A Comprehensive Review on Various Preprocessing Methods in Detecting Diabetic Retinopathy

Ramasubramanian.B, S.Selvaperumal

***Abstract*—Diabetic Retinopathy (DR) is the primary cause of visual loss in case of diabetic patients. It is mainly caused by the changes in the blood vessels of the retina even though manual screening is available but they are very much time consuming and inefficient. Therefore for automatic detection of these changes and prevention of vision loss, color retinal image is an important tool used by the ophthalmologist. This paper discusses on seven different preprocessing available in literature and found the optimum technique for enhancing the retinal images. The performance of all the techniques has been tested on more than 1000 images obtained from several publicly available DRIVE and STARE and MESSIDOR dataset.**

***Index Terms*—Bottom-hat transform, CLAHE, Diabetic Retinopathy, Green Channel, Median filter.**

I. INTRODUCTION

Diabetic Retinopathy is a severe eye disease associated with diabetes. It is the most common cause of vision loss in newly industrialized country like India. It is estimated by the World Health Organization (WHO) that 135 million people around the world have diabetes mellitus and it will increase to 300 million by the end of 2025 [1],[2]. India topped the world by 31.7 million diabetic patients in the year 2000 followed by china and the United States [3]. It is also estimated by the National urban survey that people of South India like Chennai, Bangalore and Hyderabad are affected more by diabetes than other parts of India like Kashmir (6.1 percent), Kolkata (11.7 percent) and Mumbai (9.3 percent) [4], [5].

Therefore early detection and prevention through mass screening is very important to prevent vision loss. For this mass screening, ophthalmologist widely uses retinal photography to diagnose the eye disease like Diabetic Retinopathy, Glaucoma and cataract. Preprocessing, which is the fundamental step in the automatic detection of Diabetic Retinopathy is investigated in this paper. The important reason for main focus on preprocessing is because the color retinal images are many times degraded by several problems like noise, uneven illumination, poor contrast and variation in capturing. Preprocessing helps to remove the noise and enhance the image making the ophthalmologist early to detect the disease.

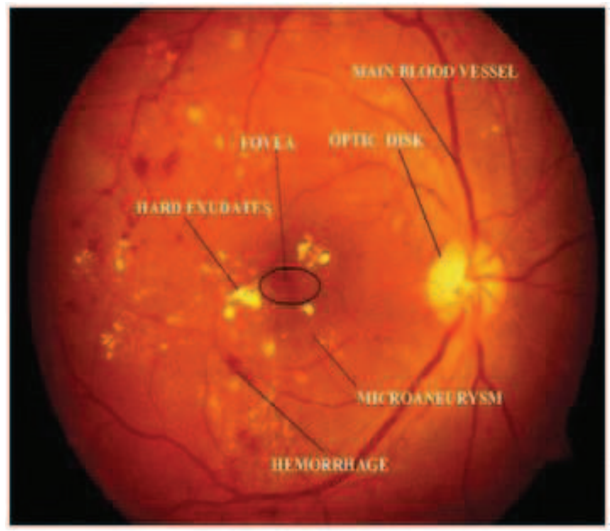

Fig. 1. Color retinal image with exudates, microaneurysm, hemorrhages, fovea and optic disc.

Fig. 1 shows an example of color retinal image. Some of the common signs of Diabetic Retinopathy are microaneurysms, exudates, haemorrhages and cotton wool spot. Microaneurysms are small pouches which appear as red dots. Exudates are the yellow lipids caused by the damage of blood vessels and appear as a bright yellow lesion. Hemorrhages are the big blood clot caused by ischemia in the retina. Cotton wool spots are caused by damage to nerve fibers in the retina and appear as fluffy white or yellow patches, [6], [7]. As these diseases are the common cause of blindness, early diagnosis and detection using the color retinal images can be very useful.

The rest of this paper is organized as follows. Section II gives the study of existing approach. The materials used in this study are discussed in Section III. The various preprocessing methods analyzed for the enhancement of retinal images are explained in Section IV. The results are explained in Section V. Finally, Section VI presents the conclusion and discussion.

