Complimentary Method of Detection of Glaucoma based on ROI Pre-Processing and Vessel Segmentation

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Abstract

Glaucoma is one of the most common causes of eye blindness and is becoming more important considering the ageing society. In this paper, the research is focused on novel automated classification system for Glaucoma, based on image features from eye fundus photographs. A new data-driven approach is developed which requires no manual supervision. Our goal is to establish a screening system that allows fast, robust and automated detection of Glaucomatous changes in the eye fundus. A study done already has revealed that the juxtapapillary diameters of the retinal vessels such as superior temporal and inferior temporal artery and vein have been shown to be significantly smaller in Glaucomatous eyes than in normal eyes. This aspect has been used by us for the detection of possible Glaucoma. Firstly, disease independent variations, such as non-uniform illumination, size differences are eliminated from the image of the fundus. Region of Interest around optic disc which contains the mentioned vessels is extracted. Simple vessel segmentation strategy is used for vessel detection. Vessel threshold comparator algorithm predicts the possible presence of the Glaucoma.

Keywords: ROI, vessels, segmentation, vessel-diameters, comparator, threshold

1. Introduction

Glaucoma belongs to group of eye diseases that can steal sight without warning or symptoms. The alarming fact about Glaucoma is that it may lead to blindness. Nearly half of those with Glaucoma do not know they have the disease. This has been shown repeatedly in studies conducted in developed countries. Glaucoma is a potentially blinding disease that affecting more than 66 million persons worldwide. It is the second leading cause of blindness worldwide. In the healthy eye, a clear fluid called aqueous humor circulates inside the front portion of eye. To maintain a constant healthy eye pressure, eye continually produces a small amount of aqueous humor while an equal amount of this fluid flows out of your eye.

In case of Glaucoma, the aqueous humor does not flow out of the eye properly. Fluid pressure in the eye builds up and, over time, causes damage to the optic nerve fibers. Glaucoma is an eye disorder that characterized by elevated Intraocular Pressure (IOP). This increased IOP leads to damage of the optic nerve head. Hence, the disease is characterized by typical changes in the optic nerve with associated visual field defects\[8\] (the area seen by the eye). Since the outer portion of the visual field is the first to be affected and most types of Glaucoma are asymptomatic, the disease is often diagnosed once significant vision/field has been lost. The most common types of Glaucoma can cause slow and silent loss of vision over years and hence early detection of the disease is extremely important. A study has revealed that the juxtapapillary diameters of the retinal vessels such as superior temporal and inferior temporal artery and vein have been shown to be significantly smaller in glaucomatous eyes than in normal eye \[1\], \[4\],\[5\],\[6\], \[7\], \[8\], \[9\], \[10\]. The differences were most marked for the inferior temporal retinal artery, followed by the superior temporal artery, the inferior temporal vein and finally the
superior temporal vein (refer Fig. 1). This reduction in vessel diameters is used to detect the presence of disease in our paper.

![Image showing various vessels](image)

**Fig. 1.** Eye fundus image showing various vessels.

1.1. **Current techniques of detecting Glaucoma**

Following general abnormalities may be observed in the eye affected by Glaucoma.

(i) IOP of eye will not be in the normal range of 10 mm Hg to 22 mm Hg. This is verified in Tonometer test. (ii) Optic nerve looks unusual, Ophthalmoscope is used to check this entity. (iii) There may be some blind spots in the vision area. Perimetry test reveals this.

![Image of healthy and Glaucoma affected eye](image)

**Fig. 2.** Fundus image of healthy eye showing the Optic Disc and Cup areas. **Fig. 3.** Fundus image of Glaucoma affected eye with enlarged Optic Disc.

Further, in the presence of Glaucoma the optic cup area of the eye enlarges and progresses towards the optic disc. Fig. 2 and 3 shows this distinction between the healthy and Glaucoma affected eye fundus images. The Cup-to-Disc diameter Ratio (CDR) is a measurement used in ophthalmology to assess the progression of Glaucoma. If the CDR value is greater than 0.5, the patient has a threat of Glaucoma. The CDR of image in Fig. 3 is nearly 0.8 and it is a prominent case of Glaucoma. Recently automated eye fundus based image processing systems are being developed which predict the Glaucoma by measuring CDR or optic cup structure [2], [3], [13] and [14].

We have developed a complimentary methodology of detecting the probable presence of Glaucoma by measuring the reduction of the thickness of the arteries and veins from the fundus image using image processing techniques, which is presented in the following section.

2. **Proposed methodology of Glaucoma detection**

![Diagram of proposed system](image)

**Fig. 4.** Block schematic of Proposed System

The proposed methodology of the system is represented in a block schematic as shown in Fig. 4. To start with fundus image of the eye is obtained using the camera. A sample image is shown in Fig. 5. The bright area in the image is the optic disc image and area around the optic disc is the significant area where the optic vessels diameters are to be measured for the detection of Glaucoma. This area is called as Region of Interest (ROI) is extracted in Pre-processing stage. The images of the prominent vessels are extracted from ROI and their diameters are measured in the next stage. Finally, the possible presence of the Glaucoma is declared by comparing the vessel diameters with the vessel diameters of the healthy eyes.

2.1. **ROI Pre-processing**

This is the unique feature of the system. Firstly, the colour image of the eye fundus is converted to Gray scale image. Samples are as shown in Fig. 5.

