ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 3, Issue 5, May 2015

Microaneurysm Detection in Digital Retinal Images Using Blood Vessel Segmentation and Profile Analysis

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Abstract: The number of diabetic patients are increasing nowadays. So the chance for diabetic retinopathic (DR) diseases are also increasing. From the different diabetic retinopathic diseases, microaneurysms (MAs) are the first detectable symptom of DR. This paper makes an attempt to MA detection using blood vessel segmentation and profile analysis. After the removal of connected blood vessels, the remaining regions are used for the exact detection of microaneurysms. Ramp analysis and peak detection step is performed on the profile of the maximum intensity regions and a set of values indicating the size, height and shape of the peaks are calculated. Detected candidates are classified using feature set and naive Bayes classifier. Score values are assigned to each detected microaneurysm regions. The results show that proposed method significantly reduces the number of false positives per image and the performance is evaluated using Free-response Receiver operating characteristics(FROC)curve and calculated sensitivity and specificity which is competitive to the existing methods.

Keywords: Retinal fundus images, Diabetic retinopathy(DR) grading, microaneurysms (MAs), CAD systems.

I. INTRODUCTION

Diabetes mainly occurs due to the lack of insulin, which leads to increased level of blood sugar in human body. There are two types of diabetes, Type 1 and Type 2. 80% of people with diabetes are having type 2 diabetes. The reason for Type1 diabetes is unknown, so the cure for this disease is also in question. By proper diet, exercise and insulin intake, one can reduce the severity of these type of diseases. Sometimes this diabetic conditions leads to the long-term complications such as damage to the retinal blood vessels, also known as Diabetic Retinopathy (DR) which may lead to blindness.

Microaneurysms on the retina are the first detectable symptom of diabetic retinopathy. Microaneurysms are dark and red spots developed on blood vessels. These tiny reddish spots sometimes may buldge outwards and break, causes leakage of blood into the retinal areas which leads to blindness. The grading of computer aided diagnosis (CAD) systems mainly depends on mocroaneurysm detection i.e., a good DR diagnosis system gives better result for MA detection.

Fig.1 shows a retinal image with signs of microaneurysm.

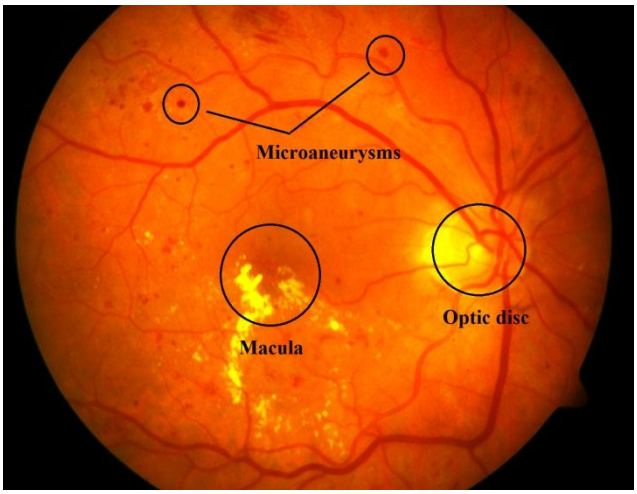

Fig. 1: Retinal fundus image with microaneurysm

II. EXISTING METHODS

There are different existing methods for MA detection. In [1] A. Mizutani et al. proposed a method for detection of microaneurysms. But there are some false positives due to capillary blood vessels and noise. L. Giancardo, et al proposed a radon transform based method [2] for microaneurysm detection. Since [1] and [2] evaluated in same database, compared to first method, latter has high performance at a low FPs rate without vessel or optic nerve segmentation. But more MAs are detected in [1]. In [3], I. Lazar et al. proposed a rotating cross section based method. MAs can be detected without using training and classification but some local maxima regions can't be detected using this method. In [4] et al proposed an ensemble based method for microaneurysm detection and diabetic retinopathy grading. In this, various pre-processing and candidate extractors are given as ensemble and from that, optimal combination are selected. In [8] T.Walter et al .proposed a method for automatic microaneurysm detection. K. Ram et al. proposed a method [9] for the detection of MAs using various pre-processing stages to reject specific classes of clutter by passing majority of true candidate objects. The proposed paper mainly depends on the ideas obtained from the papers [5] proposed by Istvan Lazar et al. and [3]

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Vol. 3, Issue 5, May 2015

proposed by I. Lazar and A. Hajdu for MA detection, which includes the detection of MAs through the analysis of the intensity values along discrete line segments of different directions centred at a candidate pixel. The profiles obtained from this intensity values are called cross sectional intensity profiles. But in [5] there may be some false positives due to blood vessels. So this paper proposes a method to reduce the number of false positives by a blood vessel segmentation algorithm along with profile analysis which leads to exact detection of microaneurysms.

