AUTOMATIC DETECTION OF OPTIC DISC AND BLOOD VESSELS FROM RETINAL IMAGES USING IMAGE PROCESSING TECHNIQUES

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Abstract

Diabetic retinopathy is the common cause of blindness. This paper presents the mathematical morphology method to detect and eliminate the optic disc (OD) and the blood vessels. Detection of optic disc and the blood vessels are the necessary steps in the detection of diabetic retinopathy because the blood vessels and the optic disc are the normal features of the retinal image. And also, the optic disc and the exudates are the brightest portion of the image. Detection of optic disc and the blood vessels can help the ophthalmologists to detect the diseases earlier and faster. Optic disc and the blood vessels are detected and eliminated by using mathematical morphology methods such as closing, filling, morphological reconstruction and Otsu algorithm. The objective of this paper is to detect the normal features of the image. By using the result, the ophthalmologists can detect the diseases easily.

Keywords: *Blood vessels, Diabetic retinopathy, mathematical morphology, Otsu algorithm, optic disc (OD)*

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1. INTRODUCTION

The visions of many people in the world are threatened by the diabetic retinopathy. Diabetic retinopathy is the eye disease that causes the blindness or blurs the visions. It arises due to the high sugar level in the blood. According to the research, the screening of diabetic retinopathy can reduce the risk of blindness by 50% [1]-[2]. Therefore, early detection could limit the severity of the disease and treating the disease more efficiently. The optic disc detection is an important step to identify the other fundus features. The optic disc can be seen as the elliptical shape in the eye fundus image. Its size varies from one person to another, between one-tenth and one-fifth of the image [3]. In colour image, it appears as the bright yellowish region as the exudates. The optic disc is the normal feature of the image but the exudates are the abnormal case. Detection the optic disc can be used to decrease the false positive in the detection of the exudates [4]. And also the detection of the blood vessels is as important as the detection of the optic disc because the optic disc and the blood vessels are the normal features of the image. Manual detection of blood vessels is difficult since the appearance of blood vessel in a retinal image is complex and having low contrast [5].

A number of methods for optic disc detection and blood vessels detection have been published.Osarehet al. [6] located the optic disc center by means of template matching and extracted its boundary using a snake initialized on a morphologically enhanced region of the optic disc. Lowell et al. [7] also localized the OD by means of template matching as well as also selected a deformable contour model for its segmentation. Another deformable model-based approach was presented in [8].Another template-matching approach for OD segmentation is the Hausdorff-based template matching presented by Lalondeet al. [9]. Initially, they determined a set of OD candidate regions by means of multiresolution processing through pyramidal decomposition. For each OD region candidate, they calculated a simple confidence value representing the ratio between the mean intensity inside the candidate region and inside its neighborhood. The Canny edge detector and a Rayleigh-based threshold were then applied to the green-band image regions corresponding to the candidate regions, constructing a binary edge map. As final step, using the Hausdorff distance between the edge map regions and circular templates with different radii, they decided the OD among all the candidates.

There are some methods for blood vessels detection in retinal fundus images such as region growing technique [10], morphological and thresholding techniques [11], neural network based approaches [12], statistical classification based methods [13-14] and hierarchical methods[12]. This paper presents the optic disc detection and blood vessels detection techniques based on mathematical morphology on the fundus images because it is very fast and requires lower computing power. Therefore the system can be used even on a very poor computer system.

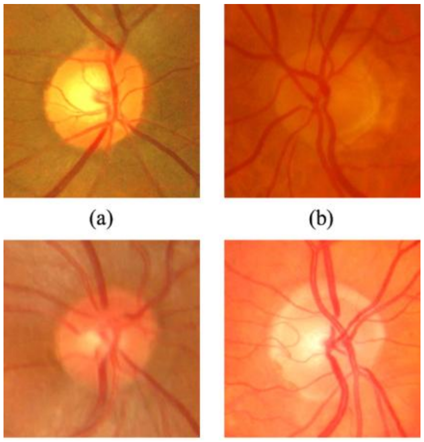


Fig -1: OD appearance. (a) Yellowish OD. (b) Brownish OD. (c) Reddish OD. (d) Whitish OD.

