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DESIGN OF AUTOMATED DIABETES SCREENING SYSTEM ON BLURRED RETINAL FUNDUS IMAGE

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Abstract : Diabetic Retinopathy (DR), a common ocular disease where the retina of human eye is damaged due to fluid leaking from blood vessels of the retina. In extreme case, the patient will become blind. Therefore early detection of DR is crucial to prevent blindness. Microaneurysm (MA), small dark round dots on retinal fundus image is the earliest clinical sign of DR disease. MA detection at early stage can help to reduce the blindness. In such cases the retinal fundus images produced by fluorescent oscilloscope are often noisy and low in contrast. Detecting the Microaneurysms using those fundus images is very difficult for ophthalmologist. In the present paper, we propose a method using location based contrast enhancement process, popularly known as Contrast Limited Adaptive Histogram Equalization (CLAHE) for the detection of retinal changes in DR images. CLAHE is an adaptive extension of Histogram Equalization which helps in dynamic preservation of the local contrast characteristics of an image. The proposed algorithm divides the retinal fundus image into a number of small, non-overlapping contextual tiles. Following CLAHE at each tile separately, median filtering of DR images is carried out in order to smooth the background noise. Results of the proposed algorithm show a considerable improvement in the enhancement of DR image quality. The proposed method tested on publicly available datasets, such as DIARETDB0, DIARETDB1, STARE and DRIVE. The result is also verified by medical practitioners of this field. The proposed technique has been tested on 45 images collected from local hospital. Mean Sensitivity of 84.48% and mean Accuracy of 98.94% has been obtained.

Keywords : Medical image processing; fundus image; diabetic retinopathy (DR); contrast limited adaptive histogram equalization (CLAHE); median filtering; microaneurysms.

1. INTRODUCTION

Nowadays 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]. The ratio of people affected with the disease to the number of eye specialist who can screen these patients is very high. Hence 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. According to the expert 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 [2]. Therefore early detection through regular screening and timely intervention will be highly beneficial in effectively controlling the progress of the disease [3]. Usually, retinal images captured from fluorescence oscilloscope are of poor in contrast as a result of the acquisition process. In medical image analysis, it is already reported that image enhancement techniques improve the quality of retinal images. Enhancement, in the present context, refers to bring out the finer details of the image under test while emphasizing the features of interest. The goal of image enhancement is to extract the important characteristics from which a detailed description of the target is henceforth possible. Such an image can serve either for improved human perception or as an input to further automated image processing technique. Thus, image enhancement technique plays a vital role for DR screening system.

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. [4] proposed a mathematical technique to segment MA within fluorescein angiogram. J.H. Hipwell et al. [5] used Gaussian matched filters to retain candidate MA for classification. D. Fleming et al. [6] proposed a method to detect MA by local contrast normalization. C. Sinthanayothin et al. [7] proposed an automated system for detection of Diabetic Retinopathy using Recursive Region Growing Segmentation (RRGS). Usher et al. [8] employed a combination of Recursive Region Growing 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 (KNN) to classify MA. Miri et al. [9] used multi resolution tools using a non linear function to modify the curvelet coefficients. Techniques based on matched filtering are ideal enhancing low contrast blood vessels over a limited area but the computation becomes complex with larger image size [9, 10]. This process is attractive in enhancing the global contrast of an image, but not readily when features of interest occupy a relatively narrow range of gray scale, especially as those noticed in Non Proliferative Diabetic Retinopathy (NPDR) images.

Most of the techniques reported in literature, used retinal images with dilated pupil where MA and other feature already distinguished and clearly visible. The rest of the sections in the paper are organized as follows: section 2 presents detailed explanation of proposed method; section 3 describes the detection of MAs using proposed enhancement process. In section 4, results and discussion are provided. Finally, conclusion is given in section 5.

