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Automatic Detection of Diabetic Retinopathy Using Image Processing

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ABSTRACT: Diabetic retinopathy is the scientific name of the diabetic eye disease which is the result of long term complications of diabetes. It is a painless eye disease which if not diagnosed at early stages, will result in permanent vision loss. Current detection procedures are manual procedures and some of them are painful for the patients getting diagnosed as well. An automatic approach for detection of diabetic retinopathy is presented in this work. The work is done on the fundus retinal images using the concepts of image processing and is implemented on the software platform of MATLAB. The first sign of the disease in the fundus images are Microaneurysms. Thus, the detection approach is focused on the detection of Microaneurysms. The computation time for screening one fundus image of size 1500×1152 is 55 seconds on the platform of MATLAB 2015.

KEYWORDS: Diabetic retinopathy, Microaneurysms (MA), Fundus images, DIRETDB1, Blood vessels, Fundus Mask.

I. INTRODUCTION

Diabetes has been increasingly prevalent in recent years. It typically causes diabetic retinopathy, which results in blindness in adults between 20 and 60 years of age in the developed countries.According to the recent National diabetes statistics report 2014,In 2005–2008, of adults with diabetes aged 40 years or older, 4.2 million (28.5%) people had diabetic retinopathy, damage to the small blood vessels in the retina that may result in loss of vision. In 2005–2008, of adults with diabetes aged 40 years or older, 655,000 (4.4%) had advanced diabetic retinopathy with conditions such as clinically significant macular edema and proliferative diabetic retinopathy that could lead to severe vision loss. The vision of the patient affected by the disease is shown in Fig. 1. Its development can be divided into four stages, and the disease is in general undiagnosed in its early stages till serious vision impairment occurs. Nevertheless, diabetic retinopathy can be prevented and its progression can be slowed down if diagnosis and treatment occur early in the course of illness. Since diabetic retinopathy is a progressive pathology, its severity can be determined by the number and the types of lesions occurring on the retina. MA is one of the most important syndromes in fundus images. Automatic detection of MAs from color fundus images can thus play a significant role in diabetic retinopathy screening at large scale to reduce the workload of the ophthalmologists and shorten the waiting time for patient to get diagnosis report.

Currently Fluorescein angiography is an imaging technique for evaluation of retinal vascular disease, particularly DR. Fluorescein dye is injected intravenously and the fluore- scence within retinal vessels is then photographed through a matched combination of excitation and barrier filters. Although FA produces very clear gray-scale retinal images and is effective for describing hemorrhages and neovascularization, it is not well-accepted by patients because of its intrusive nature. Therefore, it is essential to develop a safe, fast, easy, and comfortable way to observe and capture the retina.
The major signs of the disease in the fundus image are small circular red spots, irregularly shaped red spots, yellow spots. The small circularly shaped red spots are known as Microaneurysms as the scientific name of it, slightly bigger irregularly shaped red spots are hemorrhages, and yellow spots are soft and hard exudates. Different sign appears in the image at the different stages of the disease and thus presence of any of them can indicate the severity of the disease.

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Figure 1 the vision of patient suffering from diabetic retinopathy

The fundus images used in this study are taken from the publicly available database DIRETDB1. The database consists of 89 color fundus images of which 84 contain at least mild non proliferative signs (Ma) of the diabetic retinopathy, and 5 are considered as normal which do not contain any signs of the diabetic retinopathy according to all experts participated in the evaluation . The images were taken in the Kuopio university hospital.

II. BACKGROUND AND LITURATURE SURVEY

1. Detection of microaneurysms using multi-scale correlation coefficients -An approach in which the multi scale correlation coefficients and region growing for detection of MAs is presented by Bob Zhang, Xiangqian Wub, Jane You, Qin Li, Fakhri Karray. In this paper, the suggestion was made to use more enriched Gaussian filter bank for detection to pick more true candidates and this is implemented in the presented work.

2. Automatic detection of microaneurysms in color fundus images- A four step approach is presented in this approach.The algorithm was suggested by Thomas Walter, Pascale Massin, Ali Erginay, Richard Ordonez,Clotilde Jeulin, Jean-Claude Klein.

