Software based Automated Early Detection of Diabetic Retinopathy on Non Dilated Retinal Image through Mathematical Morphological Process

N. S. Datta
Asst. Prof.
Dept.of IT, FIEM
Kolkata, India, PIN-700150

R. Sarker
Research Scholar
Dept. of CSE, FIEM
Kolkata, India, PIN-700150

H. S. Dutta
Asst. Prof.
Dept. of ECE, KGEC,
Kalyani, India, PIN-741235

M. De
Professor
DETS, University of
Kalyani, India, PIN-741235

ABSTRACT
Microaneurysms (MAs) are the earliest clinical sign of Diabetic Retinopathy. MA detection at early stage can help to reduce the blindness. In this paper software based method is presented for early detection of diabetic retinopathy using non dilated retinal images. Here, initially an automated system is generated to identify diabetic affected eye among the several input retinal images. Graphical presentation of MA count for different images can easily classify the normal eye and the diabetic affected eye. Then the performance analysis of the above system is carried out graphically using the affected eye. The average sensitivity, specificity, precision and accuracy are the important performance analysis parameters and measured as 81.68%, 99.98%, 83.00% & 99.97% respectively for ten diabetic affected retinal images.

General Terms
Medical Image Processing.

Keywords
Microaneurysms (MAs); Diabetic Retinopathy (DR); Contrast Limited Adaptive Histogram Equalization (CLAHE); Exudates.

1. INTRODUCTION
Diabetes has emerged as a major health care problem in India. According to the International Diabetes Federation (IDF), there were an estimated 40 million patients with diabetes in India in 2007 and this number is predicted to rise to almost 70 million patients by 2025. The countries with the largest number of diabetic people will be India, China and USA by 2030[1]. It is estimated that every fifth person with diabetes will be an Indian. Diabetic retinopathy (DR) is a common retinal complication associated with diabetes. It is a major cause of blindness in middle as well as older age groups. Therefore early detection through regular screening and timely intervention will be highly beneficial in effectively controlling the progress of the disease [2]. The ratio of people affected with the disease to the number of eye specialist who can screen these patients is very high. There is a need of automated diagnostic system for detection of diabetic affected eye so that only diseased persons can be referred to the specialist for further intervention and treatment. From the experts view diabetic retinopathy screening may reduce the risk of blindness in these patients by 50% and can provide considerable cost savings to public health systems [3]-[4]. In this regard we focused our research-work on microaneurysms detection which is appeared as small dark round dots (~15 μm to 60 μm in diameter) on the fundus images. Microaneurysms are small bulges developed from the weak blood vessels and are the earliest clinical sign of diabetic retinopathy [5]-[6]. In this paper an automated software based system is developed using MATLAB software for calculating the microaneurysms area on given retinal images and plotted the pictorial view for classification between normal eye and diabetic eye. The performance of the proposed method was measured by evaluating average sensitivity, specificity, precision and accuracy, against ophthalmologist's hand-drawn ground-truth. Sensitivity and specificity are used as the performance measurement of the diabetic eye because they combine true positive and false positive rates. Accuracy values are also used to evaluate the system. In section 2, review on retinopathy is given. Proposed methods for early detection of diabetics and performance analysis are discussed in section 3 and 4 respectively. In section 5, results and discussion is provided. Finally, conclusion is given in section 6.

2. REVIEW ON EARLY DETECTION
A lot of research work published on early diagnosis of diabetic retinopathy. Most of them are based on the detection of microaneurysms at mild stage. T. Spencer et al [7]-[8] proposed a mathematical technique to segment MA within fluorescein angiogram. J.H. Hipwell et al. [9] used Gaussian matched filters to retain candidate MA for classification. D. Fleming et al [10] proposed a method to detect MA by local contrast normalization. C. Sinthanayothin et al. [11] proposed an automated system of detection of diabetic retinopathy using recursive region growing segmentation (RRGS). Usher et al. [12] employed a combination of R RG adaptive intensity thresholding to detect candidate lesions region and a neural network is used for classification to segment MA candidate regions and k-nearest neighbors (*K*NN) to classify MA. Most of the techniques reported in literature, used retinal images with dilated pupil where MA and other feature already distinguished and clearly visible.

