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AUTOMATIC DETECTION OF OPTIC DISC FROM RETINAL IMAGES

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ABSTRACT

A novel method of automatic detection of optic disc based on morphological filtering, gray level thresholding and principle component analysis is proposed. The proposed method is to detect optic disc from the fundus image employing blood vessels detection, removal of blood vessels, image inpainting and optic disc segmentation. The implemented algorithm has been validated on seven images of DRIVE dataset obtaining promising results. The parameters such as accuracy, true positive and false positive fractions and sensitivity have been evaluated to justify the better performance of the proposed method.
Keywords: **retinal blood vessels, optic disc, segmentation, glaucoma.**

I.INTRODUCTION

OPTIC disc (OD) detection and OD segmentation refer to the location of the OD center and the OD boundary, respectively. Accurate OD detection and OD segmentation are very important in ocular image analysis and computer aided diagnosis for different types of eye diseases such as diabetic retinopathy and glaucoma. Glaucoma, diabetic retinopathy, macular degeneration and hypertension are the most common causes of visual impairment and blindness [1] [2].

Early diagnosis for these diseases can prevent visual loss and these diseases can be detected through ophthalmologic examination of the risk population. However, aging, population growth, rising levels of obesity and physical inactivity are contributing to the increase of them, and the increase in the number of ophthalmologist needed for evaluation by direct examination is a limiting factor. So, automatic recognition of these pathological cases would provide a great benefit. An efficient detection of optic disc in color retinal images is a significant task in an automated retinal image analysis system. Its detection is prerequisite for the segmentation of normal and pathological features. For instance, the measurement of optic disc to cup diameter ratio is used in the detection of disease called glaucoma. The rest of the paper is organized as follows: Section II describes the description of proposed method. In section III implementation of proposed method is explained. Results and discussion are given in the section IV. Section V describes the conclusion of the proposed method.

II.DESCRIPTION OF PROPOSED METHOD

The proposed system used to detect and segment the blood vessels and optic disc based on the mathematical morphological operations, region growing, PCA and watershed transform algorithm.

First, the original retinal image is given as input and only the green channel is taken. Then the large mean kernel is used to perform the background normalization [3]. Thin vessel enhancement is achieved by using the line detection filter. Morphological operation top hat transforming with structuring element is used for enhancing vessels in the image and the morphological vessel reconstruction is used to obtain the binary maps in the image. The vessel centerline is detected by performing the candidate selection by using Difference of Offset Filter [4] and then the candidate connections are obtained by using the region growing process and also it is validated by its length and the intensity. Then by vessel filling these outputs are processed to obtain the segmented blood vessels [5] [6]. The optic disc is segmented by using the PCA, inpainting and watershed transform. PCA is performed on the preprocessed image in order to reduce the dimensionality of the image and then the image is enhanced by transformation processing and by this processing the non-uniform illumination is corrected. Then the inpainting [7] is performed on the obtained image in order to remove the blood vessels.

The optic disc is segmented by stochastic watershed transformation [8] [9], in which it make use of the random markers to build a probabilistic density function and then the image is segmented by using the markers. The region discrimination is performed based upon the average intensity of the region. This gives the discrimination between the significant and non-significant region. In the post processing, the false contours and circular approximation are performed by using the Kasa's method [10]. Finally the segmented optic disc is obtained. Fig 1 shows the Architecture diagram of the proposed method.