The general flow chart for the optic disc detection and blood vessels detection is shown in Fig.2

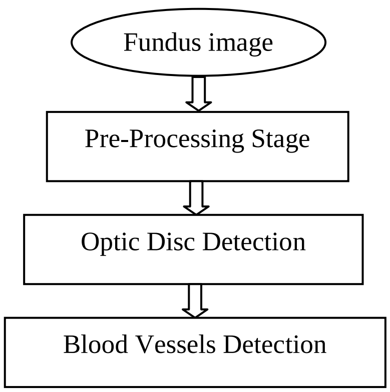


Fig -2: General flow chart for optic disc detection and blood vessels detection

2. PRE-PROCESSING STAGE

2.1 Image Acquisition

All digital retinal images are taken from patients using the non-mydriatic retinal fundus camera. The images are stored in JPEG image format file (.jpg) and taken from "Eye and ENT General Hospital (Mandalay)". In this research, the retinal images are taken from the "Eye and ENT General Hospital (Mandalay)" and also from the websites.

The original (RGB) image is transformed into appropriate colour space for further processes. And then, filtering technique is used to reduce the effect of noise. After using the filtering technique, the noise such as salt and pepper noise are removed from the image. Then contrast-limited adaptive histogram equalization (CLAHE) is used for image enhancement. Unlike histogram, it operates on small data regions rather than the entire image. This function uses a contrast-enhancement method that work significantly better than regular histogram equalization for most images.

2.2 Converting Colors from RGB to HSI

In digital image, the input image can be the RGB (Red, Green, and Blue) images or other. The RGB image can be described as M x N x 3 array of colour pixels. In this paper, the RGB input image is transformed into HSI colour space for further processes. H component of each RGB pixel is obtained using the following equation [15]

$$H = \begin{cases} \theta & \text{If } B \le G \\ 360-\theta & \text{If } B > G \end{cases}$$

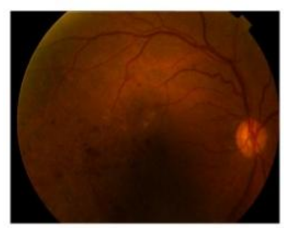
$$\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}\left[(R-G)+(R-B)\right]}{\left[(R-G)^2+(R-B)(G-B)\right]^{1/2}} \right\}$$

The saturation component is

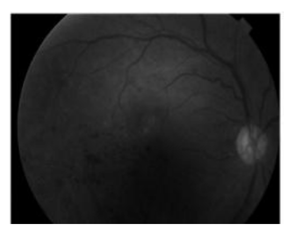
$$S = 1 - \frac{3}{(r+g+b)}\left[\min(R,G,B)\right]$$

Finally, the intensity component is

$$I = \frac{1}{3}(R+G+B)$$



(a) Original image



(b) HSI image

Fig-3: shows the result of the converting colour from RGB to HIS image. Fig.3 (a) is the original input image and Fig.3 (b) is the HSI colour image.

2.3 Filtering Techniques

Noise can cause the trouble in the detection of disease. The noise contains in the image is reduced by using the filtering technique such as median filter, averaging filter and wiener filter.

2.3.1 Median Filter

The median filter is a non-linear filter type and which is used to reduce the effect of noise without blurring the sharp edge. The operation of the median filter is – first arrange the pixel values in either the ascending or descending order and then compute the median value of the neighborhood pixels.

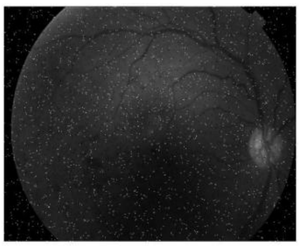


Fig- 4: (a) Image with noise

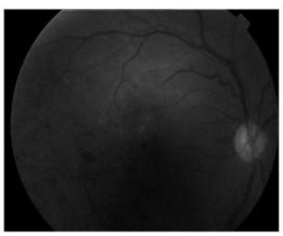


Fig-4: (b) Result of median filter

2.3.2 Averaging Filter

Averaging filter is useful for removing grain noise from a photograph. Each pixel gets set to the average of the pixels in its neighborhood. The result of the averaging filter is shown in Fig.5 (b).

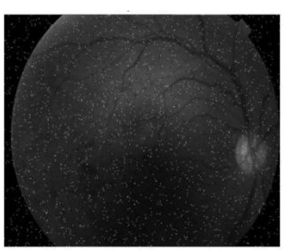


Fig-5: (a) Image with noise

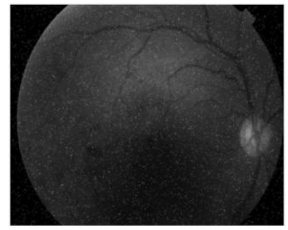


Fig-5: (b) Result of averaging filter

2.3.3 Wiener Filter

The wiener filter is used to minimize the mean square error between input and output image. But the wiener filter requires knowing the power spectral density of the original image which is unavailable in practice. The result of the wiener filter is shown in Fig.6 (b).