III. PROPOSED METHOD

As proposed in [5] here also considering the inverted green channel of the input fundus image. The reason for taking inverted green channel is that microaneurysms, haemorrhages and blood vessels will appear as bright structures and also the monochromaticity is high in green channel. Region of interest(ROI) is detected from green channel image based on a method proposed by Gagnon et al.[10]. Fig.2 shows the block diagram of proposed method.

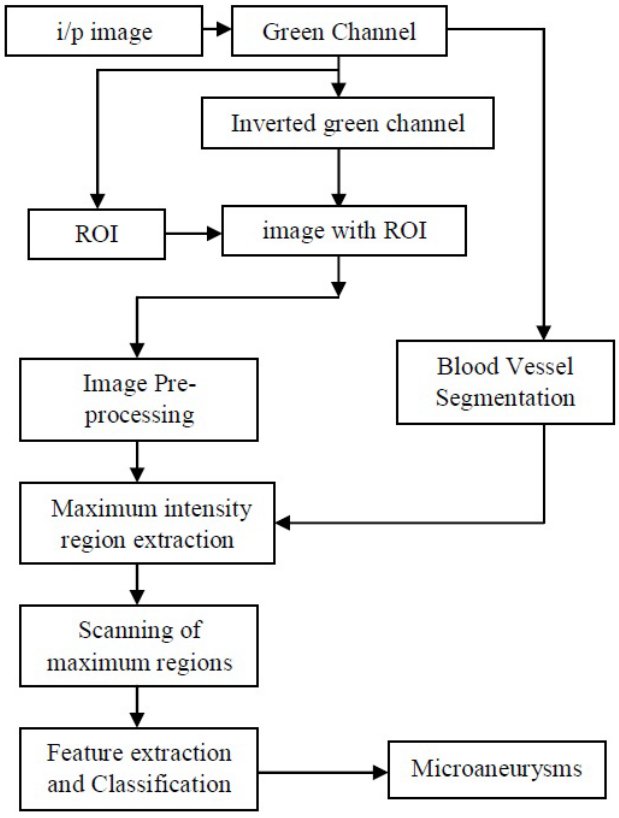


Fig. 2: Block diagram of proposed method

A. Image Pre-processing

If the image taken is noisy, in order to remove noise Gaussian filtering with a variance of 1 is used which results in suppression of noise effectively while preserving true microaneurysms. The size of the filter to be taken as 11×11.

B. Blood Vessel Segmentation

Several methods exist to detect the blood vessels. One in [11] gives comparatively better result than others. The algorithm for blood vessel segmentation is described below.

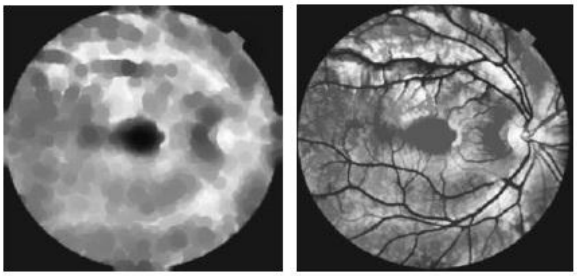
- Apply median filtering to green channel of the input fundus image.
- Enhance the median filtered image using Contrast limited adaptive Histogram Equalization.
- Apply morphological operations to the enhanced image.
- Apply Otsu's thresholding to difference image.

Blood vessel segmentation algorithm is applied to the green channel of the input image. In green channel blood vessels appears as dark regions and it is suitable for blood vessel segmentation. Median filtering is applied to the green channel image in order to remove noise. In addition to smoothing, median filtering preserves edges. Edge preserving is a requirement for blood vessel segmentation. Contrast of retinal images are low. For better segmentation of blood vessels contrast of image have to be increased. So contrast limited adaptive histogram equalization (CLAHE) is used. Adaptive histogram equalization has a tendency to amplify the noise. But CLAHE prevents the amplification of the noise by limiting the amplification to an extent. Therefore CLAHE gives better result than the regular histogram equalization.

