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Madhusudan Mishra
Department of Electronics and Electrical Engineering Indian Institute of Technology Guwahati, m.mishra@iitg.ernet.in

Malaya Kumar Nath Mr
I.I.T. Guwahati, INDIA, malaya@iitg.ernet.in

Samarendra Dandapat
Department of Electronics and Electrical Engineering Indian Institute of Technology Guwahati, samaren@iitg.ernet.in

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Glaucoma Detection from Color Fundus Images

Madhusudan Mishra, Malaya Kumar Nath and Samarendra Dandapat
Department of Electronics and Electrical Engineering
Indian Institute of Technology Guwahati
E-mail: m.mishra@iitg.ernet.in, malaya@iitg.ernet.in and samaren@iitg.ernet.in

Abstract—Glaucoma is a pathological condition, progressive neurodegeneration of the optic nerve, which causes vision loss. The damage to the optic nerve occurs due to the increase in pressure within the eye. Glaucoma is evaluated by monitoring intra ocular pressure (IOP), visual field and the optic disc appearance (cup-to-disc ratio). Cup-to disc ratio (CDR) is normally a time invariant feature. Therefore, it is one of the most accepted indicator of this disease and the disease progression. In this paper, active contour method is used to find the CDR from the color fundus images to determine pathological process of glaucoma. The method is applied on 25 nos of color fundus images obtained from optic disc organization UK having normal and pathological images. The proposed technique able to categorize all the glaucoma disease images.

Index Terms—Glaucoma, cup to disc ratio, intra ocular pressure

I. *Introduction*

Eduard Jaeger (1854) described glaucoma as the silent thief of sight which is a specific optic nerve disease with the progressive break down of nerve fibres. It occurs due to the elevated pressure in the optic nerve head. The optic nerve fibres carry the image information to the brain. When a significant number of nerve fibres are damaged by high fluid pressure, blind spot develops in the field of vision and causes permanent vision loss. Fig. 1 [1] shows how the objects are perceived by normal vision and a patient having glaucoma. It is the second leading cause of vision loss in the whole world and its progression is expected to increase [2]. Early diagnosis and optical treatment including a screening examination of the retinal fundus photographs [3] can minimize vision loss. Glaucoma diagnosis is based on the patient's family medical history, thin corneas, high intraocular pressure and manual assessment of the ONH from the color fundus images [4]. One of the glaucomatous changes observed in the color fundus images is the appearance of optic disc (OD)

i.e., enlargement of the depression called cup and thinning of the neuro-retinal rim (shown in Fig 2).

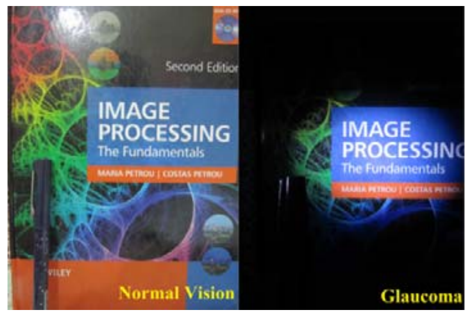

Fig. 1: Normal vision vs. patient having glaucoma [1]

Optic disc (OD) is the brightest feature in a normal fundus image and it has an elliptical shape. It appears bright orange-pink with a pale centre. Orange-pink appearance represents the healthy neuro-retinal tissue. Due to pathologies, the orange-pink color gradually disappears and appears pale. Blood vessels and the optic nerves are emanating out from the OD. Its size is about one seventh of the entire image. The pale centre is devoid of neuroretinal tissue and is called the cup. The vertical size of this cup can be estimated in relation to the disc as a whole and presented as a cup-to-disc ratio. The cup-to-disc ratio (CDR) expresses the proportion of the disc occupied by the cup and it is widely accepted index for the assessment of glaucoma [5]. For normal eye it is found to be 0.3 to 0.5 [4]. As the neuro-retinal degeneration occurs the ratio increases and at the CDR value of 0.8 the vision is lost completely.

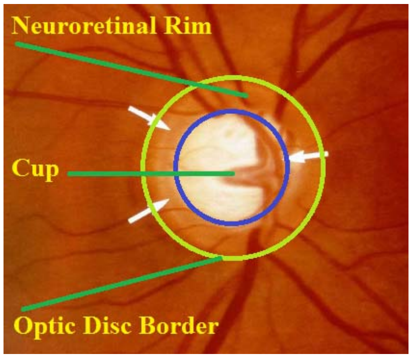

Fig. 2: Optic disc structure

Several studies are reported in the literature for the detection of optic disc and the classification of glaucoma disease. Lalonde *et al.,* uses canny edge detector for detection of OD [6]. Hough-transform is used to find the geometric shapes within an image. Ghafar *et al.,* uses Circular Hough-transform to detect OD [7]. Youssif *et al.,* detects OD by using the blood vessel's direction matched filter [8]. These methods are based on exploiting the edge characteristics. These papers do not discuss about the glaucoma progression or classification. Bock *et al.,* [5] uses the concept of principal component analysis (PCA) for feature extraction and support vector machine (SVM) classifier for glaucoma predication. This method attains an accuracy of 88%.

In this paper active contour model is proposed for detection of glaucoma. The rest of this paper is organized as follows. Section II introduces method for glaucoma detection. Experimental results are shown in Section III and conclusions are presented in Section IV.

II. *Method*

In this work, the cup and the OD are segmented for calculation of CDR and determination of glaucoma. The basic block diagram is shown in Fig. 3. Here the green channel is used for processing, as the red channel is saturated and the blue channel is noisy. The contrast of the blood vessels and the back ground is higher in the green channel.