![True Color and Gray image](image)

**Fig. 5.** True Color and Gray image of eye fundus

A median filter is used to make the background of the image uniform which improves the contrast of the vessels image. This helps in segmentation of the vessels from the fundus image. Median filter is a sliding-window spatial filter which replaces the center value in the window with the median of all the pixel values in the window. It is a nonlinear operation often used to reduce the impulse noise and it is more effective than convolution when the goal is to simultaneously reduce noise and preserve edges. Optic cup in eye fundus is the brightest area. Its intensity is used as reference and the ROI is extracted.
2.2. Vessel Segmentation and Diameter measurement

ROI region contains the optic cup and disc with maximum brightness. Since the interest of measurement lies only with the vessels images, the brightness of optic disc area is eliminated and the intensity of whole background area of ROI is made uniform (dark), thereby eliminating the effect of optic disc brightness.

Further, the image is processed to obtain an image which depicts only vessels in a uniform background. For this process we have used the Isotropic Un-decimated Wavelet Transform (IUWT)[12], which is a redundant and powerful wavelet transform as suggested by Peter Bankhead, C. Norman Scholfield, J. Graham McGeown, Tim M. Curtis [3]. The effect of applying the IUWT to a fundus image is shown in Fig. 6 and Fig. 7. The set of wavelet coefficients generated at each iteration is referred to as a wavelet level, and one may see that larger features (including vessels) are visible with improved contrast on higher wavelet levels. By using a threshold value small branches of the main vessels are eliminated from the image.

The overall effect of applying the IUWT to a fundus image from the database is shown in Fig. 8.

Vessel diameter measurement process involves (i) Thinning operation of retinal vessels (ii) Centre line refinement of vessels using Spline fitting algorithm (iii) Vessel edge identification and (iv) Vessel diameter measurement using Euclidean distance measurement.

2.2.1. Thinning

Thinning algorithm iteratively removes exterior pixels from the detected vessels, resulting in a connected lines running along the vessel centres. The number of ‘on’ neighbours for each of these pixels is counted. End pixels are identified, and branch pixels are removed.

2.2.2. Centre line refinement

Vessel border can be estimated from centre line orientation of each vessel segment. A least-squares cubic spline, approach as discussed by Lee [11] is used to obtain a smooth centre line.

2.2.3. Vessel border identification

Vessel borders are determined on the basis of pixel intensity profile along vessel cross-sections. Unless the vessels intersect, borders can be computed from center lines. For each center line pixel Cj, its perpendicular pixel along the border Dj is computed as shown in Fig. 9.

2.2.4. Vessel Diameter Measurement

Vessel diameter estimation is simplified once the vessel borders are smoothened. Thus, multiple diameter measurements along the same vessel will not present a high standard deviation any longer. The vessel diameter at point Cj lying on the centre line is estimated by computing the Euclidean distance between points Dj and Ej as shown in Fig. 10. Dj and Ej are the points belonging to the two refined borders and lying orthogonal to the centre line at Cj.
2.3. Vessel threshold comparator

It is already proven that the diameters of the inferior temporal vein decreases about 16.7% and the inferior temporal artery diameter reduces to about 28.8% in case of Glaucoma affected eyes [1].

We collected fundus image samples from the Ophthalmology department of K. L. E. Society’s Dr.Prabhakar Kore Hospital & M.R.C., Belgaum for the different age groups and studied the diameter of the vessel having the highest diameter. The variation of the vessel diameter in terms of pixel value is plotted for the different Glaucoma affected eyes for age group of 50-65 years and 65-80 years as shown in Fig. 11 and Fig. 12. From the plots a threshold value is determined to take it as reference to detect Glaucoma. Following equations were developed for the two plots, respectively.

\[ P = 98.3744 - 0.722x \]
\[ P = 74.0925 - 0.4139x \]

Given the age, particular equation (1) or (2) is selected and value of \( P \) is determined. Then, for a given test eye, its diameter is measured and compared with the value of \( P \). If it is equal to or less than \( P \), we declare that the eye under test may have developed Glaucoma.

3. Conclusion

Using image processing technique, previously Glaucoma detection has been done via optic cup to disc ratio determination and structure of optic cup [2], [3] and [14]. Glaucoma detection has been also done using ultrasound images of the eye [13]. The methodology developed by us can well be applied as an alternative method to aid the Glaucoma identification.

Vessel diameter measurements not only indicate the presence of Glaucoma but can be useful for clinical diagnosis of cerebrovascular disease[15], diabetes Arteriosclerosis and Hypertension. In fact, Diabetic Retinopathy is a disease that may cause visual impairments in patients suffering from diabetes mellitus which, after several years, could even lead to blindness. Obtaining a binary vessel map from retinal images proves to be useful for many different purposes: among others, the evaluation of vessel tortuosity, often regarded as a symptom of systemic hypertension, and the measurement of vessel diameter as a bio-marker for cardiovascular diseases. Hence, the development of a computerized system for retinal vessel segmentation and its diameter measurement would be of great benefit to improve the efficacy of ophthalmologists work, helping them in the diagnosis of some degenerative pathologies.

We are proposing to extend our studies by collecting some more fundus images of persons from different regions and apply our methodology to make the system robust.

Fig.11. Diameter variation for 50-65 years age group.

Fig.12. Diameter variation for 65-80 age group.

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