the retinal vessels. The methodology is applied and analysed on available Database Drive. In this work, a method has been presented to segment the optic disc, blood vessels and exudates. Diagnosis of diabetic retinopathy at early stage can be done through detection of blood vessels of retina. Blood vessel segmentation is a helpful tool in the treatment of diabetic retinopathy. The segmentation of retinal vessels is obtained with the help of morphological bit plane slicing from retinal images. The results are compared with standard database and it showed better results in terms of contrast and optic disc and blood vessels are segmented properly.

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ABBREVIATIONS

OD	Optic disc
DR	Diabetic Retinopathy
Drive	Digital retinal images for vessel extraction
Stare	Structured analysis of the retina
CLAHE	Contrast limited adaptive histogram equalization
Fig.	Figure
Messidor	Methods to evaluate segmentation and indexing techniques in the field of retinal ophthalmology
SE	Structuring Element
DIARETDB0	Standard retinopathy calibration level 0
DIARETDB1	Standard retinopathy calibration level 1
Equ	Equation

1. INTRODUCTION

Diabetic Retinopathy is one of the most common eye diseases. As the name suggests, it mostly affect the people with diabetes [1]. Diabetes affects vision by causing cataract, glaucoma and most importantly diabetic retinopathy. Diabetic Retinopathy usually occurs when small blood vessels gets damaged in the retina due to high glucose level. This condition tends to occur in patients who have diabetes for 5 or more years [1]. Disorders in retina occurring from eye diseases are diagnosed by particular images and are resulted from optic imaging known as fundus [2]. Inspection of colour fundus images may help to diagnose and monitor the progress of general diseases like diabetes, cardiovascular diseases, and stroke and eye diseases [2]. As we know that optic disc, fovea and blood vessels are the landmarks of retinal fundus images.

Optic disc is the bright region in the retinal image and the emergence of blood vessel occurs from its centre. The detection of optic disc in retinal fundus images is considered to be the one of the main step [3]. Any change in shape, size, and colour of OD is an important indicator of various pathologies related to eye such as glaucoma, hence OD area are used to measure abnormal features that occurs due to different retinopathies and it can be diabetic retinopathy and glaucoma [3] [4]. Exudates are one of the lesions of diabetic retinopathy and they have similar contrast and colour with that of optic disc. Identification and removal of the OD helps in improving the classification of exudates regions. Blood vessel is one of the most important features as it contains arteries and veins and it helps in detecting retinal vein occlusion, hypertension and early diagnosis and glaucoma [5]. Hence by checking the acquired changes in an early stage can help the ophthalmologist to diagnose the disease. Besides that if the extraction of optic disc and blood vessels is done manually it would be difficult and take more time to access [5]. Therefore in today's time automated detection of normal and abnormal features in retinal images attracting a lot of researchers in medical image as it reduce the severity of the disease by saving their time.

Hence if there is a need for reliable automatic retinal vessel extraction then it must follow some conditions. They are (i) The blood vessel can have different width ranging from very large pixels to small pixels and in different directions; (ii) Several features can appear in retinal image consisting of optic disc, fovea and exudates, and they destroy automatic blood vessel segmentation; and (iii) The vessel contrast is usually weak and the small vessels are surrounded by noises like Gaussian, salt and pepper [5]. Retinal blood vessels and optic disc segmentation is the first stage in automatic registration of two retinal fundus images related to a patient and helps in checking of progress of his disease at different times [5] [6]. It is known that fovea is one of the landmarks of retinal fundus images but due to the above discussed regions, the focus here is laid only on blood vessels and optic disc. Several authors have proposed their work on segmentation of optic disc and blood vessels and they are summarized in the form of literature survey given below. Therefore the work related to thesis is to segment the landmarks in the retinal fundus images that are optic disc and blood vessels so that we can diagnose the abnormalities related to disease properly.

1.1 NORMAL FEATURES OF RETINAL FUNDUS IMAGES

Every healthy retina has some normal features. These normal features are optic disc, blood vessels and fovea. Apart from these, an unhealthy retina might have some abnormal features like haemorrhages; micro-aneurysms and exudates. Some of the normal features are discussed below –

(i) Optic disc
(ii) Blood Vessels
(iii) Fovea

1.1.1 Optic Disc

Optic disc is the entry point for the major blood vessels that supply the retina. The optic disc is the bright hole in the back of the eye [7]. The location of the optic disc is an important aspect in retinal image analysis and detection as it is a significant landmark feature in the retina.

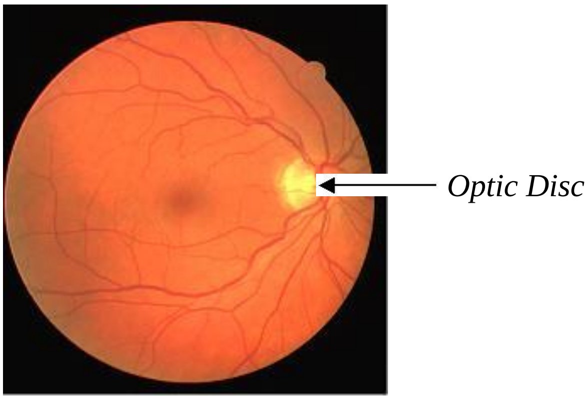


Figure 1: Optic Disc is the bright area on the right where blood vessels converge

1.1.2 Blood Vessels

The retina at the back of our eye requires a constant blood supply. The blood supply should be efficient so that the cells of the retina get all the nutrients they need to continue working. There are two main types of blood vessels – arteries and veins. Arteries carry fresh blood from the heart and lungs to your eye and veins take away the blood that has been used by the eye and return it to the lungs and heart.

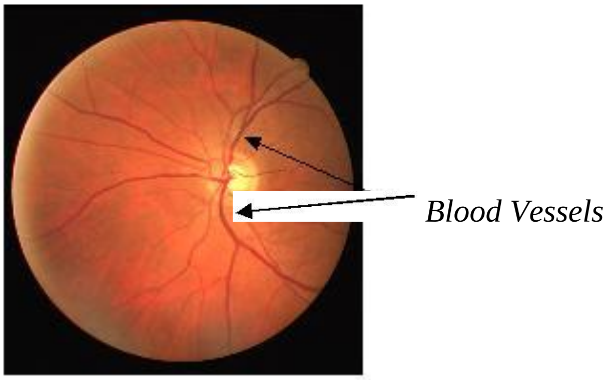


Figure 2: Blood vessels emerging from the centre of the disc

1.1.3 Fovea

The fovea depicts the center of the retina and it is located in the center of macula which is the region of highest visual activity [8].

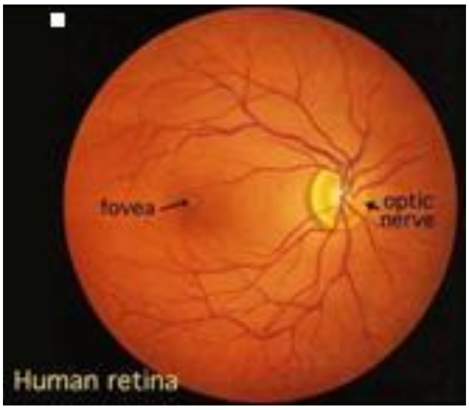


Figure 3: Fovea

1.2 ABNORMAL FEATURES OF RETINA

Abnormal features of retina are exudates, micro-aneurysms and haemorrhages. These are explained below in the following section –

1.2.1 Exudates

Exudates appear as yellowish dark spots and they are located in the posterior pole of the fundus image. Exudates are made up from serum lipoproteins and usually occur when lipid or fat leaks from abnormal blood vessel or aneurysms [9]. Exudates are one of the main features of diabetic macular edema. As the severity of the disease change the size and shape of the exudates changes.

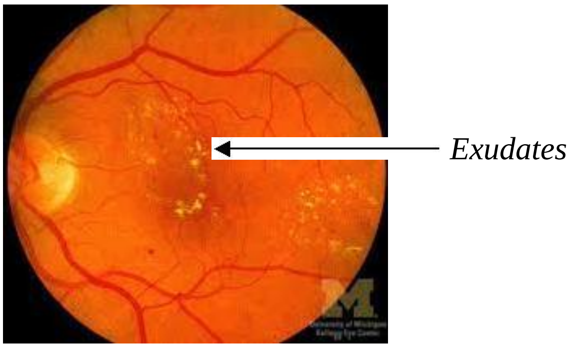


Figure 4: Exudates

1.2.2 Micro aneurysms

Micro aneurysms are the focal dilations of retinal capillaries, and appear as small, round and dark red spots [10]. Micro aneurysms occur when there is arterial blockage or retinal breakdown.

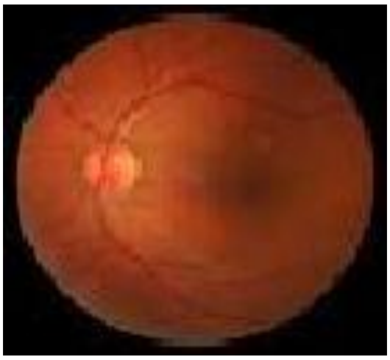


Figure 5: Micro aneurysms

1.2.3 Haemorrhage

Haemorrhage occurs when blood leaks from the retinal vessels [10]. Haemorrhage can be caused by hypertension, blockage of arterial vein or diabetes mellitus. Some retinal haemorrhage can cause severe impairment of vision.

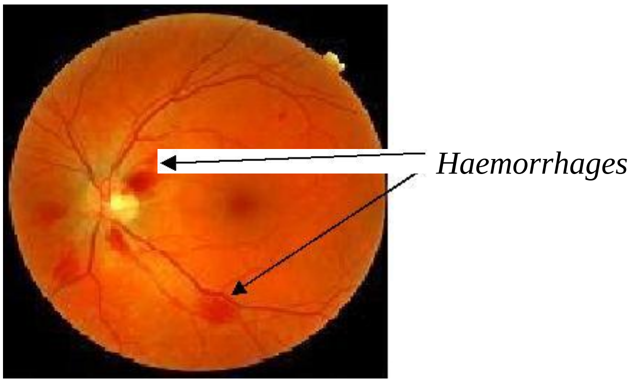


Figure 6: Haemorrhages

Exudates are one of the prior sign of the diabetic retinopathy and its detection is one of the main important tasks. Hence the detection of exudates must be done prior as optic disc and exudates are of the similar contrast [10]. For automatic assessment of retinal images, segmentation of the vessels and optic disc from the background is considered as a prior requirement. However as the retinal images acquired with a fundus camera often are identified with low grey level contrast and poor illumination, hence the problem can seriously affect the segmentation results [11].

Therefore it is very necessary to carry out contrast enhancement as one of the main step required pre-processing particularly for those cases where the original retinal image is considered not good candidate for producing the desired segmentation. Several techniques have been employed for improving the quality in terms of contrast and illumination of the retinal images. Hence in this proposed work we have removed optic disc with the help of thresholding. Firstly morphological operation dilation is applied on the contrast limited equalized image and after getting the proper region of optic disc we applied thresholding. A morphological bit plane slicing is applied on the bottom hat image for blood vessels segmentation.

1.3 OBJECTIVES OF THESIS

Primary objectives of this thesis are:

- To study the landmarks and different lesions contributing to the term Diabetic Retinopathy.
- To study the method proposed for optic disc removal
- To study the method proposed for blood vessel segmentation and comparison with standard database
- To study the method proposed for exudates detection.