2. PROPOSED CLAHE METHOD AT PRE-PROCESSING STAGE

Image enhancement technique increase the quality of image under test and ensure improved comprehend ability [11]. Histogram equalization is one of such methodology adopted for contrast enhancement that expands the pixel intensity distribution in order to utilize the entire dynamic range. It is observed that the input retinal fundus images are often very low in contrast, which is evident from their histograms that are narrow and concentrated only to certain gray level values. However, retinopathy images contain minute details of the lesions that get obscured due to limited contrast and are not easily presented to doctors. This may lead to delayed diagnosis and even wrong treatment. Histogram equalization plays an important role in such cases, however, while leaving local changes in contrast, unconsidered. Recently, CLAHE algorithm has been successfully proposed for biomedical imaging; however, it increases background in-homogeneities and hence calls for some post processing. We present a method for enhancement of DR image based on CLAHE method. The basic idea of the algorithm is to divide the image into a number of small, non-overlapping contextual regions, called “Tiles” as shown in Fig. 1. The image partitioning helps to prevent some parts of noise being dominated by others. The steps of proposed method are given below:

Step I : Retinal fundus image selected as input.

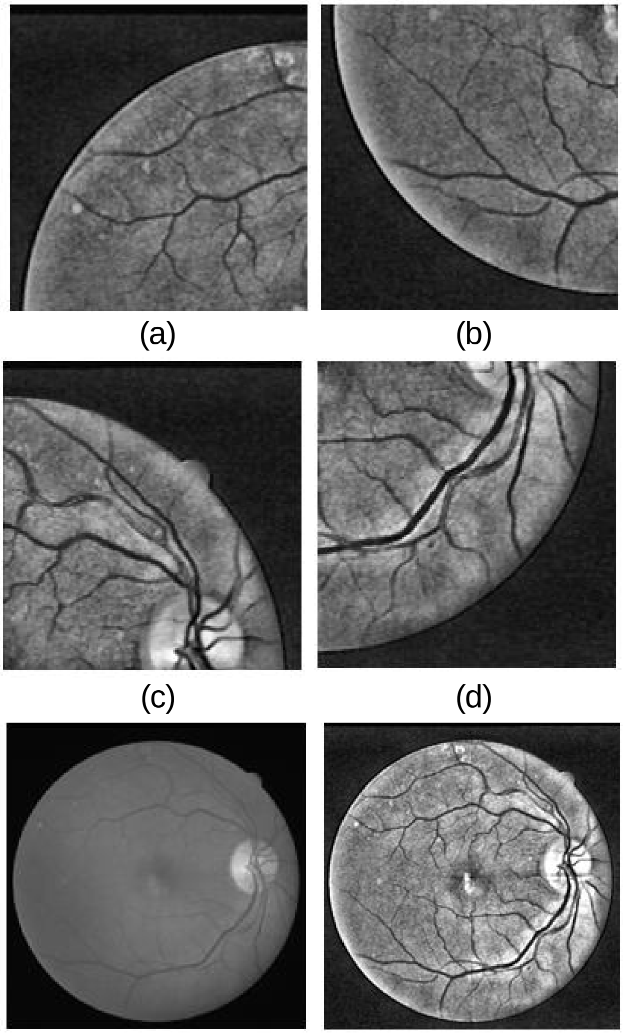

Fig 1. Region based CLAHE followed by median filter (a) Tile1, (b) Tile2, (c) Tile3, (d) Tile4 (e) Original image, (f) Resultant image

Step II : Green layer selected.

Step III : Decimate the image into two by two sized contextual regions (Tiles).

Step IV : Apply CLAHE in each tile separately.

Step V : Apply median filter in each tile separately.

Step VI : Apply image catenation method on four Tiles

In this method median filter is applied for smoothen the enhanced image. The filter works by sorting pixels covered by a N × N mask according to their intensity values. The centre pixel is replaced by the median of these pixels. The proposed image quality enhancement technique applied on automated Diabetic screening system for classification of normal and diabetic eye. The next section describes the Microaneurysms detection system.

