Automated Localization of Optic Disk, Detection of Microaneurysms and Extraction of Blood Vessels to Bypass Angiography

Patwari Manjiri[1], Manza Ramesh[2], Rajput Yogesh[2], Saswade Manoj[3], and Deshpande Neha[4]

[1] IMSIT, Vivekanand College, Aurangabad
[2] Department of CS & IT, Dr. BAMU, Aurangabad
[3] Saswade Eye Clinic, Aurangabad
[4] Guruprasad Netra Rugnalaya, Aurangabad
{manjiri.patwari,manzaramesh}@gmail.com,
yogeshrajput128@gmail.com

Abstract. Diabetic Retinopathy is considered as a root cause of vision loss for diabetic patients. For Diabetic patients, regular check-up and screening is required. At times lesions are not visible through fundus image, Dr. Recommends angiography. However Angiography is not advisable in certain conditions like if patient is of very old age, if patient is a pregnant woman, if patient is a child, if patient has some critical disease or if patient has undergone some major surgery. In this paper we propose a system Automated Diabetic Retinopathy Detection System (ADRDS) through which fundus image will be processed in such a way that it will have the similar quality to that of angiogram where lesions are clearly visible. It will also identify the Optic Disk (OD) and extract blood vessels because pattern of these blood vessels near optic disc region plays an important role in diagnosis for eye disease. We have passed 100 images in the system collected from Dr. Manoj Saswade and Dr. Neha Deshpande and got true positive rate of 100%, false positive rate of 3%, and accuracy score is 0.9902.

Keywords: DR, OD, Lesions.

1 Introduction

Diabetic retinopathy, an eye disorder caused by diabetes, is the primary cause of blindness in America and over 99% of cases in India. India and China currently account for over 90 million diabetic patients and are on the verge of an explosion of diabetic populations [1]. Over time, diabetes can damage the heart, blood vessels, eyes, kidneys, and nerves. According to WHO 347 million people worldwide have diabetes. WHO projects that, diabetes deaths will increase by two thirds between 2008 and 2030. This may result in an unprecedented number of persons becoming blind unless diabetic retinopathy can be detected early [2].

For Diabetic patient regular eye check-up and screening is required [3]. Fundus image is taken to view the abnormalities. At times lesions are not visible through

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fundus image, Dr. Recommends angiography. However Angiography is not advisable in certain conditions like if patient is of very old age, if patient is a child, if patient is a pregnant woman, if patient is suffering from hypertension ,stroke, or if patient has undergone some major surgery. Sometimes due to dye even a clinically healthy person will have side effects such as Dizziness or faintness, Dry mouth or increased salivation, Hives, Increased heart rate, Metallic taste in mouth, Nausea and Sneezing [4].

To overcome this problem we have come up with a computer aided system (Automated Diabetic Retinopathy Detection System), to detect DR lesions [5] at early stage, to preprocess retinal image, to detect optic disk and to extract blood vessels so that angiography can be avoided. We have applied image processing techniques using MATLAB 2012a. We have performed these operations on 100 images collected from Dr. Manoj Saswade, Dr. Neha Deshpande and got true positive rate of 100%, false positive rate of 3%, and accuracy score is 0.9902.

2 Methodology

Computer assisted diagnosis for various diseases is very common now a days and medical imaging plays a vital role in such diagnosis. Image processing techniques can help in detecting, lesions at early stage, localization of optic disc and extractions of blood vessels to bypass Angiography. The proposed System “Automated Diabetic Retinopathy Detection System” has five stages(fig 1). In first stage preprocessing is done to remove the background noise from input fundus image. Mask of input image is obtained using thresholding technique in the second stage. In the third stage Optic disc is localized using Speeded Up Robust Features techniques. Blood vessels are extracted in the fourth stage using 2-D median filters. In the last stage lesions are detected with the help of intensity transformation function.

