Automated Detection of Optic Disc and Blood Vessels Extraction in Retinal Fundus Images

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Abstract— ***Glaucoma is a major administering cause of blindness. An approach automatic localization of important features such as optic disc, blood vessels and the detection of glaucoma using a retinal image which mainly affects the optic disc by increasing the cup size is proposed in this paper. Automatic optic disc localization is done by a k-means algorithm. A local entropy thresolding approach followed by length filtering is proposed for blood vessels extraction. A method is proposed for segmentation of the optic disc and cup in retinal image based on morphology operation to use cup to disc ratio to distinguish between the glaucoma and non glaucoma in retinal image. The proposed method was tested on DRIVE database. The methods achieve 92.5% for optic disc and 100% for blood vessel extraction.***

Index Terms- Blood Vessels, Cup to Disc Ratio (CDR), Glaucoma, Optic Disc.

I. INTRODUCTION

The retina is the innermost layer of the eye, the retina can be visualized using adequate apparatus such as fundus camera. Retinal image analysis is essential for the detection and diagnosis of various eye diseases such as glaucoma, diabetic retinopathy, macular degeneration that leads of vision loss. The main structures used in the retinal image analysis are shown in the Fig 1. The brightest region of the retinal image is optic disc and also called as blind spot because of the lack of photoreceptor. The blood vessels originated from the center of OD. The optic cup, which is a depression within the optic disc. The optic cup and disc area are common features used for identifying glaucoma, via measures such as the cup-to-disc ratio (CDR), defined as the ratio of the cup diameter to the disc diameter.

The computer based algorithm was used to detect the main region of the fundus without intervention from an operator. In Optic disc is localized as the region with maximum intensity from its nearest pixels [1] and [2] employs pyramidal decomposing and Hausdorff-based template matching for localization and segmentation of the optic disc. OD localization by Principle Component Analysis (PCA) and detect boundary by Gradient Vector Flow (GVF) snakes [3]. Our approach for Optic disc segmentation by k-means clustering.

A survey of blood vessels extraction techniques and algorithms is reported in [5]. The design of 2D-matched filters for blood vessels detection is computationally expensive due to the large size of the convolution kernel [6]. A supervised multilayer perceptron neural network is employed for blood vessels detection [1]. The input to the network are derived from PCA and this method requires manually labeled images for training. A tracking based approach with recursive dual edge tracking and connectivity recovering is applied for blood vessels detection. The method for blood vessels detection [4] is based on quad-tree decomposing and post-filtration of edges. In this paper we propose a method based on matching filters followed by local entropy thresholding for blood vessels extraction.

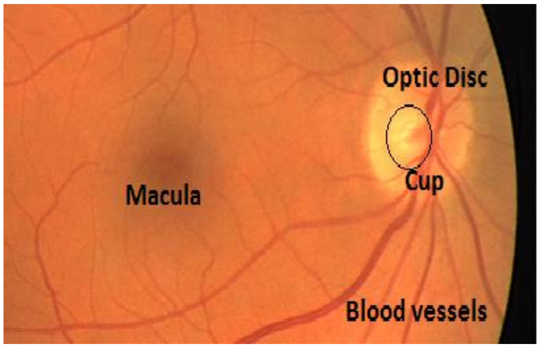


Fig 1. Colour retinal image showing the main features of the retina

The CDR is a measurement to assess of progression of glaucoma. The CDR compares the diameter of the cup portion of the optic disc to the total diameter of the optic disc. Our approach for optic disc and cup can be segmented to measure a CDR by using morphology operation.

This paper structure as follows: Section II presents proposed method and outlines the main technique used, while Section III presents the result and conclusions are presented in Section IV.

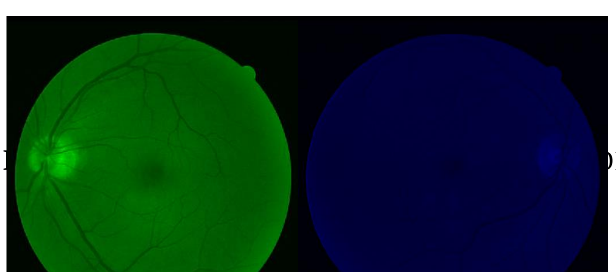
II. PROPOSED METHOD

2.1. Image Preprocessing

In the colour retinal images, blood vessels appear darker than the background similar to the colour of lesions like microaneurysms and hemorrhages. Only one step is involved in the preprocessing of retinal images for segmentation of vessels. It can be seen in the Fig 2. that the blood vessels appear most contrasted in the green channel compared to red and blue channels in an RGB image. Only the green channel image is used for detection of blood vessels for further processing.