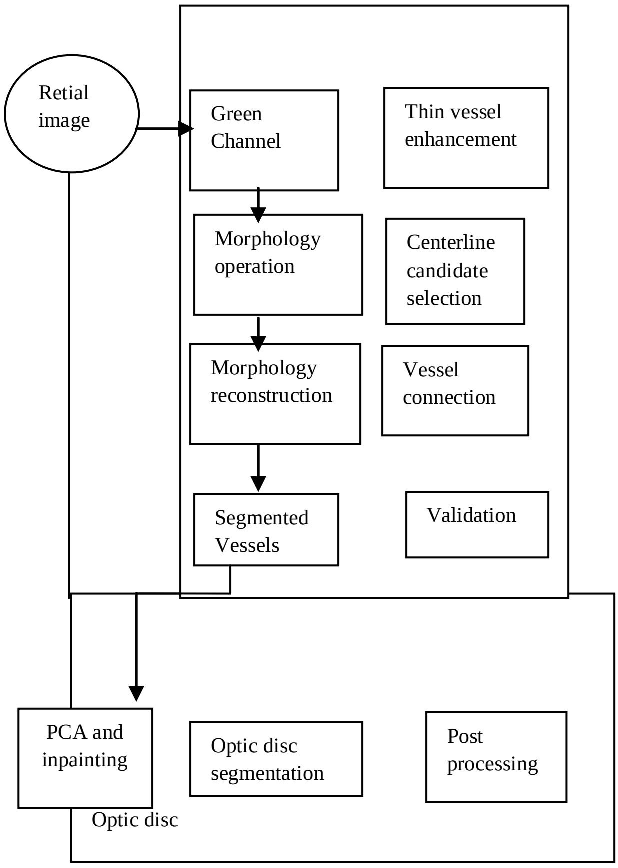


Fig .1 Architecture Diagram

Methods used in the proposed system are discussed below.

A. Vessel Segmentation

Preprocessing and Morphological Operation:

The preprocessing involves with green channel conversion of original image. For this the green component is taken from the original image of RGB. Then the morphological operations for image enhancement are performed using the given formula.

$$\text{Tophat} = f - (f \circ b) \quad (1)$$

$$f \circ b = (f \bullet b) \circ b \quad (2)$$

In equation (1) the opening operation is performed and it is subtracted from the image. For the opening operation the equation (2) is used, in which the closing and opening operations are performed with the structural element. The structuring element can be of any size and the disk is used as a structuring shape.

Then the image reconstruction is performed by morphological operations usingthersholding.

Iff(x,y) > T then f(x,y) =0 , else f(x,y)=255 (3)

The vessel centerline is detected by using the Gaussian filter and then the region growing is performed by selecting the seed and then it is iterated.

For vessel segmentation the preprocessing of the retinal image is processed in two stages. (i) Background normalization: the input image is converted into green channel image since it has the highest contrast in the intensity of the background and foreground. Then the green channel image is normalized by using the large arithmetic mean kernel. (ii) Thin vessel enhancement by processing with a set of line detection filters; for each pixel, the highest filter response is kept and added to the normalized image.

After the normalization processing, the morphological operation is carried out with the top hat transform with variable structuring element. Then the resultant image from the previous process is taken and then the morphological reconstruction is performed. The thresholding is used for the reconstruction of the image in order to obtain the binary maps of the vessels in the retinal image.

For detecting the vessel centerlines from the retinal images first selection of vessel centerline candidates, using directional information provided from a set of four directions employing Difference of Offset Gaussians filters algorithm. After finding the centerline candidate, Connection of the candidate points is achieved by using region growing process. Finally Validation of centerline segment candidates based on thecharacteristics of the line segment is processed. This operation is applied ineach one of the four directions and finally combined, resulting in the map of the detected centerlines of blood vessels. Vessel filling by a region growing process using asinitial seeds the pixels within the centerlines obtained in thevessel centerline detection phase; the growing is successivelyapplied to the four scales and, in each growing region step, theseed image is the result of the previous aggregation.

The morphological reconstruction is used to segmentation of blood vessels instead of using the k means clustering [11]. By using this method the thin lines of vessels can also be detected and it makes the detection of accurate optic disc by removing the thin vessels.

B. Optic Disc Segmentation

PCA and Image Enhancement

The idea of using PCA is to reduce the dimensionality of a data set consisting of a number of interrelated variables, while retaining asmuch as possible of the variation present in the data set.

$$Z_k = \acute{\alpha}_k v = \sum_{j=0}^{p} \alpha_{kj} \ v_j \qquad (4)$$

Where V is a vector of p random variable ,Z_k will be the linear function of $\acute{\alpha}_k$ v gives the element of v .From the above equation covariance matrix is obtained and from that the eigen value and eigen vector are obtained .

