Segmentation of Optic Disc Based on Vessel Bends in Retinal Image

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***Abstract*- The paper proposed an algorithm to segment the optic disc automatically from the fundus image. The detection of optic disc boundary is mainly based on LDA and medial axis detection. To calculate the geometric shape and size of the optic disc, the segmentation in eye imaging is an important role. The segmentation of the input is obtained through LDA. The objective of LDA is to perform dimensionality reduction. The most important region of eye is optic disc was located by using an approach based on medial axis detection. The optic disc segmentation is forecast by structure of vessel bend at disc boundary. The implementation algorithm has been tested on drive databases. The average value obtained (a precision value and Recall value are 0.9 and 0.966 respectively, the F-score of 0.9323) describes that this method is a robust tool for segmentation of optic disc.**

Keyword: Optic disc, LDA, boundary detection, Vessel bend, Medial axis detection.

I. INTRODUCTION

Early detection and treatment of retinal diseases are essential to avoid the vision loss in retinal image. Any abnormalities or change in the retina are diagnosed by clinicians using fundus image. Detection of the optic disc can be used to test the severity of some diseases are diabetic retinopathy and glaucoma. [1-4]

Due to the significant loss of optic nerve fiber leads to irreversible vision loss. The identification and treatment of eye diseases such as diabetic retinopathy and glaucoma can be employed by retinal image photograph.[5]

Although DR isn't a curable illness, if detected in early stage the major vision loss can prevent by the optical device surgical procedure. However, Diabetic retinopathy patient with no symptoms till vision develops. So the diabetic patient wants annual eye examination. The location where ganglion cell outlet the eye to from the optic nerve through which the information of the photo receptor is transmitted to the brain is called optic disc. There are two distinct zones in the OD namely a central bright zone called cup and peripheral region called the neuro retinal rim. The structure of optic disc is shown in the Fig.1. The changes in the structure appearance of OD due to the loss in optic nerve fiber. [6-9]

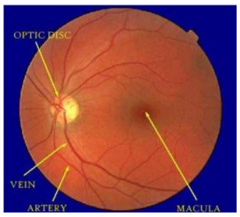


Fig 1.Optic Disc

The optic disc plays an essential role for diagnosis the proficient system for DR as its segmentation is a key preprocessing component in many algorithms intended to identify the other fundus feature. OD detection is also applicable for automated diagnosis of the other ophthalmic pathologies. Glaucoma is one of them and may be the most noteworthy. It is the second most common cause of blindness worldwide. Glaucoma is acknowledged by recognize the modification in shape, or depth that it produces in the OD.[10][11][12]

II. LITERATURE SURVEY

The OD boundary can be detected by using various OD segmentation methods. A survey has been reported for those methods. Marc et al., describes that the design for locating the OD in low resolution color fundus image. The plan of this paper has a Hausdroff-based template matching technique on a edge map. In this approach a fast computational time is important but the computational time depend upon the content of the image.[14-18]

Sekar et al., state for diagnosis and treatment of various eye diseases such as DR and glaucoma by using the retinal fundus photograph. By using the Hough transform to the gradient image, the OD boundary was detected. This method fails to incompetence of the shade correction operators and thresholding. The Hough transform is mostly depends on the number of edge pixel and number of to be matched, this makes computational complexity.[19][20]

