MS Research Work

Automatic Detection of Macula and Fovea in Human Retinal Fundus Images

Submitted By

Student Name: Tamoor Aziz

Registration No: 378-FET/MSEE/F14

Supervisor: Dr. Ihsan-ul-Haq

Co-Supervisor: Dr. Abdul Basit

Department of Electrical Engineering

FACULTY OF ENGINEERING AND TECHNOLOGY

INTERNATIONAL ISLAMIC UNIVERSITY, ISLAMABAD

November, 2017

Automatic Detection of Macula and Fovea in Human Retinal Fundus Images

Tamoor Aziz

378-FET/MSEE/F14

The work in this dissertation is submitted to Faculty of Engineering and Technology, International Islamic University Islamabad Pakistan for partial fulfillment of **MS Electronic Engineering** with specialization in **Digital Image processing** at the Department of Electrical Engineering.

Faculty of Engineering and Technology (FET)

International Islamic University, Islamabad.

Certificate of Approval

This is certify that research **"Automatic Detection of Macula and Fovea in Human Retinal Fundus Images"** was a research work of Mr. **Tamoor Aziz** with Registration No. **378-FET/MSEE/F14**, it is adequate in quality and scope of MS Electronic Engineering.

Supervisor:

Dr. Ihsan-ul-Haq

Co. supervisor:

Dr. Abdul Basit

November 2017

Acceptance by the Viva Voce Committee

Title of Thesis: Automatic Detection of Macula and Fovea in Human Retinal Fundus Images

Name of Student: Tamoor Aziz

Registration No. 378-FET/MSEE/F14

Accepted by the Department of Electrical Engineering, Faculty of Engineering and Technology International Islamic University Islamabad in partial fulfillment of the requirements for the Master of Philosophy degree in Electronic Engineering with specialization in Digital Image processing.

Viva voice committee

Dean FET:

Prof. Dr. Muhammad Amir
International Islamic University Islamabad

Chairman DEE

Dr. Suheel Abdullah
International Islamic University Islamabad

External Examiner:

Dr. Faisal Zafar
Pakistan Atomic Energy Commission

Internal Examiner:

Prof. Dr. Muhammad Amir
International Islamic University Islamabad

Supervisor:

Dr. Ihsan-ul-Haq
International Islamic University Islamabad

Co. Supervisor:

Dr. Abdul Basit
Pakistan Atomic Energy Commission

In The Name of ALLAH (SWT) the Most Beneficent

And the Most Merciful

Declaration

I declare that the research work presented in this dissertation with title **"Automatic Detection of Macula and Fovea in Human Retinal Fundus Images"** is my own research work and it was carried out in accordance with the rules and regulations of International Islamic University Islamabad. I also claim that the research has not been demonstrated anywhere else for evaluation except where cited with proper reference.

……………………

Tamoor Aziz

378-FET/MSEE/F14

ACKNOELEDGMENTS

In the name of ALLAH the most gracious and the most merciful. All praise and glory goes to almighty ALLAH (Subhanahu wa Ta'ala) who gave me the courage and patience for the successful completion of this research work. Peace and blessings of ALLAH be upon his last Prophet Muhammad (Sallulah-o-Alaihihe-wassalam) and all his sahaba (Razi-Allah-o-Anhu) who devoted their lives for the prosperity and spread of Islam.

I would like to take this opportunity and give special thanks to my supervisors Dr. Ihsan-ul-Haq and Dr. Abdul Basit, without their motivations and help this all was impossible for me. They guided me in completing thesis. They gave me the most needed supervision and took keen interest in all matters related to my thesis.

I would like to pay thanks to all my teachers and friends who contributed their knowledge with me. Particularly, the great effort of my parents who guided and encouraged me throughout my life.

There is no way, no words, to express gratitude; May ALLAH help us in following the true spirit and principles of Islam written down in the Holy Quran and Sunnah (Ameen).

List of tables

List of Figures

List of Abbreviation

Optic Disk	OD
Blood Vessels	BVs
Diabetic Retinopathy	DR
High Resolution Fundus Images	HRF
Digital Retinal Images for vessels Extraction	DRIVE
Region of Interest	ROI
Age Related Macular Degeneration	ARMD
Support Vector Machine	SVM
Particle Swarm Optimization	PSO

Abstract

Macula is central part of retina and it does high acuity tasks. In a case when macula is defunct, it may leads to permanent blindness. Macular disease should diagnose at initial stage so proper treatment can be adopted. The problem that confronts for finding macula is the surrounded region that is same as like as macula. Simple image processing concepts cannot be applicable here. In order to diminish the problem, a smart algorithm is needed so exact macula can be identified affective diagnostic of a disease can be achieved.

The proposed MS research work is to examine retinal fundus images to localize macula and fovea automatically. Retinal fundus images are imparting great assistance to find the presence of retinal diseases. Four databases of fundus images are used to experiment proposed algorithm and that are High Resolution Fundus (HRF) images, Digital Retinal Images for Vessel Extraction (DRIVE), MESSIDOR and Al-shifa. The resolution and properties of above mentioned databases are different to each other.

Macula is located through a retinal feature that is known as Optic Disk (OD) which is categorized as bright gray levels. OD is localized with the help of thresholding and correlation that yields coordinates of OD. On the basis of coordinates, orientation of the image is achieved between left and right eye. Macular region of interest (ROI) is extracted through location of OD. Image filtering methods are used to locate macula, fovea from macular ROI. The proposed technique concludes 100% accuracy on DRIVE, HRF and Al-shifa databases. The technique achieves 97% accuracy on MESSIDOR dataset.

Table of Contents

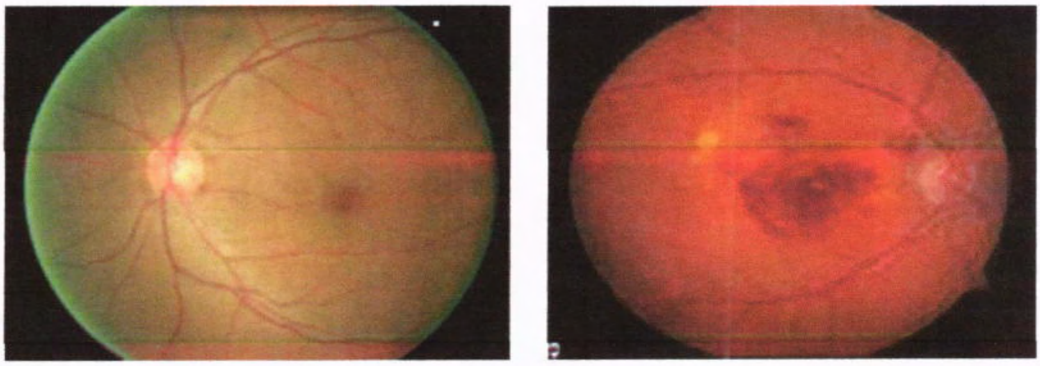
CHAPTER 1 INTRODUCTION

It is a great interest of engineering entrepreneurs to develop new, efficient, accurate and easy methods in the field of Biomedical engineering. Biomedical engineering is integration of Engineering, Biology and Medical sciences. Using cross disciplinary activities, the researchers are devising techniques that are imparting good results and easy to utilize as compared to previous methods.

Computer algorithms are extensively used in the field of Biomedical Engineering to diagnoses diseases of a particular organ of human body. In this respect, images obtained and processed through computer applications to endorse whether organ is healthy or affected. In every smart computer application, the first step that is required is to locate object in the entire image spontaneously. After localization, image is further processed to diagnose a disease.

The average diameter of an eye of human being is approximately is 20 mm [1]. An eye consists of three membranes named as cornea, choroid and retina. The cornea is external surface of an eye. Choroid is further divided into two parts called ciliary body and iris. The central structure of iris, pupil controls the amount of light by contracting or expanding. The inner part of eye is retina. When light enters in an eye, it displaced on retina. Macula is situated at the center of retina as well as fovea is the central part of macula. Macula performs high acuity jobs like writing, driving and reading. High acuity work requires large concentration of human being to accomplish. Macula has photoreceptors of an eye; on the basis of photoreceptors macula accomplish photopic and scotopic vision. There are two photoreceptors called rods and cones. Photopic vision is also called bright light vision and an eye observes Photopic vision as colour image. Scotopic vision is also known as dim light vision and an eye observes Scotopic vision as gray scale image. Macula is very important part of human eye. Change in macula decreases an eye sight. If proper treatment is not adopted at early stage, it leads to permanent blindness. Different types of diseases deteriorate macula like cherry red spot, Age related macular degeneration, toxoplasmosis, diabetic retinopathy, glaucoma and macular edema.

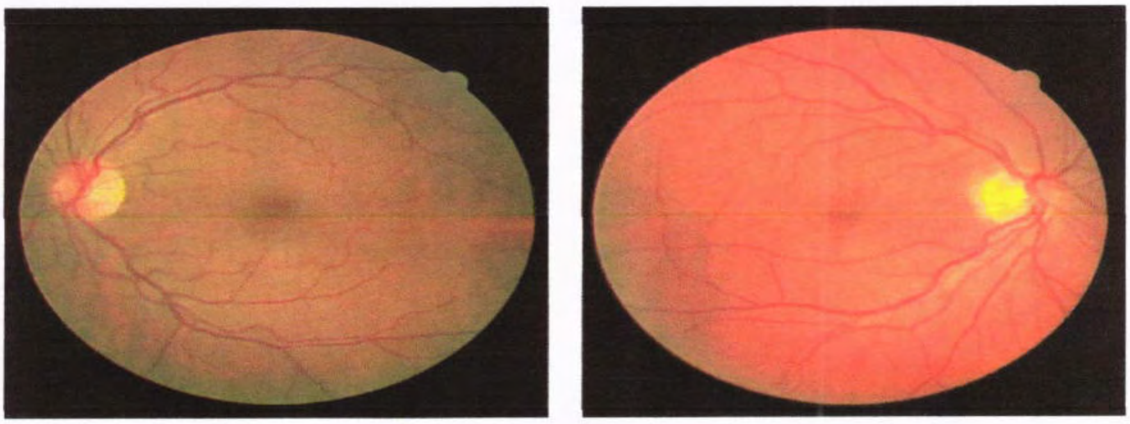
Retinal Fundus Images are wildly used to diagnose macular diseases. Fundus photography is a specified medical photography in which fundus photograph is taken by high quality camera. Ophthalmologist analyzes images whether macula is healthy or affected by diseases. Optic Disk (OD), blood Vessels, Macula and fovea are structures of fundus image. The brightest region of fundus image is optic disk. Macula is dark region. Vessels are almost same as macula propagated over the image. Two types of retinal fundus images are shown. Figure 1.1 (a) is image from healthy eye contrary figure 1.1 (b) is image where macula is affected by a disease.



(a) (b)

Figure 1.1: a) Fundus image of healthy eye; b) Fundus image of ARMD degeneration

The orientation of eye is very critical to differentiate an image between left and right eye. In left image macula is displaced right to OD as shown in figure 1.2 (a). Right eye has macula is left of its OD as shown in figure 1.2 (b). The region where gradual change happens in low level intensities is known as macular region. Macular region has property that it does not contain any blood vessels.



(a) (b)

Figure 1.2: a) Fundus image of left eye; b) Fundus image of right eye

K. W. Tobin [2] illustrates the properties of retinal fundus image. OD has diameter of 1.5mm. The macula and fivea have 3-4mm and .25mm diameter respectively as illustrated in figure 1.3.

