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To Detect and Quantify Elementary Lesions for Seriousness of Retinal Diseases using Image Processing

S. D. Mendhule[1], Dr. R. J. Bhiwani[2]

[1]M.E. (Scholar), Dept. of Electronics and Telecommunication, Babasaheb Naik College of Engineering, Pusad
[2]Professor, Dept. of Electronics and Telecommunication, Babasaheb Naik College of Engineering, Pusad,

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Abstract - *Diabetic Retinopathy (DR) is a prominent cause of blindness in the world. The early treatment of DR can be conducted from detection of microaneurysms (MAs) which appears as reddish spots in retinal images. An automated microaneurysm detection using image processing can be a helpful system for ophthalmologists. Since microaneurysm detection is decisive in diabetic retinopathy (DR) grading, for the validation of proposed method we have used two publicly available database DIARETDB1 and e-ophtha (MA) ground truth. In this paper, adaptive thresholding and morphological operations are used to detect and quantify elementary lesion (i.e. MA) and observe accuracy of 95.75% for DIARETDB1and 93.09% for e-ophtha MA*

Key Words: Diabetic Retinopathy (DR), Image Processing, Microaneurysm, Adaptive Thresholding

1. INTRODUCTION

According to recent estimates, approximately 425 million people worldwide in the 20–79 year age group were detected as diabetic in 2017 and by 2045, around 629 million people of the adult population, is expected to have diabetes [1]. The largest increases will take place in the regions dominated by developing economies. The prevalence of diabetes is rising all over the world due to population growth, aging, urbanization, changing life style, increase of obesity and physical inactivity. Unlike in the West, where older persons are most affected, diabetes in Asian countries is disproportionately high in young to middle-aged adults. This could have long-lasting adverse effects on nation's health and economy, especially for developing countries.

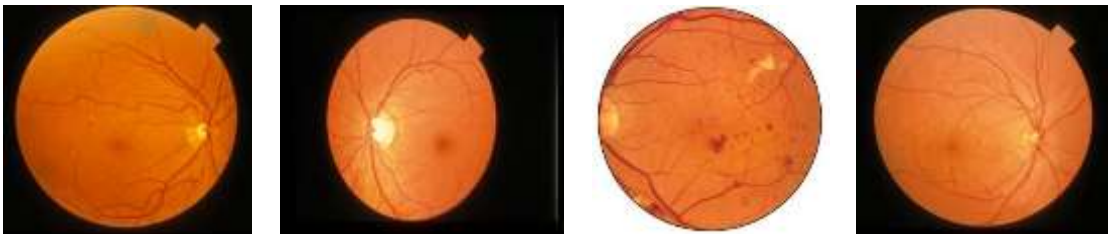
The International Diabetes Federation (IDF) estimates the total number of people in India with diabetes to be around 72.9 million in 2017, rising to 134.3 million by 2045[1],making the India diabetic capital of the World. The ratio of ophthalmologists to the number of diabetic patient is very low. Ophthalmologists in India are insufficient to support the growing diabetic population. India has one ophthalmologist per Lac. This ratio is even smaller for rural areas. Today diabetic retinopathy is a third cause of blindness in India.

Microaneurysms (MA) are focal dilations of retinal capillaries and appear as small round dark red dots. They appeared at the earliest clinically localized characteristic of DR, their detection would help to early treatment and prevention of blindness. It is difficult to detect MA because their pixels are similar to that of blood vessels. MA is hard to distinguish from noise or background variations because it has typically low contrast. In this paper concentrate on MA detection as the earliest clinically localized characteristic. A review related to retinal problems and its analysis is presented [2] in details.

2. Diabetic retinopathy

Diabetic retinopathy is a microvascular complication of diabetes, causing abnormalities in the retina. Typically there are no salient symptoms in the early stages, but the number and severity predominantly increases later. The diabetic retinopathy typically begins as small changes in the retinal capillaries. The smallest detectable abnormalities, microaneurysms (MA), appear as small red dots in the retina and are local distensions of the weakened retinal capillary. Due to these damaged capillary walls, the small blood vessels may rupture and cause intra retinal haemorrhages (HA). In the retina, the haemorrhages appear either as small red dots indistinguishable from microaneurysms or larger round-shaped blots with irregular outline. Currently, regular screenings are conducted and retinal images are obtained using fundus camera. However, a large amount of images are obtained from these screenings and it requires trained ophthalmologists to spend a lot of time for manual analysis and diagnosis. Hence, automatic detection is desired as it can help to improve productivity and be more cost effective.