3. PROPOSED METHOD
A group of digital retinal images were taken from the people with age limit 25-90 years using a Canon CR5 non-mydriatic 3CCD camera with a 45 degree field of view. Each image was captured using 8 bits per color plane at 565 by 584 pixels. In general Microaneurysms are hard to detect due to their contrast is very low, hardly visible and also difficult to distinguish from noise [6]. In proposed method the gray scale image (or green channel) are used to detect the circular border and optical disk mask. The green channel image first finds the edges using digital image processing canny edge detection methods before removing the circular border to fill the enclosed small area. The exudates are removed by applying AND logic with large area. In next stage, the larger areas are removed. Then the blood vessels and optical disks are removed. Finally, MA area is obtained as an output from the

system. The overall procedure for MA detection is shown in figure 1.

3.1 Preprocessing

A preprocessing stage is required for improving the image quality prior to the detection stage. The automated system is configured for detection of MA in such a way that it can be applied for both the gray level and green layered images. Here, the green plane of the original RGB color image used as red lesions has the highest contrast with the background in this color plane. It is observed that the contrast of the retinal images tends to be bright in the centre and diminish at the side. To equalize the image intensity level, CLAHE is applied (contrast limited adaptive histogram equalization) twice (optional). Then the image histogram is examined and also checked the equalization of the intensity level from 0-255.

3.2 Circular border formation

Pocess1: The two processes for circular border formation of the retinal images are applied here. First method applied for normal retinal eye and second for noisy images. The first method used CANNY method to detect edge and the circular border obtained after subtracting the dilated image with eroded images.

Process2: This method activated when a noisy image provided by the user and inverse the intensity of the image prior to image segmentation. The circular region is filled as a result and circular border obtained after subtracting the dilated image with the eroded image.

3.3 Detection and removal of larger area

Besides microaneurysms detection, the larger area, bright lesions such as exudates, treated as noise are also removed for perfect detection of MA. Mathematical morphological methods [13] are applied here for removing larger area than MA. The border eliminated before the image filled up with enclosed area. The area (i.e. MA with noise) obtained by subtracting away the edges with image. Next, the larger areas are removed by morphological operation. The resultant image still contains noise (blood vessels, exudates). As exudates are the bright yellow-white objects on the retinal image developed due to the leakage of blood from abnormal vessels, it has been decided to trace out exudates by applying CLAHE (Contrast Limited Adaptive Histogram Equalization) two times (optional). Then applying AND logic to remove large area such as exudates.

3.4 Detection and removal of larger area

Blood vessels are detected and extracted by applying morphological operation with image segmentation of threshold value. After removing the small area (object <=100 pixels) of noise, the clearer blood vessel image is obtained. This image is compared using AND logic with the result from the previous AND logic to remove the blood vessels.

3.5 Optical disk detection and elimination

Pictorial view of the retinal image shows that optical disk is a collection of bright pixels and it is developed in anywhere of the retinal images. So, a mask is created to enclose the optical disk. As, m*n matrix (i.e. dimension of image provided by user) of retinal input image selected for detection of MA, the maximum value for each of the n columns of the image is first pointed out before locating the largest value. The coordinates (i.e. row and column) of all brightest pixels were determined and median was calculated. Then the mask was created, using the following relation for creating circle:

$$R^2 = (x-h)^2 + (y-k)^2 \quad \ldots(1)$$

where, *h* and *k* are the coordinates (row and column) and *R* is the radius. Then created mask was subtracted from the segmented retinal image and obtained the image without optical disk. The final MA image is obtained after removing the circular border, large area or exudates, blood vessels and optical disks.

4. PERFORMANCE ANALYSIS

The performance of proposed method was evaluated quantitatively by comparing the resultant extraction with ophthalmologists, hand-drawn ground-truth images pixel by pixel. This pixel based evaluation considers four values, namely true positive (TP, a number of MA pixels correctly detected by proposed method), false positive (FP, a number of non-MA pixels which are detected wrongly as MA pixels), false negative (FN, a number of MA pixels that were not detected) and true negative (TN, a number of non MA pixels which were correctly identified as non MA pixels). The sensitivity, specificity, accuracy and precision are the important parameters for performance analysis of the system. Sensitivity and specificity are used as the performance measurement of MA detection because they combine true positive and false positive rates of MA pixels. Sensitivity is the percentage of the actual MA pixels that are detected, and specificity is the percentage of non-MA pixels that are correctly classified as non-MA pixels. Precision is the percentage of detected pixels that are actually MA. Finally, accuracy is the overall per-pixel success rate of the proposed method.