2.1 Stage I (Preprocessing)

The Preprocessing is done to remove noise (pixel whose color is distorted) from background and to enhance the image [6]. In the first stage of preprocessing green channel is taken out, because green channel shows high intensity as compare to red and blue. For enhancement of green channel, histogram equalization is used. Mathematical formula for finding green channel is as follows

$$g = \frac{G}{(R + G + B)} \tag{1}$$

Where g is a Green channel and R, G and B are Red, Green and Blue respectively. In the green channel all minute details of image can be viewed. Using red channels only boundary is visible, and in blue channel image shows lots of noise. Due to these reasons green channel is used in the proposed system [7]. For finding histogram equalization of an image following formula is used.

$$\mathrm{h(v)} = \mathrm{round}\left(\frac{\mathrm{cdf(v)} - \mathrm{cdf_{min}}}{(\mathrm{M}\times\mathrm{N}) - \mathrm{cdf_{min}}} \times (\mathrm{L}-1)\right) \tag{2}$$

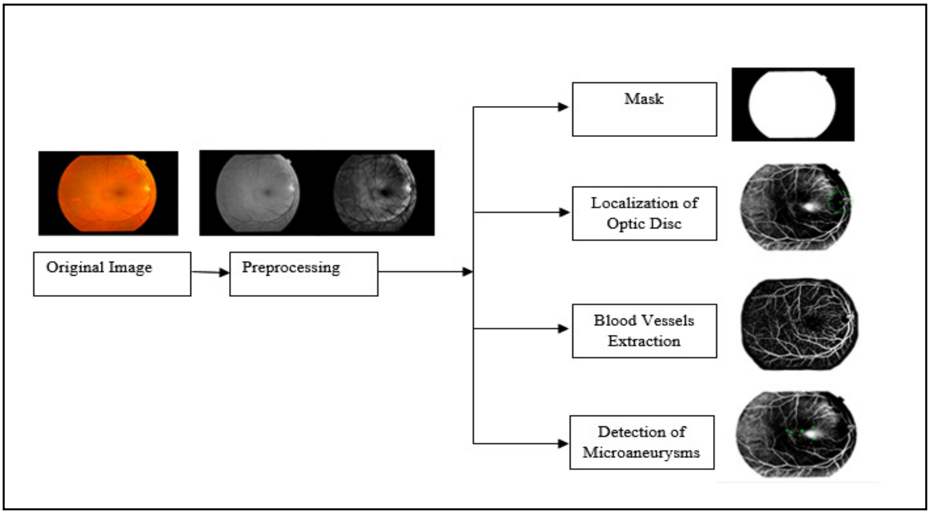


Fig. 1. Flow chart for "Automated Diabetic Retinopathy Detection System"

Here cdf_min is the minimum value of the cumulative distribution function, M × N gives the image's number of pixels and L is the number of grey levels. In histogram equalization frequencies of image are spread out, thus image gets enhanced [6].

2.2 Stage II (Extraction of Mask)

Mask detection is necessary because it displays the exact structure of boundaries of an image. If boundaries are not proper then the image can be discarded to avoid further processing[7]. To extract the mask of fundus image red channel is considered because it is used to detect boundaries. Once red channel is taken out, thresholding[6] operation is performed.

For finding threshold function following formula is used

$$T = \frac{1}{2(m1 + m2)} \tag{3}$$

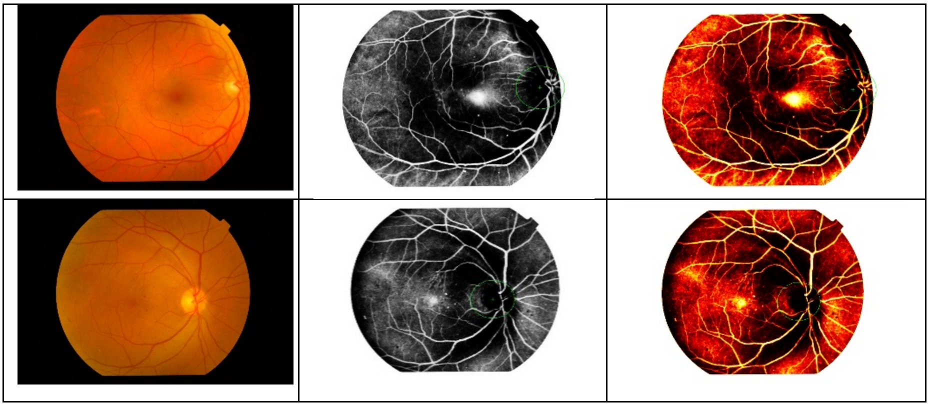
Where m1 & m2 are the Intensity Values. Threshold is the type of segmentation where required object is extracted from the background[6].