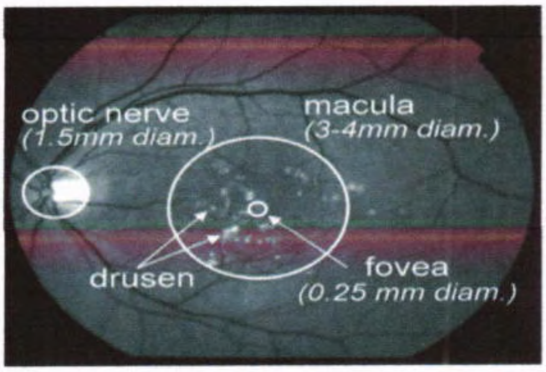


Figure 1.3: Properties of retinal fundus image.

The proposed research is to use an image processing concepts to discover an efficient algorithm to locate macula and its central part fovea. Macula is categorized as low intensities.

1.1 Problem Statement

Analysis of retina is used to diagnose various diseases of eye by the ophthalmologists. There is too much variation in the retinal images. Even normal eyes have a lot of illumination variation. Macula is the central part of retina. To diagnose eye related diseases, first step is to locate the macula. So this research focuses to locate macula and its central part (fovea). For the localization of macula, the simple image enhancement techniques cannot be used because the macula is categorized as the low level intensities and its surrounded region of retinal fundus image is also of approximately same intensities so discrimination between macula and other region cannot achieve. Intensities variation in background is also a factor that makes the task quite difficult. As discussed in the literature review the accuracy for said task is around 90%. This is very sensitive issue so accuracy should be improved. MS research work is to extract macula from retinal fundus image with high accuracy.

1.2 Thesis Organization

Chapter 1: First chapter illustrates the introduction and abstract of proposed work. It expresses the problem statement. Rest of the chapters are organized as

Chapter 2: Second chapter is literature review. This chapter is about the techniques that are utilized by other researchers and the results they achieved during their research.

Chapter 3: Proposed technique is third chapter. The proposed method and technique that is used in my thesis are described here.

Chapter 4: The results of proposed algorithm are given in this chapter. The results are compared with the latest papers.

Chapter 5: The conclusion of proposed research is given in chapter 5. Furthermore, the parameters that may be used as a future research are given.

CHAPTER 2 LITERATURE REVIEW

Retinal fundus images are extensively used to search diseases of macula. It is a specialized form of fundus photography in biomedical engineering that ophthalmologist operates it. The research that has been done is discussed here.

2.1 Macula Localization Techniques

Anushika et al. [3] experiment a new technique to locate macula. Error free localization of macula is an important task to diagnose pathologies. They used strategy based window for macula identification. They first identify OD and then extract macular ROI based on the information of OD. A local database was used from a renowned hospital to experiment their algorithm which had normal and abnormal images. Their technique yields encouraging results.

Diabetic Retinopathy was diagnoses by Israj Ali et al. [4] in their research paper. To diagnose Diabetic Retinopathy effectively, the exact location of OD and macula was required. After extraction of macula, the image is further processed to search miroaneurysms, exudates and edemas. Features detection of retinal fundus images, a intensity based preprocessing was done to fulfill the need of OD and macula location. The algorithm was tested on 100 images from MESSIDOR database. The success rate on normal images was 100% and 84% for OD and macula respectively, whereas success rate on affected images was 100% and 44% for OD and macula respectively.

Bansal et al. [5] presented a research paper where they used an intensity based approach to extract macula spontaneously. They proposed a method to identify macula based on OD. Then macular ROI was obtained and morphological operations were used to distinguish macula from background of

ROI. The algorithm was run on 10 samples of fundus photograph of MESSIDOR database. The propose technique takes 28.80 seconds of time to complete the task.

The research "A stand alone MATLAB application for the detection of optic disk and macula" was made by B. Ramasubramanian et al. [6]. An error can be in the manual selection of macula so they derived a new efficient technique to reduce error at its minimum level. Their paper illustrates a novel and fast stand alone application for identification of fundus features. K means segmentation is used for extraction of macula and morphological operation with bilateral filtering is used for the detection of OD. The experiment was conducted on 135 glaucoma affected images collected from local eye hospital and 200 diabetic retinopathy affected images from DIARETDB1 and DRIVE databases. Computational time of proposed algorithm of OD detection is 32 seconds and 13 seconds for macula localization with accuracy of 98%.

The research paper "An efficient imaging technique for automated macula localization from fundus images" was written by A. Issac et al. [7]. The paper presents an efficient algorithm of computer vision to detect macula from low contrast and images that are badly affected by diabetic retinopathy. Geometric features are used to detect OD and with the information of OD macula is localized using statistical based model. The proposed scheme was tested on 200 images from healthy and affected eyes and results were promising.

One of the severe diseases of retina that may cause of permanent blindness is Diabetic Macular Edema. A. Johny proposes a novel based approach to diagnose Diabetic Macular Edema. For the diagnostic of Diabetic Macular Edema, some features like OD, macula and fovea were required to detect first. The presence of bright lesions in macular region is validation that the eye is affected by Diabetic Macular Edema. Early detection of Diabetic Macular Edema may prevent the vision lost. The paper illustrates a computer approach to diagnose a disease. The first step of the paper is to find a disease then second step is to determine the severity of the Diabetic Macular Edema. The results were quite promising that leads to adopt the proposed method in real life.

The exact detection of macula requires exact detection of OD. There is a deep relationship between OD and macular ROI and also the BVs enter and exit from OD. The accuracy of BVs identification and macula detection relies on the detection of OD at some extent. R. R. V. eSilva et al. [8] presents a technique in their paper to detect OD. The research paper expresses five methods to detect of OD. The output of any method is based on weighted voting. The proposed algorithm was experimented on five publicly available databases.

Age related macular degeneration (ARMD) is one of common disease of macula that reduces eyesight with the passage of time. ARMD usually affects old people. ARMD may come from macular tissues by thinning them, pigment deposition, abnormal BVs growth and combination of mentioned problems. V. Asokan [9] elaborates a computer aided approach where abnormalities are found by multi stage segmentation. Threshold with canny edge detection are used to identify problem in region of interest. The abnormalities that are known as lesions are bright gray levels. They tested their algorithm on fundus images that were taken from Pattern Recognition Lab (PRL) from the department of ophthalmology, Friedrich Alexander University with the accuracy of 90%.

L. Ichim et al. [10] wrote a research paper named as "Intelligent feature selection for regions of interest identification of retinal images". The paper expresses an intelligent method for the selection of retinal image features like OD, macula, exudates and their ROI. For that purpose, different confusion matrices are created and then voting scheme uses the values that are main diagonal of those matrices. Retinal image is further sub-divided into patches by sliding box and fixed box and ROI of different retinal features. 100 images from MESSIDOR database were utilized to benchmark the proposed technique where 20 images used for training process. 96% and 98% accuracy achieved for OD and macula respectively.

The paper "Detection of foveal avascular zone in colour retinal fundus images" was implemented by H. A. Nugroho et al. [11]. DR is the one of most common disease of adult blindness. The presence of DR yields stretch of foveal avascular zone (FAZ), generation of new BVs, hard and soft exudates and hemorrhages. The objective of the paper is to locate FAZ area automatically. FAZ detection is a critical step for the assessment of pathologies of retinal fundus images. 59 retinal fundus images were carried out to evaluate the technique. The research paper comprises of three main steps that are preprocessing, BVs extraction and FAZ localization. In first step, the quality of an image is increased by contrast stretching. BVs are identified using matched filter and entropy based thresholding. FAZ area is extracted by connecting vessels end-points. Evaluation was done by correlation between polygon area and ophthalmologist area. Correlation coefficient of 0.912 was achieved in validation step.

The property that macula region is a vessel free region. J. P. Medhi et al. [12] used this property and wrote a research paper named as "Automatic detection of fovea using property of vessel free region". The proposed research was simple and for achievement of task the information about OD localization does not required. First BVs are taken from green channel and vessel free property is used to extract macular ROI. Dark intensity phenomenon is used to identify fovea. Various morphological operations were performed on different colour planes. The algorithm was tested on 759 images DRIVE, DIARETDB0, DIARETDB1, LOCAL, MESSIDOR and HRF databases which are comprises of both normal and abnormal images with success rate of 100%, 96.85%, 97.67%, 98.46%, 96.25% and 100% respectively.

Diabetic Macular Edema (DME) is malicious that affects macula and may lead to permanent blindness. In this regard, N. Sengar et al. [13] wrote another paper "Detection of Diabetic Macular Edema in retinal images using a region based method". Macular location is an important step to diagnose DME and the proposed method does not require the localization of OD. Level of DME is done by dividing retina according to international standard and bright lesions define the severity of disease. The macular ROI is adaptive according to fundus images. The benchmark was marked on 100 images of MESSIDOR database the successful rate was 80% – 90% was different cases.

The macula and fovea were localized by J. K. Medhi et al. [14] in their paper "Detection of macula and fovea for disease analysis in colour fundus images". When any abnormality falls on macula the central vision is lost. J. K. Medhi et al [21] presented a new technique to identify macula and fovea and purpose was achieved using BVs of fundus photographs. DRIVE, MESSIDOR, HRF, DIARETDB1 and STARE databases were used to experiment the technique. The success rate of DRIVE, MESSIDOR, DIARETDB1, STARE and HRF were 100%, 97.75%, 95.5%, 96% and 100% respectively.

G. Mittal et al. [15] proposes a method to extract macula based on OD in their paper "Optic disk and macula detection from retinal images using generalized motion pattern". The method was novel and unified to benchmark OD and macula using Generalized Motion Pattern (GMP) which is used to induce motion to eliminate noise and unwanted information. The method was checked on five datasets that are MESSIDOR, DIARETDB0, DIARETDB1, DMED and DRIVE with accuracy rate of 98.3, 96.15, 95.51, 97.04 and 100%.

R. Radha et al. [16] utilize a simple operation to detect macula and OD in the paper of "Identification of retinal image features using bit plane separation and mathematical morphology". The paper illustrates simple technique to identify OD and macula using bit planes. The OD and macula is localized using bit plane 0 and bit plane 1 respectively and boundary is identified using mathematical morphology. The method was evaluated on dataset collected from local aye hospital with accuracy of 91%.

The research paper "Automatic detection of fovea in retinal images using fusion of colour bands" was written by R. Veras [17] where they express a method of fovea detection. The method extracts Macular region by taking account OD and then finds Fovea. The algorithm searches for lowest mean intensity in an enhanced image that is fusion of green and red channel of colour image. The algorithm was tested on three publicly available datasets with a total number of 254 images. The levels of accuracy rate were defined in which 72.42% result was exact detection and 20.65% result was satisfactory and 6.93% result was failure cases.

A. Tewari et al. [18] proposed a new technique for the detection of landmarks of fundus images in their research paper "Bilateral symmetry based approach for joint detection of landmarks in retinal images". The paper exploits a method of bilateral symmetry for the joint detection of OD and macula. Vessel density based matrix is generated to define axis of symmetry which is utilized with geometric constraint of OD and macula for their extraction. The method was benchmark on three public and one local dataset and that are DIARETDB0, DIARETDB1, DRIVE and Local. The efficiency rate on DIARETDB0, DIARETDB1, DRIVE and Local was 96.6%, 96.9%, 90% and 92.6%.

The research paper "Automatic and efficient detection of fovea center in retinal images" was published by S. Zheng et al. [19]. The method uses information of anatomical structures on relative location and gray level information in OD. Adaptive thresholding and morphology bottom-hat transform are used to achieve OD boundary. Fovea ROI is identified by measuring intensities in OD and center is determined using morphological operations. The DRIVE, HEI-MED and DIARETDB1 datasets were used to experiment the algorithm. The accuracy was 100% for DRIVE database, 98.8% for HEI-MED and 93.3% for DIARETDB1 and consumes 12 seconds per image computational time.