The image enhancement uses the formula (5) given below. By using this operation the non-illumination is corrected. For this operation,t_{max}- maximum gray level, t_{min} - minimum gray level and the target level such as u_{max} and u_{min} are used as follows.

$$\tau(f)(t) = \begin{cases} \frac{\frac{1}{2}(\mathrm{umax}-\mathrm{umin})}{(\mu - t_{min})^r}(t-t_{min})^r + u_{min} & \text{if } t \le \mu_f \\ \frac{-\frac{1}{2}(\mathrm{umax}-\mathrm{umin})}{(\mu - t_{max})^r}(t-t_{max})^r + u_{max,} & \text{if } t > u_f \end{cases} \qquad (5)$$

$$Z'_k = \Gamma(Z_k)(t) \qquad (6)$$

Where t is the output of the image enhancement method,Γ is the transformation operation symbol and $Z'_k$is the transformed output.

The inpainting algorithms are used for the restoration of damaged photographs to the removal/replacement of selected objects. These algorithms try to fill selected parts of an image by propagating external information so that structure continuity is preserved.

$$Z''_k = \gamma \ (Z'_{k}k, \ \Omega) \qquad (7)$$

Where Ω is the binary mask image, γ is for inpainting and Z''_k is the inpainted image output.

Let Ω(x) a binary image stand for the region to be inpainted. For each -pixel, x the inpainted pixel value is computed as

$$p(x) = \frac{\sum_{k=1}^{n} \frac{p_k(x)}{l_k}}{\sum_{k=1}^{n} \frac{l}{l_k}} \qquad (8)$$

Where $p_k$denotes the pixel values in a neighborhood of the pixel under consideration, l_k is the distance between the pixel x and each neighboring pixel and n is the number of neighboring pixels.

StochasticWatershedTransformation

The segmentation method make use of the stochastic watershed transformation that uses random markers to build a probability density function of contours, according to (9) and this is then segment the disc by watershed for defining the most significant regions.

$$\mathrm{pdf}(x) = \frac{1}{M}\sum_{i=1}^{M}(\mathrm{WS_i} * G(x;s)) \qquad (9)$$

Where G(x;s) is Gaussian kernel of variance σ^2andmeanμ ($\mu = 0$).

The internal and the external marks are combined by using the logical OR, to obtain the fm marker. With this maker the optic disc is segmented. The formulas for the marker calculation are shown in (10).

$$f_m = f_{int} \vee f_{ext} \quad (10)$$

The geodesic transformation is used to find the markers for segmenting the optic disc contour.

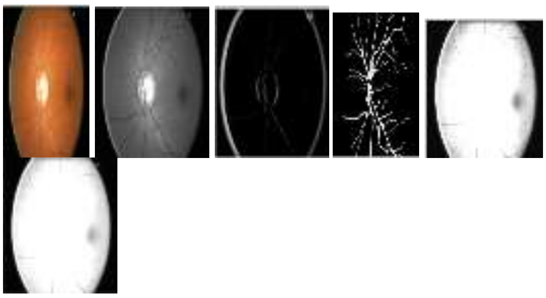
After this process, the discrimination between the significant and non-significant region is achieved by region discrimination process. In the post processing, the false contours and circular approximation are performed by using the Kasa's method. The optic disc contour has been estimated in a circle and the circular fit is performed by means of Kasa's method, which calculates the center and the radius ofthe circle that better is adapted to a binary region.

III IMPLEMENTATION

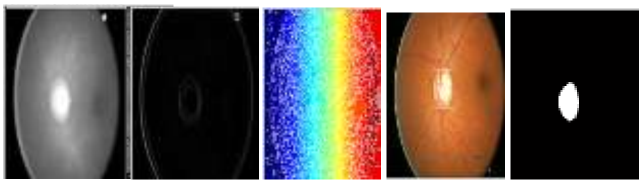
The proposed method is implemented by taking the color retinal image as input for detection and segmentation of the optic disc. MATLAB version 7.6.0.320 is used as simulation software. In this, the performance is measured using the parameter Ac, TPF, FTP and sensitivity.