3. Fast Detection of Microaneurysms in Color Fundus Images- A multi-stage strategy to screen candidate MAs is used in this study. The technique is presented by Sean H.F. Chen and Han C.W. Hsiao.

4. Automatic Detection of Diabetic Retinopathy in Non-dilated RGB Retinal Fundus Images- A simple approach for detection of microaneurysms is presented in this paper. This algorithm is presented by Sujith Kumar S B and Vipula Singh.

5. Retinal blood vessel segmentation approach based on mathematical morphology- A novel method for blood vessel detection and segmentation is presented in this paper. The paper is presented by Gehad Hassan, Nashwa El-Bendary, Aboul Ella Hassanien, Ali Fahmy,Abullah M.Shoeba, and Vaclav Snaself.

III. SCOPE OF RESEARCH

The scope of research is medical image analysis. The analysis of medical images has taken the attention of research community from over a decade. This is quite interesting and important as well to develop such automated procedures so that they can replace manual detection practices. Manual detection practices are suffering from a number of problems such as human errors, time taken in detection, unavailability of the expert for diagnosis in rural areas, painful nature of the current diagnostic methods etc. The motivation for developing such procedures comes from the fact that the diseases for those the automatic methods for detection have already developed the things are much easier for the doctors and the patients as well. Thus, the scope of the research is very wide indeed. In the research work presented the objective is achieved by going through a certain number of steps. The results of individual steps can also contribute significantly for further researches in detection of this disease in addition to the overall result.

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IV. METHODOLOGY OF DETECTION

The detection methodology can be understood from the block diagram shown in the figure 3.The input image is one taken from the images provided in DIRETDB1 database.

Green channel extraction and inversion of green channel: The image taken from the fundus camera is consisting of three channels red, green, blue. The green channel of the image is most suited for further processing as it contains all the details in the image represented by only 256 shades of gray color. Thus, it provides ease of further processing with required perfection. The green channel after extraction is inverted for further processing. The results of green channel extraction and inversion of it is shown in the figure 3.

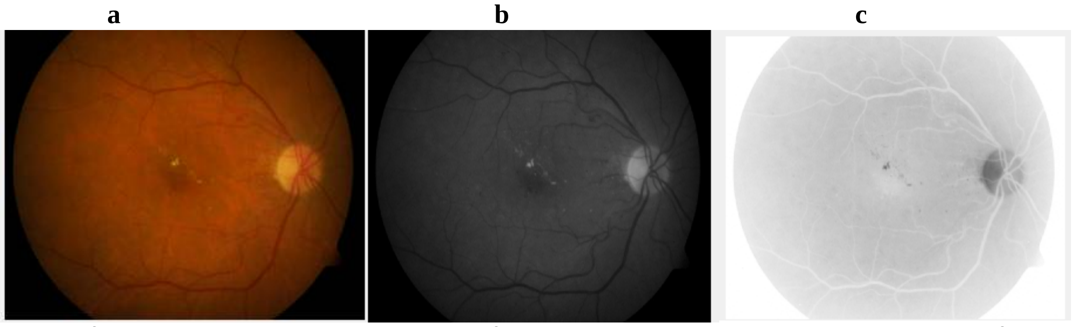

Figure 2 In figure 2(a) the sample image is taken figure 2(b) shows the green channel image and figure 2(c) shows inverted green channel image

Walter Klein Contrast Enhancement: The quality of the original image may not be good enough due to many reasons, which result in difficulty in the screening task. Normal adaptive histogram equalization can be used but it results in the increased contrast and amplified noise as well. Since the microaneurysms are local maxima in certain window, the amplification of the noise can increase false maximum in the considered window thus can increase difficulty in detection of MAs.