Signal processing concepts were used in the research paper of "Optic disk and macula detection in fundus images by means of template matching" by T. G. Alvarado et al. [20] to identify retinal features of fundus photograph. Luminosity variation correction is made using polynomial approximation of background image. Steerable template is generated, which contains both anatomical structures, and cross correlation is performed between image and template. 100% accuracy was achieved for OD and 90% success rate was made for macula during the evaluation process on local database.

V. K. Govinda et al. [21] diagnosed the severity level of Diabetic Macular Edema in their paper "Automatic grading of severity of Diabetic Macular Edema using colour fundus images" where prior knowledge of images. Semantic Image Transformation (SIT) is used to automate macula and OD. The proposed SIT classifies the local structure of fundus photograph and amplifies the retinal structure like macula and OD. Experiment was tested on 5928 images with success rate of 99.44% for OD detection, 93.49% for macula localization and while having accuracy of 97.33% for left/right identification.

2.2 Blood Vessels Extraction Techniques

The paper "Automatic extraction of blood vessels and veins using adaptive filters in fundus images" was written by J. Minar et al. [25]. A novel based method was implemented to diagnose veins and BVs. The technique of adaptive histogram equalization by CLAHE [9] was used on green channel of fundus photographs. Later the adaptive filters, convolution with filter mask and erosion were used to accomplish the proposed task. DRIVE and HRF databases were used to evaluate the performance of experiment. The accuracy of proposed technique was 91% – 96% on HRF and 96.07% to 97.19% on DRIVE database.

Some researchers use prior knowledge of BVs to identify macula and fovea. So BVs are critical part of the algorithm because identification and removal of BVs are used in the other features of fundus photograph. N. Sengar et al. [26] describe a technique to identify BVs in the paper of "Extraction of retinal vasculature by using morphology in fundus images". For that purpose, simple morphological operations are used that makes the technique efficient. Green and L channels are used to extract macular ROI and BVs. The proposed method was tested on DRIVE dataset and 75 to 80% accuracy was achieved.

2.3 Optic Disk Extraction Methods

The technique to extract optic disk is presented by U. Farooq et al. [27] in their paper of "Improve automatic localization of optic disk in retinal fundus images using image enhancement technique and SVM". Localization of OD is a vital task to diagnose pathologies in fundus images. The proposed algorithm was done by using support vector machine (SVM) that is application of machine learning. Training was carried out through some images and results of SVM were stored in database. Then the algorithm was run on the rest of the images and results were verified through SVM. The 100 images of MESSIDOR and STARE databases were used. 80 images of MESSIDOR database were used and 90% accuracy was found. 20 images of STARE database selected and 100% accuracy was achieved.

Research paper "Hybrid classifier based drusen detection in colour fundus images" presented by Raza et al. [28]. The method uses prior information of OD so later the difference can be made between OD and drusen. The proposed technique uses Gabor Kernel Based Filter Bank (GKBFB) and eliminates those information that may interfere while drusen detection. To distinguish between drusen and non drusen, Support Vector Machine and hybrid classifier are used. The proposed algorithm was tested on STARE database yields 98% accuracy.

M. Zubair et al. [29] presented a method to detect optic disk in their paper "Automated detection of Optic Disk for the analysis of retina using colour fundus images". Contrast Limited Adaptive Histogram Equalization (CLAHE) [30] is used as a preprocessing step. Morphological opening and closing is performed to eliminate OD. Sensitivity, specificity and accuracy are utilized with geometric constraint of OD and macula for their extraction. The method was benchmark on three public and one local dataset and that are DIARETDB0, DIARETDB1, DRIVE and Local. The efficiency rate on DIARETDB0, DIARETDB1, DRIVE and Local was 96.6%, 96.9%, 90% and 92.6%.

The research paper "Automatic and efficient detection of fovea center in retinal images" was published by S. Zheng et al. [19]. The method uses information of anatomical structures on relative location and gray level information in OD. Adaptive thresholding and morphology bottom-hat transform are used to achieve OD boundary. Fovea ROI is identified by measuring intensities in OD and center is determined using morphological operations. The DRIVE, HEI-MED and DIARETDB1 datasets were used to experiment the algorithm. The accuracy was 100% for DRIVE database, 98.8% for HEI-MED and 93.3% for DIARETDB1 and consumes 12 seconds per image computational time.

Signal processing concepts were used in the research paper of "Optic disk and macula detection in fundus images by means of template matching" by T. G. Alvarado et al. [20] to identify retinal features of fundus photograph. Luminosity variation correction is made using polynomial approximation of background image. Steerable template is generated, which contains both anatomical structures, and cross correlation is performed between image and template. 100% accuracy was achieved for OD and 90% success rate was made for macula during the evaluation process on local database.

V. K. Govinda et al. [21] diagnosed the severity level of Diabetic Macular Edema in their paper "Automatic grading of severity of Diabetic Macular Edema using colour fundus images" where prior knowledge of anatomic structures like OD and macula were required. Particle Swarm Optimization (PSO) is utilized to identify exudates where segmentation of OD and macula is done by mathematical morphology. Severity of Diabetic Macular Edema is categorized regarding the location of exudates. 100 image of MESSIDOR dataset are used to evaluate the method and 93% of accuracy is achieved.

The disease of Diabetic Maculopathy is one of reason that affects central vision. A. Punnolil [22] devised a research work to diagnose Diabetic Maculopathy in the paper "A novel approach for diagnosis and severity grading of Diabetic Maculopathy". OD and fovea are obtained using superior and inferior vascular arcades in retina. Multi scale SVM evaluates the localization of OD and fovea. Four grading levels of a disease are defined like normal, mild, moderate and severe. Sensitivity and specificity evaluation methods were used to check the performance of algorithm and the performance is found 96.89% and 97.15% respectively.

OD, Macula and BVs are the main features of retinal fundus images. N. S. Labeeb et al. [23] detected three main features of fundus photograph in their paper "A framework for automatic analysis of digital fundus images". BVs are identified with the help of morphology then concerning the brightest gray level in OD the temporal side is achieved. The information about BVs and temporal side yields entire OD. Spatial relationship defines the macula with respect to OD. Images of DRIVE and DIARETDB1datasets were used and 100% and 97.6% success rate was marked.

X. Cheng et al. [24] presented his paper "Automatic localization of retinal landmarks" in 34th annual conference held in 2012. The research estimates OD and macula as they are the most important landmarks of fundus images. Semantic Image Transformation (SIT) is used to automate macula and OD. The proposed SIT classifies the local structure of fundus photograph and amplifies the retinal structure like macula and OD. Experiment was tested on 5928 images with success rate of 99.44% for OD detection, 93.49% for macula localization and while having accuracy of 97.33% for left/right identification.

2.2 Blood Vessels Extraction Techniques

The paper "Automatic extraction of blood vessels and veins using adaptive filters in fundus images" was written by J. Minar et al. [25]. A novel based method was implemented to diagnose veins and BVs. The technique of adaptive histogram equalization by CLAHE [9] was used on green channel of fundus photographs. Later the adaptive filters, convolution with filter mask and erosion were used to accomplish the proposed task. DRIVE and HRF databases were used to evaluate the performance of experiment. The accuracy of proposed technique was 91% – 96% on HRF and 96.07% to 97.19% on DRIVE database.

Some researchers use prior knowledge of BVs to identify macula and fovea. So BVs are critical part of the algorithm because identification and removal of BVs are used in the other features of fundus photograph. N. Sengar et al. [26] describe a technique to identify BVs in the paper of "Extraction of retinal vasculature by using morphology in fundus images". For that purpose, simple morphological operations are used that makes the technique efficient. Green and L channels are used to extract macular ROI and BVs. The proposed method was tested on DRIVE dataset and 75 to 80% accuracy was achieved.

2.3 Optic Disk Extraction Methods

The technique to extract optic disk is presented by U. Farooq et al. [27] in their paper of "Improve automatic localization of optic disk in retinal fundus images using image enhancement technique and SVM". Localization of OD is a vital task to diagnose pathologies in fundus images. The proposed algorithm was done by using support vector machine (SVM) that is application of machine learning. Training was carried out through some images and results of SVM were stored in database. Then the algorithm was run on the rest of the images and results were verified through SVM. The 100 images of MESSIDOR and STARE databases were used. 80 images of MESSIDOR database were used and 90% accuracy was found. 20 images of STARE database selected and 100% accuracy was achieved.

Research paper "Hybrid classifier based drusen detection in colour fundus images" presented by Raza et al. [28]. The method uses prior information of OD so later the difference can be made between OD and drusen. The proposed technique uses Gabor Kernel Based Filter Bank (GKBFB) and eliminates those information that may interfere while drusen detection. To distinguish between drusen and non drusen, Support Vector Machine and hybrid classifier are used. The proposed algorithm was tested on STARE database yields 98% accuracy.

M. Zubair et al. [29] presented a method to detect optic disk in their paper "Automated detection of Optic Disk for the analysis of retina using colour fundus images". Contrast Limited Adaptive Histogram Equalization (CLAHE) [30] is used as a preprocessing step. Morphological opening and closing is performed to eliminate OD. Sensitivity, specificity and accuracy are used as evaluation criteria which was achieved 100%, 98.25% and 98.65% on MESSIDOR database respectively.

2.4 Macular Region of Interest Extraction

Classification of the level of a disease that how much image is affected from a disease is a very difficult task. It is crucial so that according to grading level the treatment can adopt. M. K. Dutta et al. [31] presented a research paper "An efficient grading algorithm for non proliferative Diabetic Retinopathy using region based detection". To reduce computational time, the segmentation of macular ROI is achieved and then searches the abnormalities in ROI. The research expresses a simple and direct method to diagnose the classification of a disease. The overall accuracy of 80% was achieved on different databases.

M. Gandhi et al. [32] proposed a technique in the paper "Investigation of severity of Diabetic Retinopathy by detecting exudates with respect to macula". The disease can be identified by detection abnormalities, hemorrhages, exudates and micro aneurysms in macular ROI. JSEG segmentation technique was presented to detect all abnormalities. The severity of a disease is measured by distance between exudates and macular region. The critical part of the paper is second part that is locating exudates in macular region and the results were promising.

Identify pathologies like drusen, exudates and spots like white cotton in entire image as well as in ROI of OD and macula presented by A. F. Aqeel [33]. Condition of a disease can be determined by measuring the size of exudates and drusen, lies in OD and macular regions, by comparing them with background image. The paper proposed a robust algorithm for the segmentation of exudates and drusen in fundus images. The size of abnormalities is measured by numerical methods. First the illumination correction and contrast enhancement are performed in retinal images then segmentation method is implemented. The algorithm also proposes a technique to diminish OD so effective drusen can be made. DRIVE dataset was used to evaluate the results and the results were fine enough to implement the algorithm in real life and can help ophthalmologist in diagnose Diabetic Retinopathy.

CHAPTER 3 PROPOSED TECHNIQUE

This research work proposes a technique to detect the critical retinal features of fundus photographs. The proposed research is a further extension of D.W.K. Wong et al [34]. Figure 3.1 illustrates the hierarchy of algorithm. The retinal fundus images are comprises of colour images that are blend of red, green and blue channels. Green channel is extracted and utilized for the proposed research work. Optic Disk (OD) and macula are prominent in green channel as compared to red and blue channels. As mentioned earlier that the Macula and OD are two critical features of fundus photography where OD is categorized as the brightest region and macula is classified as the low gray levels. Fovea is center of macula. Simple image processing techniques cannot be applicable here due to two reasons. First is the surrounded region that is exactly same as macula. Second are the Blood Vessels (BVs) that are almost same like macula. BVs and surrounded region may mislead the correct localization of macula and fovea so smart algorithm has been developed in this research work to achieve the goal.