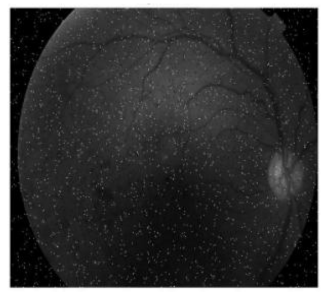


Fig-6: (a) Image with noise

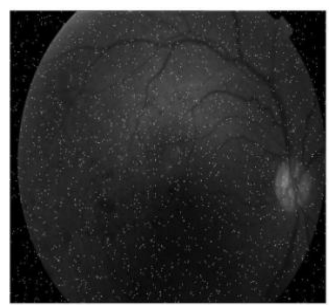


Fig-6: (b) Result of wiener filter

According to the result images, the median filter is the best suit to reduce the effect the noise. And also, it can reduce the noise without blurring the edge. Therefore, the median filter is chosen for the filtering purpose.

2.4 Image Enhancement

The result image of the median filter is enhanced by using the histogram equalization technique. The histogram equalization technique is used to overcome the uneven-illumination case. There are two methods to enhance the image: Histogram equalisation and Adaptive histogram equalisation.

2.4.1 Histogram Equalisation

It enhances the contrast of the images by transforming the values in an intensity image. The procedures of the histogram equalisation are-
(i) Find the running sum of the pixel values
(ii) Normalise the values by dividing the total number of pixels
(iii) Multiply by the maximum gray-level value and round the value

The result of the histogram equalization is shown in Fig.7 (b)

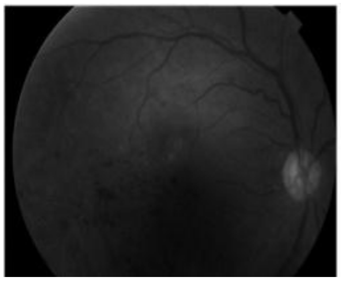


Fig: 7- (a) Original Image

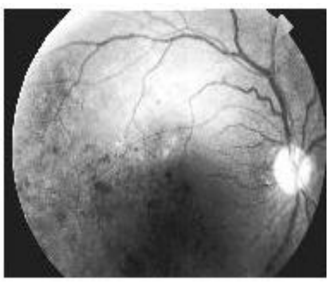


Fig-7: (b) Result of histogram Equalisation

2.4.2 Adaptive Histogram Equalisation

Unlike histogram, it operates on small data regions (tiles) rather than the entire image. And also contrast enhancement can be limited in order to avoid amplifying the noise which might be presented in the image. So, Adaptive histogram equalisation technique works significantly better than regular histogram equalization for most images.

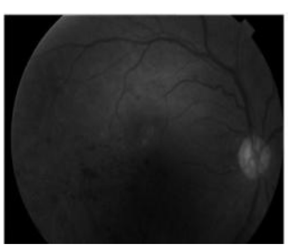


Fig-8: (a) Original Image

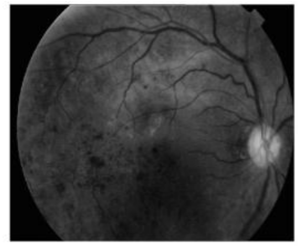


Fig-8: (b) Result of adaptive histogram equalization

According to results, the adaptive histogram equalisation technique is used for image enhancement purpose.

3. OPTIC DISC DETECTION AND ELIMINATION

There are many methods to detect the optic disc and the blood vessels for example; K-means clustering algorithm, Fuzzy C means, Mathematical Morphology and so on. The disadvantage of the Fuzzy C means ; for noisy images it does not take into account spatial Information, which makes it sensitive to noise & other image artifacts based on distribution of pixel intensity, so it is sensitive to intensity variations in the illumination.

The disadvantage of the K-means clustering algorithm is: K the number of clusters must be determined; it does not yield the same result each time the algorithm is executed.

But for the mathematical morphology, it doesn't have these disadvantages and it doesn't need highly efficient computer, so it can work on a poor computer. Therefore, it is suitable for the rural area in developing country. So, the mathematical morphology is chosen for the optic disc and blood vessels detection.

3.1. Mathematical Morphology

The basic mathematical morphology operators include the following:

- Dilation
- Erosion
- Closing
- Opening

Dilation adds pixels to the boundaries of objects in an image.
Erosion removes pixels on object boundaries.