The performance of proposed method analyzed by the following equations, where T_P, T_N, F_P, F_N stands for true positive, true negative, false positive and false negative respectively:

$$SENSITIVITY = \frac{T_P}{T_P + F_N} \quad \ldots(2)$$

$$SPECIFICITY = \frac{T_N}{F_P + T_N} \quad \ldots(3)$$

$$PRECISION = \frac{T_P}{T_P + F_P} \quad \ldots(4)$$

$$ACCURACY = \frac{T_P + T_N}{T_P + F_P + T_N + F_N} \quad \ldots(5)$$

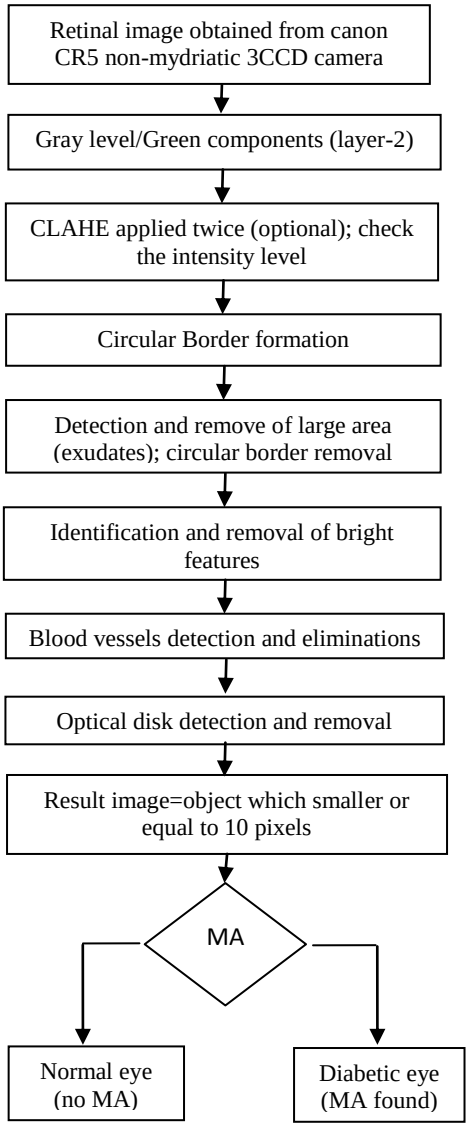
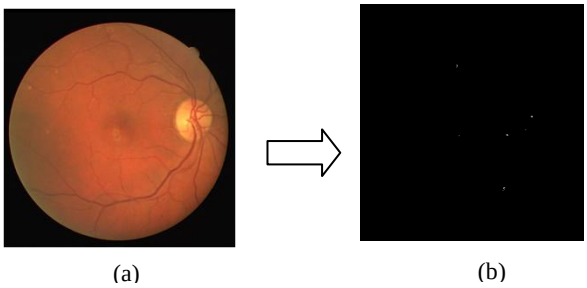


Figure1. Proposed method for Diabetics detection

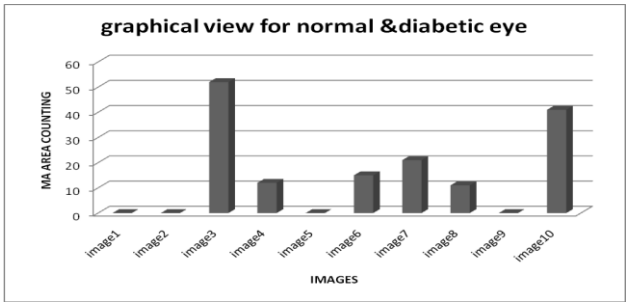
5. RESULT AND DISCUSSION

In this paper, the proposed method is applied for tracing out normal eye and diabetic retinal eye. Next, MA area are calculated for randomly selected ten images for showing nature of MA area of retinal image in respect with Diabetic disease. Here, graphical presentation for classification between normal eye and diabetics affected eye is given in figure 2. As shown in figure 2, the zero level of MA area indicates normal eye, otherwise positive level of MA area indicates early symptoms depicts for retinal diabetics.

