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Detection of Glaucoma by Segmenting Retinal Images and evaluating the DDLS stage

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***Abstract*—** Automatic analysis of retina image is important screening tool for early detection of eye diseases. This paper proposes an image processing technique for the detection of stage of glaucoma. The methodology is used to segment optic disc and cup. The method starts with preprocessing of digital fundus image to extract region of interest surrounding optic disc. Hough transform is used to define approximate initial boundary of the optic disc which is then deformed to find out exact optic disc boundary by active contour model. This technique gives effective results to determine rim to disc ratio for detection of glaucoma and thus to detect its DDLS i.e. stage of glaucoma.

Keywords- *Digital Fundus Image; Optic Disc; Cup; Hough Transform; Active Contour*

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I. INTRODUCTION

Glaucoma is a group of diseases that damage the eyes optic nerve results in vision loss and blindness. About 79 million in the world are likely to be afflicted with glaucoma by the year 2020[6]. Glaucoma is not a curable disease. Early detection and prevention is the only way to avoid loss of vision. Optic Disc segmentation is also important for automatic detection of other ophthalmic pathologies. Optic Disc analysis and segmentation can be used to detect evidence of ophthalmic disease such as diabetic retinopathy[3].

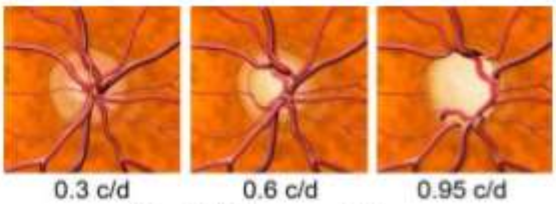

Fig. 1 Enlargement of cup

Retinal optic nerve fibres converge to the optic disc and form a cup-shaped region called as "cup". Enlargement of this optic cup with respect to optic disc as shown in fig.1 is key indicator of glaucoma progression. Ophthalmologists manually examine the digital fundus image and evaluate various parameters to determine progression of glaucoma. Automatic assessment of fundus image could help ophthalmologists for glaucoma detection.

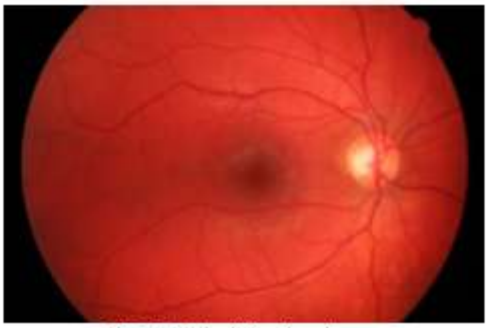

Fig.2 Digital fundus image

A digital fundus image is a projection of retinal structure on 2D color plane where optic disc (OD) appears as a bright circular or elliptic region partially occluded by blood vessels as shown in fig.2. The existing work has mainly focused on finding cup to disc ratio but this system does not consider the influence of optic disc size. The disc damage likelihood scale (DDLS) was devised by Spaeth et al in 2002 to incorporate the effect of disc size and focal rim width[7]. It is highly reproducible and strongly correlates with the degree of field loss. This system categorises the disc as small size (<1.5mm), medium size (1.52.0mm) or large size (>2.0mm) as shown in table I. This ensures that the disc size is considered thus reducing misclassification bias based on disc size [7].

Table I
THE DISC DAMAGE LIKELIHOOD SCALE

Narrowest width of rim (rim/disc ratio)			DDLS Stage
For Small Disc <1.5mm	For Average Size Disc 1.5-2.0mm	For Large Disc >2.00mm	
0.5 or more	0.4 or more	0.3 or more	0a
0.4 to 0.49	0.3 to 0.39	0.2 to 0.29	0b
0.3 to 0.39	0.2 to 0.29	0.1 to 0.19	1
0.2 to 0.29	0.1 to 0.19	less than 0.1	2
0.1 to 0.19	less than 0.1	0 for less than 45^0	3
less than 0.1	0 for less than 45^0	0 for 46^0 to 90^0	4
0 for less than 45^0	0 for 46^0 to 90^0	0 for 91^0 to 180^0	5
0 for 46^0 to 90^0	0 for 91^0 to 180^0	0 for 181^0 to 270^0	6
0 for 91^0 to 180^0	0 for 181^0 to 270^0	0 for more than 270^0	7a
0 for more than 180^0	0 for more than 270^0		7b

II. PROPOSED METHOD

In this method, the measurement of narrowest rim to disc ratio and evaluation of DDLS stage are considered as major parameters for glaucoma detection and they are extracted and evaluated through the designed algorithm as shown below.