The morphological open operation is an erosion followed by a dilation, using the same structuring element for both operations.

$$A \circ B = (A \ominus B) \oplus B$$

The closing operator is a dilation followed by erosion.

$$A \bullet B = (A \oplus B) \ominus B$$

3.2. Thresholding

The Otsu's thresholding technique is applied to the image to detect the desire area.
Equations of Otsu algorithm are

$$\sigma^2_{Between}(T)=w_B(T)w_o(T)[\mu_B(T)-\mu_o(T)]^2$$

$$w_B(T)=\sum_{i=0}^{T-1} p(i) \quad , \quad \mu_B=\sum_{i=0}^{T-1}\left(\frac{ip(i)}{p(i)}\right)$$

$$w_0(T)=\sum_{i=T}^{L-1} p(i) \quad , \quad \mu_{O}=\sum_{i=T}^{L-1}\left(\frac{ip(i)}{p(i)}\right)$$

- $\sigma^2_{Between}(T)$= Between-class variance
- w=weight, B=background of the image, o=object of image
- μ= combined mean,
- T= threshold value

The optic disc is the largest and brightest region of the image. The optic disc detection is useful because it can reduce the false positive detection of the exudates. Fig.5 shows the general flow chart of the optic disc detection.

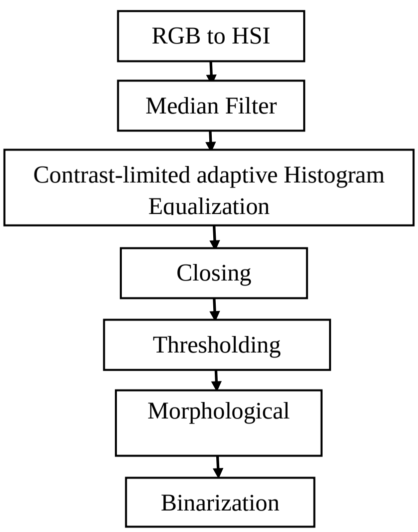
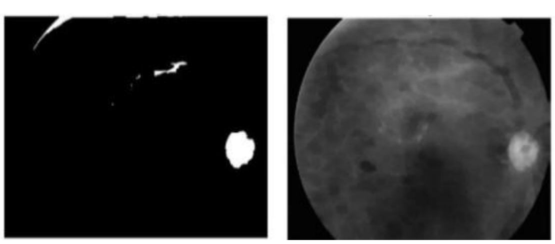
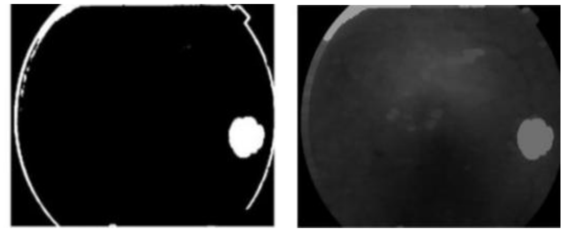


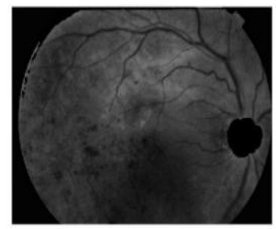
Fig-5: Flow Chart of Optic disc Detection



(a) (b)



(c) (d)



(e)

Fig-6: (a) Closing (b) Thresholding (c) Filling (d) Reconstruction (e) Detected Optic disc

The results of the optic disc detection are shown in Fig.6 (a), (b), (c), (d) and (e). Fig.6 (a) shows the result of the closing operator. To remove the vessels, the closing (morphology) operator is applied. When the closing operator is used, the choice of structuring element is important. The closing is a dilation followed by an erosion that joins the very close objects together.Then, the result image is binarized by thresholding using Otsu algorithm [16]. The result image is shown in Fig.6 (b).The filling operator is applied to fill the holes in the image and the result image is shown in Fig.6 (c). The result image is reconstructed by using the morphology reconstruction and is shown in Fig.6 (d). To detect the optic disc region, the Otsu algorithm is applied on the difference between the original image and the reconstructed image.The optic disc detected area is shown in Fig.6 (e).

4. BLOOD VESSELS DETECTION AND ELIMINATION

The blood vessels detection and elimination is also important as the optic disc detection for further process because the optic disc and the blood vessels are the normal features of the images. The general flow chart of the blood vessels detection is shown in Fig.7. To detect the blood vessels, first the input image is converted into grayscale image due to strengthen the appearance of the blood vessels. Then the median filtering and the CLAHE techniques are used for reducing noise and image enhancement purposes. Then, the closing and the filling operators are used to close the same intensity values and fill the holes in the vessels.

$$I_{(Difference)}=\phi^{(B1)}(I)-fill(I) \qquad [1]$$

Where, B1 is the morphological structuring element.