1.4 ORGANIZATION OF THESIS

The thesis is organized into five chapters. Chapter 1 introduces the term Diabetic Retinopathy and brief idea about the factors contributing to diabetic retinopathy. Chapter 2 discusses the literature survey of optic disc removal, detection of exudates and blood vessel segmentation. Chapter 3 discusses the methodology applied or the steps proposed for the removal of optic disc, blood vessel segmentation and the detection of exudates and results and discussion with limitations. Chapter 4 deals with results and discussions. Chapter 5 deals with conclusions and future scope.

2. LITERATURE REVIEW

A. W. Reza *et al.* [1] proposed a method for detection of blood vessel in retinal fundus images based on RGB components and quadtree decomposition. The proposed method makes use of median filtering, quadtree decomposition, and morphological reconstruction on retinal images. The application of pre-processing helps in improving the contrast of the image by making it more useful for subsequent analysis. Quadtree decomposition provides information about the different types of blocks and intensities of pixels within the blocks. The proposed algorithm used three colour components and tested on various available databases.

K. Jeyasri *et al.* [2] proposed a new algorithm for the detection of blood vessels. Firstly enhancement of the image is carried out with the help of curvelet transform. Morphology processing with multistructural elements is used to extract blood vessels from retinal images. A simple thresholding with connected components analysis indicates the remaining ridges indicate the remaining ridges belonging to vessels.

A. W. Reza *et al.* [3] proposed an algorithm for the extraction of OD, exudates and cotton wool spots from fundus images based on marker controlled watershed segmentation is used. Average filtering and contrast adjustment are used as pre-processing steps in the proposed algorithm**.** The performance is evaluated on the test images of Stare and Drive.

Ana Maria Mendonca *et al.* [4] presented an algorithm for the segmentation of vessel tree in retinal images. In the first step they extracted out the vessel centrelines, which are used for the vessel filling phase. In the last final segmentation is done with the help of iterative region growing method.

Ahmed Hamza Asad *et al*. [5] used two classification problems. They proposed the idea of ant colony system for automatic segmentation of retinal blood vessels. The first improvement is done with the help of discriminant features. The second can be done with the help of application of new heuristic model based on probability theory.

Diego Martin *et al.* [6] presented a robust method for segmentation of blood vessels in retinal images. They used a new method that is Neural Network scheme for pixel classification and consists of 7-D vector composed of grey scale and moment invariants based features for pixel classification.

G. B. Kande *et al.* [7] proposed two different approaches for automatic detection and segmentation of exudates and optic disc. The centre of the optic disc is estimated with the help of finding a point which has maximum local variance. The boundary of the optic disc is located with the help of geometric active contour. For exudates detection the enhanced segments are extracted with the help of spatially weighted fuzzy c- means clustering algorithm.

D. Welfer *et al.* [8] proposed a new method based on mathematical morphology for detection of exudates in retinal fundus images. The evaluation of the proposed method was done on publicly available database DIARETDB1.

A. W. Reza *et al.* [9] proposed an algorithm for automatic segmentation of OD and exudates. The proposed algorithm uses here the green component of the image and several pre-processing steps such as average filtering, contrast adjustment and thresholding. They used morphological operators also and they are morphological opening, minima imposition and watershed transformation.

A. Sopharak *et al.* **[**10] proposed to investigate a set of morphological operators to be used for exudates detection on diabetic retinopathy non dilated pupil and with low contrast images**.** The results were evaluated in terms of sensitivity and specificity**.**

T. Walter *et al*. [11] proposed a method for detection of exudates and they are found with the help of high grey level variation, and contours are recognized with the help of morphological reconstruction techniques. They proposed the idea of morphological filtering techniques and watershed transformation for the detection of optic disc**.**

Mahendran Gandhi *et al.* [12] proposed a method for automatic detection of diabetic retinopathy for detection of exudates in retinal fundus images and also classified the rigorousness of the lesions.

Eman M. Shahin *et al.* [13] presented a system for automatic classification of normal, and abnormal retinal images by automatically detecting the blood vessels, hard exudates and micro- aneurysms. The objective measurements are blood vessels area, hard exudates, micro – aneurysms, entropy and homogeneity. Finally these objective measurements are fed to artificial neuron network.

S. Ravishankar *et al.* [14] proposed an efficient method for localization of different features and lesions in fundus retinal images. They proposed a new novel method for detection of optic disk detection by first detecting the major blood vessels. Many features such as blood vessels, exudates and micro-aneurysms can be detected with the help of morphological operators.

M. G. F. Eadgahi *et al.* [15] proposed a method for segmentation of hard exudates. They used mathematical morphological operation for segmentation of hard exudates. Pre-processing of retinal images is done earlier and optic disc and blood vessels identified properly and then they are removed. Hard exudates are removed with the help of morphological operations such as Top hat, Bottom hat and reconstruction operations.

Kevin Noronha *et al.* [16] presented the methods to detect main features of fundus images such as optic disc, blood vessels, fovea and exudates. For determining the optic disc and its centre Hough transform was used. The detection of fovea can be done with the help of using its spatial relationship with optic disc. Exudates are determined by morphological reconstruction technique. The blood vessels are highlighted with the help of bottom hat transform and morphological reconstruction techniques.

M. M. Fraz *et al.* [17] presented an automated method for segmentation of blood vessels in retinal images. They used the combination of morphological bit plane slicing and vessel centreline detection for extracting the blood vessel tree from retinal images. Gaussian filter was used for extraction of blood vessel tree from retinal images. Top hat transform was applied on the vessel enhanced grey scale image for shape of the blood vessels.

M. Z. Che Azemin *et al.* [18] proposed a method to perform retinal vascular fractal analysis from retinal images. In this method they used the Gabor wavelet transform so that retinal image enhances and they used Gabor wavelet on green component of the image for pre-processing. Fourier fractal dimension is applicable on these pre-processed images and they do not require segmentation of the vessels.

Aliaa Abdel – Haliem Abdel Razzik Youssif *et al.* [19] proposed a simple matched filter method for matching the direction of the vessels near the optic disc region. 2D Gaussian matched filter is implemented to segment retinal vessels. The vessels segmented are thinned and filtered representing finally the Optic Disc centre.

Ana Salazar Gonzalez *et al.* [20] proposed a robust method to segment blood vessel and optic disc in retinal fundus images .He performed two methods for optic disc segmentation. First method includes Markov Random field image reconstruction for segmenting the optic disc by removing vessels from optic disc region. Compensation Factor method segment the optic disc with the help of local intensity knowledge of the vessels.

Arturo Aquino *et al.* [21] presented template matching methodology for segmentation of optic disc from retinal fundus images. In their work, they used morphological and edge detection techniques and circular transform to obtain the circular boundary.

James Lowell *et al.* [22] proposed an algorithm for localization and segmentation of the optic nerve head boundary in retinal fundus images having low resolution .Template matching is applied for localization of optic disc and segmentation with the help of deformable contour model.

M. H. S. P. Kumara *et al.* [23] proposed a method based on active contour model generally named as snakes for removing the optic disc from retinal images. The proposed method is followed by two main steps. In the first step, the optic disc boundary is estimated with the help of edge detection, morphological operations and circular Hough transform. The second step is followed by active contour model which is used to detect optic disc boundary.

M. Forracia *et al.* [24] proposed a geometrical model for describing the general direction of retinal vessels at any given position in the image, where two of the model parameters are the coordinates of the OD centre. With the help of experimental data samples of vessel centrelines points and their corresponding vessel directions, model parameters can be determined with the help of simulated annealing optimization technique. From these estimated values the coordinates of the centre of the OD can be determined.

H. Yu *et al.* [25] proposed a fast and automatic method for Optic disc localization and segmentation. They used template matching for locating optic disc candidates. Template matching is done to adapt to different image resolutions .Then vessel pattern on the OD are used for determining Optic Disc location. Then they used morphological filtering for removal of blood vessels and bright regions other than the OD.

D. W. K. Wong *et al.* [26] proposed a supervised learning scheme method for the detection and segmentation of optic disc. This method employed pixel and local neighbourhood features taken from Region of Interest of retinal fundus images. Support Vector Machine classification mechanism is used to categorize whether image point belongs to cup and retina.

Ahmed E. Mahfouz *et al.* [27] presented a fast localization technique for localization of OD. It is based upon the projections of the image that helps in encoding the x and y coordinates of the OD. The resulting OD projections are used for determining the location of the OD.

Fengshou Yin *et al.* [28] proposed a method based on combination of edge detection, Circular Hough transform and a statistical deformable method for detecting the optic disc from retina.

M. Usman Akram *et al.* [29] presented a method for blood vessel enhancement and segmentation. They proposed a wavelet based method for vessel enhancement, piecewise threshold probing and adaptive thresholding for vessel localization and segmentation of fundus images.

Sookpotharom Supot *et al.* [30] proposed an efficient method for segmentation of blood vessels in retinal fundus images. The proposed algorithm is divided into three steps: matched filter, fuzzy k-median, and length filter. The results are evaluated in terms of sensitivity and specificity.

S. H. Rezatofighi *et al.* [31] proposed a multiscale method for contrast enhancement of retinal image using contourlet transform. In his work he presented a combination of feature extraction approach utilizing Local Binary Pattern, morphological method and spatial image processing for segmentation of the retinal blood vessel in fundus images.

Jun Cheng *et al*. [32] presented an optic disc segmentation method based on per papillary atrophy elimination .The method used for elimination are edge filtering, constraint elliptical Hough transform and per papillary atrophy detection.

Shuying Huang *et al.* [33] proposed an automatic approach for segmentation of retinal image and comprises two steps. In the first step after analyzing the feature of retinal images, mathematical operations are used to smooth and strength images in order to remove background and enhance the brightness of retinal blood vessels. In second step, maximal entropic thresholding algorithm is used to extract retinal blood vessels.

Clara I. Sanchez *et al.* [34] proposed an automatic algorithm for the detection of hard exudates. The algorithm used mixture models to detect for threshold the images so that exudates can be separated from background. Post processing techniques based on edge detection is applied so that hard exudates can be distinguished from cotton wool spots.

S. Chaudhari *et al*. [35] addresses the problem of detection of blood vessels in retinal fundus images. They introduce an operator for feature extraction which is based upon the optical and spatial properties of the objects. Piecewise linear segmentation of blood vessels in an image can be detected with the help of matched filter. They constructed 12 templates for blood vessel segments in all possible different directions.

Xinge You *et al.* [36] proposed a method of extracting the retinal vessels based on the radial projection and semi supervised method is presented in this paper. The radial projection is used to locate the vessel centrelines which include the low contrast and narrow vessels. The semi supervised training for the major structure of vessels.

M. M. Fraz *et al.* [37] proposed the methodologies in two dimensional retinal images taken from a retinal camera and a survey of techniques is presented. They reviewed, analyzed, and categorized the retinal vessel extraction algorithms, and techniques and methodologies. The performance is analyzed on two available databases Drive and Stare.

A. Dehgani *et al.* [38] presented a new method for localization of optic disc in retinal images. For segmentation of blood vessels and for diagnose purpose, localization of optic disc and its centre is one of the most important step. The method is performed on the Drive and Stare database.