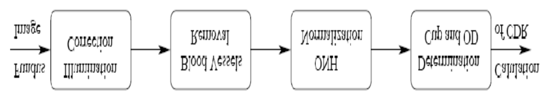

Fig. 3: Steps for glaucoma detection

A. Illumination correction

Due to different visual angles during the image acquisition, the bright speckles are distributed over the images. Due to the curve retinal surface and the geometrical position of the light source and the camera, the peripheral part of the retina appears darker than the central region. This influences the performances of statistical analysis methods for the glaucoma detection [5]. Homogeneously corrected fundus image is obtained by subtracting the estimated background from the original image. In this work, mathematical morphology based illumination correction is used due to its simplicity over linear approaches and it incorporates the geometric interpretation. Morphological opening is used for estimation of the background image.

B. Blood vessels removal

Optic nerve fibres are mainly affected by glaucoma. Vessels are removed as their characteristics (such as diameter, location) are minimally affected by glaucoma. To suppress the behavior of vessels in the fundus image, inpainting of the blood vessels is performed. A large number of vessel segmentation techniques are available in the literature. In this work, morphology based vessel segmentation is used as this method achieves higher accuracy [9].

Blood vessel patches emanating from the ONH covers large proportion of neuroretinal rim and their existence makes the analysis more difficult. So, image inpainting [10] is used to replace the blood vessels regions of the retinal image with plausible background. Fig. 4 shows the output of the inpainting process, where the blood vessels are suppressed. Fig. 4(a) is a normal fundus image. The extracted blood vessels are shown in Fig. 4(b), which is used as a mask for inpainting. Fig. 4(c) is the inpainted image. The inpainted image does not contain any blood vessels. ONH structure changes with glaucoma disease. It is obtained by circular haugh transform [11].

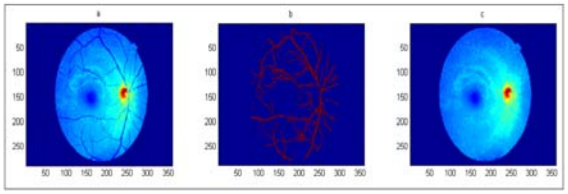

Fig. 4: Inpainting (a) normal Fundus image, (b) extracted blood vessels, (c) inpainted image

C. Detection of cup and OD

The boundary and area of the cup and OD is determined by multi-thresholding and active contour method [12]. The cup is assigned a higher threshold value as compared to the OD. In this work, active contour model is used for detection of cup and OD. The principle is based on the staring of a curve around the object to be detected, which moves inwards and stops at the boundary. Then CDR is calculated by taking the ratio of the area of cup to OD. Fig. 5(a) shows fundus image with glaucoma. The contour of the cup and the disc is shown in Fig. 5(a) and Fig. 5(b) respectively.

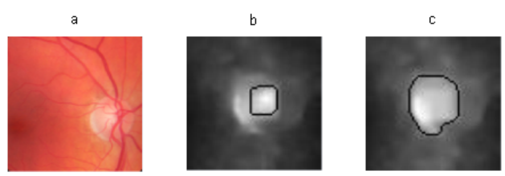

Fig. 5: Detection of cup and disc (a) fundus image, (b) extracted cup, (c) extracted disc

III. *Results*

The above discussed method is applied to the publicly available Messidor and Optic-disc databases. They consist of normal and pathological fundus images. Messidor [13] retinal images are divided into 4 zipped sub sets containing 100 images, with 1488×2240 pixels in TIFF format. The images are acquired with pupil dilation and without pupil dilation. Twenty five images are available from optic-disc organization consist of 7 normal and 18 pathological images. They have 144×144 pixels in JPEG format.

Fig. 6 shows the output of different steps for determination of CDR. Here a normal fundus image is shown (Fig. 6(a)). Then the green channel image is used for further processing as this image has higher contrast between the blood vessels and the background. Blood vessels are extracted by morphological method as it helps in smoothing the images. The extracted blood vessels are shown in Fig. 6(c). Then the cup and disc are determined by thresholding and active contour method. For this image the CDR is found to be 0.43. For normal images CDR is found to be less than 0.5 where as for glaucoma images it is found to be greater than 0.q8. Fig. 5 shows cup and disc for the glaucoma images.

Seven normal and 18 pathological images are taken for the study. The CDR value is correctly determined for all the pathological images. For normal fundus images the CDR value lies between 0.3 to 0.5. For pathological images CDR varies between 0.5 to 0.8.

IV. *Conclusion*

In this paper CDR is determined for both glaucoma affected and normal fundus images. The method fails for some images due to the presence of other pathologies. The CDR value gives the progression about the disease. This approach can be improved by some pre-processing steps.

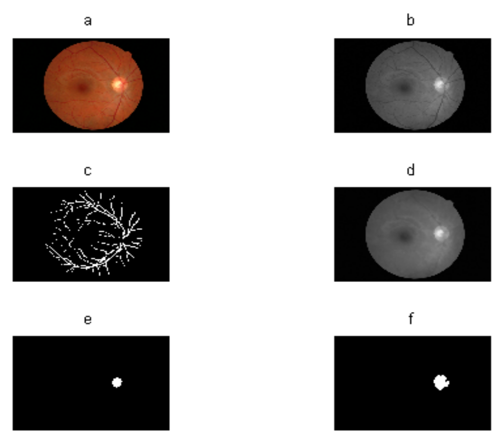

Fig. 6: Determination of CDR, (a) normal fundus image, (b) green channel image, (c) extracted blood vessels, (d) smoothed image, (e) detection of cup, (f) detection of disk

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