In my research, I used thresholding by selecting the gray levels that are above 95% because OD resides in this portion. The resultant image comprises of OD and small pixels that are approximately same as OD and rest of the features of image have been diminished. The OD is almost a round shape retinal bright feature. In order to remove noise and to localize the (x, y) coordinates of OD, the correlation is performed. A square mask is utilized in correlation. Correlation gives the central point of OD because the maximum correlation will happen when mask is almost in the center of OD. The circle is drawn using a function "Draw a circle" around the (x, y) coordinate of OD that was achieved using correlation. An automatic cropping technique is used to extract the exact OD from original image that is further used as a mask for correlation on all images.

As mentioned earlier that blood vessels are one the impediments to localize macula precisely. The morphological opening is carried out to diminish the effect of blood vessels in the entire image. Square structuring element is used for morphological opening. An accuracy of an algorithm directly depends upon the quality of an image. In the case of retinal images, the blood vessels are taken as reference to measure the quality of an image. If the quality of an image is best then to detect OD and macula will be easy and accurate. In my research work, high boost filtering is used to increase the quality of an image. As a result, the OD and macula will be more prominent than original image. Again correlation is performed throughout database to achieve the location of OD. The location of an OD defines the orientation of an image.

The databases that are executed to check the performance of proposed algorithm have both images that can be from left or right eye. The orientation of an image describes whether image is belonging to left eye or right eye. The orientation of an eye is decided on basis of the location of OD. OD is situated left from macula in left eye images whereas OD is displaced right from macula in right eye images.

The macula resides at a particular distance from OD. The distance between OD and macula varies according to databases. That distance of 1.8 to 2.8 of the radius of an OD is taken to get the macular region of interest (ROI). In the case of left eye the y coordinate of OD is smaller than the half of the width of an image and in right eye the y coordinate of OD is greater than the half of the width of an image. Macular ROI is extracted with the help of equation that defines relationship between OD and macula.

A circular ROI of macula is taken by using automatic cropping as well as a function that draws circle. After the extraction of macular ROI, the automatic thresholding is executed to eliminate noise from macular ROI as a result the image has macula. Because fovea is a center of macula so fovea is achieved as a mean value of macula. A flow chart of proposed method is given below in figure 3.1.

extract the exact OD from original image that is further used as a mask for correlation on all images.

As mentioned earlier that blood vessels are one the impediments to localize macula precisely. The morphological opening is carried out to diminish the effect of blood vessels in the entire image. Square structuring element is used for morphological opening. An accuracy of an algorithm directly depends upon the quality of an image. In the case of retinal images, the blood vessels are taken as reference to measure the quality of an image. If the quality of an image is best then to detect OD and macula will be easy and accurate. In my research work, high boost filtering is used to increase the quality of an image. As a result, the OD and macula will be more prominent than original image. Again correlation is performed throughout database to achieve the location of OD. The location of an OD defines the orientation of an image.

The databases that are executed to check the performance of proposed algorithm have both images that can be from left or right eye. The orientation of an image describes whether image is belonging to left eye or right eye. The orientation of an eye is decided on basis of the location of OD. OD is situated left from macula in left eye images whereas OD is displaced right from macula in right eye images.

The macula resides at a particular distance from OD. The distance between OD and macula varies according to databases. That distance of 1.8 to 2.8 of the radius of an OD is taken to get the macular region of interest (ROI). In the case of left eye the y coordinate of OD is smaller than the half of the width of an image and in right eye the y coordinate of OD is greater than the half of the width of an image. Macular ROI is extracted with the help of equation that defines relationship between OD and macula.

A circular ROI of macula is taken by using automatic cropping as well as a function that draws circle. After the extraction of macular ROI, the automatic thresholding is executed to eliminate noise from macular ROI as a result the image has macula. Because fovea is a center of macula so fovea is achieved as a mean value of macula. A flow chart of proposed method is given below in figure 3.1.

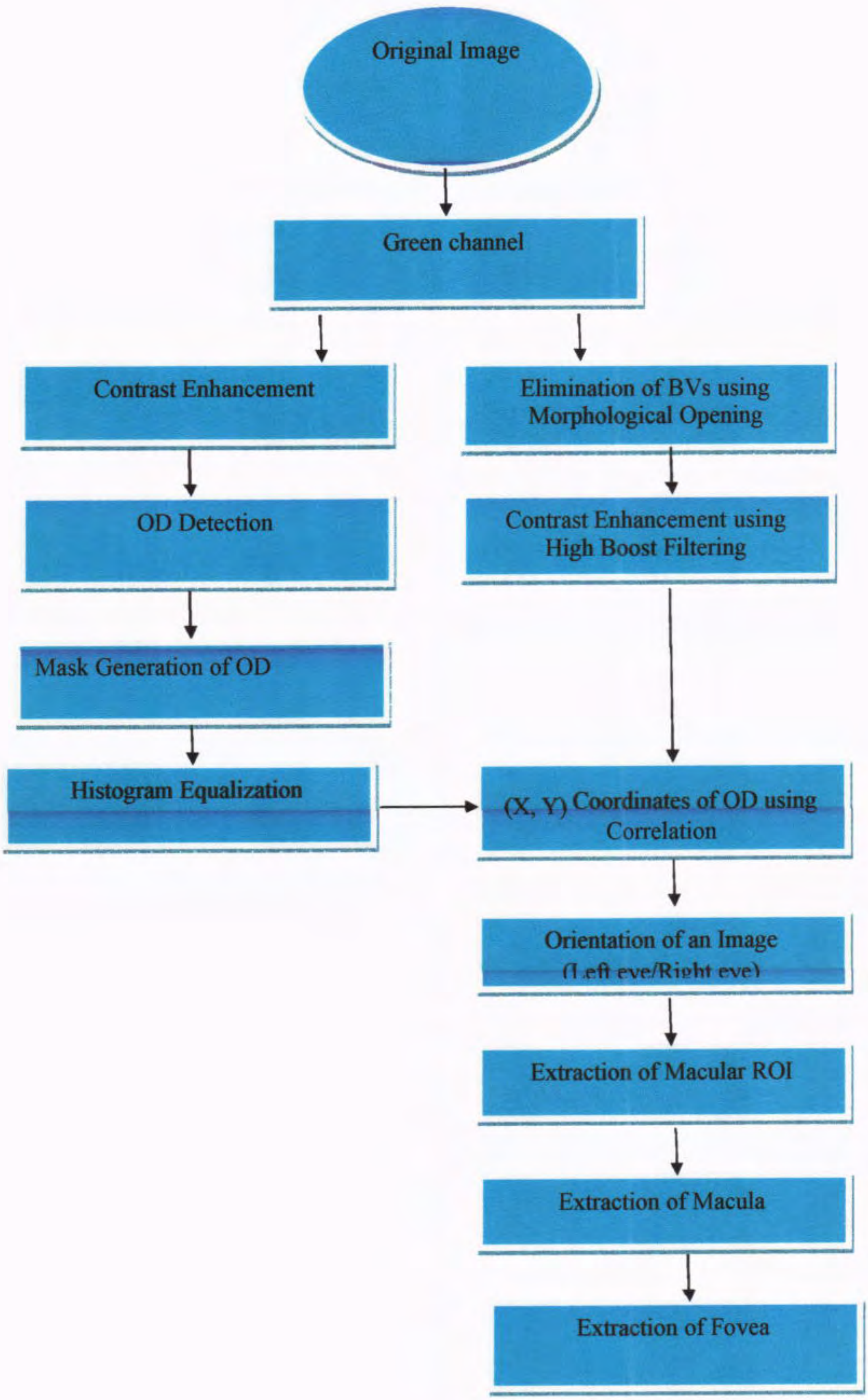
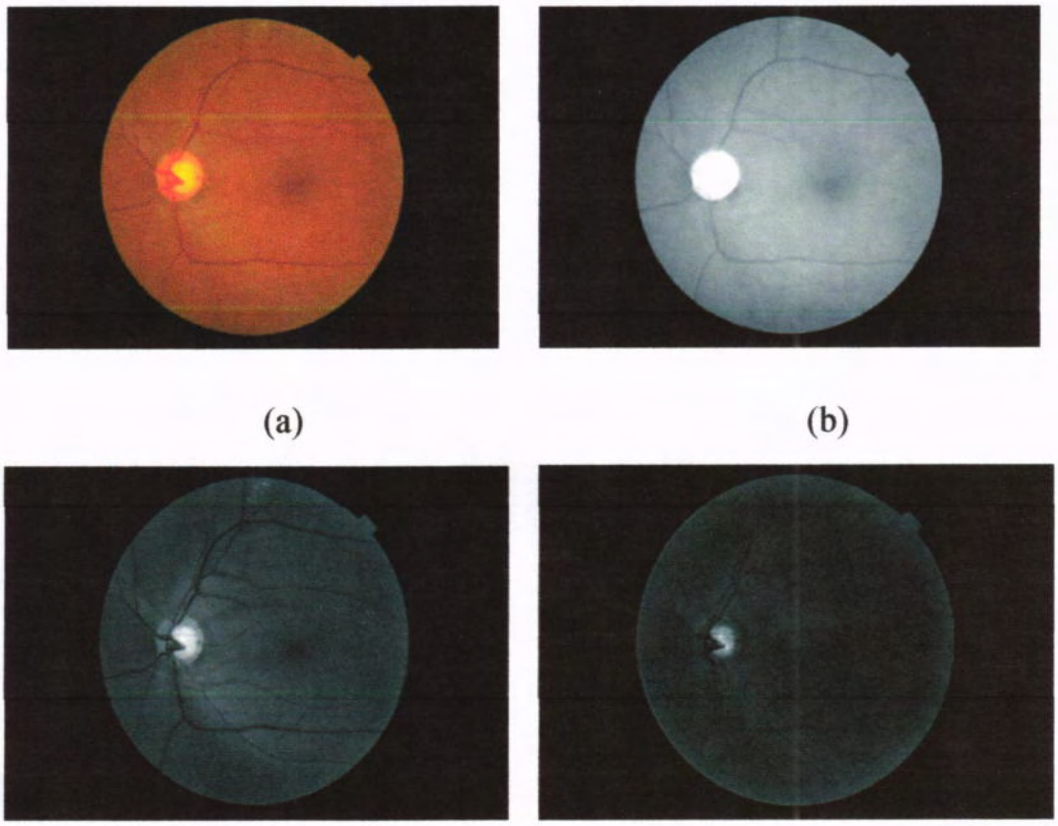


Figure 3.1: Flow Chart of Proposed Algorithm

3.1 Retinal Fundus Images

Retinal fundus image are taken by ophthalmologist using fundus camera. Fundus image consists of red, green and blue channels. Red channel is saturated where blue component has low level intensities and noise. Green channel provides the best contrast. The green channel of fundus image is further used to detect retinal features in proposed algorithm. Colour retinal image and red, green and blue channels are shown in figure 3.2.



(a) (b)

(c) (d)

Figure 3.2: a) Original fundus image; (b) Red channel; (c) Green channel; (d) Blue channel.

3.2 Contrast Enhancement

The accuracy of the localization of OD and macula are depending on the quality of an image. The quality of an image is good then an algorithm can easily and accurately detect the retinal features. The quality of retinal fundus image is measured through the appearance of BVs in image. If the BVs are good in appearance then it means that the quality of entire image is good. After extracting green channel from RGB retinal image, the quality of image is increased using contrast adjustment.

3.3 Mask Generation of OD

The OD is the brightest part of an image. Image is then thresholding is applied and resultant image will have OD with noise. The noise comes from the intensity variation in an image that has the same intensity levels like OD. For the removal of noise correlation is performed and square structuring element is used. The correlation provides the (x, y) coordinates of OD and circle is drawn around the center of OD that shows the OD of an image. Automatic cropping is used to extract the OD from green channel that is used further as a mask for correlation on the entire database. Mask of OD is shown in figure 3.3.