F. Zana *et al.* [39] proposed an algorithm based upon mathematical morphology and curvature evaluation for the detection of vessel like patterns. In order to define vessel as a vessel like pattern, piece wise connected and locally linear mathematical morphology is used. To differentiate vessels from patterns, a cross curvature evaluation is performed. The detection algorithm is based upon four steps noise reduction, linear pattern with Gaussian like profile improvement, cross curvature evaluation, linear filtering.

M. Esmaeili *et al*. [40] proposed an algorithm which consists of three main stages. In first step, bright candidate lesions are detected with the help of DCUT and modifications in curvelet coefficients. They introduced a new OD detection and boundary extraction based on DCUT and level set model. Lastly they introduce, bright lesions map (BLM) to distinguish between exudates and OD.

M. D. Saleh *et al*. [41] proposed their work on the extraction of retinal blood vessels which helps in early diagnosis and prevention of several diseases, such as hypertension, diabetes, cardiovascular diseases and stroke. The proposed algorithm makes use of image processing techniques such as, contrast enhancement, filtration and thresholding. They evaluated their performance on Drive database.

A. Hoover *et al.* [42] presented an algorithm for detection and location of retinal blood vessels in ocular images. They used local and global vessel features for segmentation of the vessel network. They evaluated their method using hand labelled ground truth segmentation of

20 images.

D. Karthika *et al.* [43] proposed an algorithm that is contourlet transform for detection of blood vessels. In addition to contourlet transform, wavelet transform is used for enhancement of retinal image, then that image is used for segmentation part. Certain morphology operators like multistructure elements are applied to enhanced image in order to locate the retinal image ridges. Morphological reconstruction is used to remove the ridges which are related to vessel tree. Ostu thresholding method is used in combination with Connected Component analysis which indicates the remained ridges related to vessels.

Michael D. Abramoff *et al.* [44] proposed a method for 2-D imaging and techniques for

3-D optical coherence topography. They paid special attention to quantitative techniques for analysis of fundus photographs focussing on assessment of retinal vasculature, identification of retinal lesions, and assessment of optic nerve head shape.

P. C. Siddalingaswamy *et al.* [45] proposed a computer based system for automatic detection of optic disc, fovea and exudates. The OD is detected automatically and its location and diameter is used to detect fovea.

Maria Garcia *et al.* [46] proposed to extract a set of features from image regions and selected the subset which best discriminates between the Hard Exudates and the retinal background. The selected features were used as inputs to the multilayer perceptron (MLP) classifier.

Handyani Tjandrasa *et al.* [47] proposed a methodology to for segmenting hard exudates using mathematical morphology and the extracted features are classified with the help of SVM.

Wang Huan *et al.* [48] focussed on automatic detection of abnormal features-the presence of exudates / lesions in the retinal fundus images. They combined median filtering and dynamic clustering for the purpose of detection of exudates.

Jun Cheng *et al.* [49] implemented super pixel classification method for segmentation of optic disc and optic cup for glaucoma screening. For optic disc segmentation histogram and centre surround statistics are used for classification whether each super pixel is disc or non-disc. In optic cup segmentation besides histogram and centre surround statistics, the local Information is also added.

P. C Siddalingaswamy *et al.* [50] proposed a method for localization and segmentation of optic disc. Optic disc is achieved with the help of iterative threshold method for identifying the candidate regions which is followed by connected component analysis for exact location of optic disc.

Qin Li *et al.* [51] proposed a method that includes a multiscale analytical scheme using Gabor filters and scale production and a threshold probing technique utilizing the features of retinal vessel network.

Attila Budai *et.al* [52] proposed a variant of the fast radial symmetry transform (FRST), adapted to its application in the detection of optic disc in fundus images. They evaluated and compare the performance of the method to the standard FRST and the similar gradient based circular Hough transform.

M. Sofka *et al.* [53] proposed a method for tracting vessels in retinal images. A training technique is used for mapping of this vector to likelihood ratio that measures the “vesselness” at each pixel. The Hessian can be used in place of matched filter in order to obtain to obtain similar results as that of matched filter. A new vesselness likelihood ratio is embedded into a vessel tracing framework.

X. Zhu *et al*. [54] proposed a method to locate optic disc (OD) in retinal fundus images. Depending on the properties of the OD, the proposed method used sobel or canny method for edge detection and detection of circles with the help of Hough transform. The Hough transform helps in the detection of the centre and radius of a circle that approximates the margin of the OD. As we know that OD is one of the bright areas in a fundus image, circles can be detected with the help of Hough transform. The performance was evaluated on Drive database.

M. H. A. Hijazi *et al.* [55] proposed and compared two data mining techniques for automated screening of AMD. They used two methods for their work first requires spatial histograms that help in maintaining colour and spatial information, for image representation. The second is based on hierarchical decomposition of the image so that a tree representation is generated.

Chapter 3

3. METHODOLOGY

The method is divided into four phases: Pre-processing, Optic disc removal, Blood vessel segmentation, and Detection of exudates. In the first step of proposed methodology landmarks are segmented as it was described earlier they are optic disc and blood vessels. Then in the next step exudates are detected taken on a different image. Fig 7 shows a chart of the proposed scheme. First the retinal image is taken from the database and converted into grey scale image. Basically pre-processing steps include contrast enhancement and dilation and it is applied to the grey image. Contrast Limited Adaptive Histogram Equalization (CLAHE) is applied as the original image taken is blurred and the contrast is very low. Hence to improve the contrast of the image is a very necessary step.

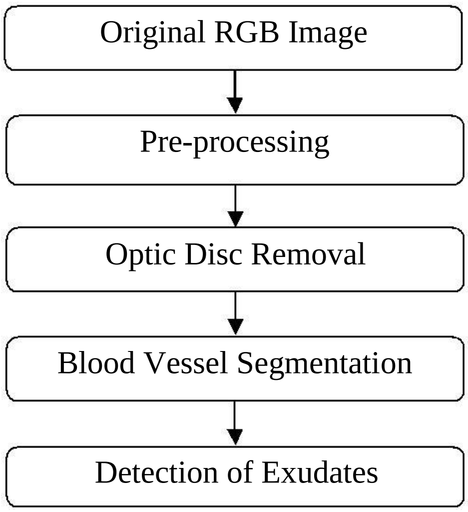


Figure 7: Flowchart of the proposed methodology

3.1 PRE–PROCESSING

Pre-processing of retinal image is an important step and it helps in simplifying the following steps such as blood vessel segmentation, optic disc detection and other abnormal structures. As we have seen that most of the authors have done their work on pre-processing. Survey of the already proposed work is given in tabular form below.

Table 1: Literature Survey of Pre-Processing

Author	Year	Methods Used	Database
1. Thomas Walter Massin *et al.*	2002	Standard Contrast starching techniques	Small Image database

2. Agung W.Setiawan *et al.*	2003	CLAHE	Not specified
3. Chanjira Sinthanayothin *et al.*	2003	Adaptive, Local contrast enhancement	484 normal images, 283 diabetic retinopathy images
4. Cheng *et al.*	2004	Multi pick histogram equalization method	Not specified
5. Hyunsup Yoon *et al.*	2005	Sub histogram equalization	Not specified
6. Di Wu, Ming CHANG *et al.*	2006	Adaptive Contrast Enhancement	Drive, Stare
7. Peng Feng *et al.*	2006	Contourlet Transform	Drive
8. Jao V.B. Soares et al.	2006	Morlet Wavelet Transform	Drive, Stare
9. Di Wu *et al.*	2008	Standard Deviation of Gabor Filter responses	Stare
10. S. H. Rezatofighi, A.Roodaki *et al.*	2008	Segmentation of Blood vessels using contourlet	Drive
11. Akara Sopharak *et al.*	2008	CLAHE	40 abnormal images, 20 normal
12. Thitiporn Chanwimaluang and Guoliang Fan *et al.*	2009	Matched filter to enhance blood vessels	Drive
13. Girish Singh Ramlugam *et al.*	2011	2D matched filters are used on digital fundus, CLAHE	Drive
14. Eman M. Shahin *et al.*	2012	CLAHE	Drive, Stare
15. Zafer Yavuz *et al.*	2011	Gabor filter, Top hat transform	Stare
16. R. V. Prasanna PG Scholar et al.	2013	Histogram equalization	Drive
17. M.Maruthusivarani et al	2013	Blood vessels are enhanced with the help of matched filter	Drive, Stare, Messidor

One of the main purposes is to improve the contrast of the retinal image so that we can easily detect and localize optic disc. Hence to segment the optic disc is one of the prior task and to analyse the normal and abnormal features from colour retinal images. Many techniques have been employed for enhancing the colour retinal images before the detection of optic disc. But we are using here Contrast Limited Adaptive Histogram Equalization. Procedure of the pre-processing in tabular form is presented below –

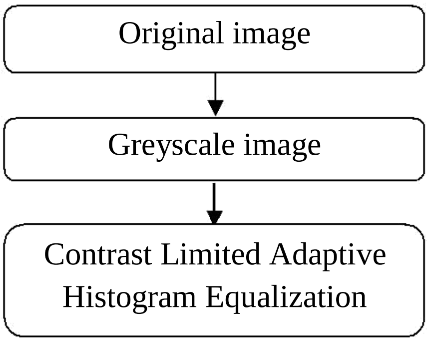


Figure 8: Flowchart of the proposed pre-processing

3.1.1 Steps for pre-processing

Step 1: Original Image

First and foremost step is to acquire an original image. They are originally RGB in nature and hence it is necessary to convert it into the grey scale image.

Step 2: Greyscale image

After taking the original image we are going to convert it into grey scale image. As we know that original image is RGB and only green and grey scale image has to be extracted. Hence greyscale image is used for pre-processing. Greyscale image is considered as the natural basis for many segmentation algorithms.

Step 3: Contrast Enhancement

Contrast enhancement is one of the main parts of pre-processing. It consequently improves the contrast of every region and thus helps in making the invisible features of the image more visible. The main purpose of using this technique is that the CLAHE algorithm partitions the images into different regions and then applies the histogram equalization to each region. Here the CLAHE algorithm has applied on the grey image. Earlier simple histogram equalization was also applied but it showed little improvement in the colour balance. That’s why CLAHE is applied in this procedure instead of simple histogram equalization.

3.1.2 Importance of Pre-Processing

1. Helps to improve original image data
2. Helps in extracting morphological features
3. Morphological features of different pathological structures can be obtained
4. Provides important information essential for clinical diagnosis

3.2 OPTIC DISC REMOVAL

The optic disc is the brightest feature of the normal fundus in retinal image and it has oval shape. Normally in coloured fundus images, the optic disc appears as a bright yellowish in colour [10]. The detection of optic disc in fundus images is an important task as it is similar in brightness, colour and contrast to the exudates. So it is necessary to eliminate optic disc from the retinal image. Moreover optic disc is an important feature of retina and can be used for selection of retinal images. The process of automatic detection/ localization of optic disc depend upon the correct detection of centroid (centre point) of the OD. The work that has been proposed for the removal of optic disc and it is illustrated in the tabular form.