II. STATE OF ART

Few investigations in the past have confirmed that the good quality of color retinal images is required for accurate and early diagnosis of DR [8]. On a survey, it is predicted that nearly 12% of the color retinal photography cannot be

Ramasubramanian.B is with Department of Electronics and Communication Engineering, Syed Ammal Engineering College, Ramanathapuram, TamilNadu, India. (e-mail: ramatech87@gmail.com.)

Dr.S.Selvaperumalis with Department of Electrical and Electronics Engineering, Syed Ammal Engineering College, Ramanathapuram, TamilNadu, India. (e-mail: perumal.om@gmail.com)

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analyzed for detection because of their poor quality [8][9][10]. Therefore an enhancement in the retinal image quality is very much essential in the diagnosis of DR. So to enhance the quality, preprocessing of color images should be applied.[11],[12],[13] performed image segmentation using histogram specification for their preprocessing stage. Agurto et al [14] described the detection of exudates in the macula using mean normalization of histogram of all the color channels as their preprocessing method. In [15], Lazar et al performed image smoothing and suppressed noise in the retinal image by applying convolution with a Gaussian mask. This method of smoothing suppressed noise sufficiently. Franklin et al [16] have proposed the identification of exudates using an artificial neural network (ANN) by applying color, shape, size and texture features. In the preprocessing stage, the authors applied Contrast Limited Adaptive Histogram Equalization technique to improve the contrast and for enhancing the difference between the exudates and background in the retinal image. The authors considered mean filter for image smoothing before enhancing. But mean filter does not have monotonically decreasing frequency response and it is not the best filter for image smoothing.

In [17], Fathi et al segmented the retinal blood vessels and estimated the vessel diameter using complex continuous wavelet transform. For the preprocessing of the images, Fathi et al used contrast adjustment on the inverted green channel to reduce the effect of non-uniform illumination. The performance parameter obtained on both DRIVE and STARE database was less.

Based on the details obtained by studying the existing works, the importance of preprocessing in color retinal image was understood. The main importance of this work is to present a comparative study on various enhancement techniques available in research work. From the study and the obtained result, this work suggests a simple and efficient method for the preprocessing stage.

III. MATERIALS

To evaluate the performance of our algorithm, the color retinal images were obtained from the publicly available databases, STARE and DRIVE [18]-[21].

The STARE database consists of 20 color fundus images. These images were captured with a field-of-view (FOV) of 35°. The images were digitized to 8-bits per color channel and stored at a size of 700x605 pixels.

The DRIVE (Digital Retinal Images for Vessel Extraction) database consists of 40 color fundus images, captured with a canon CR5 non-mydriatic camera with a field-of-view of 45°. The images were saved in jpeg format with a size of 768x584 pixels. Some of the other important retinal images are MESSIDOR, DIARETDB1, and DIARETDB0.

IV. METHODS

In our work, various preprocessing methods have been used to enhance the digital color fundus images. This work was tested with some common methodology that were introduced previously for the improvement of contrast level and removal of noise.

A. Contrast Enhancement using Bottom-hat transform

A common technique for the enhancement of contrast of an image is the use of morphological operation like bottom-hat transform.

The bottom-hat transform is performed by obtaining the difference between closing of original image with the original image.

$$B_{hat}(f) = (f \bullet b) - f \tag{1}$$

Where $(f \bullet b)$ denotes the closing operation and f is the original image.

The closing of an image ‘f’ by structuring element ‘b’ is defined as dilation of ‘f’ by b, followed by erosion of the result with the structuring element b.

$$(f \bullet b) = (f\, dilation\, b)\, erosion\ b \tag{2}$$

A disk shaped structuring element was considered since it gives a good result for image enhancement.

B. Contrast Enhancement by Histogram Equalization

To enhance the contrast of color retinal images, histogram equalization is applied on the green channel of the color image.

The Histogram equalization of image f is defined by

$$HE = \text{floor}(L\text{-}1) \sum_{j=0}^{k} \Pr(rj) \tag{3}$$

Where floor() rounds down to the nearest integer. L denotes the number of possible intensity levels in the image f and $P_r(r_k)$ denotes the probability of occurrence of intensity level r_k.

$$P_r(r_k) = \frac{nk}{MN} \tag{4}$$

Where M and N are the total number of pixels in the image. If it is a STARE database, M and N is 700 and 605 and for a DRIVE database, the value of M and N is 768 and 584.