2.3 Stage III (Optic Disk Localization)

A ganglion cell is a cell found in a ganglion, which is a biological tissue mass, most commonly a mass of nerve cell bodies. The optic nerve head in a normal human eye carries from 1 to 1.2 million neurons from the eye towards the brain. The optic disc or optic nerve head is the location where ganglion cell axons exit the eye to form the optic nerve. The optic disc is also the entry point for the major blood vessels that supply the retina. Patten of these blood vessels near optic disc region plays an important role in diagnosis for eye disease. An Ophthalmologist checks this region to detect normal and abnormal vessels. Abnormal vessels are called as tortuous vessels. If blood vessels get tortuous then the chances of leaking the blood is more, which in turn can damage Retina. For localization of Optic Disc green channel is used as it shows high intensity for the pixel values compared to red and blue. After applying some image processing techniques seed-up robust features is used [7 to 10]. Following is the formula for Speed Up Robust Features

$$I_{\Sigma}(x,y) = \sum_{i=0}^{i \le x} \sum_{j=0}^{j \le y} I(x,y) \tag{4}$$

Given an input image I and a point (x; y) the integral image I_{Σ} is calculated by the sum of the values between the point and the origin. Figure 2 shows original images in column A and localized optic disk images in column B and C.



A Fundus Image B – Optic Disc Localized Image C – Optic Disc localized color Image

Fig. 2. Optic Disc Localization

2.4 Stage IV (Extraction of Blood Vessels)

For extraction of blood vessels, Image processing operations are performed on green channel image. Figure 3 shows original images in column A and Extracted blood vessels of images are shown in column B and C. Histogram equalization function is used for enhancing the green channel image followed by 2-D median filter[11 to 14]. Morphological structuring element is applied for highlighting the blood vessels of the retina.

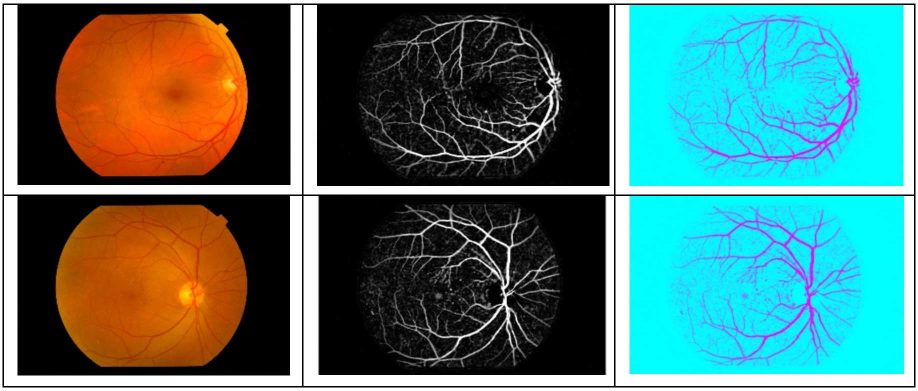
$$I_{dilated}\,(i,j) = \max_{f(n,m)=true} I(i+n, j+m) \tag{5}$$

$$I_{eroded}\,(i,j) = \min_{f(n,m)=true} I(i+n, j+m) \tag{6}$$

Morphological open function is used for thickening the retinal

$$A \circ B = (A \ominus B) \oplus B \tag{7}$$

Where $A \circ B$ is morphological opening, $\ominus$ is Erosion and $\oplus$ is Dilation.



A – Fundus Image B – Blood Vessels extracted C –Blood vessels Extracted

Fig. 3. Blood Vessels Extraction

To remove noise 2D median filter is used.

$$y[m,n] = median\{x[i,j], (i,j) \in \omega\} \tag{8}$$

Where ω Represents a neighborhood centered around location (m, n) in the image.

In the last Threshold function is used for extracting the retinal blood vessels.

$$T = \frac{1}{2(m1+m2)} \tag{9}$$

Where m1 & m2 are the Intensity Values.

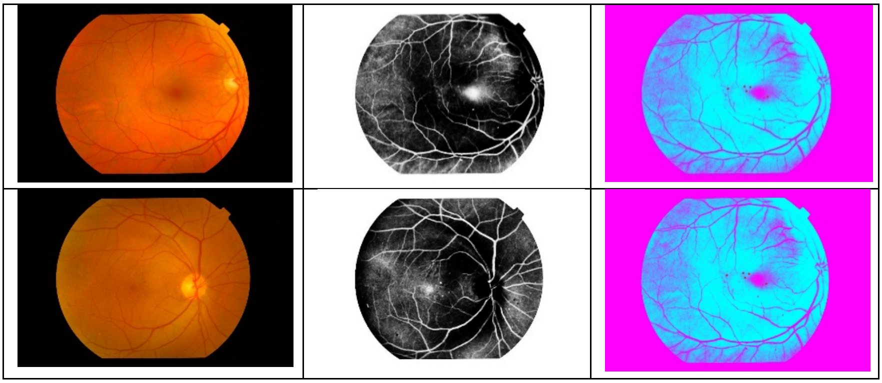
After using image processing techniques in the end intensity-transformation functions is used. Following is the formula for Intensity Transformation Function