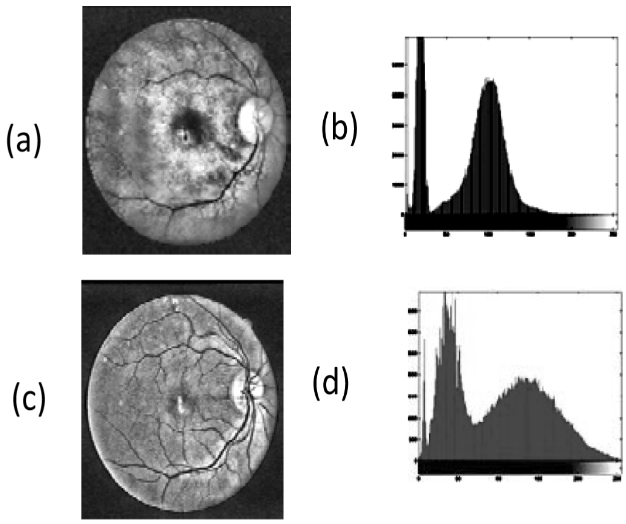

Fig 2. (a) Conventional CLAHE image with (b) Histogram of conventional CLAHE image, (c) Resultant image of proposed method with (d) Histogram of resultant image of proposed method

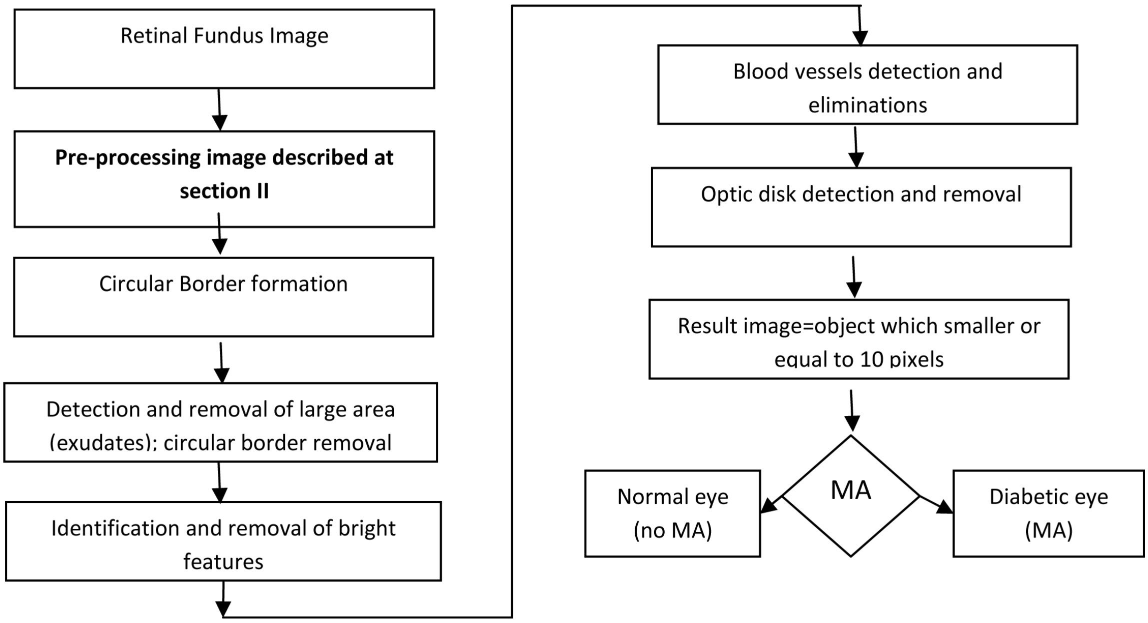

Fig 3. Proposed method for Diabetes detection system

3. MICROANEURYSMS DETECTION

In experts point of view detection of MAs become difficult due to low contrast noisy retinal images [12, 13]. In this paper automated software based Diabetes screening system is developed using MATLAB software for calculating the microaneurysms area on given retinal images. In the proposed method the green channel are used to detect the MAs. Next, few subsections describe the intermediate steps for detection of MAs. The overall procedure for MA detection is shown in figure 3.