(a)

(b)



(c) (d)

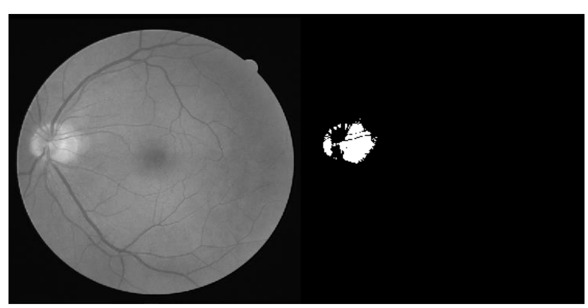
Fig 2. a) Colour retinal image; (b-d) Red, Green and Blue component images.

2.2 Optic Disc Localization

The optic disc is brighter than other features of the normal retina image. K-means algorithm plays a vital role in localization of the optic disc. A k-means algorithm that find the center of n clusters and groups the sample input around the clusters to define k-centroid, one for each clusters. After this point k-new centroid are calculated as the mean value of the clusters resulting from centroid of clusters. As a result of repeat the application of these two steps,the k-centroid changes their location step by step until no more changes take place. Algorithm as follows,

1. Place k-point of the object, it represent an initial group of centroid.
2. Assign each object to the group, that is closest to the centroid.
3. Recalculate the position of the centroid, when all objects have been assigned.
4. Repeat step 2 and 3 until the centroid no more changes take place.

before applying k-means algorithm, First we need to convert colour retinal image to grayscale image is shown in Fig 3(a) and later we applies above algorithm than we get the result of localization of the optic disc in retinal image is shown in Fig 3(b).



(a) (b)

Fig 3. Result of localization of the Optic Disc
a) Gray Image b) Optic Disc

2.3. Blood Vessels Extraction

A proposed algorithm is composed of three steps. Since blood vessels usually lower contrast compared with the background, we apply the matched filters to enhance the blood vessels. Second step a local entropy thresolding can be used to distinguish between blood vessel segment and background image and the third step is followed by length filtering is used to remove misclassified pixels. Block diagram of blood vessels extraction is shown in Fig 4.

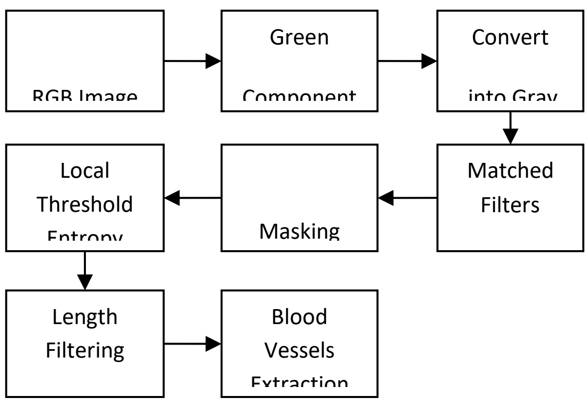


Fig 4. Block Diagram of Blood Vessels Extraction

Matched Filter

The matched filter detection is used to detect piecewise linear segments of blood vessels in retinal images. Blood vessels usually have poor low contrast. The 2D matched filter kernel is designed to convolve with the original image in order to enhance blood vessels. An equation for matching filters is expressed as

$$(x, y) = -exp\left(\frac{-x^2}{2\sigma^2}\right), for\ |y| \le L/2 \qquad (1)$$

Where L is the length of the segment for which the vessel is assumed to have a fixed orientation. Here the vessels direction is assumed to be aligned along the y-axis. Because a vessel may be oriented at any angles, the kernel needs to be rotated for all possible angles. A set of twelve 16x15 pixel kernels is applied by convolving to a fundus image and at each pixel only the maximum of their responses is retained.

Local Entropy Thresholding

Based on the gray level variation between background and objects, the gray level co-occurrence matrix is divided into four quadrants. Let T_E be threshold within the range $0 \le T_E \le L-1$ that partition the gray level co-occurrence matrix into four quadrants, namely A, B, C and D.