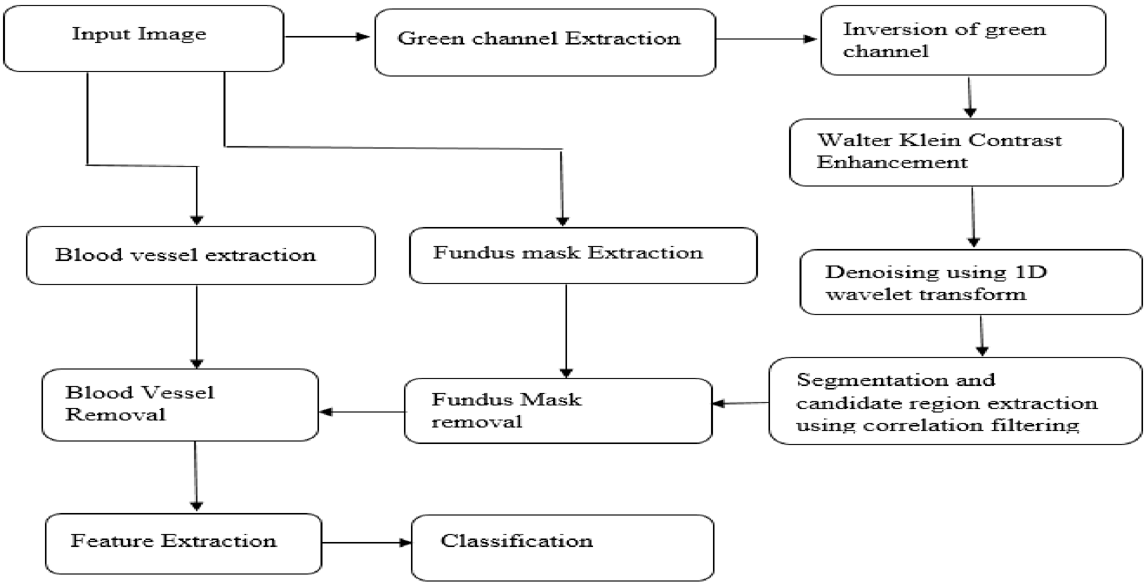

Figure 3 Block diagram of detection method

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Walter-Klein contrast enhancement is employed to improve the quality by performing gray level transformation. This increases contrast but does not amplify noise. The contrast operator is defined as

$$u = \begin{cases} \frac{1}{2} \cdot \frac{(u_{\max} - u_{\min})}{(\mu_f - t_{\min})^r} \cdot (t - t_{\min})^r + u_{\min} & , t \le \mu_f \\ -\frac{1}{2} \cdot \frac{(u_{\max} - u_{\min})}{(\mu_f - t_{\max})^r} \cdot (t - t_{\max})^r + u_{\max} & , t \ge \mu_f \end{cases}$$

where {tmin, ..., tmax} and {umin, ..., umax} are the gray values of the fundus and the enhanced image, respectively, μf is the mean value of the fundus image. The value of r taken is 2, the result is shown in figure4.

Image denoising and low pass filtering using 1D wavelet transform: The elimination of noise is very important for the detection process to be more precise. Wavelet transform converts an image to the low pass and high pass counterpart of the image. For the purpose of denoising wavelet transform is applied on the image for a considerable number of levels such that the high pass image consists only of the noise component of the image and thresholding technique is applied get a threshold which when applied on this result, will remove the high frequencynoise component. In the presented work five level one dimensional wavelet transform with Sureshrink thresholding technique is used. The result of this is exactly same in appearance as the result of previous step.

Figure 2Result of Walter Klein contrast enhancement

Correlation filtering and segmentation of candidate region: The microaneurysms exhibit the Gaussian shape in the terms of their intensity distribution in the inverted green channel image. Thus, if we correlate the Gaussian filter with image then the parts of image with high correlation coefficient can be considered as candidate MA.After the experimentation for the standard deviation to be used we have correlated 45 filters with standard deviation from 1.1 to 5.5 with difference of 0.1 in the standard deviation of two filters are correlated with image and the maximum correlation coefficient for each pixel out of all 45 responses is collected in an image matrix.This process ensures inclusion of all possible candidates in an image.The region with coefficients greater than 0.5 represents candidates.

a b

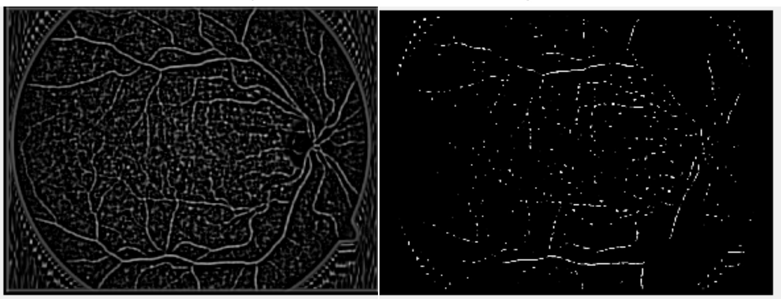

Figure 3(a) shows the result of correlation and 5(b) shows the result of segmentation