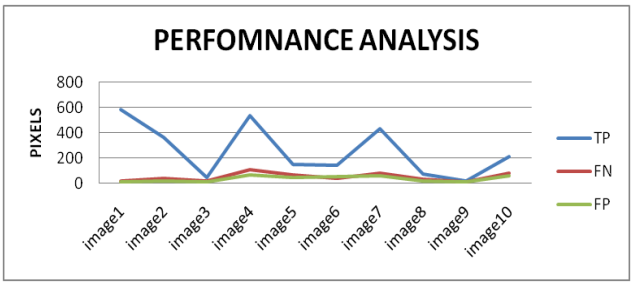
Here, ten diabetic retinal images are selected with positive MA area for performance measurement of proposed method against ophthalmologists hand –drawn ground –truth. From these pixel area based evaluation, the average sensitivity, specificity, precision and accuracy are successfully calculated as 81.68%, 99.98%, 83.00% and 99.97% respectively (shown in Table 1). The British Diabetic Association (Diabetes UK) has established standards for any diabetic retinopathy



(a) (b)



(c)



(d)

Figure2. (a)Input retinal image, (b)corresponding detected MA (area counting=52), (c)classification of normal and diabetic eye, (d)Graphical view of Performance

screening programme of at least 80% sensitivity and 95% specificity [14].

6. CONCLUSION

This method satisfactorily detects the presence of abnormalities in the retina such as microaneurysms using mathematical morphological operation of the digital image processing. The results are encouraging and these methods contribute to overall goal of development of a system for the automated screening of diabetic retinopathy. Thus, the method can help the ophthalmologist to detect the microaneurysms in the screening process.

7. REFERENCES

[1]. Wild S., Roglic G., Green A., Sicree R., King H.,"Global prevalence of diabetes: estimates for the year 2000 and projections for2030", Diabetes Care 2004; 27:1047–53.

[2]. Iqbal M.I., Aibinu A.M., Gubbal N.S., Khan A., "Automatic DiagnosisofRetinopathy using fundus Images''- Master's Thesis (2006), Blekinge Institute of Technology.