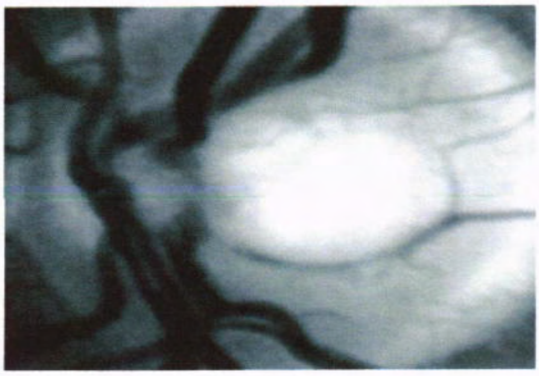


Figure 3.3: Mask of Optic Disk.

3.4 Elimination of Blood Vessels

The BVs are the major hurdles to detect macula because they are similar to macula therefore it is critical need to diminish the effects of BVs for that purpose morphological opening is executed. Morphological erosion followed by dilation is morphological opening. Morphological erosion is denoted by $\ominus$, dilation is denoted by $\oplus$ whereas Opening is defined by the equation given below.

$$f \circ s = (f \ominus s) \oplus s$$

s is structuring element whereas *f* is an image and blood vessels eliminated image is shown in figure 3.4.

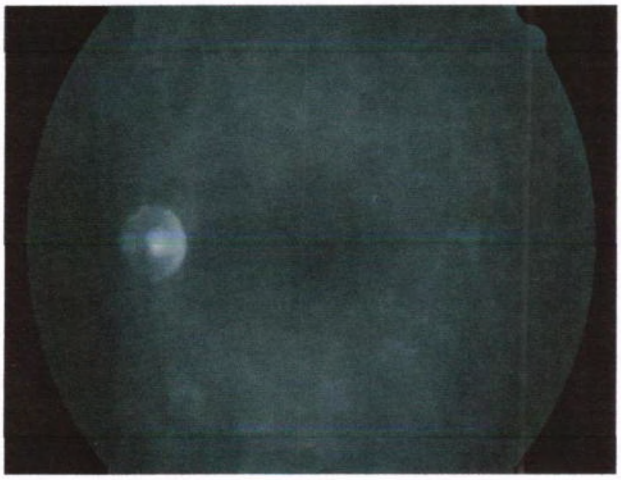


Figure 3.4: Blood Vessels eliminated image.

3.5 Contrast and Luminosity Enhancement

There are two much intensity variation is an image that makes the detection of OD and macula complicated. High boost filtering is used to remove intensity variation and enhancement of contrast. Square mask of Gaussian filter is used to filter out the image. Then filtered image is subtracted from original image to generate low pass image then image is multiplied by a constant to increase the contrast. Resultant image is added to original image to create high boost filtered image that will yield a high quality image. High boost filtered image is shown in figure 3.5.

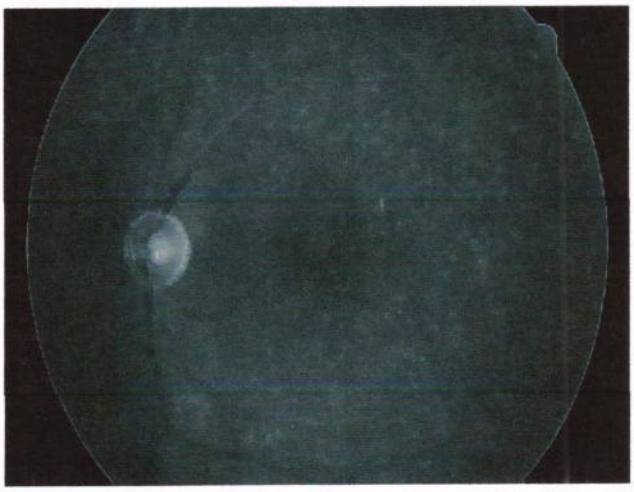


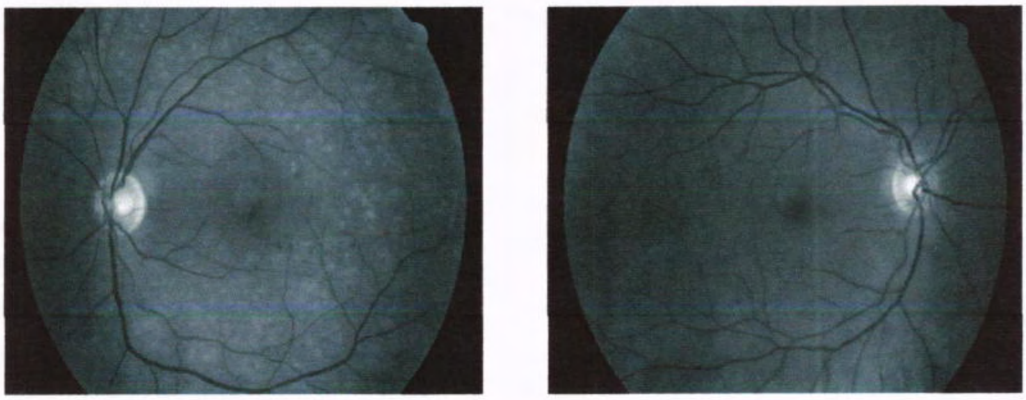
Figure 3.5 High Boost Filtered Image

3.6 Obtain the Centers of OD

The centers of all the images that are included in the database are achieved by using correlation. Correlation is performed on high boost filtered image and the mask is used that was obtained in step 3.3. Correlation will provide the centers of all the images that will used for the orientation of an image.

3.7 Orientation of an Image

The information about the orientation of an image is crucial for the proposed algorithm. The orientation differentiates the image between left or right eye. The orientation is done from the information of the y coordinate of OD. If the y coordinates of OD is less than the half of the width of the image then image is belong to left eye otherwise it is belong to right eye. Figure 3.6 (a) is the image of left eye whereas right eye image is shown in figure 3.6 (b).



(a) (b)

Figure 3.6: a) Retinal fundus image of left eye; b) Retinal fundus image of left eye.

3.8 Extraction of Macular ROI

There is a special relationship between OD and macula. If image belongs to left eye then y_0 is obtained by multiplying a constant value with the diameter of OD and add the product value in the y coordinate of OD whereas x coordinates of OD and macula is same. A circle is drawn around (x, y_0) and automatic cropping is used to extract macular ROI from green channel. The macular ROI is used to detect macula and its central part fovea. The equation that defines the relationship between macula and OD is given in eq. 1 and the macular ROI is shown in figure 3.7.

$$X = \begin{cases} \{x \,\varepsilon\, Z^{+} : x = x_{od} + \mu_x \pm\Delta\, x\}, & for\ left\ eye \\ \{x \,\varepsilon\, Z^{+} : x = x_{od} - \mu_x \pm\Delta\, x\}, & for\ right\ eye \end{cases}$$

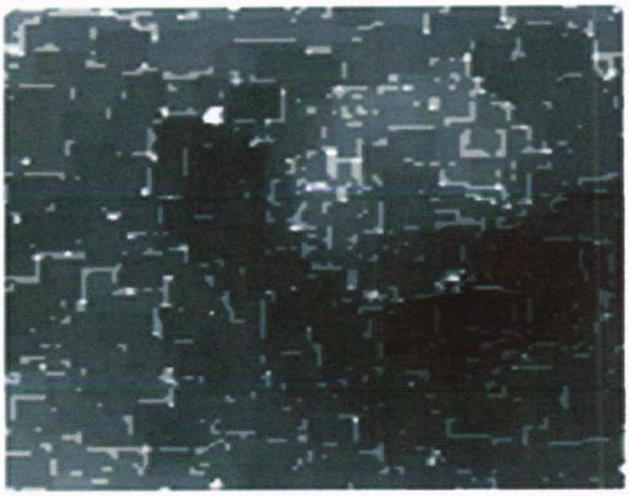


Figure 3.7: Macular region of interest.

3.9 Extraction of Fovea and Macula

As it is already described that the fovea is the center of macula and the macula is classified as the low level intensities. An automatic thresholding using otsu's method is applied on macular ROI so that the background intensities can be discriminated from macular intensities. That yields the resultant image has macula only and then mean value is taken as fovea. A circle of fixed radius is drawn around the (x, y) coordinates of fovea to represent macula and then task is accomplished. The inner circle shows fovea whereas the outer big circle represents the macula. The image that is the outcome of the proposed algorithm is shown in figure 3.8.

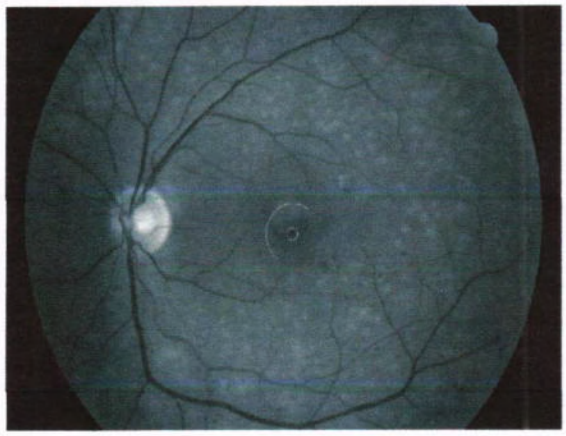


Figure 3.8: Resultant image with fovea and macula.

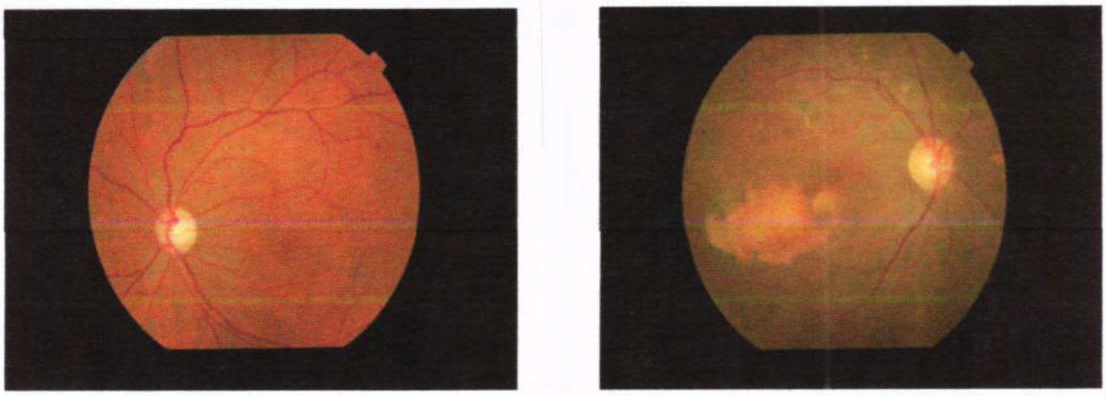
CHAPTER 4 RESULTS AND DISCUSSION

4.1 Discussion

Retinal fundus images are being extensively used to diagnose retinal diseases. Different databases are publicly available for the researchers to benchmark their algorithm. Local hospitals are also imparting role by providing various databases of fundus images. Four databases were used i.e. HRF, DRIVE, MESSIDOR and Al-shifa to check the performance of the propose methodology.

4.2 Al-shifa

Al-shifa database is local dataset that was collected from Al-shifa International hospital H-8 Islamabad. There are 111 images included in Al-shifa database and some images belong to healthy eye whereas some images have pathological symptoms. The resolution of Al-shifa database is 1936×1236 and some images are shown in figure 4.1.