There are four stages used for grading DR, grade 0 (no DR), grade 1 (mild), grade 2 (moderate) and grade 3(severe) shown in figure 1. Each grade is classified by an appearance and number of microaneurysms. Diabetic retinopathy can be classified into i) mild, ii) moderate and iii) severe [3]. In mild DR, microaneurysms are small areas of balloon-like swellings in the retina's tiny blood vessels as shown in figure1(A). As the disease progresses, some blood vessels that nourish the retina are blocked and this stage is called Moderate DR as shown in figure1(C). The next stage is Severe DR during which many more blood vessels are blocked as shown in figure1(D).



A B C D

Figure 1: (A) Healthy retina (B) Mild DR (C) Moderate DR (D) Severe DR

This paper detects and quantifies microaneurysm for seriousness of the retinal disease. The microaneurysm detection can be used to grade the progression of DR into four stages: no DR, mild DR, moderate DR and severe DR, as shown in Table 1.

Table 1.Grading criteria of Diabetic Retinopathy

DR Grade	Parameters
Grade 0 (No DR)	MA=0
Grade 1 (Mild)	1<MA<5
Grade 2 (Moderate)	5 < MA < 15
Grade 3 (Severe)	MA ≥ 15

3. RELATED WORK

Microaneurysms are the first clinical sign of diabetic retinopathy, a major cause of vision loss in diabetic patients. Early microaneurysm detection can help reduce the incidence of blindness. Automatic detection of microaneurysms is still an open problem due to their tiny sizes, low contrast and also similarity with blood vessels. It is particularly very difficult to detect fine microaneurysms, especially from non-dilated pupils.

A literature survey is carried out and various techniques proposed by different authors are discussed.

Akara Sopharak and et al. [4] used segmentation technique to detect fine microaneurysms, from non-dilated pupils. The process consists of two segmentation steps:

a) Coarse segmentation using mathematic morphology and
b) Fine segmentation using naive Bayes classifier.

A total of 18 microaneurysms features are proposed in this paper and they are extracted for naive Bayes classifier. The detected microaneurysms are validated by comparing at pixel level with ophthalmologists' data.

Balint Antal et al. [5] proposed an ensemble-based framework to improve microaneurysm detection. They proposed a combination of internal components of microaneurysm detectors, namely preprocessing methods and candidate extractors, and approach for microaneurysm detection.

M. Usman et al. [6] presented a method for accurate blood vessel detection which can be used for detection of neovascularization and presents method for vessel segmentation using a multilayered thresholding technique. The method is tested using two publicly available retinal image databases.

Akara Sopharak et al. [7] investigated a set of optimally adjusted morphological operators used for microaneurysm detection on non-dilated pupil and low-contrast retinal images. The detected microaneurysms are validated by comparing with ophthalmologists' data.

Joshi Manisha Shivram et al. [8] proposed an algorithm for the detection of Haemorrhages from Diabetic Retinopathy images. The algorithm proceeds through three main steps:

1. Color image enhancement
2. Image subtraction to extract blood vessels and haemorrhages and
3. Use of set of optimally adjusted morphological operators to suppress blood vessels and to highlight only haemorrhages.

These automatically detected haemorrhages are validated by comparing with expert ophthalmologists' data. Quantitative performance of algorithm is evaluated by calculating sensitivity and specificity and predictive value (PV).

Atsushi Mizutani et al. [9] investigated a computerized method for the detection of microaneurysms on retinal fundus images. After image preprocessing, candidate regions for microaneurysms were detected using a double-ring filter. Any potential false positives located in the regions corresponding to blood vessels were removed by automatic extraction of blood vessels from the images. Twelve image features were determined, and the candidate lesions were classified into microaneurysms or false positives using the rule-based method and an artificial neural network. The true positive fraction of the proposed method was 0.45 at 27 false positives per image. Forty-two percent of microaneurysms in the 50 training cases were considered

invisible by the consensus of two co-investigators. When the method was evaluated for visible microaneurysms, the sensitivity for detecting microaneurysms was 65% at 27 false positives per image.

Lee Streeter et al. [10] developed a prototype microaneurysm detection system for non-mydriatic colour fundus images. Candidate microaneurysms are located by a standard method that enhances small round features after background intensity correction. Each candidate is then classified based on colour and standard morphological features. New non-linear feature combinations were also investigated. Various classification methods were trialed to determine the most effective and efficient. A microaneurysm detection sensitivity of 56% at 5.7 false positives per image was achieved.

P M D S Pallawala et al. [11] proposed microaneurysm segmentation and detection algorithm that is based on generalized eigenvectors of affinity matrix. This technique is robust and has a minimal interference from other structures and lesions.