IV.RESULTS AND DISCUSSIONS

The method described in the previous sections was tested onimages of two publicly available databases, the DRIVE database. The DRIVE database contains 4color images of the retina, with 565 x 584 pixels and 8 bits per color channel, represented in JPEG format and the other 3 images with 700x605 pixels, 8 bits per color channel.In Fig.2 the results of the proposed method are given. Fig 2(a) shows the input image and Fig 2 (b) shows the converted green channel image, which has only the green component among the RGB channels. By using the green channel the high intensity between the pixels can be obtained. Fig 2(c) shows the vessel centerline detection. The detection of centerlines of the vessels is useful in identifying the thin vessels which makes the detection of optic disc task easier. Fig 2(d) shows the segmented blood vessels present in the retinal image. Fig 2(e) shows the output of the PCA, which reduces the dimensionality of the image. Fig 2(f) shows the image enhancement process output. Fig 2 (g) shows the output image of inpainting and Fig 2(h) shows the removal of segmented blood vessels in order to detect the optic disc present in the given image. Fig 2(i) shows the result of Difference of offset Gaussian filter (DOOG). Fig 2(j) shows the watershed transformation output. Fig 2 (k) shows the detection of optic disc contour and Fig 2(l) shows the segmented optic disc from the retinal images.



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



(g) (h) (i)
(j) (k) (l)

Fig 2 .(a) Input Retinal image , (b) Green Channel image , (c) – (d) Vessel Segmentation , (e) PCA output, (f) Image enhancement, (g) Vessel removal, (h) Inpainting output. (i) DOOG filter (j) Stochastic Watershed Transformation (k) optic disc contour, (l) optic disc segmentation

True positive fraction (TPF) and False Positive Fraction (FPF) [5] are calculated as shown in equations (11) and (12).

$$TPF = \frac{TP}{n} \quad (11)$$

$$FPF = \frac{FP}{n} \quad (12)$$

Accuracy (Ac) and sensitivity [5] are calculated as shown in equations (13) and (14).

$$Ac = \frac{(TP + FP)}{n} \quad (13)$$

$$Sensitivity = \frac{TP}{TP + FN} \quad (14)$$

Where TP is total number of true positive pixels, FP is total number of false positive pixels, FN is the total number of false negative pixels and n is the total number of pixels.

Table I shows the performance measure of the proposed method.

TABLE I Performance calculation

s.no	TPF	FPF	Ac	sensitivity
1	1.000	0.0869	1.000	0.9909
2	1.000	0.0473	1.000	1.000
3	1.000	0.0458	1.000	1.000
4	0.9998	0.0482	1.000	1.000
5	1.000	0.0002	0.9800	1.000
6	0.9990	0.0221	1.000	1.000
7	1.000	0.0001	1.000	1.000

Sandra et al [12] proposed a method for detecting the optic disc. In order to segment the optic disc, the blood vessels are segmented used the k means algorithm and it is removed by using the inpainting. For segmenting the optic disc the watershed transformation is used. Walter et al [13] proposed the detection of optic disc by using morphology filtering operations and watershed transformation. Morphological operations such as opening and closing are performed with the structuring element and the optic disc contour is detected using the watershed transformation. The optic disc contour region pixels are identified by using the markers. In [12] [13] the performance is measured using the TPF, FTP, AC and sensitivity. TABLE II shows the comparison of performance measurement.

TABLE II Comparison of performance measurement

	Proposed method	**Sandra et al[12]**	**Walter et al[13]**
Sensitivity	1.0000	0.9084	0.6813
Ac	1.0000	0.9984	0.9689
TPF	0.9498	0.9281	0.6715
FPF	0.0031	0.0040	0.0210

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V CONCLUSION

In this paper, a novel approach for the automatic detection of the optic disc has been presented. It makes use of the green channel imageas input for segmenting the blood vessels and a grey image obtained through PCA. Several operations based on mathematical morphology are implemented with the aim of locating optic disc present in the retinal image. For that purpose, watershed and geodesic transformation have been used. The algorithm has been validated on seven images of DRIVE dataset. Its advantage is the automation of the algorithm since it does not require any intervention by clinicians, which reduces the consultation time.

As for future enhancement, the optic cup will also be detected with the goal of measuring the cup-to-disc (C/D) ratio. A high C/D ratio will indicate that a fundus is suspicious of glaucoma.

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