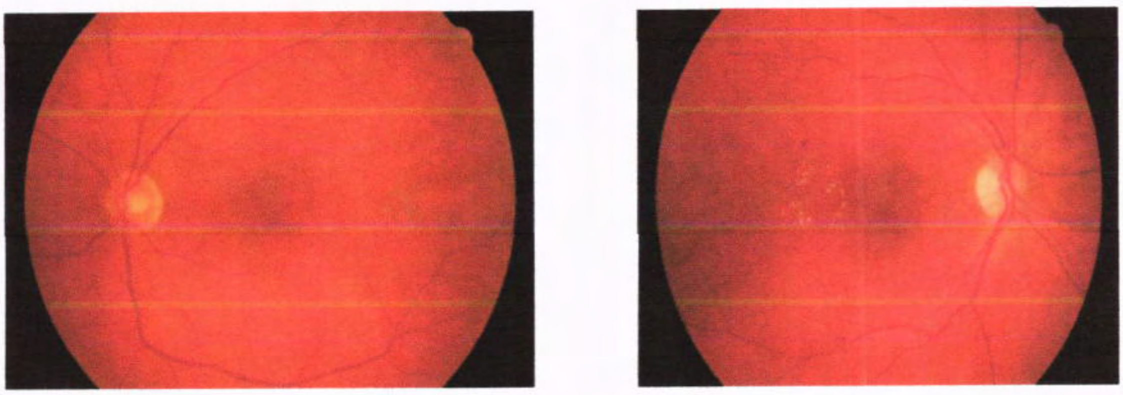


(a) (b)

Figure 4.1: a) Fundus image of healthy eye; b) fundus image with pathological symptoms.

4.3 High Resolution Fundus images

High Resolution Fundus (HRF) database has 45 retinal images in which 15 images are taken from healthy eye whereas 15 images are relevant from Diabetic Retinopathy (DR) and 15 images were taken from glaucomatous patients. The resolution of HRF images is 3504×2336. HRF fundus images of healthy and effected by diabetic retinopathy (DR) are shown in figure 4.2.

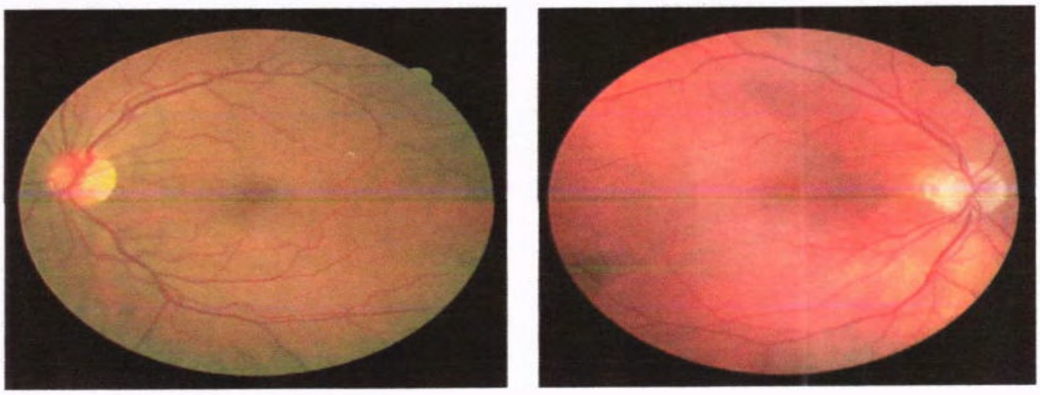


(a) (b)

Figure 4.2: a) healthy fundus image; b) fundus image with pathological symptoms.

4.4 Digital Retinal Images for Vessels Extraction

Digital Retinal Images for Vessels Extraction (DRIVE) database has 40 images that are blend of healthy and affected by various diseases. 33 images are relevant from healthy patients that do not have any symptom of DR and 7 images have mild symptoms of early stage DR. the resolution of DRIVE image is 3504×233.

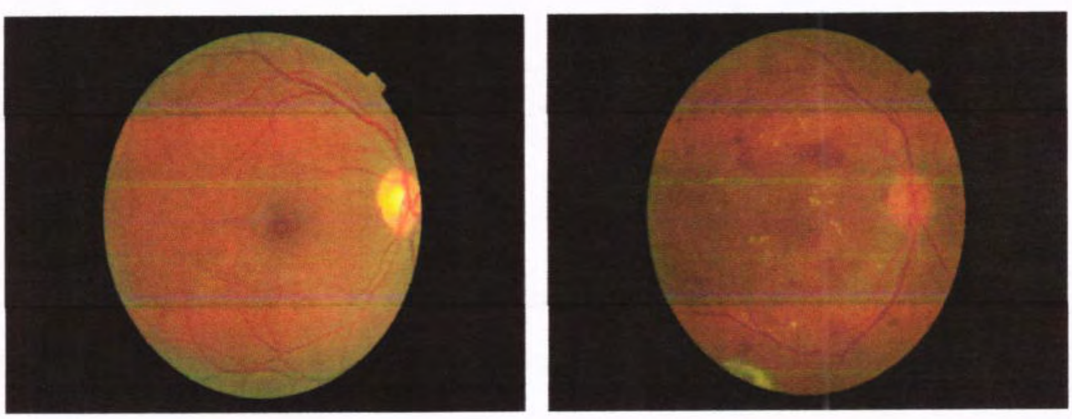


(a) (b)

Figure 4.3: a) Healthy image; b) fundus image of pathological symptoms.

4.5 MESSIDOR

There are 1200 fundus images in MESSIDOR database that are categorized into three sub-datasets. Each sub-dataset has different resolution i.e. $2240 \times 1488, 1440 \times 960$ and 2304×1536.Some images of MESSIDOR database are shown in figure 4.4.



(a) (b)

Figure 4.4: a) Healthy fundus image; b) Image with affected by a disease.

4.6 Results and Comparison

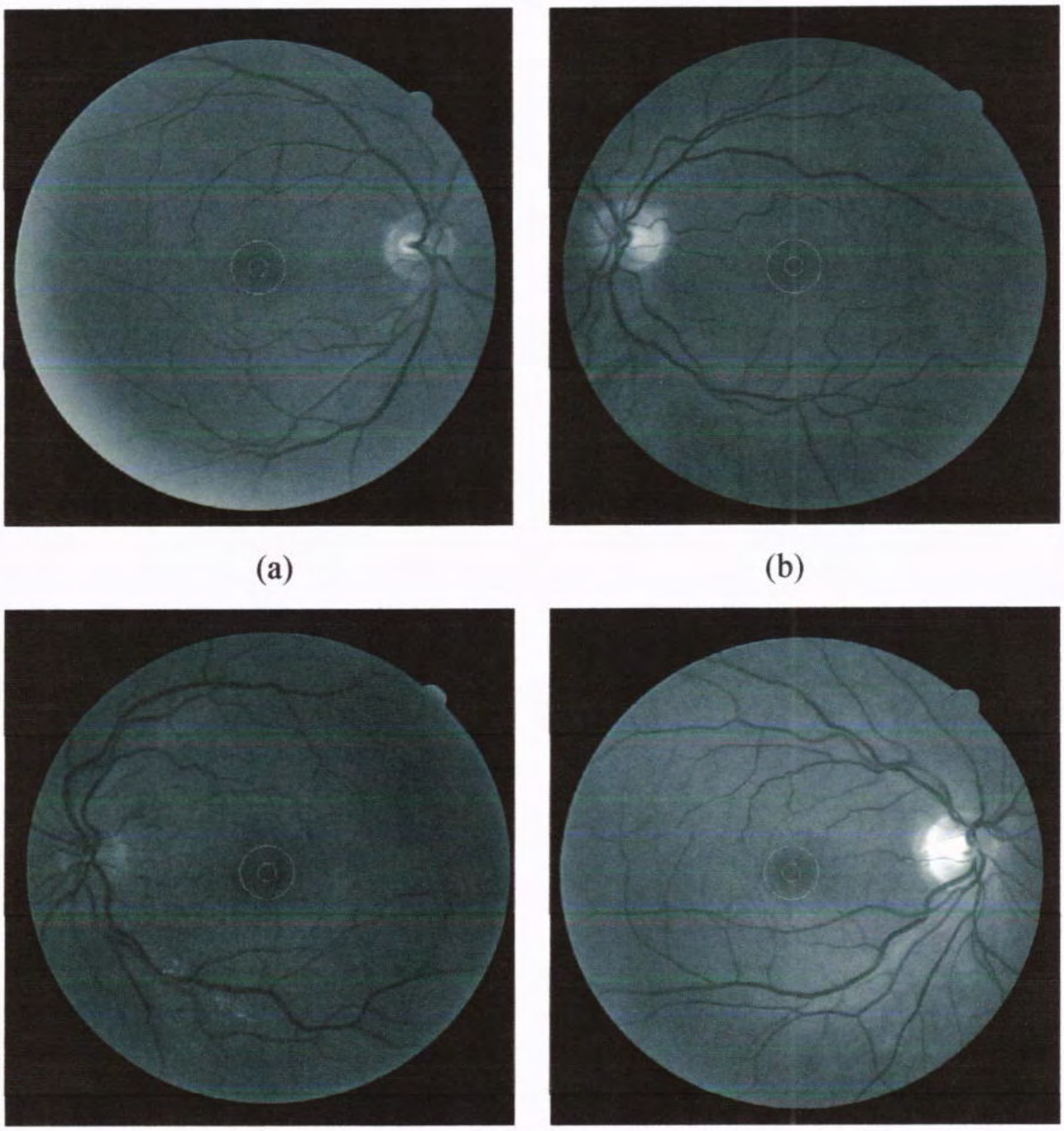
The proposed algorithm was experimented on the total of 1391 images that is comprises of four databases as discussed earlier. Two parameters were measured to evaluate the performance of the algorithm that is accuracy and execution time. The proposed algorithm was executed on MATLAB 2015a with computer hardware specifications are 2.3GHz core i5 processor with 4GB RAM. The overall accuracy is achieved on the entire 1391 images is 99.25% and the average processing time is 1.5 seconds that is so promising.

In HRF, DRIVE and Al-shifa databases, the number of images are very less therefore variations in the size of OD is also less. So OD is affectively localized using correlation phase. 100% accuracy was obtained during this step. In the next step i.e. macula and fovea localization, the relationship given in equation 1, is used to estimate macula ROI. The relationship detects the macular ROI with the success rate of 100%. Mathematical morphology and local minima is extracted for macular ROI that yields Fovea and macula. 100% accuracy was obtained during the last step of proposed algorithm.

The case of MESSIDOR database is quite different because 1200 images are included in the database. MESSIDOR database consists of three groups of images each contains images of different sizes as described above. There are great changes in intensities as well as abrupt variation in the sizes of OD that also decreases the accuracy. 1.5% accuracy lost during this phase. The geometrical relationship of OD and macula is defined by Wong et al. [37], does not benchmark the macular ROI exactly is also a reason that decreases check parameter. Almost 1% accuracy decreased during the extraction of macular ROI. 97% of accuracy was benchmarked on MESSIDOR database by the proposed algorithm. The macula and fovea is highlighted through a function that draws a circle around macula and fovea to represent the respective retinal features. The table 1 shows the comparison between the proposed algorithm with renowned research papers. The resultant images of proposed algorithm are shown in figure 4.5.