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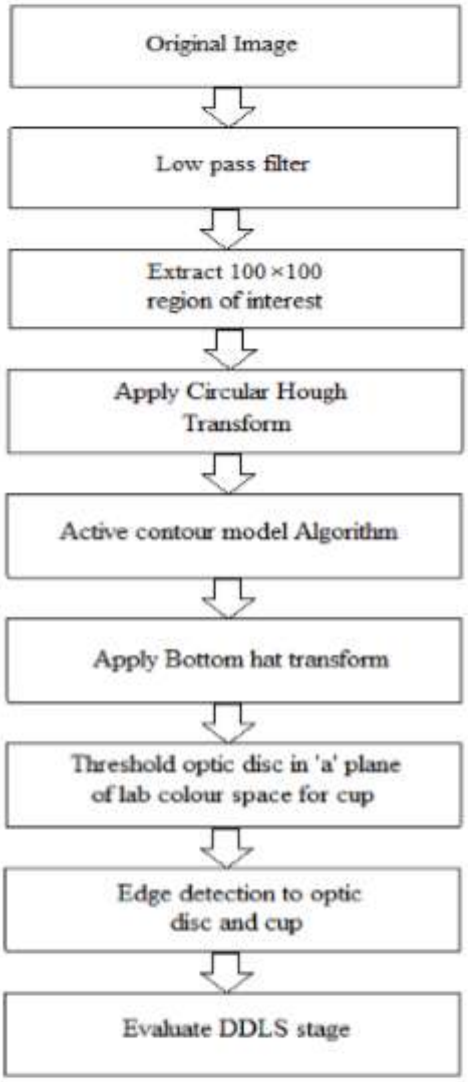

The first step is to extract region of interest i.e. region containing optic disc and its surrounding. Next step is removing blood vessels by bottom hat transform. Next step is to define initial approximate boundary for active contour model algorithm. This initial boundary is determined by applying circular Hough transform. Then, the active contour model algorithm is applied to segment optic disc. A cup is segmented by its contrast in LAB color space and symmetry around optic disc centre. Finally, narrowest rim to disc ratio is calculated and DDLS is evaluated.

A. *Region of Interest*

Initially it is important to extract 100×100 pixels region of interest i.e. optic disc and region surrounding it from digital fundus image.

Low pass filter method: Maximum gray level pixel is extracted from low pass filtered image using this method. Though the OD is generally the brightest area in a retina image, the highest gray level pixel could not be located within it. In many cases, this pixel may be inside other small bright regions. In order to smooth out these distractions, the image I is transformed to the frequency domain and filtered by the Gaussian low-pass filter defined as follows:

$$H(u,v) = e^{-\frac{D^2(u,v)}{2D_0^2}} \qquad - (1)$$

where, D(u,v) is the Euclidean distance between the point (u,v) and the origin of the frequency plane, and D0 is the cutoff frequency with a value of 25 Hz

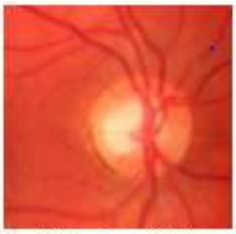

Fig.3 Region of Interest

The highest gray-level pixel in the filtered image returned to the spatial domain is the result of this method. After finding this pixel, we find region of interest by cropping image 100×100 pixel area surrounding this pixel as center as shown in fig.3.

B. *Elimination of blood vessels*

The Bottom Hat Transform is applied to cropped image as using linear structuring element at various angles. Bottom hat transform is the residue between a closing and original image I0 defined as:.

$$\rho_s^\theta(I_0) = \varphi_s^\theta(I_0) - I_0 \qquad - (2)$$

where, φs^θ denotes morphological closing operation with linear structuring element s of orientation θ and I0 is cropped image. The width of linear structuring element is kept equal to width of blood vessels[5].

C. *Segmentation of Optic Disc*

Initial efforts have been taken to segment optic disc with shape based template matching in which optic disc is modeled as circular or elliptical object[1]. This approach suffers because optic disc does not have perfectly circular or elliptical shape in all cases due. Hence, active contour model is proposed to capture shape irregularity in the disc region. The important step is to initialize approximate boundary for active contour evolution. In this method, we define approximate boundary by applying Circular Hough transform on extracted region of interest. We select the circle which has maximum value in the accumulator matrix while performing Circular Hough transform. The circle determined is used as initial approximate boundary for active contour evolution. Active contours are contours that move within images to find exact object boundaries[10]. It begins with the calculation of a field of forces called Gradient Vector Flow (GVF) forces over the image. The GVF forces are used to drive the contour towards the boundaries of the object. The GVF forces are calculated by applying generalized diffusion equations to both components of the gradient of an image edge map. The original snake v(s) is a two dimensional dynamic contour that minimizes the energy function:

$$E = \int_0^1 E_{int}(v(s)) + E_{image}(v(s)) + E_{conv}(v(s))ds - (3)$$

where, Eint denotes the energy of the contour due to bending, the Eimage represents the energy due the intensity of the image and Econ is a constraint energy established by GVF field. The GVF field g(x,y) = (u(x,y), v(x,y)) is defined as equilibrium solution that minimizes the function

$$\varepsilon = \iint \mu\left(u_x^2 + u_y^2 + v_x^2 + v_y^2\right) + |\nabla f|^2 |g - \nabla f|^2 dxdy - (4)$$

where, µ is a parameter that adjusts between the first smoothing term and second data term. In order to find the value of g, it"s necessary to solve the following two Euler equations:

$$\mu\nabla^2 u - (u - f_x)(f_x^2 + f_y^2) = 0 - (5)$$
$$\mu\nabla^2 v - (v - f_y)(f_x^2 + f_y^2) = 0 - (6)$$

where, ∇2 is Laplacian operator. After obtaining the GVF field g(x,y) and substituting as the energy constraint Econ in equation-(3) and computed iteratively to find exact boundary.

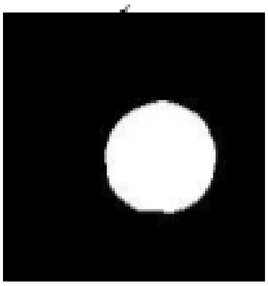

Fig. 4 Optic Disc

After detecting the optic disc boundary, boundary is smoothing operation is carried out. Thus, the optic disc boundary is detected as shown in fig.4.

D. Segmentation of Cup

The segmentation of cup is more challenging than segmentation of optic disc due to high density of vessels traversing the cup boundary. The disc and cup could not be easily distinguished as the border between the two is unclear.

After examining cup in various colour spaces it is found that it shows better contrast in "a" plane of Lab colour space.

For further processing, we take "a" colour plane in which cup region appears dark. A morphological opening with a small circular is carried out to smooth small blood vessels present in the cup region[1]. Then, threshold operation is carried out to segment cup.

E. Evaluation of DDLS stage

The next step is to measure the width of the thinnest part of the rim. This forces the examiner to evaluate the rim throughout its entire circumference in order to identify the area of greatest thinning. For this, Edge detection is done for the optic disc and cup. The measurement is expressed in rim:disc. Where there is no rim present at the thinnest point the value is 0. The circumferential extent of rim absence is then measured in degrees. And then, the DDLS stage is evaluated[7].

III. EXPRIMENTAL RESULTS

First column shows the region of interest, second shows optic disc edge and third shows calculation of DDLS stage.

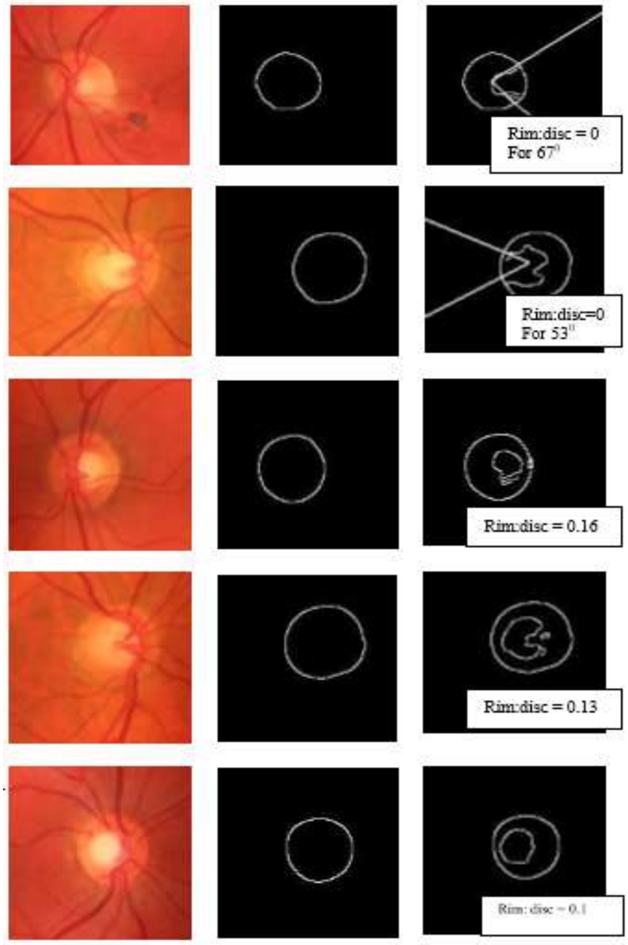

Fig. 5 Results

IV. CONCLUSION

The algorithm for the identification of Glaucoma stage by detecting rim to disc ratio and DDLS stage is developed in this paper. The optic disc is segmented using active contour method. Cup is segmented by doing threshold operation in lab color space. The rim to disc ratio is calculated to determine DDLS stage.

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