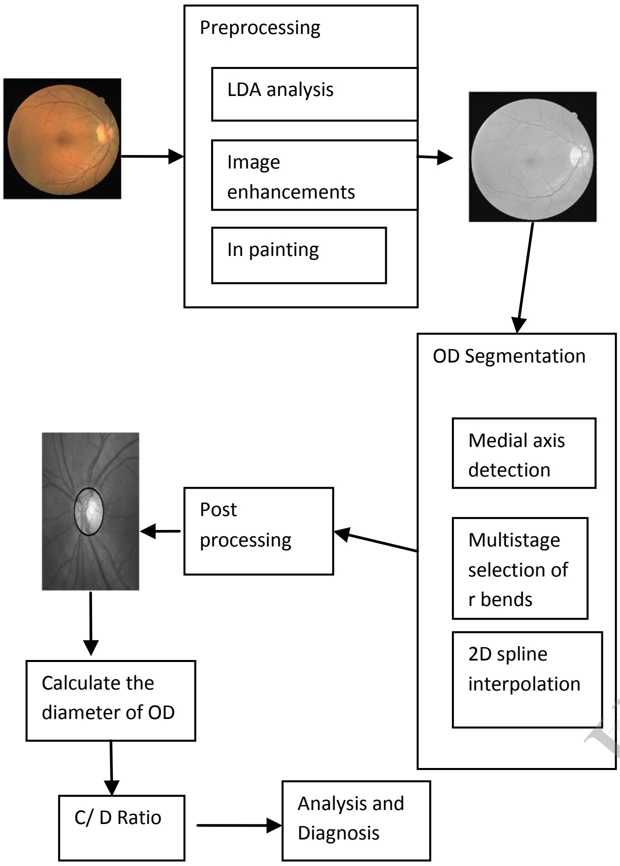


Fig 2: The Proposed System Architecture

Adam et al., Proposed method that automatically locate the optic nerve in image of visual fundus image. A fuzzy convergence algorithm was used to find the origin of the blood vessel network. If the nerve is gets completely buried due to hemorrhaging then it is difficult for detecting the optic nerve. The fuzzy convergence algorithm was used to detect vessel network convergence but it has intricate to identify the starting point of blood vessel network.[2]

Juan et al, state that to detect the OD and cup boundary using deformable model based approach. This method has two aspect 1) knowledge based clustering and other is smoothing. The combination of both local and global are used to update these two aspects. This method fails to encode the various shape of OD from different pathological change.[10][20-25]

III. Proposed approach

Our objective is to segment the optic disc from a fundus image by using LDA and medial axis detection. Fig 2 shows the proposed system architecture. The proposed system follows three main steps. The first step is the preprocessing, in that apply LDA to perform the dimensionality reduction while preserving as much of the class discriminator information as possible. It is also used to achieve the gray scale image that it represents the RGB image better. From this image a different structure of retina are differentiated more clearly to get more accurate detection of OD. By using the inpainting method, the vessels are removed to make the segmentation easier. The vessel bends can occur at many place in the OD region and its detected with the different source of information. The pallor region describes the inner limit of r bend, bending angle and location of OD. The r-bends are thin and not uniformly distributed across the sectors. To estimate the boundary, 2D spline interpolation method is used.

III.1. PREPROCESSING

A. Linear Discriminant Analysis:

LDA basically handle the case everywhere within-class frequency is not equally and their recital has been tested on the generated test data. It guaranteeing the maximum separations by qualitative relation of between class variance to within class variance in any data sets. The flow diagram of LDA is shown in the Fig. 4. A decision region is drawn between the given classes and it tries to provide more class separability. The distribution of the feature data was better understood by this method.

(a) (b)

Fig 3: Linear Discriminant analysis a) Original fundus image. (b) LDA.

Step1: Represent the input image as matrix by converting into ycbcr.

Step2: The mean of each data is computed by

$$\mu 3 = p1 * \mu 1 + p2 * \mu 2$$

$\mu 3 \rightarrow$ mean of entire data.

$\mu 1$ & $\mu 3 \rightarrow$ mean of each data

Step3: Compute the between –class scatter and with in class scatter matrix by using

$$Sb = \sum (\mu j - \mu 3) * (\mu j - \mu 3)^{-T}$$

$$Sw=\sum (xj-\mu 1j)*(xj-\mu j)^{T}$$

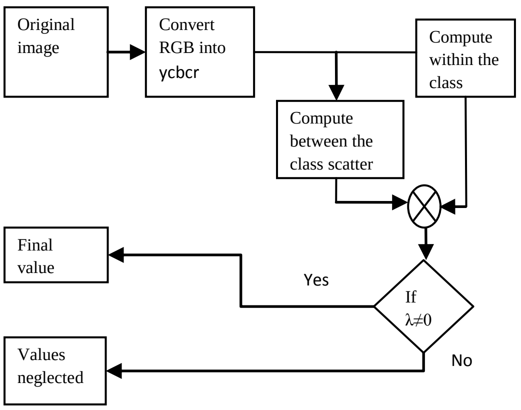


Fig 4. Flow Diagram of LDA

Step4: The eigen values are calculated by using $\lambda=Sw^{-1}Sb$.

Step5: The linearly independent between feature is indicated when eigen values are Non-zero. If eigen values are zero, then it is neglected and indicate its linearly dependent between feature.

The original color retinal image of LDA is shown in the Fig. 3(a). To find the eigen value the input image is converted into ycbcr matrix. To differentiate the structure of retina more clearly, it convert into grey scale image as shown in the Fig 3 (b).