Mathematical morphology operations like closing and filling is applied to the CLAHE enhanced image in order to get the desired vessels. Closing operation is dilation followed by erosion and it is done using structuring element. Selection of structuring element is important for closing operation and here disc shaped structuring element is used. Closing operation can be expressed as,

$$A \bullet B = (A \oplus B) \odot B \tag{1}$$

Filling is applied to fill the holes in the image. Fig. 3(a) and 3(b) shows the images obtained after morphological operations.



(a) (b)

Fig. 3: Morphological operations (a) closing (b) filling

Thresholding is applied to the difference image in order to get the desired blood vessels. Difference image is obtained by,

$$I_D = I_{close} - I_{fill} \tag{2}$$

where I_{fill} is the filled image and I_{close} is the image obtained after closing operation.

DOI 10.17148/IJIREEICE.2015.3533

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INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 3, Issue 5, May 2015

Fig.4(a) shows the difference image obtained after filling and closing.

In order to get the desired blood vessels Otsu's thresholding technique is applied to the difference image. Otsu's equation is given by,

$$\sigma^2(T) = W_B(T)W_F(T)[\mu_B(T) - \mu_F(T)]^2 \quad (3)$$

where $W_B(T)$ and $W_F(T)$ is given by,

$$W_B(T) = \sum_{i=0}^{T-1} p(i) \quad (4)$$

$$W_F(T) = \sum_{i=T}^{N-1} p(i) \quad (5)$$

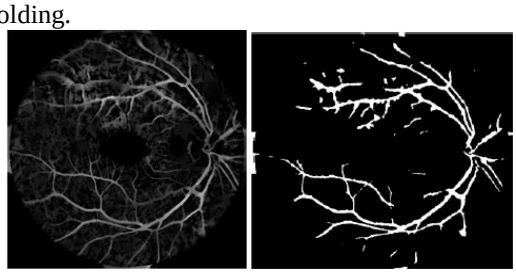
and $\mu_B(T)$ and $\mu_F(T)$is given by,

$$\mu_B(T) = \sum_{i=0}^{T-1} \frac{p(i)x(i)}{W_B} \quad (6)$$

$$\mu_F(T) = \sum_{i=T}^{N-1} \frac{p(i)x(i)}{W_F} \quad (7)$$

where $x(i)$ is the value at the centre of i^{th} histogram and $p(i)$ is the probability at i^{th} histogram . $W_B(T)$ and $W_F(T)$ are the weight of the background and foreground of the image. $\mu_B(T)$ and $\mu_F(T)$ are the mean value of the background and foreground of the image.

Fig.4(b) shows the segmented blood vessels obtained after thresholding.



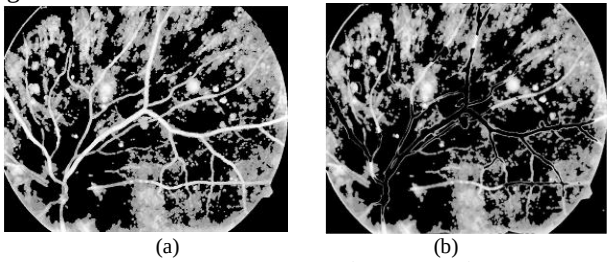
(a) (b)

Fig. 4: (a) Difference image and (b)Segmented blood vessels

C. Maximum Intensity Region Extraction

Maximum intensity regions are extracted from the pre processed image. Morphological gray scale reconstruction is used to reconstruct the pre-processed image. From the reconstructed image Isodata technique calculates the threshold to extract the maximum intensity regions.

The segmented blood vessels are removed from the maximum intensity regions and the remaining region is used for the exact detection of microaneurysms. Microaneurysm regions are maximum intensity regions having Gaussian like profile[3]. Fig.5 shows the extracted maximum intensity regions before and after blood vessel segmentation.