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The results are shown in the figure 5. The illustration of the Gaussian kernel of the MA is shown in the figure 6.

a *b* c

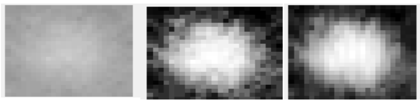

Figure 4(a) shows the cropped MA from inverted green channel image 6(b) shows the result of Walter Klein contrast enhancement and 6(c) shows the result of denoising (low pass filtering)

Blood vessel Extraction: Blood vessels are extracted by following steps and results are shown in figure 8a.

1.1. Green channel extraction and inversion of it then Adaptive Histogram equalization.
1.2. Find the background of image using the median filter of 40x40 on the previous result.
1.3. Subtract the result of 4^{th} stage from that of 3^{rd}stage.
1.4. Apply morphological opening on the image using 12 line structures of length 50 with inclination of 0 to 165 with the difference of 15º in two consecutive structures.
1.5. Add all the above 12 results.
1.6. Dilate the result with diamond structuring element of size 2 and then reconstruct it.
1.7. Find regional minimum in above result and then complement it.
1.8. Morphologically close the above result and then again open it using the structuring element of size 1.

a b c

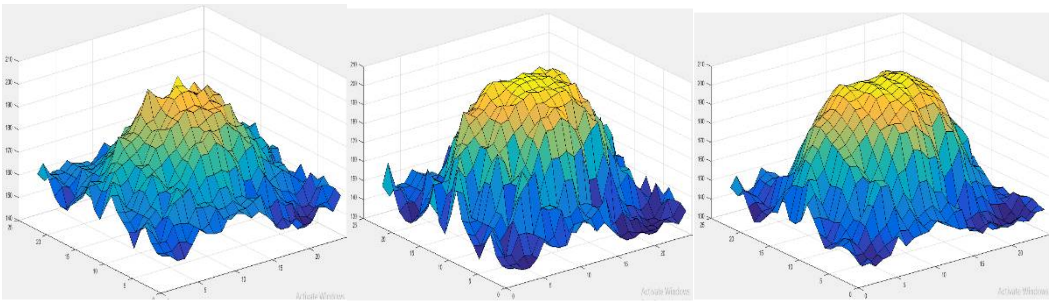

Figure 5(a) shows the Gaussian profile of the original MA i.e. shown in 6(a), 7(b) shows the Gaussian profile of contrast enhanced MA and 7(c) shows the Gaussian profile of the denoised (low pass filtered) MA

Fundus Mask Extraction: It can be done by following steps and results are shown in figure 8b

1.1. Green channel extraction and the take log of this image.
1.2. Apply Otsu thresholding on the image.
1.3. Apply morphological closing on the above result with disk structuring element of radius 1.

Blood vessel and fundus mask removal: The candidates in the figure 5(b) clearly shows some false one situated at the blood vessels and outside the retinal fundus mask. These false candidates are removed by subtraction of the blood vessel map and the complemented fundus mask from the result shown in figure 5(b).

Feature Extraction: The feature set that we have used are of two types:

1. **Binary features:**

   1.1. Aspect Ratio of the candidate: True MAs have their major and minor axis lengths approximately equal. It should be close to one for MAs.

   Aspect ratio = (major axis length/minor axis length)

   1.2. **Circularity:** It is close to one for true MAs

   Circularity=(4*$\pi * area$)/(perimeter)^2

2. **Gray level features:**

   2.1. Total intensity of the candidate: True MAs have higher gray level intensities in the inverted green channel image.

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2.2. Average intensity of the candidate: True MAs have higher average gray level intensities in the inverted green channel image.