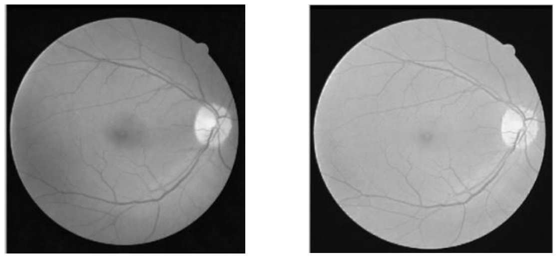
B. *Image enhancement:*

Image enhancement is basically improving the perception of information in image for human viewers and providing better input for other automated image processing technique.To enhance the visual appearance of an image or to convert the image for better analysis by human or machine is done by the image enhancement process. The improvement of an image appearance by increasing the dominance or by decreasing uncertainty between the dissimilar region of the image. The obtained grey scale image is not uniformly elucidated. The local transformation is used to correct the non uniform elucidate and improve its contrast. The transformation expression is given by equation 1.

The minimum and maximum grey level of image is t_{min} and t_{max}. The mean value of the image is μ_f and the target levels are U_{max} and U_{min}.

$$Y(f)(t)=\begin{cases}\dfrac{\frac{1}{2}(U_{max}-U_{\min})}{(\mu_f-t_{min})^r}(t-t_{min})^r+U_{min}, & \text{if } t \le \mu_f\\ \dfrac{-\frac{1}{2}(U_{max}-U_{\min})}{(\mu_f-t_{max})^r}(t-t_{max})^r+U_{max}, & \text{if } t > \mu_f\end{cases} \qquad (1)$$

The input and output of image enhancement is shown in the Fig. 5 (a) and Fig. 5(b).



(a) (b)

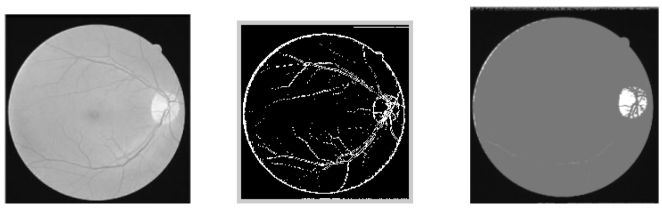
Fig 5: Image enhancement a) Input (b) Image enhancement

C. *Vessel mask*:

The discrimination of OD is very difficult due to the numerous vessels crossing its border. The removal of vessels from the enhanced image is obtained by using the inpainting method. The Inpainting algorithm is used for various applications, from the refurbishment of damaged photograph to the removal of selected object. The structure permanence is preserved by using the external information. The image is categorized by their pixel value. If the range of the pixel value lies within 0 to 150 consider as black. The pixel value lies between 150 to 200 is considered as grey. The range above this is considered as white. In Fig 6 shows the vessel masking of the input image and inpainted image.

III.2. Optic Disc Segmentation:

A multiple source of information are needed to segment the optic disc. The pallor region describes the inner limit of r bends, bending angle and the location of OD. The r bends are not equally distributes in the OD boundary. 2D spline interpolations are used to smooth the OD boundary.



(a) (b) (c)

Fig 6: Vessel mask (a) Input image (b) vessel masking (c) Inpainted

A. *Medial axis detection:*

Detecting the both thick and thin vessel in the OD region is very difficult due to large inter- image variation. The trench region are characterized and slanting in particular direction by means of high curvature. The expression used to find the curvature is defined in the equation

$$Y(x) = (d^2y/dx^2)/(1+ (dy/dx)^2) \qquad (2)$$

Y (x) is computed in 4 different directions for each point. To obtain the trench point, maximum value of Ymax and its corresponding orientation α are used. If the value of Ymax is greater than both the threshold value t and neighboring pixel in α direction, then it is declared as trench point. A high contrast of vessel point(set 1) is obtained by applying the high value of t. Similarly a low contrast vessel point(set 2) is obtained by applying the value of t. This helps to extract the low contrast vessel while rejecting the noise. The final trench point detect the vessel structure more accurately quantify the vessel bends through medial axis detection.

B. *Vessels bend detection:*

The vessel bends are varied according to the caliber vessel. Due to inflexibility of thick vessel it doesn't show large bending but thin vessel sows large bending. The proper selection of scale is important for detecting both types of bend because the bend in the thick vessel is clear only at large scale compared to the bend in the thin vessel.