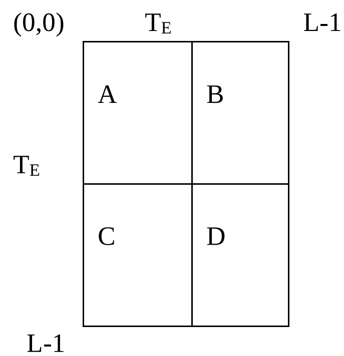


Fig 5. Representation of four quadrants

Where quadrant A represents a gray level transition within the object while quadrant C represents gray level transition within the background. The a gray level transition between the object and the background or across the object's boundary is placed in quadrant B and quadrant D. These four regions can be further grouped into two classes, referred to as local quadrant and joint quadrant. Local quadrant is referred to quadrant A and C as the gray level transition that arises within the object or the background of the image. Then quadrant B and D is referred as joint quadrant because the gray level transition occurs between the object and the background of the image.

The local entropy threshold is calculated considering only quadrants A and C. The probabilities of object class and background class are defined as

$$P_A = \sum_{i=0}^{T_E} \sum_{j=o}^{T_E} P_{i,j} \qquad (2)$$

$$P_C = \sum_{i=T_E+1}^{L-1} \sum_{T_E+1}^{L-1} P_{i,j} \qquad (3)$$

the normalized probabilities of the object class and background class are functions of threshold vector (T_E, T_E) are defined as

$$P_{i,j}^{C} = \frac{P_{i,j}}{P_C} \qquad (4)$$

$$P_{i,j}^{A} = \frac{P_{i,j}}{P_A} \qquad (5)$$

The second-order threshold entropy of the object is given by

$$H_A(T_E) = -\frac{1}{2}\sum_{i=0}^{T_E}\sum_{j=0}^{T_E} P_{i,j}^{A} \, log_2 \, P_{i,j}^{A} \qquad (6)$$

the local transition threshold entropy A denoted by $H_A(T_E)$. Similarly, the second-order threshold entropy of the background is given by

$$H_C(T_E) = -\frac{1}{2}\sum_{i=0}^{T_E}\sum_{j=0}^{T_E} P_{i,j}^{C} \, log_2 \, P_{i,j}^{C} \qquad (7)$$

up the local transition threshold entropies, the total second-order local entropy of the object and the background is given by

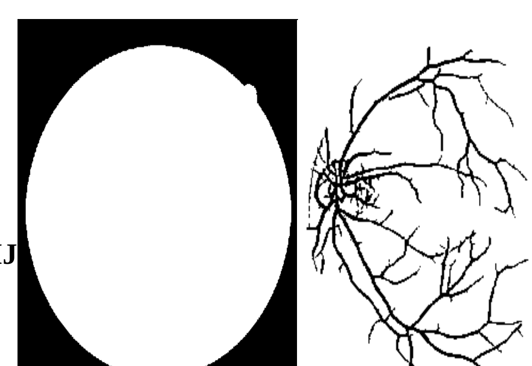
$$H_T\,(T_E) = \,H_A\,(T_E) + H_C\,(T_E) \qquad (8)$$

Finally T_o the gray level corresponding to a maximum of H_T (T_E) gives the optimal threshold for vessels and non vessels classification.

$$T_O = arg\left[{}_{T=0L_{T1}}^{max} H_T(T_E)\right] \qquad (9)$$

Length Filtering

Length filtering is used to produce clean and complete blood vessels structure by removing misclassified pixels and also used to remove isolated pixels by using the concept of connected pixels labeling. Connected pixels region correspond to individual objects. Length filtering, first identify separate connected regions and later tries to find the individual objects by using eight–connected neighborhood and label propagation. Once the algorithm is completed, only the resulting classes exceed a certain number of pixels is shown in Fig 6(b).



(a) (b)

Fig 6. The result for blood vessels (a) Masking Image (b) Blood Vessels Extraction

2.4 Cup to Disc Ratio

The ratio of the optic cup disc to the area of the optic disc is compared between a patient diagnosed with glaucoma and a normal patient. A patient who is diagnosed with glaucoma will have the results of an enlarged swollen optic cup compared to a normal patient's result. Therefore an increase in the Cup to disc ratio will show a significance of a glaucomatous eye.