Table 2: Literature Survey of Optic Disc Segmentation

Author	Year	Methods Used	Database
1. Artino Aquino et al.	2010	Morphological and edge detection techniques, Circular Transform.	Messidor
2. Aliaa Abdel-Haleim Abdel-Razik Youssif	2008	2-D Gaussian matched filter	Stare
3. Jun Cheng et al.	2011	Peripapilliary atrophy detection	Database of 650 images
4. Fengshou Yin et al.	2011	Edge Detection, Circular Hough Transform and Statistical Deformable Method	325 digital colour fundus images
5. R. Radha	2014	Bit Plane Separation, Mathematical Morphology	Images from reputed eye hospital
6. Attila Budai et al.	2013	Fast Radial Symmetry Transform, Gradient Circular Hough Transform	45 images of a high resolution database
7. M. H. S. P. Kumara et al.	2013	Active Contour	130 coloured images
8. M. Foracchia et al.	2004	Simulated annealing optimization technique	STARE
9. H. Yu et al.	2012	Fast, hybrid level set model comprises local and gradient information	Messidor
10. Ana Salazar- Gonzalez et al.	2013	Markov random field method, compensation factor method	Not specified

3.2.1 Related Work

Before working on proposed methodology, several already imposed methods have been applied and results are shown below. Mahendran Gandhi *et al*. [12] proposed the use of edge detection algorithm and applied on the pre-processed image to make it suitable for detection of the optic disc, blood vessel and exudates. For contour detection, canny edge detector is employed. This algorithm is useful in finding the edges where the greyscale intensity of the image changes. It also enhances the blurred edges which are not visible properly. The mask image was created in the region of interest, is the optic disc. The masked image, optic disc is subtracted from the edge detected image.

In second method, Eman M. Shahin *et al.* [13] proposed that the optic disc can be removed by subtracting the image after histogram equalization from the image after applying morphological opening operator. The removed optic disc can be shown in Fig 9. The method has certain limitation, although it is showing blood vessels clearly but the region of optic disc is not clear. **S. Ravishankar** *et al*. [14] proposed a method by applying morphological closing operator on the grey scale image as it will help in eliminating the vessels and provides a more homogeneous region for optic disc. The result of the proposed method is shown in Fig 10. Therefore after analysing these results, the flow chart of the proposed methodology is presented in Fig. 11.

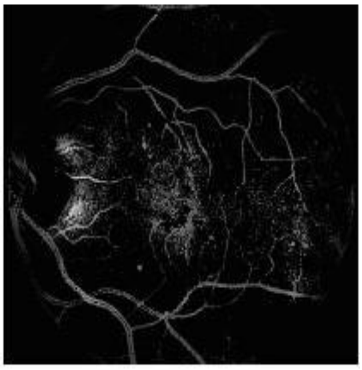


Figure 9: Subtraction of closing image after histogram equalization

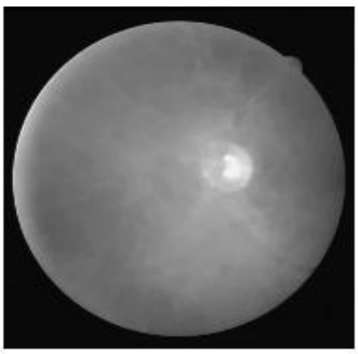


Figure 10: Removal of optic disc after applying closing operator

3.2.2 Proposed Work

The method herein presented can be schematically described by the functional block diagram in Fig 11. We have seen that in pre-processed image optic disc region was showing clearly hence for this reason we are using here pre- processed image. To make optic disc more clearly we are going to use dilation.

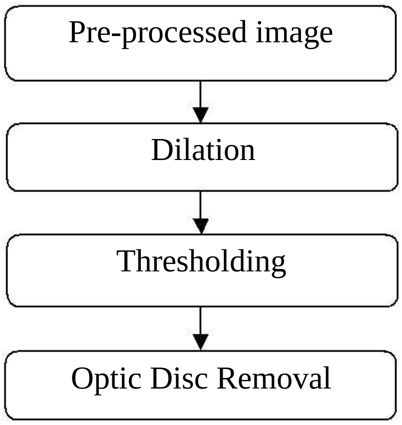


Figure 11: Flowchart of the procedure of the proposed methodology

3.2.3 Steps for Optic disc removal

Step 1: Pre-Processed Image

The first step to this approach is pre-processing. As it has been described earlier that CLAHE is an important part of pre-processing, hence it is necessary to take the pre-processed image for optic disc removal.

Step 2: Dilation

In the second step dilation is applied on the contrast enhanced image. Dilation is a morphological operator and it grows or expands the boundaries of an image. A flat disc shaped structuring element (SE) was used. With the help of dilation it was observed that the region of optic disc has been shown clearly. Certain types of SE elements are available and they are categorized as disc, diamond and square. Structuring element is a matrix consisting of zeros and ones only.

Step 3: Thresholding

The resulting image after applying dilation was binarized by thresholding. Thresholding is useful for removing those components of the image which are not useful. It can also be used to bring out hidden details. Thresholding is useful in that region of the image which is occupied by similar grey levels. In this global thresholding is applied on the dilated image.

3.3 BLOOD VESSEL SEGMENTATION

Any change in shape, size, diameter and branching pattern of retinal blood vessels is an important indicator of the disorder of the eye. The main foundation of this work depends upon the detection of vessel shape and morphological features. The shape and orientation map of retinal vessels is obtained with the help of morphological bit plane slicing on bottom hat image. Bottom hat transform is defined as the difference between the closing image and the input image. Bottom hat transform is applied on the contrast enhancement image. So many authors have proposed their work on vessel segmentation. Literature survey of the proposed work is given below.

Table 3: Literature Survey of Blood Vessel Segmentation

Author Name	Year	Methods Used	Database
1. Joes Staal *et al.*	2004	Extraction of image ridges	40 manually labelled images
2. Ana Maria Mendonca *et al.*	2006	Four directional differential operators, Iterative region growing method	Drive and STARE
3. Shuying Huang *et al.*	2006	Gray mathematical morphology, maximal entropy thresholding	Hoover database
4. Sookpotharam Supot *et al.*	2007	Matched Filter, Fuzzy k-median and length filter	Not specified
5. S. H. Rezatofighi *et al.*	2008	Local Binary Pattern, Morphological method, Spatial Image Processing	Drive
6. Yedidya , T *et al.*	2008	Kalman filter	Drive
7. M. Usman Akram *et al.*	2009	2 D Gabor Filter and Sharpening filter	Drive
8. M.Usman Akram *et al.*	2009	2-D Gabor Wavelet and Adaptive Thresholding	Drive
9. Sukritta Paripurana *et al.*	2010	Fractal dimension in spatial frequency domain	STARE
10. Diego Marin *et al.*	2010	Neural Network scheme, 7-D vector composed of grey scale, Moment based invariant pixel classification	Drive, STARE
11. M. M. Fraz *et al.*	2011	Vessel centreline detection, morphological bit plane slicing	Drive, Stare, Messidor
12. Selvathi D *et al.*	2011	Comparison of Kernel classifiers	Publicly available database
13. Chien Cheng Lee *et al.*	2012	Non Sampled Contour Transform, Line detector	Drive

14. Saied Fazli *et al.*	2013	First derivative of Gaussian matched filter, adaptive histogram equalization	Drive
15. K. Jeyasri *et al.*	2013	Multidirectional structuring elements, Connected Component analysis	Not specified
16. Ahmed Hamza Asad *et al.*	2013	Ant Colony system	STARE
17. Ocbagabir H. *et al.*	2013	Star Network Pixel Tracking	Drive

3.3.1 Related Work

Mehdi ghafourian fakhar eadgahi *et al.* [15] proposed the use of morphological operator for the detection of optic disc. In the first step, input image is taken and closing operation is applied with the help of structuring element having radius 11. The operation is as follows:

$$f \cdot B = (f + B) - B \qquad \ldots \textbf{(1)}$$

Here f is the original image, B is the structuring element used and symbol (·) is the greyscale morphological closing operation, symbol (+) is the dilation and symbol (-) is the greyscale erosion operation. Now the resultant image obtained from Eq. (1) is subtracted from the original image. This operation is defined as bottom hat transform. From this operation the vessels which contain low level components can be extracted.

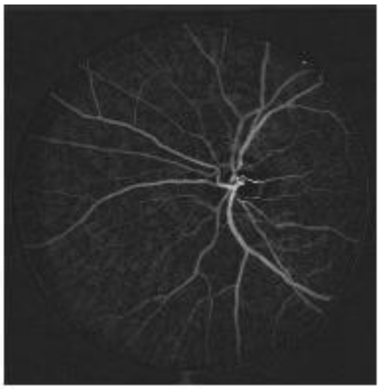


Figure 12: Blood vessels removed after applying bottom hat transform

Kevin Noronha *et al.* [16] presented the use of the help of edge detector filters such as Gaussian Laplacian, Prewit edge detector, Sobel edge operator and canny edge operator for blood vessel segmentation. Canny edge detection technique is the best technique among other edge detection techniques because it uses two thresholds for detection of edges and hence accordingly both weak and strong edges are detected.

Figure 13: Blood vessels detection with the help of canny edge detector

The extraction of blood vessels can also be done with the help of Kirsch templates. The Kirsch operator is a non-linear edge detector and finds the maximum edge strength in different directions. Hence in this method filtering of output can be done with kirsch template in different alignments. Threshold value can be varied to improve the quality of blood vessels.

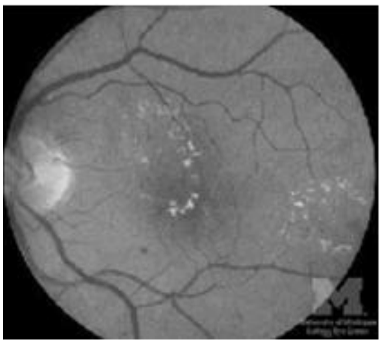


Figure 14: Original Image

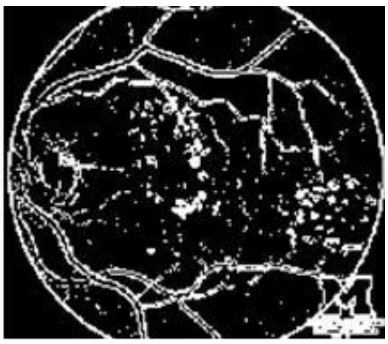


Figure 15: Blood vessels removed after applying Krisch Template

3.3.2 Proposed Work

The method presented here can be schematically described by the functional block in Fig. 16.

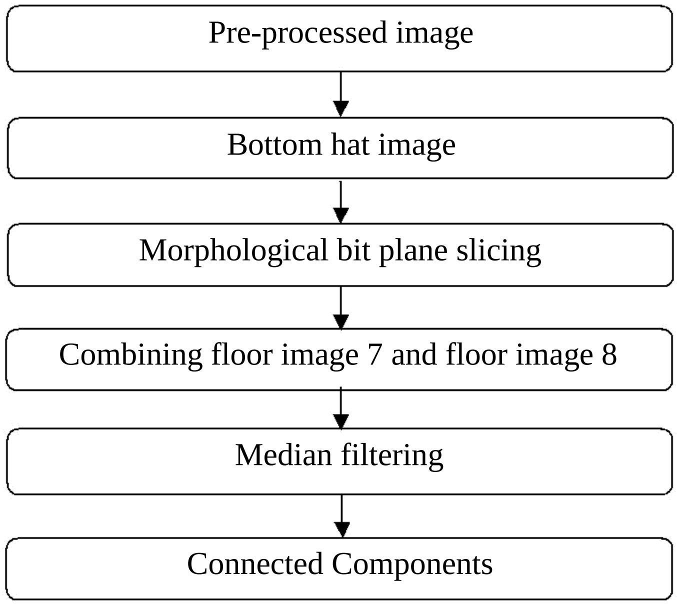


Figure 16: Flowchart of the procedure of the methodology for blood vessel segmentation

3.3.3 Steps for Blood Vessel Segmentation

Step 1: Contrast Enhancement

Mathematical morphology is a very important tool in image analysis and is used for detection of retinal pathologies in retinal fundus images. The basic morphological operations are opening, closing and dilation with the help of structuring element. The morphological opening operation, which is usually erosion followed by dilation removes objects from the image that are not in the same size than the used structuring element [17]. Therefore enhancement of the objects can be done with the help of subtracting the opened image from the original image. For removal of blood vessels morphological opening operator can be used with a small structuring element.