Author	**Year**	**Database**					**Time (sec)**
		Total images	HRF	DRIVE	Local	MESSIDOR	
Proposed Algorithm	2017	1391	100%	100%	100%	97%	1.5
Dashtbozorg [34]	2016	1200				98.8%	2.4
Ramasubramanian [6]	2016			98%			13
Ashish Issac [7]	2016						12
Anushikha Singh [3]	2016						12
J. P. Medhi [15]	2015	400	100%	100%		96.25%	
Dharitri Deka [20]	2015	800	100%	100%		97.75	
R.Radha [22]	2014	95			90%		
Ayush Tewari [25]	2014	1200				97%	
Shaohua Zheng [26]	2014	35		100%			12

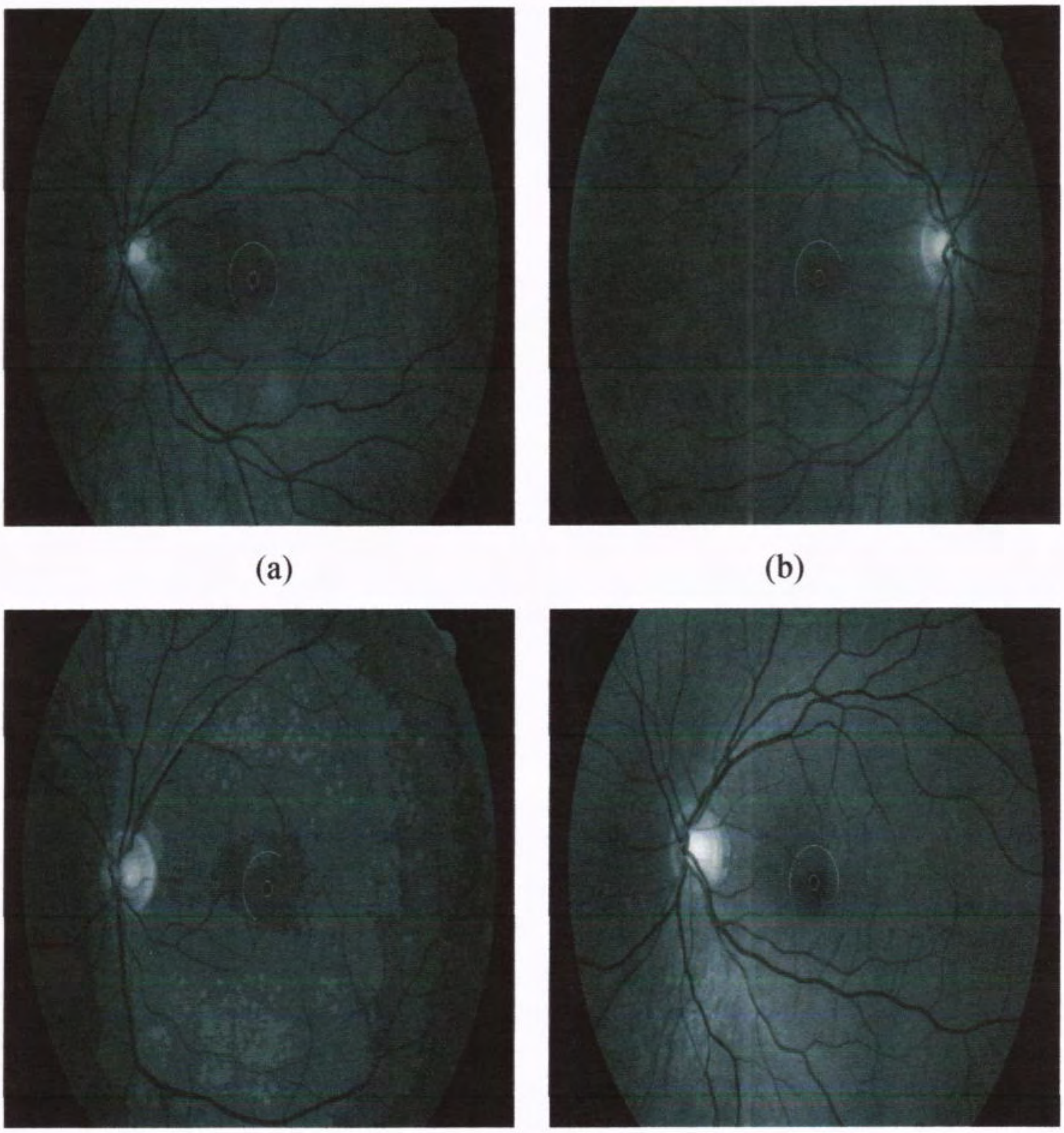
Table 4.1: Comparison of the Macula Localization.



(a) (b)

(c) (d)

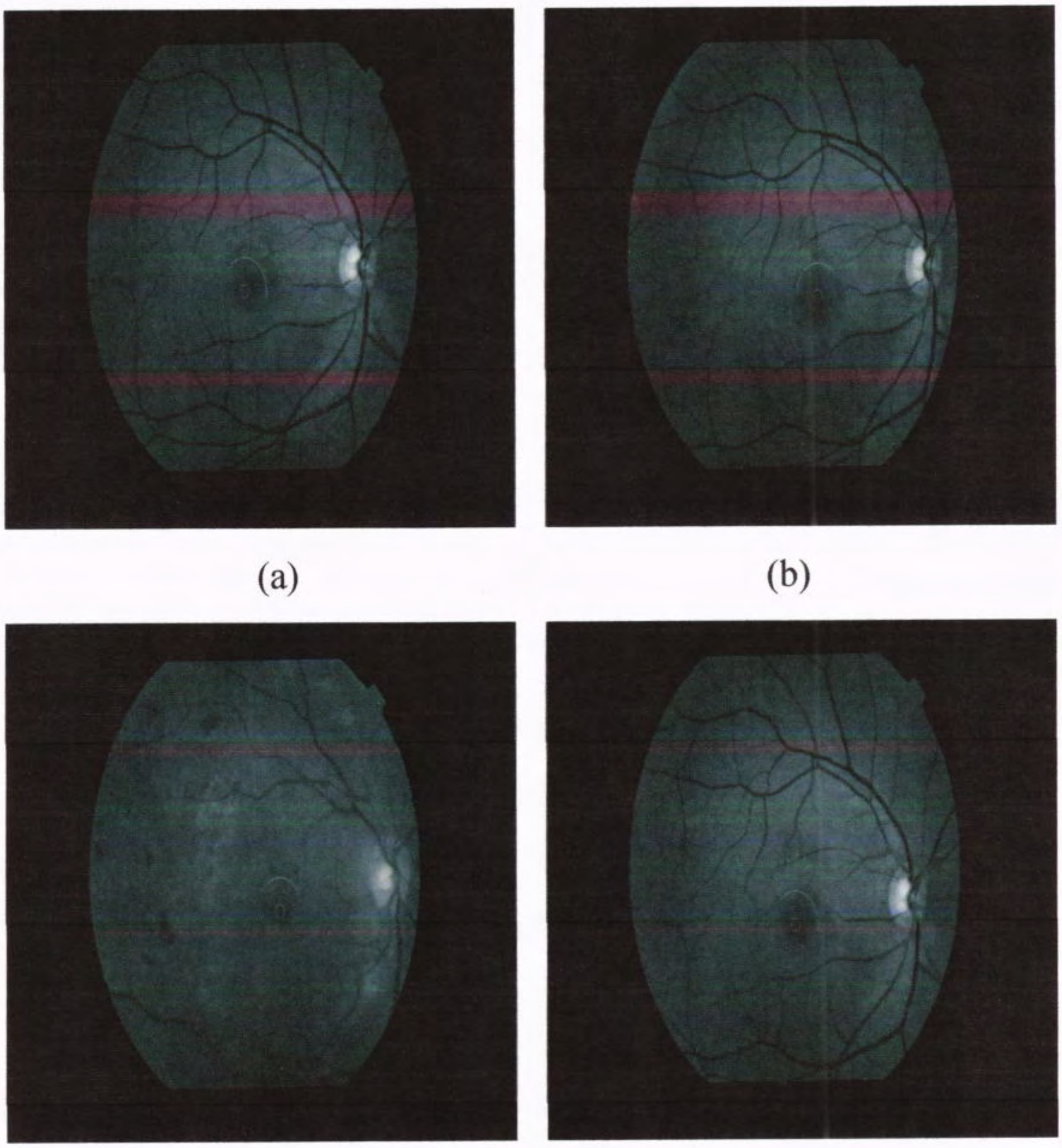
Figure 4.5: Resultant images of 'DRIVE' database.



(a) (b)

(c) (d)

Figure 4.6: Resultant images of 'HRF' database.



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

Figure 4.7: Resultant images of 'Local' database.

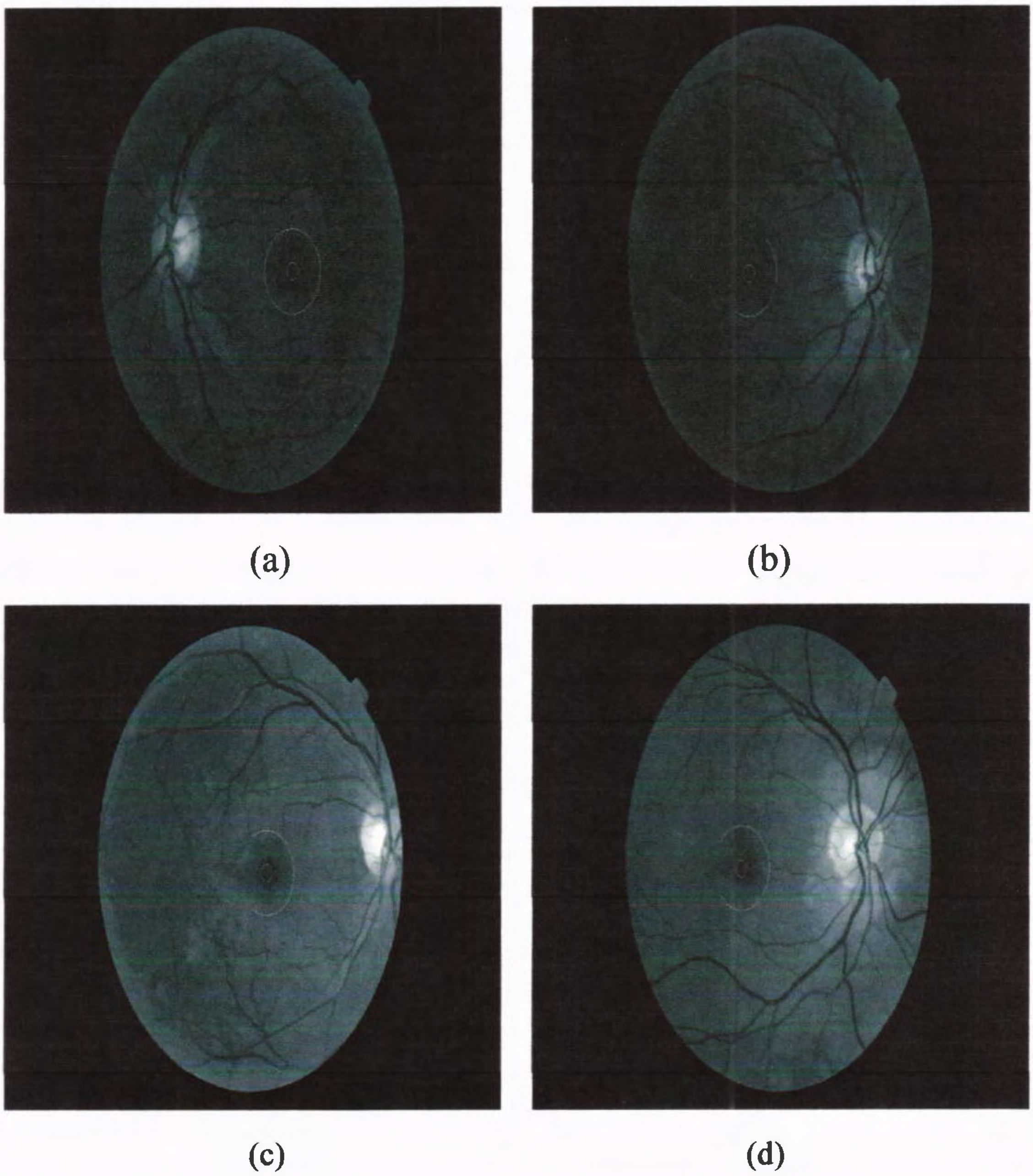


Figure 4.8: Resultant images of 'MESSIDOR' database.