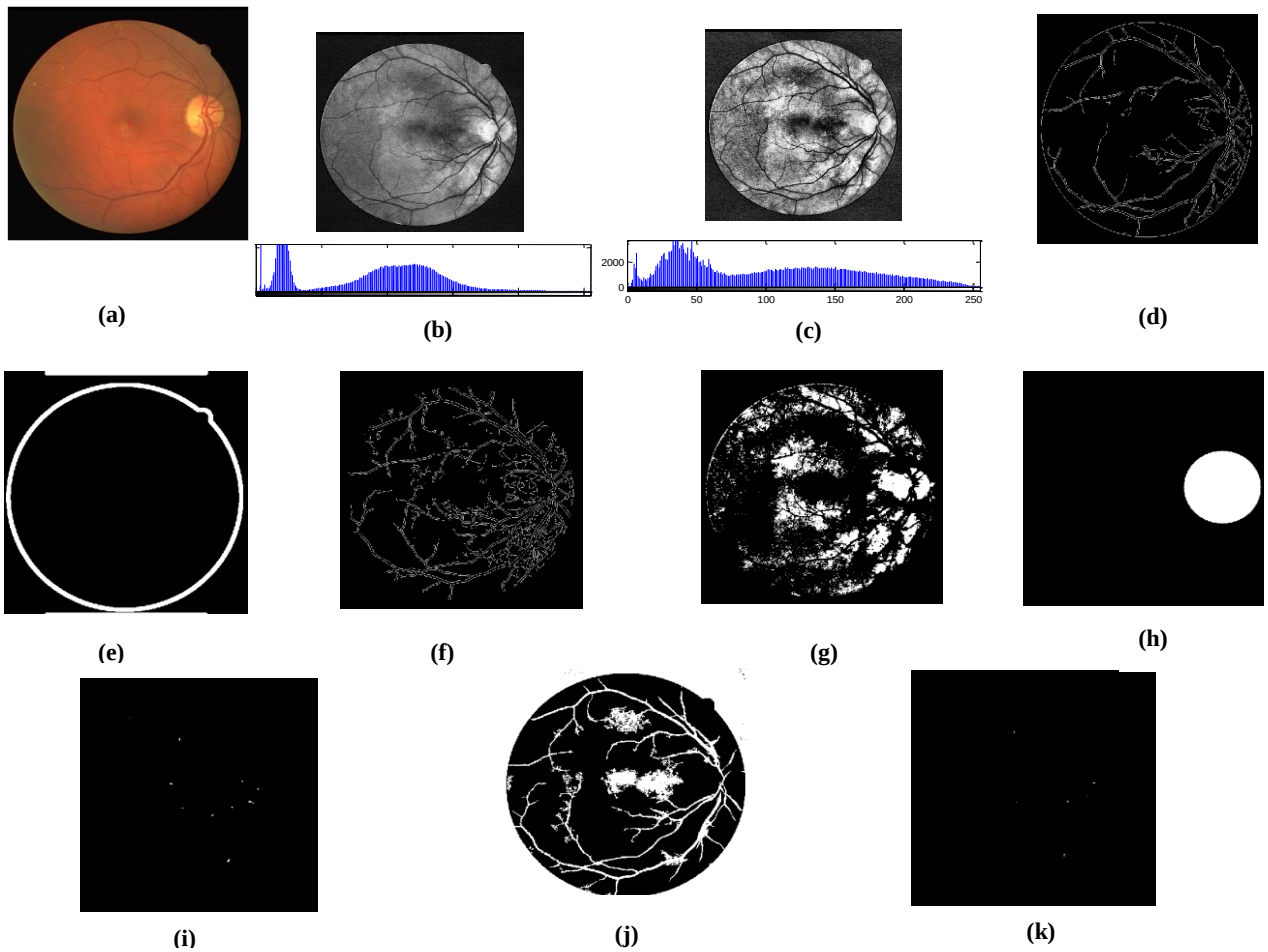
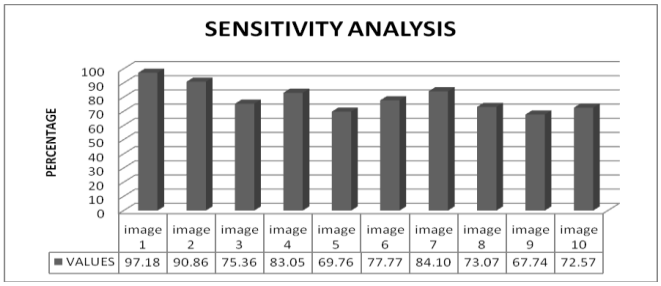


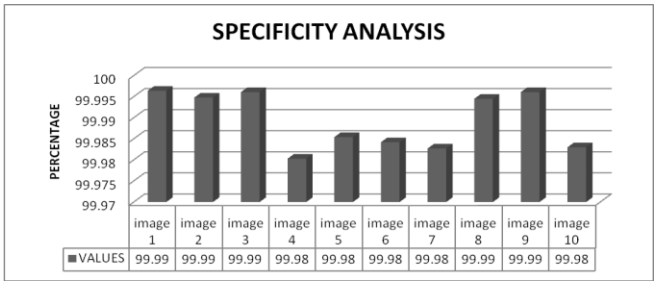
Figure 3. Experimental results:(a) Retinal image as input, (b) Green layered image with histogram after first CLAHE, (c) Green layered image with histogram after second CLAHE, (d) CANNY edge detection, (e) Circular border, (f) Edge without circular border, (g) Bright features of retinal image, (h) Mask for optical disk, (i) MA with noise, (j) Blood vessels with small objects, (k) Finally MA detected after removing blood vessels and noise