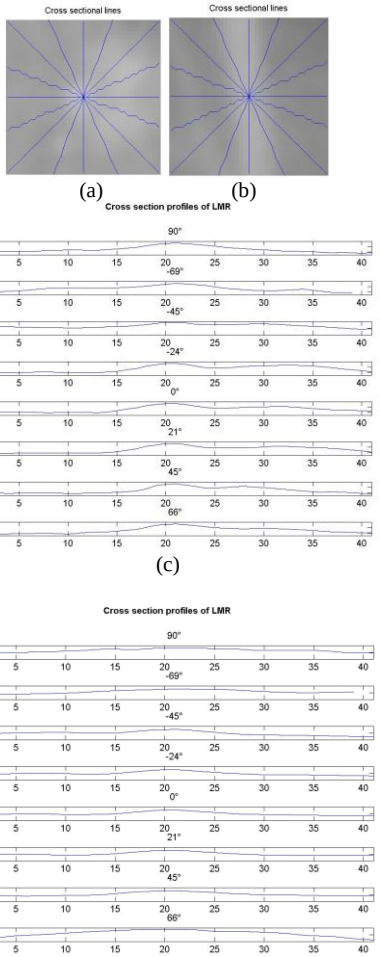


(a) (b)

Fig. 5: Maximum intensity regions (a) before and (b) after blood vessel segmentation

D. Scanning of maximum intensity regions

For examining the maximum intensity regions, the image is divided into blocks, each having a size of 41×41. Cross sectional scanning is done on each block. Scan lines at different angles 90, -69, -45, -24, 0, 21, 45, and 66 are taken. The length of cross-sections was chosen to be 41. The profiles obtained by plotting intensity values along these lines are called cross sectional intensity profiles.



(a) (b)

(c)

(d)

Fig. 6: Cross-sectional lines of (a) MA (b) non-MA regionsand cross sectional profiles of corresponding (c) MA (d) non-MA regions

Let y=mx+b be the slope-intercept equation of the line. For a given value of m, by varying the parameter b, every pixel i.e., x and y coordinates of the image can be accessed. But for the vertical case which has to be accessed separately, since x coordinates are same. Fig.6 shows sample cross-sectional profiles of MA and non-MA regions. It shows that cross sectional profiles of MA region shows peaks for all directions particularly at the centre of the profile.

E. Ramp Analysis and Peak Detection

Peak detection step is performed on each cross-sectional profile to decide whether there is a peak presented at the centre of the profile, since microaneurysms shows a Gaussian like peak for all given directions. The first step in the peak detection method [5] is the ramp analysis

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INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 3, Issue 5, May 2015

i.e.,localizing monotonically increasing or decreasing segments of the profile.

Once the ramp analysis step is performed peak detection is applied to test whether there is a full peak at the centre of the profile. As in [5] different properties of peaks are calculated including peak width, top width, increasing ramp height , decreasing ramp height, increasing ramp slope, decreasing ramp slope and peak height.

F. Feature Extraction

To define the final feature set, the peak properties are stored in different variables. RHEIGHTS stores the increasing and decreasing ramp height values, and the ramp slope values are stored in RSLOPES. Top width, peak width and peak height values are stored in TWIDTHS, PWIDTHS and PHEIGHTS. Let μ, σ and cv represents the mean, standard deviation and coefficient of variation of the values. cv is the ratio of the standard deviation and mean. Final feature set consists of mean, standard deviation and cv of these values.

G. Classification

Classification is performed using naive Bayes classifier. For classification it requires two sets namely training set and test set . Training set consists of both microaneurysm regions and non microaneurysm regions. The final step of proposed method is assigning score value. Using (8) score values are assigned to the candidates that were classified as true microaneurysms. Final result consists of microaneurysm regions with score values.

$$score = \frac{min_{PHEIGHTS} . \mu_{RSLOPES}}{1+\sigma_{PWIDTHS}+\sigma_{TWIDTHS}+\sigma_{RSLOPES}+\sigma_{RHEIGHTS}+\sigma_{PHEIGHTS}} \quad (8)$$

IV. MATERIALS

Blood vessel segmentation algorithm was tested in both STARE and DIARETDB1 database. 30 images from STARE database, each having a size of 700×605 are selected for testing of blood vessel segmentation algorithm . The proposed method is evaluated using DIARETDB1 database consists of 89 images each having a size of 1500×1152. 40 images out of 89 is used for training. Remaining 59 images are used for testing. All the vasculature has been manually segmented and proposed MA detection algorithm is applied on each image.

V. RESULTS AND DISCUSSION

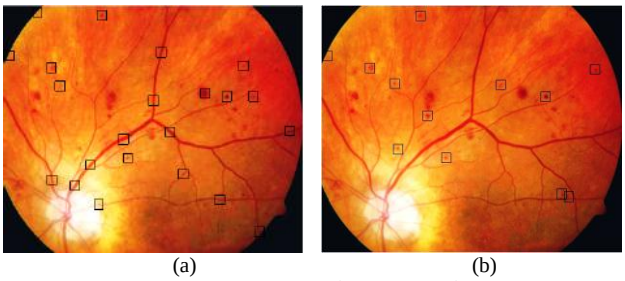
Proposed method classifies the detected regions into MA and non-MA regions. So a training set containing both microaneurysm and non microaneurysm regions are required.