C. Removal of Noise using Adaptive Wiener filter

The wiener filtering is a linear estimation of the original image. In our case, the original image is the green channel of the color fundus image. The wiener filter minimizes the mean square error in an optimal way. The filter also preserves the edges and other frequency components of our anatomical structure.

The frequency domain representation of wiener filter is given by

$$W(f_1, f_2) = \frac{H''(f1,f2)Sxx(f1,f2)}{[square(|H(f1,f2)|)*Sxx(f1,f2)]+S\eta\eta(f1,f2)} \tag{5}$$

Where $S_{xx}(f_1,f_2)$, $S_{\eta\eta}(f_1,f_2)$are the power spectral density of original image and additive noise. $H(f_1,f_2)$ is the filter transfer function.

D. Removal of Noise by median filter

Median filter is most suitable when our image is affected by impulse noise or salt and pepper noise. It involves finding the median value in a local neighborhood and it is a non-linear operation. To simultaneously reduce noise and preserves edges in color fundus images, median filtering is more effective than the convolution.

E. Enhancement using Contrast Limited Adaptive Histogram Equalization

Contrast Limited Adaptive Histogram Equalization (CLAHE) partition the green channel of the retinal image into contextual regions and then histogram equalization is applied to each region. This equalizes the distribution of used gray levels and makes the hidden features more visible. CLAHE process on small region of image rather than the entire image itself.

F. Optimal preprocessing technique

On the basis of analysis of various enhancement and noise removal method, an optimal technique for preprocessing was introduced. It is as follows.

i) Extraction of green channel from the original RGB retinal image since green channel contains more information and shows better discrimination between our symptoms and background.

ii) After extracting, the median filter is applied to this green channel. This mainly removes the salt and pepper noise and also preserves the edges.

iii) The filtered image is enhanced by applying CLAHE. This makes the hidden features in the retinal image like exudates, microaneurysms, fovea, blood vessels to become more visible.

V. EXPERIMENTAL RESULTS

The effect of different preprocessing techniques was evaluated on images from publicly available standard database like DRIVE and STARE.

Since green channel contains more information about exudates, microaneurysms, haemorrhages, it is extracted and used for all our processing.

A. Result of Contrast Enhancement using Bottom-hat transform

The original RGB image is shown in Fig. 2. The green channel is extracted and it is shown in Fig. 3.

Fig. 2. Original RGB Retinal Image.

Fig. 3. Green channel from the RGB image.

The bottom-hat transform is applied to this green channel and the output is shown in Fig. 4.

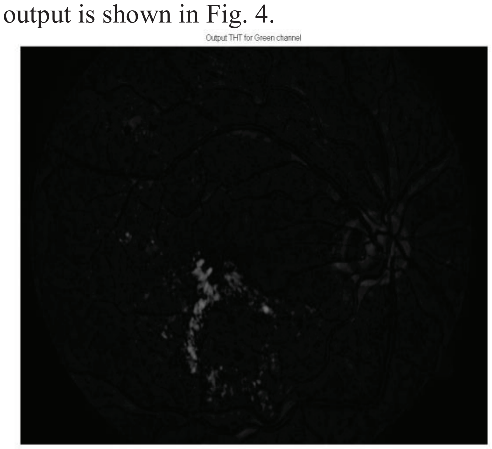

Fig. 4. Output of Bottom-hat transform.

B. Result of Contrast Enhancement by Histogram Equalization

The image enhanced by histogram equalization of the green channel is shown in Fig. 5.