Table1.Datatable for performance analysis

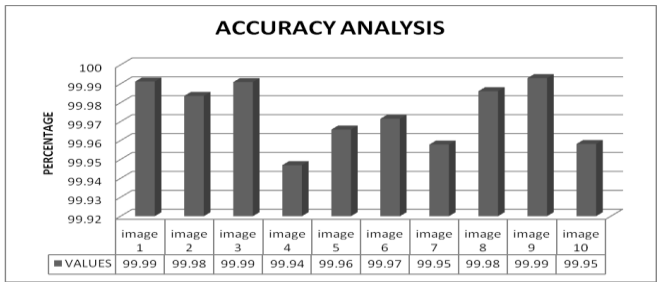
IMAGES	TP	FN	FP	TN	SENSITIVITY (%)	SPECIFICITY (%)	PRECISION (%)	ACCURACY (%)
image1	586	17	12	329345	97.1808	99.9964	97.9933	99.9912
image2	368	37	17	329538	90.8642	99.9948	95.5844	99.9836
image3	52	17	13	329878	75.3623	99.9961	80.0000	99.9909
image4	539	110	65	329246	83.0508	99.9803	89.2384	99.947
image5	150	65	48	329697	79.0697	99.9854	77.9816	99.9718
image6	147	42	52	329719	77.7778	99.9842	73.8693	99.9715
image7	434	82	57	329387	84.1085	99.9827	88.3910	99.9579
image8	76	28	18	329838	73.0769	99.9945	80.8511	99.9861
image9	26	05	13	329916	83.8709	99.9961	66.6666	99.9945
image10	217	82	56	329605	72.5753	99.9830	79.4872	99.9582



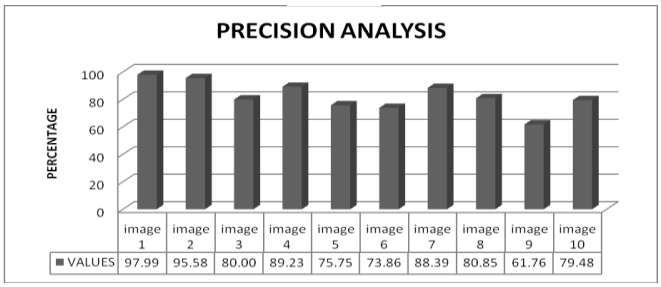
(a)



(b)



(c)



(d)

Figure 4. Graphical view of (a) Sensitivity, (b) Specificity, (c) Accuracy and (d) Precision Analysis

[3]. Jelinek H. J. , Cree M. J., Worsley D. , "Luckie A., and Nixon P., "An automated microaneurysm detector as a tool for identification of diabetic retinopathy in rural optometric practice". Clinical and Experimental Optometry, 89(5):299–305, September 2006.

[4]. Massin P., Erginay A., and Gaudric A. "Retinopathie Diabetique", Elsevier, Editions scientifiques of medicales, Elsevier, SAS, Paris 2000.

[5]. Wareham N.J.," Cost-effectiveness of alternative methods for diabetic retinopathy screening [letter]". *Diabetes Care*, 16:844 (1993).

[6]. Javitt J.C. Canner J.K., Sommer A., "Cost effectiveness of current approaches to the control of retinopathy in type I diabetics". Ophthalmology, 96:255-264 (1989).

[7]. Jelinek H. J., Cree M. J., Worsley D., Luckie A., and Nixon P. "An automated microaneurysm detector as a tool for identification of diabetic retinopathy in rural optometric practice". Clinical and Experimental Optometry, 89(5):299–305, September 2006.

[8]. Spencer T.,Olson J.A.,MCHardy et al "An image processing strategy for the segmentation and quantification of microaneurysms in fluorescein angiograms of the ocular fundus, "comp Biomed Res 29,1996,pp.284-302.

[9]. Hipwell J.H., Strachan F., Olson J.A. et al., "Automated detection of microaneurysms in digital red-free photographs: a diabetic retinopathy screening tool," Diabetic Medicine 17, 2000, pp.588–594.

[10]. Fleming D., Philip S., Goatman K. A., Olson J. A. "Automated microaneurysm detection using local contrast normalization and local vessel detection". IEEE Transactions on Medical Imaging, 5(9):1223–1232, September2006.

[11]. Sinthanayothin C., Boyce J.F., Williamson T.H., T., "Automated Detection of Diabetic Retinopathy on Digital FundusImage," *Diabetic Medicine* 19(2), 2002, pp. 105–112, 2002.

[12]. Usher D., Dumskyj M., Himaga M. et al., "Automated Detection of Diabetic Retinopathy in Digital Retinal Images: A Tool for Diabetic Retinopathy Screening," *Diabetic Medicine* 21(1), 2004, pp. 84–90.

[13]. Rafael C.Gonzalez, Richard E.Woods, Steven L.Eddins, "Digital Image Processing using MATLAB" ISBN 81-297-0515-X, second Indian reprint, 2005.

[14]. Mead A., Burnett S., Davey C., "Diabetic Retinopathy screen in the UK", Journal of the Royal Society of medicine, volume94March2001.