CHAPTER 5 CONCLUSION AND FUTURE WORK

5.1 Conclusion

The MS thesis is comprises of detection of macula and fovea in retinal fundus images. Retinal fundus images are being used to diagnose diseases. In fundus image macula is categorized as lowest gray levels whereas OD is classified as brightest part. A smart algorithm is needed to locate macula because macula and surrounded region is almost same.

The retinal images may comprise of poor illumination so images were preprocessed to remove intensity variations. The proposed methodology consists of two major steps. First is localization of OD and other is estimation of macula. OD is located using correlation because of its brightest property. Orientation of an image is obtained using the location of macula between left and right eye. There is a special geometrical relationship between macula and OD and that relationship is used to localize macular ROI. Morphological operations and minimum intensity of macula are used to locate fovea.

5.2 Future Work

Performance of the proposed method was checked utilizing two parameters i.e. execution time and accuracy. In first step of OD detection, 100% accuracy is achieved on HRF, DRIVE and Al-shifa whereas 98.3% of accuracy was achieved on MESSIDOR database during the first step of proposed algorithm. In second critical phase of macula and fovea estimation, 100% accuracy was marked on HRF, DRIVE, Al-shifa database but the accuracy was fallen down to 97% on MESSIDOR database. The overall accuracy of 99% is achieved on four databases that are being used in this research work.

The task is accomplished using an un-supervised technique of OD detection. Approximately 2% of accuracy was lost during the process of OD detection in MESSIDOR database. If 100% of accuracy can be obtained regarding OD detection then the accuracy can be raised above 99%. In this thesis an unsupervised algorithm is developed so there is no criterion about detection of OD whether it is correct or incorrect. In a case of correct OD detection then there will be more than 95% probability that the exact localization of macula will be achieved by using technique innovated in this thesis. In a case of wrong detection of OD then there is less than 5% probability to mark the macula and fovea exactly. So there is future prospect to innovate a technique so that criterion can be generated regarding OD. When analyzing the properties of OD, it is observed that the OD is the brightest part of retinal fundus image as well as OD has almost round shape. Utilizing these properties of OD, an algorithm can be developed in future that examines whether correct OD is detected or not. That technique will be called supervised technique. If wrong OD is localized then process the entire image again so that the correct brightest rounded shape of OD is detected in supervised method. In this manner the overall accuracy can be increased towards 99%.

References

[1] R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, 3rd edition, New York, Prentice Hall, pp. 36-38, 2007.

[2] K. W. Tobin, E. Chaum, V. P. Govindasamy, and T. P. Karnowski, "Detection of anatomic structures in human retinal imagery," *IEEE transactions on medical imaging*, *26*(12), 1729-1739.

[3] A. Singh, N. Sengar, A. Issac, and M. K. Dutta, "An automated imaging algorithm for macula detection in fundus images," In *Contemporary Computing (IC3), 2016 9th International Conference on* (pp. 1-4).

[4] S. S. G. Ashe, and I. Ali, "A new method for detection of optical disc and macula for diabetic retinopathy," In *Communication Control and Intelligent Systems (CCIS), 2016 2nd International Conference on* (pp. 136-140).

[5] A. Bansal, A. Vats, A. Jain, M. K. Dutta, R. Burget, and J. Prinosil, "An efficient automatic intensity based method for detection of macula in retinal images," *2016 39th Int. Conf. Telecommun. Signal Process. TSP 2016*, pp. 507–510, 2016.

[6] B. Ramasubramanian, and S. Selvaperumal, "A stand-alone MATLAB application for the detection of Optic Disc and macula," *International Conference on Advanced Communication Control and Computing Technologies (ICACCCT), 2016* (pp. 241-245).

[7] N. Sengar, M. K. Dutta, R. Burget, and L. Povoda, "Detection of diabetic macular edema in retinal images using a region based method," *International Conference on Telecommunications and Signal Processing (TSP), 2015 38th* (pp. 412-415).

[8] R. R. V. E Silva, F. H. D. De Araújo, L. M. R. Dos Santos, R. M. S. Veras, and F. N. S. De Medeiros, "Optic disc detection in retinal images using algorithms committee with weighted voting," *IEEE Lat. Am. Trans.*, vol. 14, no. 5, pp. 2446–2454, 2016.

[9] V. Asokan, and S. A. Jerome, "Computer aided approach for detection of age related macular degeneration from retinal fundus images," *2016 International Conference on Circuit, Power and Computing Technologies (ICCPCT)*, (pp. 1-7).

[10] T. Caramihale, D. Popescu, and L. Ichim, "Detection of regions of interest in retinal images using artificial neural networks and K-means clustering," *2016 22nd Int. Conf. Appl. Electromagn. Commun.*, pp. 1–6, 2016.

[11] H. A. Nugroho, D. Purnamasari, I. Soesanti, K. Z. W. Oktoeberza, and D. A. Dharmawan, "Detection of foveal avascular zone in colour retinal fundus images," *Proc. - 2015 Int. Conf. Sci. Inf. Technol. Big Data Spectr. Futur. Inf. Econ. ICSITech 2015*, pp. 225–230, 2016.

[12] J. P. Medhi and S. Dandapat, "Automatic detection of fovea using property of vessel free region," *2015 21st Natl. Conf. Commun. NCC 2015*, 2015.

[13] A. Issac, N. Sengar, A. Singh, M. K. Dutta, J. Prinosil, and K. Riha, "An efficient imaging technique for automated macula localization from fundus images," *Int. Congr. Ultra Mod. Telecommun. Control Syst. Work.*, vol. 2016-Decem, pp. 387–391, 2016.

[14] D. Deka, J. P. Medhi, and S. R. Nirmala, "Detection of macula and fovea for disease analysis in color fundus images," *2015 IEEE 2nd Int. Conf. Recent Trends Inf. Syst. ReTIS 2015 - Proc.*, pp. 231–236, 2015.

[15] G. Mittal, and J. Sivaswamy, "Optic disk and macula detection from retinal images using Generalized Motion Pattern," In *Computer Vision, Pattern Recognition, Image Processing and Graphics (NCVPRIPG), 2015 Fifth National Conference on* (pp. 1-4).

[16] R. Radha and B. Lakshman, "Identification of retinal image features using bitplane separation and mathematical morphology," *Proc. - 2014 World Congr. Comput. Commun. Technol. WCCCT 2014*, pp. 120–123, 2014.

[17] R. Veras, F. Medeiros, R. Silva, and K. Aires, "Automatic detection of fovea in retinal images using fusion of color bands," *Brazilian Symp. Comput. Graph. Image Process.*, pp. 119–124, 2014.

[18] A. Tewari, D. Gupta, and J. Sivaswamy, "Bilateral symmetry based approach for joint detection of landmarks in retinal images," *2014 International Conference on Signal Processing and Communications (SPCOM)*, (pp. 1-6).

[19] S. Zheng, L. Pan, J. Chen, and L. Yu, "Automatic and efficient detection of the fovea center in retinal images," *Proc. - 2014 7th Int. Conf. Biomed. Eng. Informatics, BMEI 2014*, no. Bmei, pp. 145–150, 2014.

[20] T. Garduno-Alvarado, M. E. Martinez-Perez, M. A. Martinez-Castellanos, L. Rodriguez-Quinones, and S. M. Salinas-Longoria, "Optic disc and macula detection in fundus images by means of template matching," *Conf. Proc. ... Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. IEEE Eng. Med. Biol. Soc. Annu. Conf.*, vol. 2014, pp. 134–137, 2014.

[21] K. S. Sreejini and V. K. Govindan, "Automatic grading of severity of diabetic macular edema using color fundus images," *Proc. - 2013 3rd Int. Conf. Adv. Comput. Commun. ICACC 2013*, pp. 177–180, 2013.

[22] A. Punnolil, "A novel approach for diagnosis and severity grading of diabetic maculopathy," *Proc. 2013 Int. Conf. Adv. Comput. Commun. Informatics, ICACCI 2013*, pp. 1230–1235, 2013.

[23] N. S. Labeeb, a. M. Mossa, Z. El Sanabary, I. a. Badr, and M. Y. El Nahas, "A framework for automatic analysis of digital fundus images," *2013 9th Int. Comput. Eng. Conf.*, pp. 5–10, 2013.

[24] X. Cheng *et al.*, "Automatic localization of retinal landmarks," *Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBS*, pp. 4954–4957, 2012.

[25] J. Minar, M. Pinkava, K. Riha, M. K. Dutta, and N. Sengar, "Automatic extraction of blood vessels and veins using laplace operator in fundus image," *Proc. 2015 Int. Conf. Green Comput. Internet Things, ICGCIoT 2015*, pp. 23–26, 2016.

[26] N. Sengar, M. K. Dutta, M. Parthasarthi, and R. Burget, "Extraction of retinal vasculature by using morphology in fundus images," *2nd Int. Conf. Signal Process. Integr. Networks, SPIN 2015*, pp. 139–142, 2015.

[27] U. Farooq, N. Y. Sattar, and S. A. Khan, "Improved automatic localization of optic disc in Retinal Fundus using image enhancement techniques and SVM," *Control System, Computing and Engineering (ICCSCE), 2015 IEEE International Conference on.* IEEE, 2015.

[28] G. Raza, M. Rafique, A. Tariq, and M. U. Akram, "Hybrid classifier based drusen detection in colored fundus images," *2013 IEEE Jordan Conf. Appl. Electr. Eng. Comput. Technol. AEECT 2013*, pp. 1–5, 2013.

[29] M. Zubair, A. Yamin, and S. A. Khan, "Automated detection of Optic Disc for the analysis of retina using color fundus image," *IST 2013 - 2013 IEEE Int. Conf. Imaging Syst. Tech. Proc.*, pp. 239–242, 2013.

[30] Zuiderveld, Karel. "Contrast Limited Adaptive Histograph Equalization." *Graphic Gems IV.* San Diego: Academic Press Professional, 1994. 474–485.

[31] M. K. Dutta *et al.*, "An efficient grading algorithm for non-proliferative diabetic retinopathy using region based detection," *2015 38th Int. Conf. Telecommun. Signal Process. TSP 2015*, pp. 743–747, 2015.

[32] M. Gandhi and R. Dhanasekaran, "Investigation of severity of diabetic retinopathy by detecting exudates with respect to macula," *2015 Int. Conf. Commun. Signal Process. ICCSP 2015*, pp. 724–729, 2015.

[33] A. F. Aqeel and S. Ganesan, "Automated algorithm for retinal image exudates and drusens detection, segmentation, and measurement," *IEEE Int. Conf. Electro Inf. Technol.*, pp. 206–215, 2014.

[34] D. W. K. Wong *et al.*, "Automatic detection of the macula in retinal fundus images using seeded mode tracking approach," *Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBS*, pp. 4950–4953, 2012.

[35] S. S. G. Ashe, and I. Ali, "A new method for detection of optical disc and macula for diabetic retinopathy," In *Communication Control and Intelligent Systems (CCIS), 2016 2nd International Conference on* (pp. 136-140).

[36] C. Agurto *et al.*, "A multiscale optimization approach to detect exudates in the macula," *IEEE J. Biomed. Heal. Informatics*, vol. 18, no. 4, pp. 1328–1336, 2014.

[37] B. Dashtbozorg, J. Zhang, F. Huang, and B. M. Romeny, "Automatic optic disc and fovea detection in retinal images using super-elliptical convergence index filters," In *International Conference Image Analysis and Recognition*(pp. 697-706).

[38] M. Haloi, S. Dandapat, and R. Sinha, "An Unsupervised Method for Detection and Validation of The Optic Disc and The Fovea," *Comput. Vis. Pattern Recognit.*, pp. 1–8, 2016.