Then the Otsu's thresholding technique is applied to the result image to obtain the vessels area. The blood vessels detected area is shown in Fig.8 (e).

$$I_{(vessels)}=Thresholding(I_{(Difference)}) \quad [2]$$

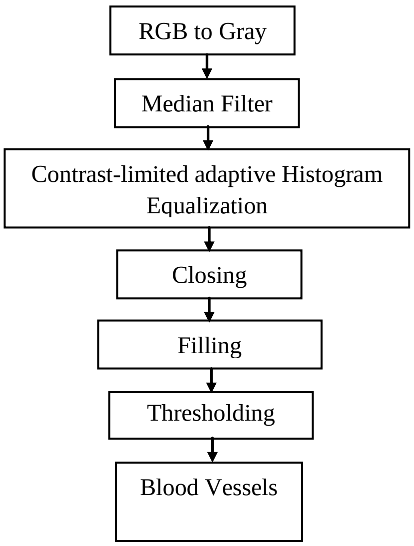
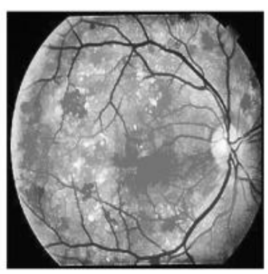
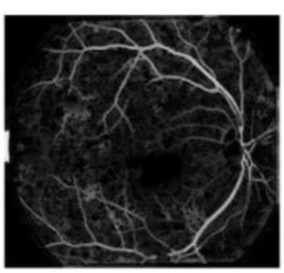


Fig-7: Flow Chart of Blood Vessels Detection

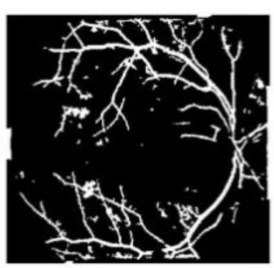
(a)



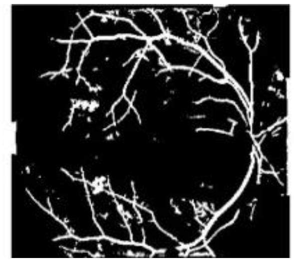
(b)



(c)



(d)



(e)

Fig-8:**(**a) Closing (b) Filling (c) Difference (d) Thresholding (e) Detected Blood Vessels

The results of the blood vessels detection are shown in Fig.8 (a), (b), (c), (d) and (e).The closing and the filling operators are used to close the same intensity values and fill the holes in the vessels. The result of the closing and the filling of the images are shown in Fig.8 (a) and 8 (b). To get the blood vessels area, Otsu algorithm is applied to the difference image between the closing and the filling images. The result images are shown in Fig.8 (c) and (d). The blood vessels detected area is shown in Fig.8 (e).

5. DISCUSSION

In this paper, the mathematical morphology is applied to detect the optic disc and the blood vessels. Detection of optic disc and the blood vessels is the important step for further processes in the detection of diabetic retinopathy. And also it helps the ophthalmologists to detect the optic disc and the vessels more easily and faster. Even on a poor computer system, this technique can work effectively. This method can work faster and it can process within a few minutes. Therefore, this method is suitable for rural area in developing countries.

6. CONCLUSIONS

Mathematical morphology method is used for optic disc and the blood vessels detections. For these detections, the input images are taken from the websites and "Eye and ENT General Hospital (Mandalay). The input image is in RGB colour space and for the further processes the image is converted into appropriate colour space. The median filter, averaging filter and the wiener filter are used for the noise reduction. Among these filter, median filter is chosen for the filtering purpose because median filter can reduce the effect of noise without blurring the edge. And then, the adaptive histogram equalisation technique is used for image enhancement. It is also used to overcome the uneven illumination case. Therefore, median filter and the adaptive histogram equalisation techniques are used for noise reduction and image enhancement purposes. Optic disc detection and the blood vessels detection are the major role in the screening of eye diseases. The results of this work can be used in the future processes such as the screening of diabetic retinopathy, glaucoma and so on. This detection method doesn't need the highly efficient computer so it is suitable for rural area in developing countries.

ACKNOWLEDGEMENT

The author would like to thank to his supervisor Dr.Aung Soe Khaing who gives the good advices for this research. The author also would like to acknowledge the head of Department of Electronic Engineering, Mandalay Technological University. The author is highly grateful to all his teachers, Department of Electronic Engineering, Mandalay Technological University. And also the author would like to thank to all doctors in "EYE and ENT General Hospital" (Mandalay).

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