First, the vessel segments are extracted by terminated end points. The local maxima are compute by 1D shape profile and constitute a set of bends. A segment of vessel around bi and bound on either side by nearest minimum curvature defines the region of support. The line joining a bend point and centre of the mass of ROS has been used to compute the bending angle θ. The bending angle which exceeds 170˚ then it has to be removed from the set of bends.

C. *Multi-state selection of r bends:*

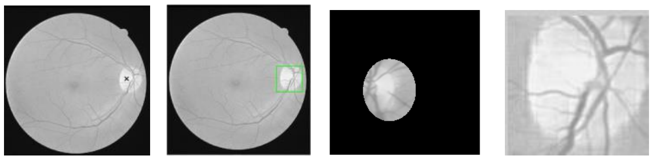
There are two stages for identifying the r bends from bi, by utilizing anatomical knowledge associated with r bends.

First Stage:

Based on bend's proximity to the pallor region, a coarse selection was done. Consider the points within pallor region be P :(x_p,y_p). The Points are finding by keeping the top 25% of the bright pixel within OD. The bends bi located in b :(x_p,y_p). The region has the potential r bends is limit by finding a paramount fit circle to set of points. The radius and centre of the circle is R and (x_c,y_c). The minimization of error function is given by $S=\sum_i((x_i-x')-x_{c)})^2+((y_i-y')-y_{c)})^2 - R^2$. The bends are agreed to next stage which lies in the area of the circle.

Second stage:

The spatial position and bending information are identified by using a set of r bends. The bends can be scrutinized by sector-wise location and vessel orientation. A sector is radially examined with step size of 20˚ and in each step, only bends shaped by vessel with correct orientation are preserved.



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

Fig 7: OD Segmentation (a) Medial axis detection (b) Fitted area (c) bend points (d) optic vessel

D. *2D spline interpolation*

The r bends are emaciated and not evenly distributed across the sector. It is difficult to get the boundary in the region where the r bends are absent. According to sector the bending behavior and shape are control by using the parameter t. Compared to sector1&3, a sector 2&4 has low vessel density so the value of t is kept high in sector 2&4. A closed form 2D spline curve is obtained by considering a subset of r bends. The medial axis detection of disc boundary and vessel bends are detected in an image are shown in the Fig.7 (a) and Fig 7(b). Fig. 7(c) and Fig. 7(d) shows the final optic disc boundary can be computed by using optic vessel.

IV. PERFORMANCE EVALUATION OF DISC BOUNDARY

The overall performance of the OD boundary was assed by the comparative analysis method. The boundary detection similarity is done by the evaluation process. The area overlap between computed region and ground was evaluated by precision and recall values. The expression for Precision and Recall values are given in the equation 3 and 4.

$$Precision = \frac{TP}{TP+FP} \quad (3)$$

$$Recall = \frac{TP}{TP+FN} \quad (4)$$

tp→ number of true positive pixels .
fp→ number of false positive pixels.
fn→ number of false negative pixels.

To compute a single performance measure called traditional F-score (F) is calculated by the equation 5.

$$F = \frac{2\,Precision * Recall}{Precision+Recall} \quad (5)$$

The Value of F-score should lie between 0-1 and for accurate method; F-score should be high. The Performance of disc boundary of various techniques has been evaluated with drive data base. From the various techniques, the proposed method detect the disc boundary more accurately with the precision value of 0.9, recall value of 0.966 and F-Score of 0.9383.

TABLE-I
PERFORMANCE EVALUATION OF DISC BOUNDARY BY VARIOUS TECHNIQUES

TECHNICQUES	PRECISION	RECALL	F-SCORE
Hausdorff-based template	0.94	0.716	0.81
Morphological method	0.773	0.836	0.80
Supervised method	0.98	0.70	0.82
SVM	0.85	0.84	0.84
Hough Transform	0.99	0.82	0.90
Fuzzy Convergence	0.99	0.85	0.91
Active contour Method	0.72	0.82	0.81
Proposed Method (Medial Axis Detection)	0.9	0.966	0.9323

V. CONCLUSION & FUTURE WORK

In this paper, we proposed a disk boundary detection using medial axis detection method. First, the LDA method is used to differentiate more clearly to detect the OD more accurately. Next the trench based vessel modeling and ROS based bend detection is used to detect the variation of the vessel thickness. Finally the 2D spline interpolation is applied on detected r bends to smoothen the OD boundary. In this method, it detected OD boundary accurately with precision of 0.9 & recall of 0.966. The F-Score of the detected boundary is 0.9323.

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