S.Jimenez et al. [12] designed and developed tool consists of three stages of processing:
(1) Obtaining of the basic image of eye with the retinal camera, inverted image on the green channel, and a high-pass filter of the image. This phase enhances the microaneurysms.
(2) Detection of the candidates for microaneurysms, by means of an adaptive prediction filter and regions growth.
(3) Selection, among the candidates, of whom microaneurysms must be considered to fulfill the criteria of circular shape, high intensity in the inverted green channel and contrasts with respect to the surrounding pixels.

4. Database used:

Two publicly available retinal image databases DIARETDB1 and e-ophtha MA are used for the proposed method and validate the result with the ground truth of the database.

4.1DIARETDB1

(http://www2.it.lut.fi/project/imageret/diaretdb1/) consists of 89 colour fundus images.84 contain at least mild non-proliferative DR signs (microaneurysms) and 5 are considered normal, not containing DR signs according to all experts who participated in the evaluation. Images were captured using the same 50-degree FOV digital fundus camera with varying imaging settings. The data correspond to a good (not necessarily typical) practical situation, where images are comparable and can be used to evaluate the general performance of diagnostic methods. 4 medical experts were asked to mark the areas related to the microaneurysms, haemorrhages, and hard and soft exudates. Ground truth confidence levels, {<50 %,~> 50%, ~100%}, represented the certainty of the decision that a marked finding is correct, are included. [13]

4.2 e-ophtha: Designed for research in DR, it contains color fundus images obtained from the examinations of patients during 2008-2009 through the OPHDIAT network [14, 15]. e-ophtha-MA contains 148 images with microaneurysms or small hemorrhages and 233 images with no lesion.

5. The proposed method:

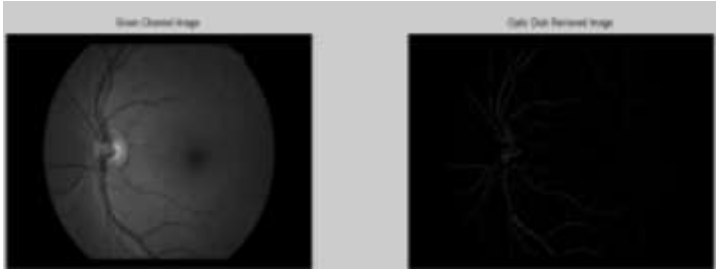
The proposed method has two main steps. In first step preprocessing is done to remove noise, contrast enhancement and shade correction. Vessels and optic disk are detected and eliminated in this step. The second step includes candidate i.e. MAs detection by using region growing method by three level thresholding.

5.1 Vessels and Optic Disk Detection:

For the detection images are acquired from [13, 14] which are publically available. The retinal images obtained from database are unprocessed images; to improve the visibility preprocessing is done. This preprocessing stage improves the quality of unprocessed images. Preprocessing stage is used to remove the noise and eliminate irrelevant information. Firstly, the retinal colored image is preprocessed i.e. only green component are extracted as intensity of green channel is high. Mathematically, the green channel image can be obtained using equation 1 as shown in figure 2 (A).

$$g = \frac{G}{R+G+B} \quad \text{..... (1)}$$

Where, g is Green channel and R, G, B are Red, Green and Blue shares in the components. After getting the green component image, enhancement is done to obtain the clear image. The green plane of the original image in RGB plane is used as red lesions such as MA and blood vessels which have the highest contrast with the background in this color plane. On applying horizontal and vertical mask using sobel operator, horizontal and vertical blood vessels are detected. After that morphological bottom hat filtering with disk shaped structuring element(SE) with radius of 3 is used to remove optic disk as shown in figure 2 (B). Proposed method flow chart for the detection of vessels and optic disk is shown in figure 3 and detected vessels and optic disk using the method is shown in figure 4.



A B

Figure 2: Preprocessing steps. (A) Green band (B) Optic Disk removed image.