Table I shows the mean and standard deviations of the feature values for the MA and non-MA regions in the training set. These values indicate the configuration of naive Bayes classifier. Without applying any blood vessel segmentation step there should be some false positive microaneurysms due to blood vessels and vessel crossings. Without applying any blood vessel segmentation step there should be some false positive microaneurysms due to blood vessels and vessel crossings. After applying blood vessel segmentation step number of false positives are reduced and regions obtained are only the true positives.

TABLE I
MEAN AND STANDARD DEVIATION

Feature	MA	Non-MA
σRSLOPES	0.6355±0.2456	2.4467±0.6700
cvPHEIGHTS	0.2900±0.2354	0.3349±0.0876
cvRHEIGHTS	0.2594±0.0600	1.5654±0.0455
μTWIDTHS	2.3009±8.9000	2.9899±4.4563
σTWIDTHS	1.7885±1.9830	2.7786±2.4945
μPWIDTHS	10.6543±7.0789	13.2544±9.4344
σPWIDTHS	2.7859±1.1098	4.6611±2.9987

Using (8) large microaneurysms achieved high score than faint ones, which is approximately 13.0653. Fig.7 shows MA detection before and after blood vessel segmentation.



(a) (b)

Fig. 7: Detected MA regions (a) before and (b) after bloodvessel segmentation

The proposed method highly concentrated on reducing the number of false positives, but it also attained a better sensitivity. Table II shows results of tested samples.

TABLE III
TESTED SAMPLE OUTPUTS

Tested sample	Number
TOTAL	59 Images
TP	134
FP	15
TN	276
FN	20

Sensitivity, specificity can be calculated using (9) and (10) and attained a sensitivity of 87% and specificity of 94.8%.

$$SENSITIVITY = \frac{TP}{TP + FN} \quad (9)$$

$$SPECIFICITY = \frac{TN}{TN + FP} \quad (10)$$

TP- Number of true positive regions.
TN- Number of true negative regions.
FN- Number of false negative regions.
FP- Number of false positive regions.

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INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
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The performance of the proposed method is evaluated using free-response ROC(FROC) curve which plots sensitivity against 7 average number of false positives (1/8, 1/4, 1/2, 1, 2, 4 and 8). Fig.8 shows the FROC curve of proposed method(after blood vessel segmentation) and previous method(before blood vessel segmentation) obtained on DIARETDB1 database. As shown in figure proposed method achieves higher sensitivity than the previous one[5].

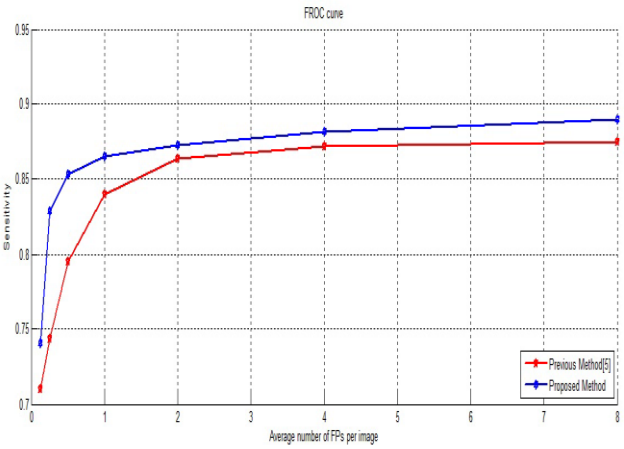

Fig. 8: FROC curve of proposed method and previous method.

VI. CONCLUSION

In this paper a method for the detection of MAs on retinal images is presented. In most of the existing methods, there is false positives due to vessel crossings and blood vessels in the retina. So a blood vessel segmentation algorithm is applied at the initial detection of the proposed method. The method tested on DIARETDB1 database. By applying proposed method, detected regions are only the true positive regions and points hard to detect are identified using this method. And also the number of false positives are reduced. The performance is evaluated using FROC curve and obtained a sensitivity and specificity which is comparable with the result of previous methods.

ACKNOWLEDGMENT

I would like to take this opportunity to express my sincere gratitude to all those who have guided in the successful completion of this paper.

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