a b c

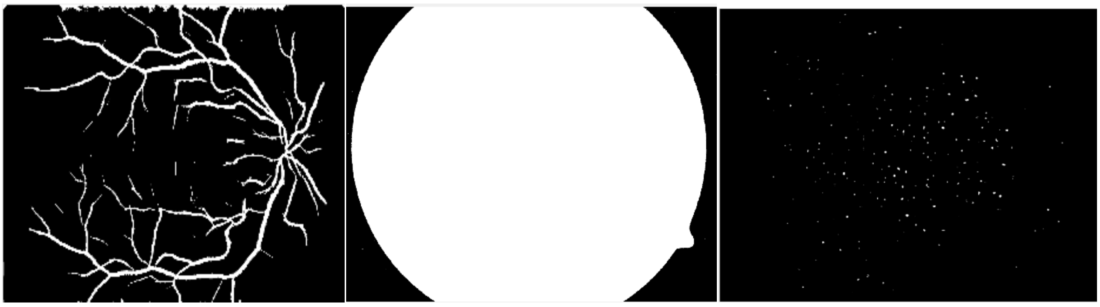

Figure6(a) shows the extracted blood vessel map, 8(b) shows the fundus mask, 8(c)shows the candidates after removal of candidates those are outside the retina and those are at blood vessels

Table 1 The value of features used in the detection process

S.No.	Feature name	Value
1.	Aspect ratio	0.9 to 1.1
2.	Circularity	Greater than 0.75
3.	Total gray level intensity of the image	Greater than 5500
4.	Average gray level intensity of image	Greater than 180

Result of the application of features is shown in the figure 9

a b

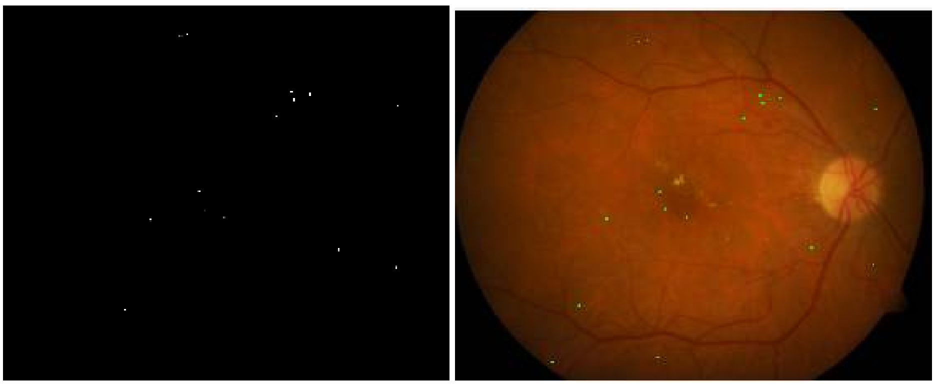

Figure 7(a) shows the final detected MAs and 9(b) shows the MAs located on the fundus image being diagnosed

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V. RESULTS AND DISCUSSION

S.No.	Image used	Actual no. of Mas	No. of MA detected
1.	Image001	25	17
2.	Image008	16	14
3.	Image011	70	62
4.	Image012	17	11
5.	Image013	31	22
6.	Image015	53	48
7.	Image044	0	0
8.	Image048	0	0

The results in the above table shows that the algorithm proposed is giving quite satisfactory results as the healthy images are detected as healthy and number of MAs detected in the diseased image are also consistent with the data given in the DATABASE with the sensitivity of 74.87%.figure 1 is showing vision of the person affected by diabetic retinopathy. Figure 2 is showing results of the green channel extraction. Figure 3 is showing block diagram of the methodology used. Figure 4 shows result of contrast enhancement. Figure 5 shows the result of correlation filtering. Figure 6 and 7 show the results of the applied procedure on the MA profile and its Gaussian shape. Figure 8 shows the result of blood vessel extraction, fundus mask extraction, and their removal. Figure 9 shows the results after feature extraction. Table 1 is containing features with the values used in present work. The procedure is taking the time of 50 seconds to 1 minute in execution at platform of MATLAB 2015, image size being used is 1152x1500. The sensitivity is calculated using the number of true and false positives for all the 89 images provided in DATABASE.

VI. CONCLUSIONS

The detection of Microaneurysms is done successfully using this procedure. The contribution of this procedure can be considered in the analysis of the effect of the different steps on the MA profile and the determination of standard deviation range for the MA profile. The sensitivity of the procedure can be increased by using some procedures for elimination of the false peaks before the correlation filtering and by using more enriched gray level feature set to eliminate false MAs.

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