The optic disc is more easily discriminated in the Red component as compared the Blue and Green component is shown in Fig 8(b). However, the optic cup is not able to be distinguished due to the border between the two was unclear. Therefore the Green component will be used to distinguish the optic cup is shown in Fig 8(c).

Blood vessel of the image is removed so as to achieve the accuracies for the measuring of the optic disc and the cup areas. A morphological operation such as erosion, dilation, opening and closing are implemented in the image. As the basic effect of morphological erosion operation erodes away the regions of foreground pixels and for dilation was to gradually enlarge the regions of the foreground pixel, therefore this technique help to remove unwanted bright spots or boundaries present in the image. A disc shaped structuring element of size 15 was created and a closing and opening operation was performed on both the red and green component images. A value of 1 (white) was obtained in the region that contains the optic disc and cup, whereas a value of 0 (black) for the background. The close operation will help to fill in the gaps and help to smooth the outer edges and the open operation will help to remove any small stray bright spot that is present in the image.

A threshold value of 0.805 was used to show the boundary of the optic disc and cup which is important as it is very helpful for extraction in the areas of the optic disc and cup for the later part of the project. Threshold operation will convert the 8 bit red and green image to binary images to obtain the optic disc and cup.Finally, erode and dilate operation was performed on the image so as to further smoothen the outer boundaries.

The area of the optic disc and cup were evaluated by the counting of the number of white pixels in the region. In order to get the ratio of the Cup to Disc ratio, the optic cup area is divided by the optic disc area is shown in Fig 8(e). Results of the greater Cup to Disc ratio signify a glaucomatous eye and lower Cup to Disc ratio signify a normal eye. Fig 7 shows a block diagram of cup to disc ratio.

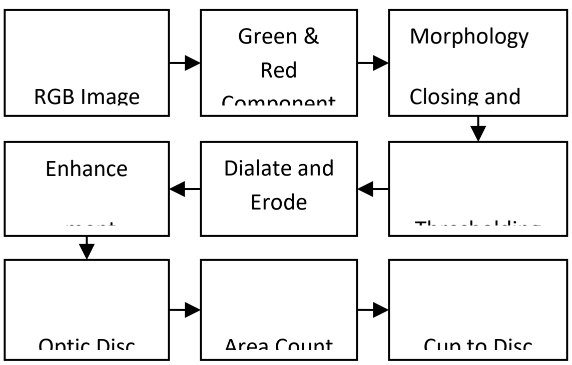
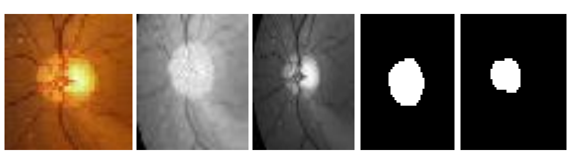


Fig 7. Block diagram of Cup to Disc Ratio



(a) (b) (c) (d) (e)

Fig 8. a) Glaucoma color image (b-c) Red and Green Component (d-e) Optic Disc and Cup area

III. RESULTS

The proposed method was tested on DRIVE data set that is composed of 40 retinal images [7]. This images contain both normal and abnormal retinas. In this study 38 of these retinal images were used consisting of 31 normal and 7 abnormal images. The proposed method is capable of localizing the optic disc correctly for 36 of these images with success rate is 92.5% and success rate of blood vessels extraction is 100% . Table 1 shows the result of CDR for both glaucoma and non glaucoma cases.

Cases	Disc	Cup
Glaucoma cases	0.82	0.60
Non-Glaucoma cases	0.85	0.47
All cases	0.83	0.51

Table 1. The result of CDR for both glaucoma and non -glaucoma retinal images

CONCLUSION

An automatic localization of optic disc, blood vessels extraction and determination of cup to disc ratio has been presented in this paper. K-means algorithm proposed to identify the optic disc. We can conclude that matched filters and local entropy thresholding provide better blood vessels extraction. The CDR which is the ratio between the area of the optic disc and the area of the optic cup is computed by using morphology operation and a threshold value. The proposed method shown relative simplicity, accuracy and robustness for a variety of input retinal images. It is hoped that automated localization of optic disc, blood vessels and CDR technique can detect the signs of glaucoma in the early stage, monitor the progression of disease, minimize the examination time and assist the ophthalmologist for a better treatment plan.

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