Step 2: Bottom hat transform

Morphological operator bottom hat transform is used with the help of structuring element. The size of the structuring element can vary from 1 to 8 pixels. For images with different range the size of the structuring element should vary accordingly. Bottom hat transform is used to extract low level grey components such as vessels. In bottom hat transform input image is subtracted from closed image. If a larger structuring element is used then larger vessels can be eliminated and thinner vessels will get blurred. Therefore it would be more preferable to use larger structuring element because in this the blood vessels are showing more clearly. The results of different structuring element are shown in results and discussions section.

Step 3: Morphological Bit Plane Slicing

Bit plane slicing plays an important role in order to change the total image appearance by specific bits. By separating a digital image into its bit planes, then each bit is helpful in examining the importance of each bit of the image. The image that results from the bottom hat transform is an improved greyscale image in which blood vessels are seen more than the background. The 8 bit gray image can be shown in the form of bit planes and the bit plane 1 is having the least significant bit whereas bit plane 8 is known for its higher significant bit. It can be seen that in bit plane 7 and bit plane 8 more relevant information related to the vessels is present. The other bit plane image is also important but it does not contain any useful information related to vessels and often neglected. Hence the binary image can be obtained by taking the sum of two bit planes and they are bit plane 7 and bit plane 8. Hence the resultant image contains important information related to vessels.

Step 4: Median Filtering

The final result after combining floor image 7 and floor image 8 although contains relevant information related to vessels but there is also little existence of salt and pepper noise. Hence for proper extraction of blood vessels and to reduce the effect of noise, median filtering plays an important role. Here median filtering is implemented two times due to the presence of noise.

Step 5: Connected Components

After applying combined morphological bit plane floor image 7 and floor image 8, it was observed that the blood vessels are highlighted but there are many connected components around the blood vessels. Hence the main aim is to remove connected components so that blood vessels can be shown properly with good combination of contrast. The final result is compared with the standard database.

3.4 EXUDATE DETECTION

Early detection of DR is necessary for the prevention of visual loss. Hard exudates are one of the main signs of the DR. Due to their high occurrence; their detection would play an important role in the screening purpose, and helps in monitoring and for estimation of the disease. Hence automatic detection of exudates is a very crucial task because normally they have poor contrast, uneven illumination and colour variation in retinal fundus images. Exudates become difficult to identify as the stage of diabetic retinopathy changes. Most of the work has been done by the researchers for the detection of exudates. Literature survey of the already work done is given below.

Table 4: Literature Survey of Exudate Detection

Author	Year	Methods Used	Database
1. Kevin Noroha *et al*.	2006	High grey level variation, Morphological reconstruction	Not specified
2. Maria Garcia *et al.*	2007	Error propagation algorithm	100 images
3. WANG Huan *et al.*	2009	Median filtering, Dynamic clustering	Not specified
4. Saiprasad Ravishankar *et al.*	2009	Different morphological operations	Drive, Stare
5. Michael D. Abramoff *et al*.	2010	Optical Coherence Tomography	Stare, Drive, Messidor
6. P. C Siddalingasway *et al.*	2010	Clustering and mathematical morphological operations	143 images
7. Amit Kumar Mishra *et al.*	2011	Distance Learning Metric using non linear kernels	Database from institute
8. M.Esmaeili *et al.*	2012	Curvelet transform	Diaretdb0
9. Eman M.Shahin *et al.*	2012	Morphological operation	Drive, Stare, Diaretdb1, Diaretdb0
10. Mehndi Ghafourian Fakhar Eadgahi *et al.*	2012	Top hat, Bottom hat, Reconstruction operations.	Diaretdb0
11. Mahendra Gandhi *et al.*	2013	Morphological operations	Set of 5 images
12. Sumathy. B *et al.*	2013	Binary Thresholding, Morphological operation	Drive, Diaretdb0
13. Handayani Tjandrasa *et al.*	2013	Mathematical Morphology	Messidor
14. Anam Tariq *et al.*	2013	Filter bank	Diaretdb0, Diaretdb1
15. Diptoneel Kayal *et al.*	2014	Median filtering, Image thresholding	Diaretdb1, Diaretdb0

After removing the optic disc and blood vessels from the retinal fundus images, exudate detection is our main aim. Therefore exudates can be identified with the help of *impixelifo* operator. *Impixelinfo* tool helps in creating a pixel information tool in the current figure. The pixel information tool displays information related to the pixel in that image where the pointer is positioned over. *Impixelinfo* operator will be performed on the threshold image.

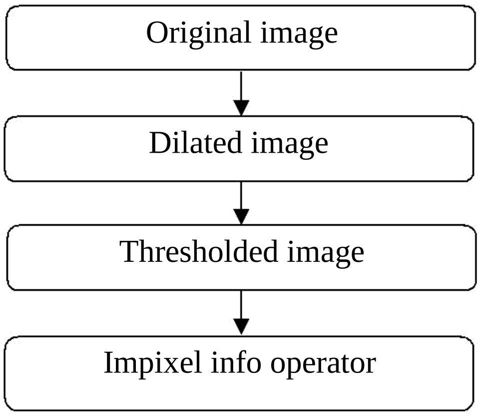


Figure 17: Flowchart of the procedure of the proposed exudates detection

The thresholded image will be same as we have eliminated in case of optic disc. By altering pixels and by getting the desired area, exudates can be localized.

3.5 EVALUATING PARAMETERS

We know that manual segmentation and measurement of DR lesions are quite difficult, time consuming, and the user may make mistakes also. The results of the segmentation can vary depending on the image quality and experience of user. Hence for this application certain standard parameters are used to evaluate the segmentation performances. First one is shown in Eq. (1) and it determines the accuracy of the segmentation results.

When a pixel is classified as vessel in both the ground state and segmented state it is known **as true positive.** When a pixel is classified as a non vessel in the ground truth and segmented image it can be defined **as true negative.** In **false negative** a pixel is classified as non vessel in the segmented image but as a vessel pixel in the ground truth image**.** When a pixel is marked as vessel in the segmented image but non vessel in the ground truth image it is known as **false positive.** Some other parameters are used to present the results in more understandable form. They are positive predictive value (PPV), sensitivity and specificity.

Accuracy: The accuracy is measured by the ratio of the total number of correctly classified pixels (sum of true positive and true negative) to the number of pixels in the image field of view.

$$\textbf{Accuracy = (TN+TP) / TN+TP+FN+FP} \qquad \ldots (1)$$

where TP, TN, FN, FP stand for true positive, true negative, false negative, and false positive.

Positive Predictive Value is the proportion of the true positives to positive test results.

PPV is shown by Eq. (2).

$$PPV = TP / TP+FP \qquad \ldots (2)$$

Sensitivity is the proportion of true positives classified by the system. Sensitivity is shown by Eq. (3).

$$\text{Sensitivity} = TP / (TP+FN) \qquad \dots (3)$$

Specificity is the ability to detect non vessel pixels. Specificity is shown by Eq. (4).

$$\text{Specificity} = TN / (TN+FP) \qquad \dots (4)$$

4. RESULTS AND DISCUSSIONS

4.1 RESULTS & DISCUSSIONS OF PRE–PROCESSING

In the following section results of the pre- processing are explained below. As it has been discussed earlier that pre- processing is done with the help of CLAHE algorithm. The CLAHE algorithm has been applied on the grey scale image.

Step 1: In the step 1 Fig. 18 shows the result of the original image.

Figure 18: Original image

Step 2: The result of the grey scale image is shown in Fig 19.

Figure 19: Greyscale image

Step 3: Fig 20 shows the result after applying CLAHE. The result shows that the contrast of the image has been improved and the optic disc and blood vessels are showing clearly.

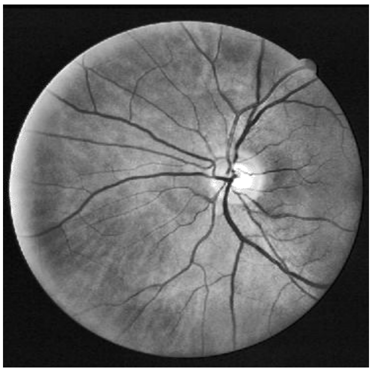


Figure 20: Contrast enhanced image

The methodology has been evaluated using publicly available database named Drive. It has been observed that the image after contrast enhancement is more illuminated and the details like blood vessels and optic disc are shown clearly. Also from the results it has been observed that the finer details of each and every region got enhanced. The area of the optic disc is more highlighted and can be used for optic disc detection. The method has been evaluated on Drive database and it contained 40 images divided into test and training set. Each set of test and training comprises 20 images. Contrast enhancement is applied on the entire test and training set and each image has shown improvement in contrast and the quality of the image has improved.

4.2 RESULTS & DISCUSSIONS OF OPTIC DISC REMOVAL

The results of the optic disc removal are described in the following section according to the steps applied above. As in the methodology several methods have been applied for optic disc removal. Optic disc is an important landmark in retinal fundus images and hence it is essential to remove for further diagnosis. The results are compared with the already proposed methods described above and it has showed better results in terms determining the exact boundaries of bright objects especially optic disc.

Step 1: The result of the pre- processed image is shown in Fig 21. Here the pre-processed image is the same as described in the above section.

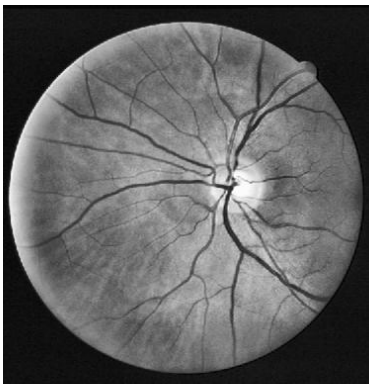
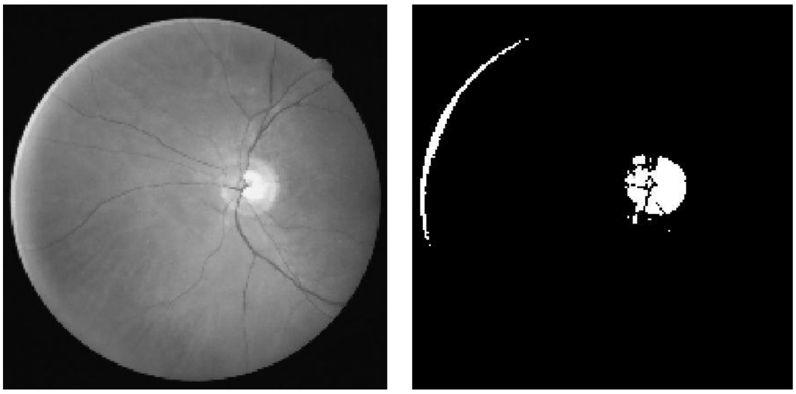


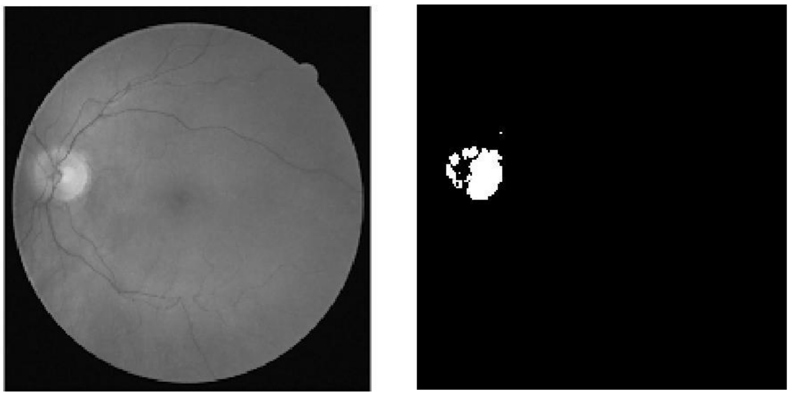
Figure 21: Contrast enhanced image

Step 2: The result after applying dilation and thresholding are shown in Fig 22(a) and 22(b). After applying dilation proper region of optic disc is shown and after applying thresholding optic disc is removed.