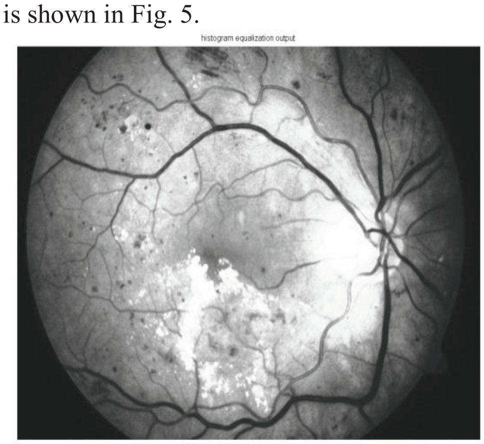

Fig. 5. Output image Enhanced image by histogram equalization

C. Result of Removal of Noise using Adaptive Wiener filter

Green channel is extracted from the Original image. Noise is added to the green channel. The noisy image is shown in Fig. 6. It is then filtered by wiener filter. The filtered image obtained by wiener filtering of the green channel is shown in Fig. 7.

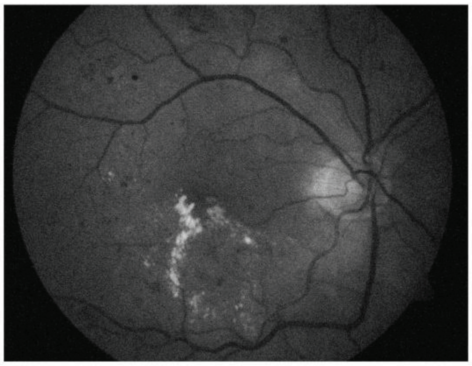

Fig. 6. Noisy green channel

Fig. 7. Output of Wiener filter.

D. Result of Removal of Noise by median filter

The green channel of the retinal image which is affected by salt and pepper noise is shown in Fig. 8.

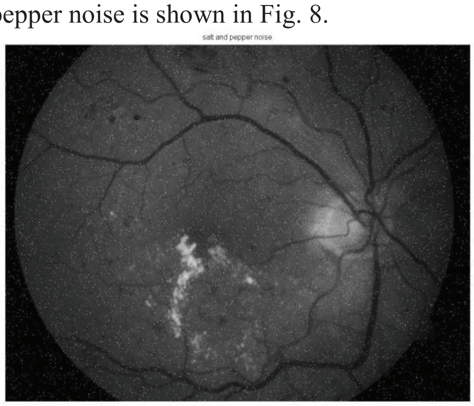

Fig. 8. Image affected by salt and pepper noise

The output of median filtering is shown in Fig. 9. This output is obtained by providing the noisy green channel of the RGB retinal image to a median filter.

Fig. 9. Output of median filter

E. Result of Enhancement using Contrast Limited Adaptive Histogram Equalization

The resultant enhanced image by performing CLAHE on the green channel is shown in Fig. 10.

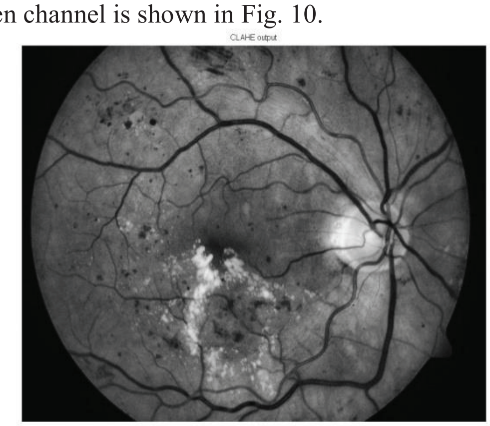

Fig. 10. Output image enhanced by CLAHE

F. Result of Optimal preprocessing technique

The green component of the original RGB image is extracted and shown in Fig. 3. This image is applied to a median filter and the output obtained andthe filtered image is enhanced by CLAHE and the result is shown in Fig. 11.

Fig. 11. Output of Optimal preprocessing technique

Fig. 11 gives a better discrimination compared to the results that were obtained by the above methods.

VI. CONCLUSION

This paper investigated and compared five different preprocessing method of color retinal images and found an optimum technique for preprocessing. This work evaluated the diagnostic accuracy of the proposed method in terms of image-based criteria. Even though, the morphological top hat operation gives a good result; it failed to remove the noise completely. Median filter produces good result against noise but the features are not enhanced. Robustness and accuracy have been evaluated by our optimum technique on publicly available databases and it is found to be high when the result was consulted with an expert ophthalmologist.

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