3.1 Pre-Processing Stage

A pre-processing stage is required for improving the image quality prior to the detection stage. Here, the green plane of the original RGB colour image is used as because red lesions have the highest contrast with the background in this colour 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, proposed CLAHE method is applied. Then, the image histogram is examined and also checks the equalization of the intensity level from 0-255. Pre-processing stage shown in Fig. 2. Canny edge detection method is applied to detect edge and the circular border is obtained after subtracting the dilated image with eroded images. Then, detection and elimination of large object (object size>100 pixels) of retinal fundus image is carried out. Mathematical morphological methods [14] are applied here for removing large object like exudates, bright lesions etc. The border is eliminated before the image filled up with enclosed area. Area (i.e. MA with noise) obtained by subtracting away the edges with image. The resultant image still contains noise (blood vessels, exudates). As, exudates are the bright yellow-white objects on the retinal image can be traced out by applying proposed CLAHE method. In our method AND logic is used to remove noise for the detection of exudates. Regions with exudates are marked out after applying column filter but this includes non-exudates such as hemorrhages and has to be removed as noise.

3.2 Blood Vessel Detection and Eliminations

Blood vessels are detected and extracted by applying morphological operation with image segmentation of threshold value. Removing the small area (object size <=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 and remove the blood vessels. The dilate function expands the exudates area while erode function removes the blood vessels.

3.3 Optic Disk Detection and Elimination

Pictorial view of the retinal image illustrates that optic 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 optic disk. As m by n matrix (i.e. dimensions of image provided by the 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 are determined and median was calculated. Next, the mask is created using the following relation for creating circles:

$$R^2 = (x - h)^2 + (y - k)^2 \qquad \text{... (i)}$$

where h and k are the coordinates (row and column) and R is the radius. Then, created mask is subtracted from the segmented retinal image and obtained the image without optic disk. Microaneurysms area obtained after removing other existing elements (Visualize Fig. 4.

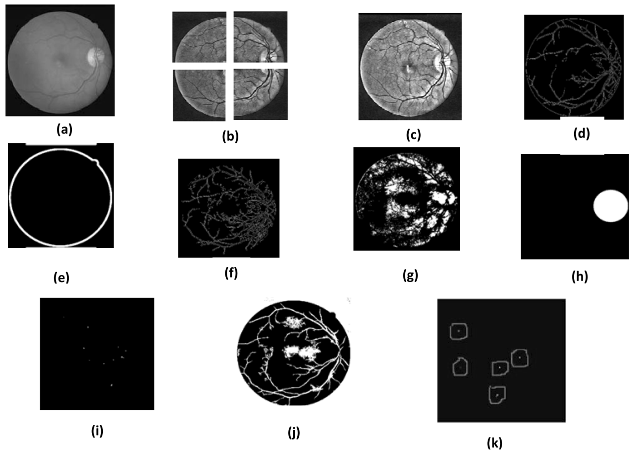

Fig.4. Experimental results:(a) Retinal image as input,(b) Decimate the image into two by two sized contextual regions (c) Pre-processing image using proposed method (d) CANNY edge detection, (e) Circular border, (f) Edge without circular border, (g) Bright features of retinal image, (h) Mask for optical disk, (i) MA with noise, (i) Blood vessels with small objects, (k) MA detected after removing blood vessels and noise

4. PERFORMANCE ANALYSIS

The performance of proposed method is evaluated quantitatively by comparing the resultant extraction with ophthalmologists. This pixel based evaluation consider four values, specifically true positive (T_P, a number of vessel pixels correctly detected by proposed method), false positive (F_P, a number of non-vessel pixels which are detected wrongly as vessels pixel), false negative (F_N, a number of vessel pixels that are not detected) and true negative (T_N, a number of non vessel pixels which are correctly identified as non vessel pixels). The Sensitivity, Specificity, Accuracy and Precision are the important parameters for performance analysis of the system and are the function of T_P, F_P, F_N and T_N. All these parameters are calculated using Eqn. (ii), (iii), (iv) and (v) respectively.