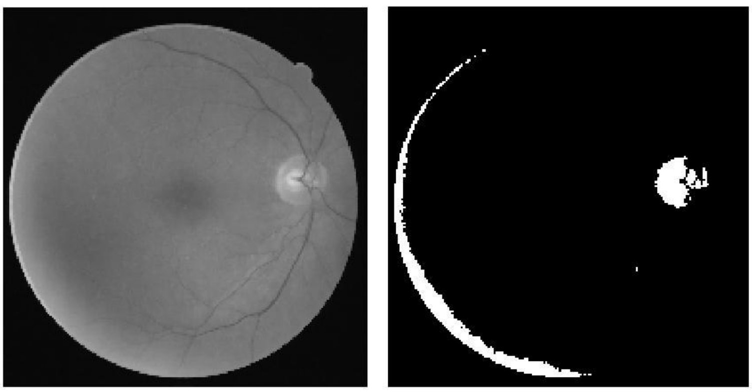
(a) *(b)*

Figure 22: (a) Dilated image; (b) Optic disc removal



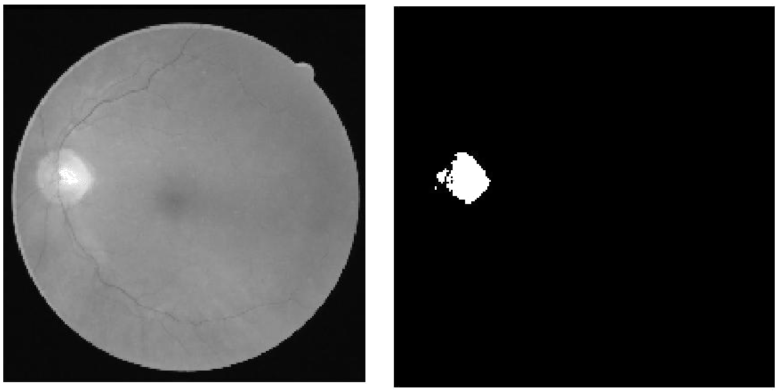
(c) *(d)*

Figure 23: (c) Dilated image; (d) Optic disc removal



(e) *(f)*

Figure 24: (e) Dilated image; (f) Optic disc removal



(g) (h)

Figure 25: (g) Dilated image; (h) Optic disc removal

The objective of this work is to investigate a method for automatic analysis of retinal images for the detection and recognition of retinopathy diseases. In this work several methods have been investigated and a set of suitable morphological steps for automatic detection of optic disc have been proposed. Despite the existence of pathological reasons, the results of the applied method are satisfactory, and the localization of the centre of the optic disc found to be effective. Images were taken from Drive database. The method was tested on the training set and test set of Drive and it showed remarkable results.

4.3 LIMITATIONS

From the results above, it can be observed that although the area of optic disc is clear, but half circular region white in colour appears around the optic disc. This portion is coming in most of the results as this cannot be concluded as the part of the optic disc region. So this is one of the limitations and it needs to be overcome in future.

4.4 RESULTS & DISCUSSIONS ON BLOOD VESSEL SEGMENTATION

Step 1: The result after applying CLAHE is shown in Fig 26.

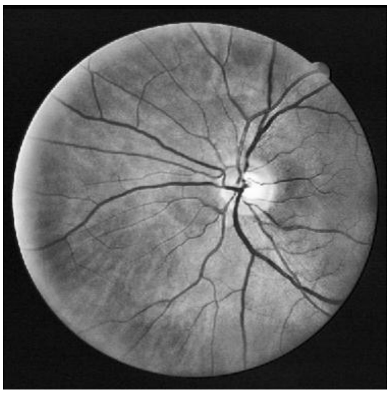
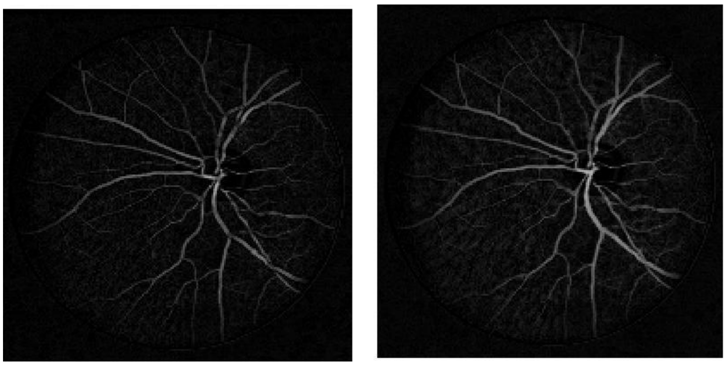


Figure 26: Contrast enhanced image

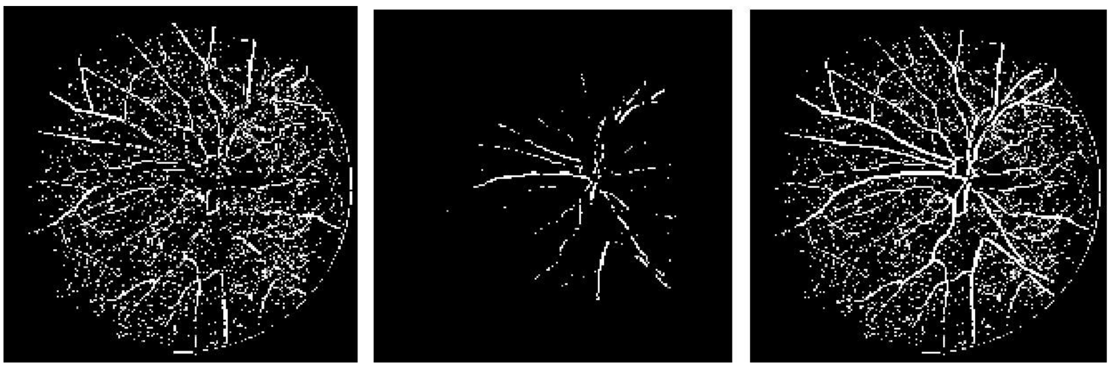
Step 2: Bottom hat transform is applied on the contrast enhanced image. The result of the bottom hat transform with smaller and larger structuring element is shown in Fig 27.



(a) *(b)*

Figure 27: (a) Bottom hat transform with smaller structuring element; (b) Bottom hat transform with larger structuring element

Step 3: Morphological bit plane slicing has been applied for blood vessel segmentation. Fig 28 (a) shows the result of morphological floor bit plane 7. The result of morphological floor bit plane 8 is shown in Fig 28 (b). The result of combined morphological floor image 7 and floor image 8 is shown in Fig 28 (c).



(a) *(b)* *(c)*

Figure 28: (a) Morphological bit plane floor image 7; (b) Morphological bit plane floor image 8; (c) Combined morphological bit plane slicing 7 and 8

Step 4: The results after applying median filtering are shown in Fig 29 (a) and Fig 29 (b).

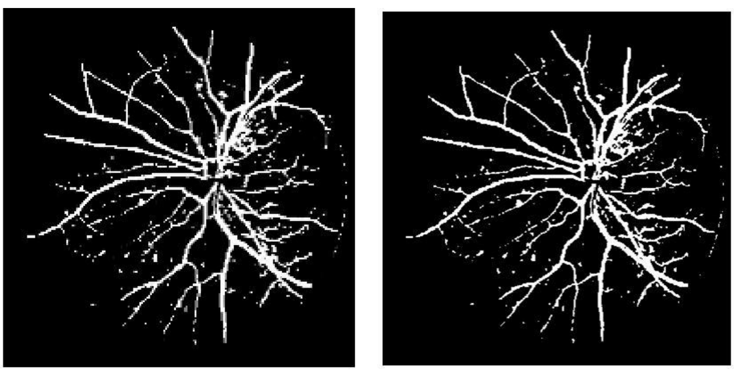
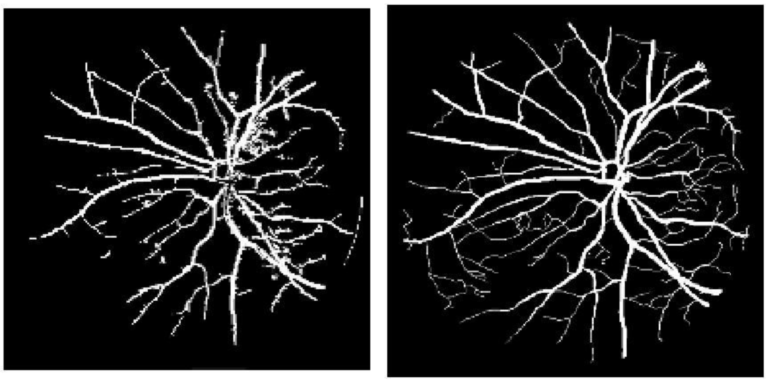