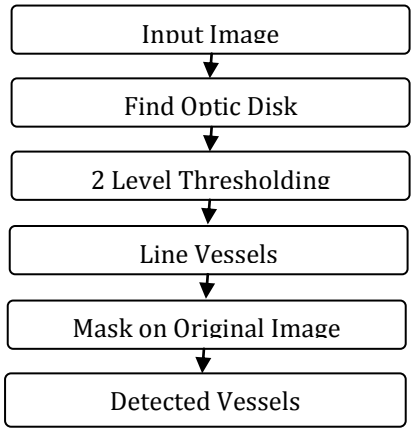


Figure 3: Flow chart for detection of Vessels and Optic Disk

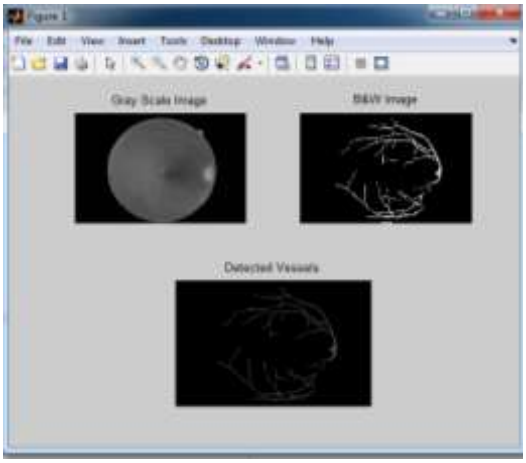


Figure 4: Detected Vessels and Optic Disk

5.2 Microaneurysm Detection:

After the preprocessed image and detection of Vessels and Optic Disk, segmentation using region growing technique is used to detect MA. After completion of the segmentation stage, the resulting regions are classified to discriminate true microaneurysms. In this method reference threshold value is taken as 9 by defining constant alpha_l = 0.95, alpha_u = 0.5, beta = 0.5. By changing the threshold value more red areas can be achieved for the desired output. Thresholed image is then enhanced using histogram equalization.

To detect red lesions, firstly morphological operation erosion is used to remove the vasculature, leaving the other small structures representing the MAs. Erosion shrinks or thins the objects in a binary image by the use of structuring element. The mathematical representation of erosion is as shown below.

$$A \ominus As = \{z | (As)\, z \cap Ac \neq \Phi\}$$

Where 'Φ' is an empty element and 'As' is the structuring element.

This morphological operation gives high degree of discrimination between linear and circular shapes and then is suitable for discriminating red lesions from blood vessels. The detailed Flowchart and results are shown in figure 5 and Figure 6 respectively.

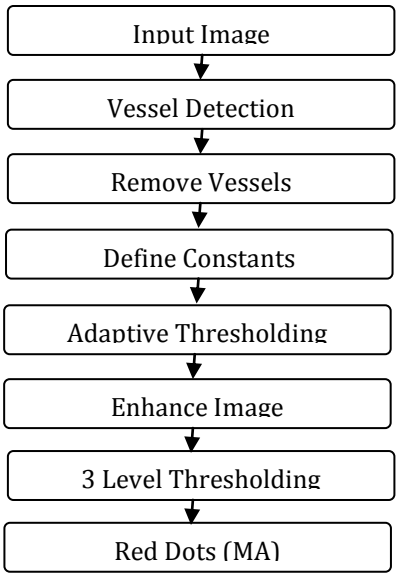
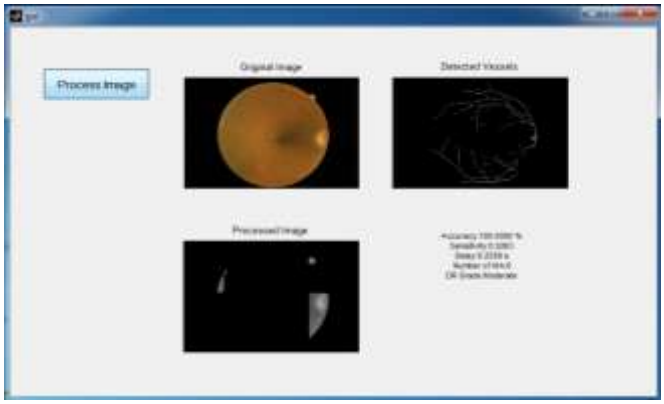


Figure 5: Flow chart for detection of Microaneurysm

Figure 6: Detection and quantification of MA using GUI



6. Result:

We have tested our method on 157 images selected from two databases: e-ophtha MA [13], DIARETDB1 [14] and validate the result with the ground truth of these databases and achieved the accuracy shown in table 2.

Table 2. Comparison of Average result obtained by using proposed method from two databases

Database used	No. of Images	Accuracy (%)
DIARETDB1	89	95.75
e-ophtha MA	68	93.09

7. Conclusion:

In this work, adaptive thresholding for detection of red lesions is proposed. Morphological operation is used to remove the vasculature, leaving the other small structures representing the MAs give the good result. The retinal image contrast was improved and prepared better for detection step. The proposed method is simple and the images used for detecting red lesion are obtained from publically available database. The algorithm is tested on 89 images of DIARETDBI, 68 images of e-ophtha MA and found satisfactory result.

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