Table 1: Data table for outcome of the proposed method

Databases	Resolution	No. of Images	Normal Images	Diseased image	Sensitivity (%)	Accuracy (%)
DIARETDB0	1500×1152	130	20	110	84.69	97.91
DIARETDB1	1500×1152	89	5	84	85.01	97.94
STARE	605×700	81	31	50	84.52	98.08
DRIVE	565×584	40	33	7	84.76	98.44
COLLECTED (HOSPITAL)	480×512	45	36	9	85.26	97.49
TOTAL TESTED	————	385	125	260	MEAN:84.84	MEAN:97.90

Sensitivity and Specificity are used for the performance measurement of vessel detection system as they combine true positive and false positive rates of blood vessel pixels. Sensitivity is the percentage of the actual vessel pixels those are detected, and specificity is the percentage of non-vessel pixels which are correctly classified as non vessel pixels. Precision is the percentage of detected pixels that are actually vessel. Finally, Accuracy is the overall per-pixel success rates of the proposed method. In this paper, Fig.4 shows the graphical view of performance analysis of vessel detection technique. The performance of proposed method analyzed by the following equations, where T_P, T_N, F_P, F_N stand for true positive, true negative, false positive and false negative respectively:

$$\text{Sensitivity} = \frac{T_P}{T_P + F_N} \times 100 \qquad \text{(ii)}$$

$$\text{Specificity} = \frac{T_N}{T_N + F_P} \times 100 \qquad \text{(iii)}$$

$$\text{Precision} = \frac{T_P}{T_P + F_P} \times 100 \qquad \text{(iv)}$$

$$\text{Accuracy} = \frac{T_P + T_N}{T_P + F_P + T_N + F_N} \times 100 \qquad \text{(v)}$$

5. RESULTS AND DISCUSSION

The proposed method is tested on publicly available datasets DIARETDB0, DIARETDB1, STARE and DRIVE. The results are shown in Table 1. The proposed method applied for forty five retinal images collected from local hospitals where nine images were abnormal (i.e. damaged for DR) and thirty six images were normal. The performance of the proposed method is evaluated quantitatively by comparing the resultant extraction with ophthalmologists, hand drawn ground truth images pixel by pixel [15]. The mean sensitivity and specificity revealed as 84.84% and 97.90% respectively. The mean sensitivity is the percentage of the actual MA pixels that are detected and specificity is the percentage of the non MA pixels that are correctly classified as non MA pixels. In this context the British Diabetic Association (Diabetes UK) has established standards for any Diabetic Retinopathy screening programmed of at least 80% sensitivity and 95% specificity [16]. This research work started with the development of pre-processing techniques to improve image quality using histogram analysis. However, the contrast enhancement technique not only enhances the image quality, but also enhances the noise. Then image processing techniques are applied for identification of normal features such as optic disk, retinal blood vessels and elimination of abnormal features such as Microaneurysms. The overall procedure for MA detection divided into three fundamental steps. The first step consists of image enhancement of the green channel as green channel has most information of image than other channels. The second step detects all possible patterns corresponding to MA. The last step classifies the normal eye and Diabetic eye according to MAs area calculation (i.e. for zero area revealed as normal eye) based on the proposed method.

6. CONCLUSION

The development of automated Diabetic Retinopathy screening system becomes a highly effective way of reducing the burden of eye specialist, i.e. only Diabetic eye send for further diagnoses. This has major implementation for the reduction of the cost of the public health systems. The proposed method enhances the quality of the DR image while preserving the sharpness and minute of the details. Finally, proposed Diabetic screening system shows the satisfactorily results for classifying normal and Diabetic eye. In view of its modest computational requirements and simplicity, the proposed method may be directly implemented in any image processing engine both for large and high resolution Diabetic Retinopathy images.

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