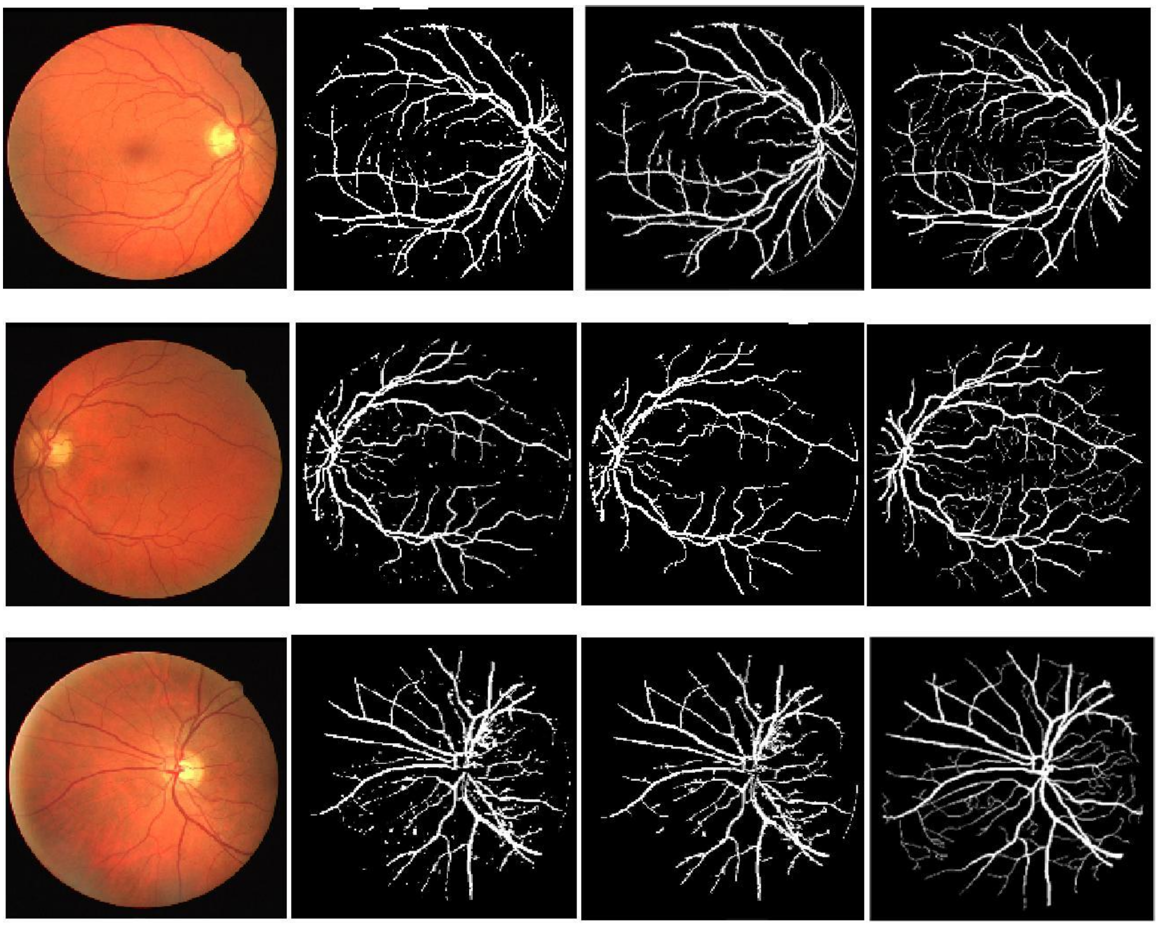
Figure 29: (a) Median filtering; (b) Blood vessel segmentation

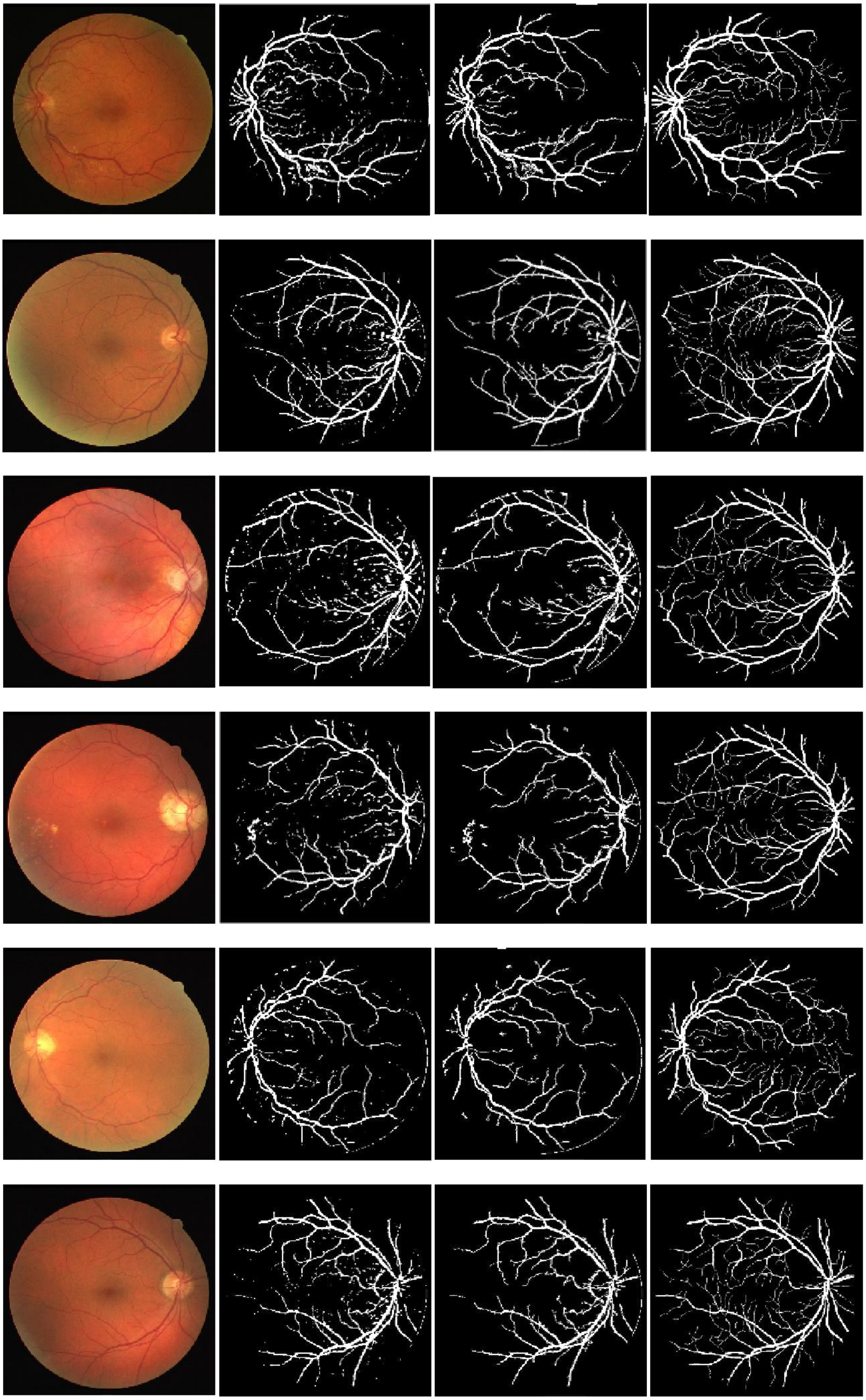
***Step* 5:** The results of the blood vessel segmentation after removing connected components are shown in Fig 30 (a). The results are compared with the standard database and are shown in Fig 30 (b).