$$s = T(r) \tag{10}$$

Where T is Transformation and r is Intensity

2.5 Stage V (Detection of Lesions (Microaneurysm))

Microaneurysms are the first clinically detected lesions. It is Tiny swelling in the wall of a blood vessel. It appears in the retinal capillaries as a small, round, red spot. Usually they are located in the inner nuclear layer of the retina[5]. To begin with the detection of microaneurism, Green channel is taken out, which is followed by compliment function, and histogram equalization function. In figure 4 original images are shown in column A and Microaneurysm detected images are shown in column B and C.



A – Fundus Image B – Microaneurysms C – Microaneurysms

Fig. 4. Detection of Microaneurysms

3 Result

We have applied this algorithm on 120 images. For result analysis Receiver Operating Characteristic (ROC) curve[18] is used. This algorithm achieves a true positive rate of 100%, false positive rate of 0%, and accuracy score of 0.9902. For detection of blood vessels this algorithm achieves 0.9937 accuracy (Table1), for Optic disc detection 0.9932(Table2) and for microaneurysms 0.9962(Table 3) compared to other algorithms. We have developed GUI in matlab(Figure 5) for blood vessel extraction, detection of microaneurisms and Optic disc.

Table 1. Comparison of optic disc

	AUC
Rangaraj et al.	0.8890
Usman et al.	0.9632
Chandan et al.	0.9100
Ahmed et al.	0.9500
Proposed	**0.9932**

Table 2. Comparison of blood vessels

	AUC
Chaudhuri et al.	0.9103
Jiang et al.	0.9327
Staal et al.	0.9520
Soares et al.	0.9614
Proposed	**0.9937**

Table 3. Comparison of microaneurysms

	AUC
Yuji et al.	0.6700
Sujith et al.	0.9444
Proposed	**0.9962**

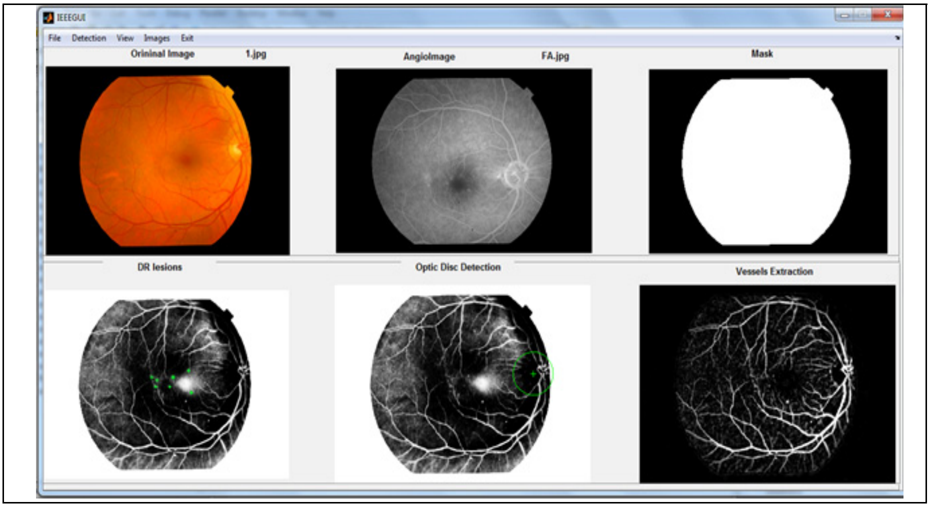


Fig. 5. Graphical User Interface

4 Conclusion

In the developed system "Automated Diabetic Retinopathy Detection System (ADRDS)" we have used Image processing techniques through which fundus image is processed in such a way that it has the similar quality to that of angiogram where lesions are clearly visible. System is also able to identify the Optic Disc (OD) and it can extract blood vessels. Pattern of these blood vessels near optic disc region plays an important role in diagnosis for eye disease. We have passed 120 images collected from Dr. Manoj Saswade, Dr. Neha Deshpande to this system, and we have got true positive rate of 100%, false positive rate of 3%, and accuracy score is 0.9902.

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