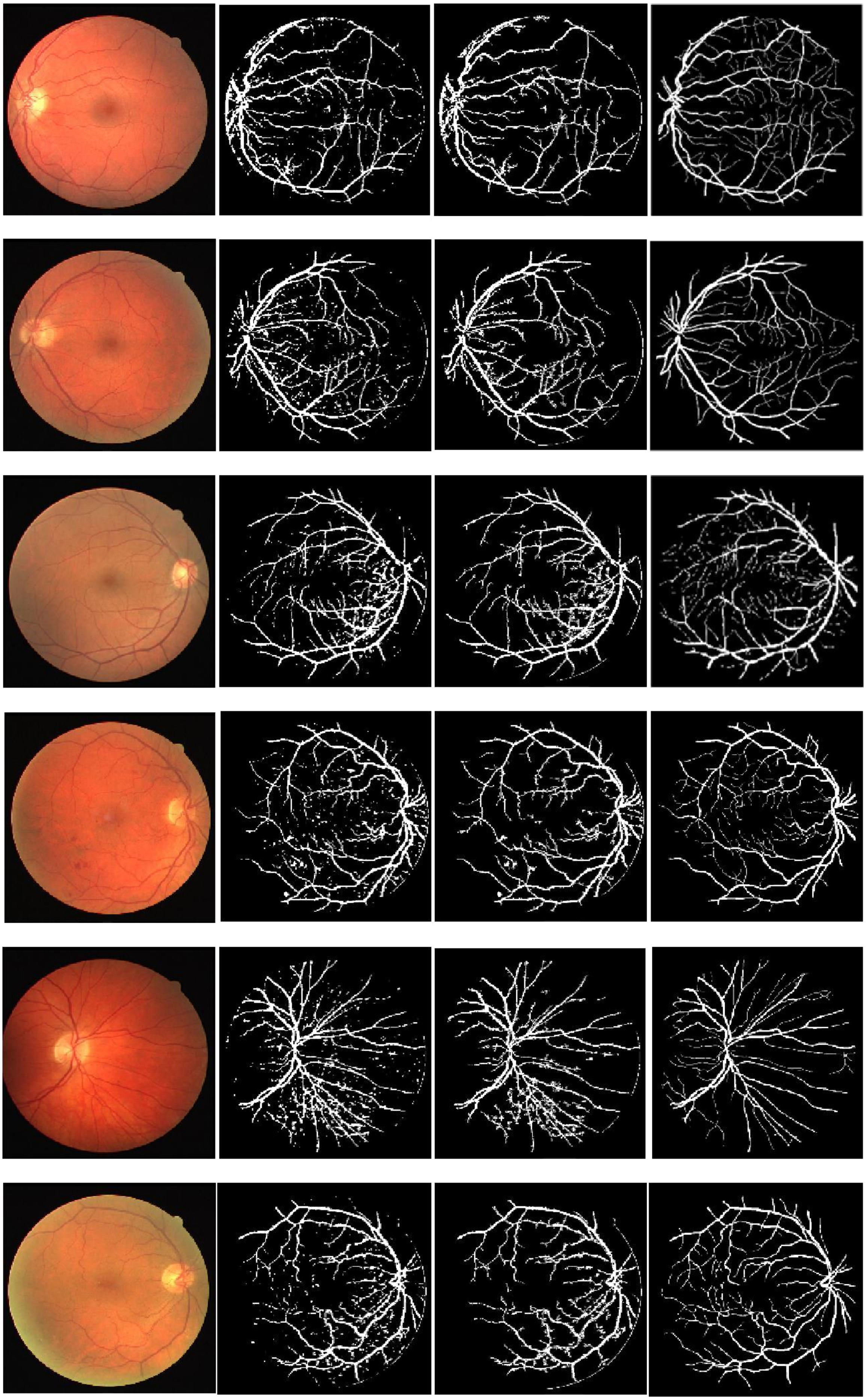


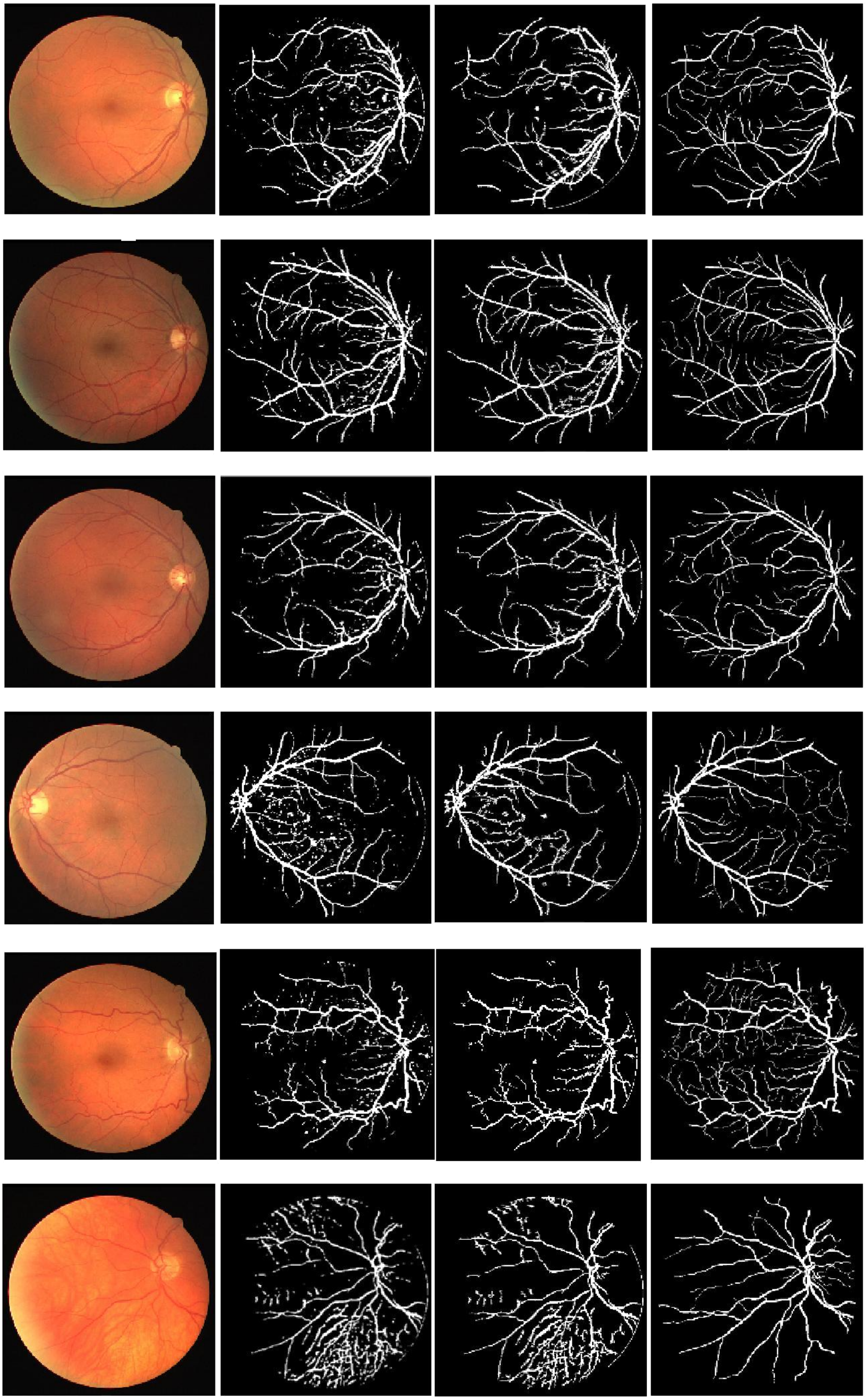
(a) *(b)*

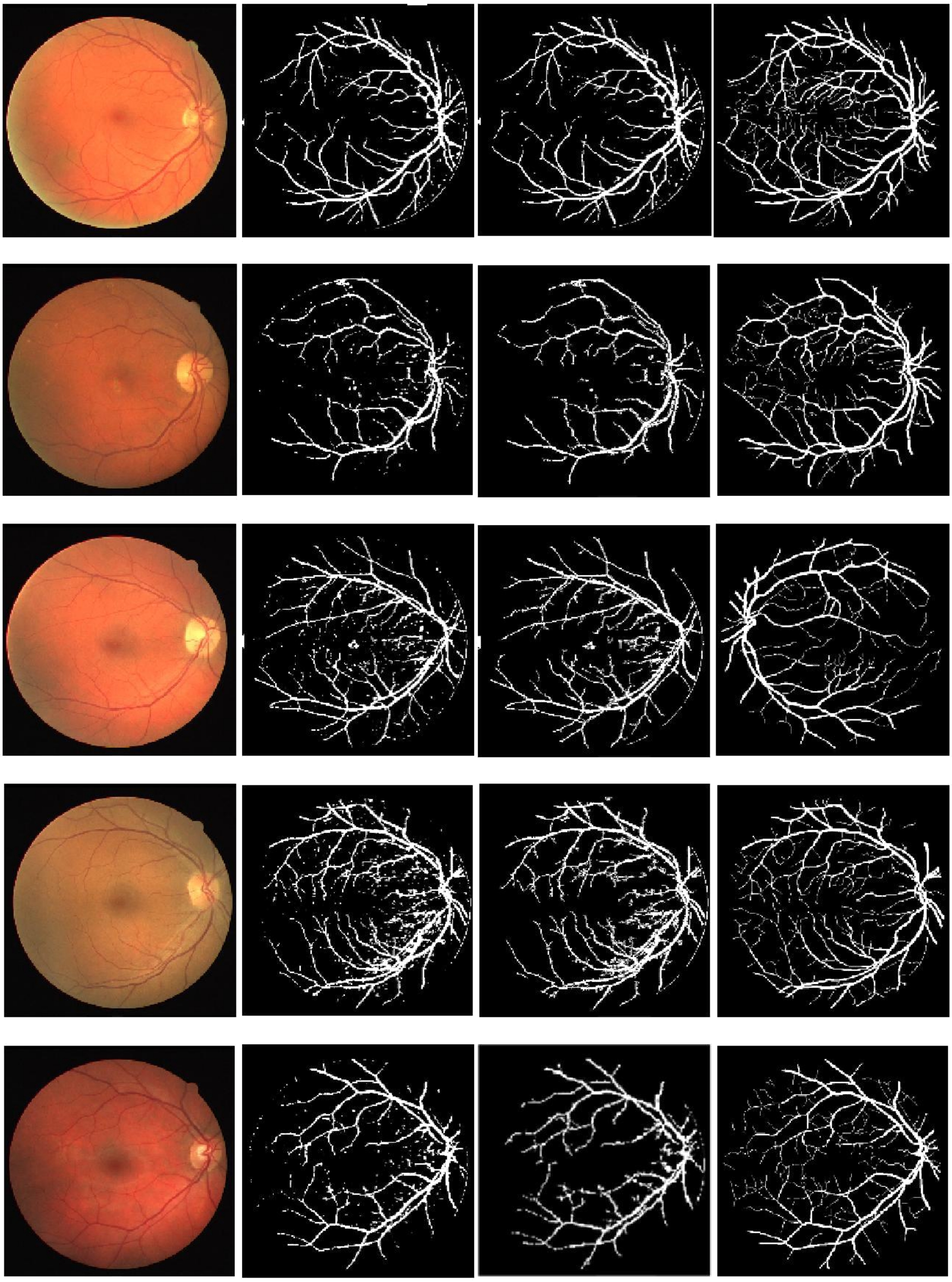
Figure 30: (a) Blood vessel segmentation; (b) Standard database











(a) *(b)* *(c)* *(d)*

Figure 31: (a) First column of images represents Original images; (b) Second column represents Final result # 1 of blood vessel segmentation; (c) Third column represents the final result # 2 of blood vessel segmentation; (d) Fourth column represents standard database

An automated segmentation method has been proposed for identification of blood vessels. Mathematical morphology and bit plane slicing have been used to extract the blood vessels clearly. The shape and orientation maps are generated by the application of a multidirectional bottom hat transform with a linear structuring element which emphasizes the vessels in a particular direction and after that important information is extracted from gray scale with the help of morphological bit plane slicing. The final image containing vessels is obtained with the help of median filtering using two times. The methodology has been tested on Drive database. The results are compared with recently published results, and it shows that that results are good and blood vessels are showing clearly.

4.5 LIMITATIONS

Blood vessel segmentation plays an important role in the diagnosis of various retinal eye diseases. As from the above results it is observed that blood vessels are showing clearly but if comparison is done with the standard database some parts of the vessels are eliminating. We are using two methods above; in the first method we are applying median filtering we are observing that some noise is present and if we are using connected components method in that also some of the part of the vessels is eliminating. But these are very little problems and can be overcome in the future.

4.6 RESULTS & DISCUSSIONS ON EXUDATE DETECTION

Step 1: Exudates are hard yellowish deposits on the retina and is shown in Fig 32.

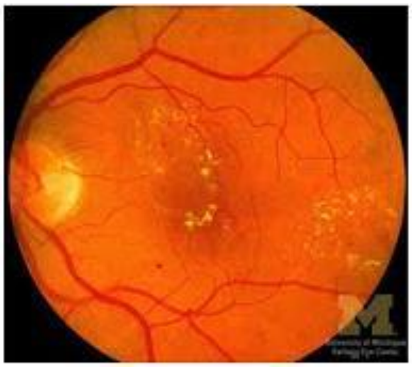


Figure 32 : Original image containing exudates

Step 2: Fig 33 shows the segmented image with exudates. They are seperated with the help of *impixelinfo* operator.

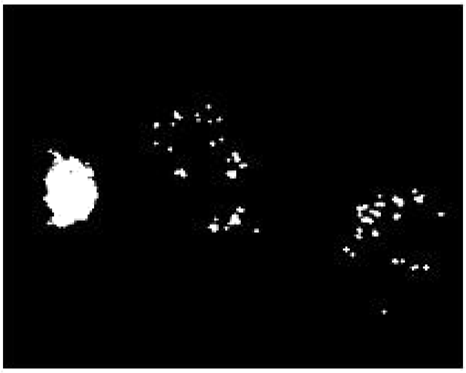


Figure 33: Segmented image containing exudates

From the above results, it has been observed that in the proposed method, exudates were clearly distinguished from the optic disc. Fig. 34 shows the enhanced exudates and is shown clearly in the retinal fundus image which is affected by the diabetic retinopathy. Thus the morphological operation dilation and thresholding is used to detect the presence of exudates. It can be seen from the observed results that the features we have detected can be used as a complementary tool for the diagnosis of diabetic retinopathy. The detected exudates can be used to identify that how much it has affected the retinal fundus image. The early diagnosis of the DR can help the patients to take proper treatment to eliminate the disease.

5. CONCLUSION AND FUTURE WORK

An automated segmentation method of identifying blood vessels, optic disc and exudates detection in retinal images has been proposed. The methodology employed a combination of different image processing techniques and the application of morphological bit plane slicing for blood vessel segmentation. The shape and orientation maps can be initiated with the help of morphological operator bottom-hat transform with the help of structuring element which helps in orientation of blood vessels in the particular direction and after that useful information can be selected from the morphological bit plane slicing. The morphology has been tested and compared with two publicly available databases Drive. Experimental results show that the results achieved with the proposed methodology are good and can be compared with the published results and almost equal to the performance of human observers. The vessel tree segmented it depends upon the centrelines of the vessels and the shape and orientation of the vessels. By applying the median filtering and connected components it was found that the vessels are segmented properly although some noise is present but important features are extracted. The vessels which are segmented can be used for the diagnosis of many diseases such as glaucoma and diabetic retinopathy. If a comparison is done between the blood vessels of a diseased person with the normal person the diameter of the blood vessels may change or the occurrence of some new blood vessels. Hence our future work deals with the segmented blood vessels if they belong to normal person or diseased person. In this work a set of morphological steps has been proposed for the detection of optic disc and exudates. If the detection of exudates is required then optic disc must be removed prior to that because they have similar colour and contrast with that to exudates. The method developed to detect exudates will help the doctors in screening process of diabetic retinopathy process to detect symptoms faster.

The method has been evaluated and compared with the database images of Drive on both the test and training images both containing 20 images. All the images showed good results either in terms of contrast, optic disc removal and blood vessel segmentation.

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