AN APPROACH FOR DETECTION OF PRIMARY OPEN ANGLE GLAUCOMA

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ABSTRACT

In this paper the research is focused on novel automated classification system for primary open angle glaucoma, based on image features from fundus photographs. Glaucoma is one of the most common causes of eye blindness and is becoming even more important considering the ageing society. A new data-driven approach is developed which requires no manual supervision. Here, 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 is used by us for Glaucoma suspect Detection. Firstly, disease independent variations, such as nonuniform illumination, size differences, are eliminated from the images. Region of Interest around Optic disc which contains the mentioned vessels is extracted via Pre-processing algorithm. Simple vessel segmentation strategy is used for vessel detection. Vessel Threshold comparator algorithm predicts the suspect of disease using vessel diameter constraints.

Keywords: ROI, Vessels, Segmentation, Vessel-Diameters, Comparator.

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. It can be roughly divided into two main categories, "open-angle" and "closed-angle" Glaucoma. 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. Primary Open angle 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 (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 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 eye[1]. 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. In the current work this reduction in vessel diameters is used to detect the presence of disease.

1.1 CURRENT TECHNIQUES TO DETECT PRIMARY OPEN ANGLE GLAUCOMA

Regular Glaucoma check-ups include two routine eye tests: Tonometry and Ophthalmoscopy. The Tonometry test measures the intraocular pressure (IOP) of the eye. The normal range of this IOP is in between 10 mmHg and 22 mmHg. Ophthalmoscope is used to examine the inside portion of the eye, especially the optic nerve. This helps the doctor look at the shape and color of the optic nerve. If the pressure in the eye is not in the normal range (10mmHg to 22mmHg), or if the optic nerve looks unusual, then Perimetry test is performed. This helps doctor to detect the blind spots caused by Glaucoma & to interpret the presence of it. Most often, Perimetry testing is done with a machine that determines the person's ability to see small dots of light in all areas of the visual field. Recently automated eye fundus based image processing systems are being developed which predict the suspect of Glaucoma based on optic cup to disc ratio or optic disc structure detection[2]. These all methods involve segmentation of optic disc portion by eliminating retinal vessels from eye fundus image.

In our proposed methodology of Primary Open Glaucoma detection, we propose an complimentary method of eliminating optic disc from eye fundus image & vessel segmentation is used which is the unique feature of the system which helps to detect the disease.

2. IMPLEMENTATION

![Block Diagram Of The System](image-url)
Block diagram of the proposed system is shown in Fig.1. To start with fundus image of the eye is obtained using the camera. As mentioned in introduction the juxtapapillary diameters of the vessels such as superior temporal and inferior temporal retinal artery and vein have been shown to be significantly smaller in glaucomatous eyes than in normal eyes[1]. Significant diameters which can be measured are present around the area of optic disc. This area is extracted in ROI (Region of Interest) Preprocessing. Vessel segmentation consists of obtaining binary map of vessels from the o/p of preceding stage. Vessel diameter measurement is also done. Vessel threshold comparator predicts the suspect of Glaucoma depending upon the diameters.

2.1 ROI Pre-processing

This is the unique feature of the system. Firstly, the color image is converted to Gray scale image as shown in Fig.2 & Fig.3. The 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. Median filtering is a nonlinear operation often used to reduce the impulse noise (outlying values, either high or low). A median filter is more effective than convolution when the goal is to simultaneously reduce noise and preserve edges. Optic cup in eye fundus image is the brightest area. Significant diameters which can be measured are present in and around this optic cup and it is the Region of Interest. Intensity of optic cup is taken as reference and 15% of area including the optic cup is extracted from image. Extracted image is again converted to RGB format. The algorithm used is shown in Fig.4. and extracted image is shown in Fig.5.
2.2 Vessel Segmentation & Diameter measurement

ROI is subjected to suitable mask and Binary image containing only vessels is extracted. The Isotropic Un-decimated Wavelet Transform (IUWT) is a powerful, redundant wavelet transform which is used[11]. The effect of applying the IUWT to a fundus image is shown in Fig.6. & 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. Segmentation can then be carried out very simply by adding the wavelet levels exhibiting the best contrast for vessels and thresholding based upon a percentage of valued coefficients. We set the threshold to identify the lowest 30% of coefficients as vessels. Objects less than 0.05% of value are removed.

The overall effect of applying the IUWT to a fundus image from the database is shown in Fig.8.
Vessel diameter Measurement can be put in terms of algorithm as shown in fig.9.

![Fig.9. Vessel Caliber measurement](image)

### 2.2.1 Thining
Segmented image is subjected to morphological thinning algorithm. It iteratively removes exterior pixels from the detected vessels, finally resulting in a new binary image containing connected lines of ‘on’ pixels running along the vessel centers. The number of ‘on’ neighbors for each of these pixels is counted. End pixels are identified, and branch pixels are removed. The removal of branches divides the vascular tree into individual vessel segments in preparation for later analysis. This is useful because diameters are not well-defined at branches, and also because diameters measured before a significant branch or bifurcation are not directly comparable with those measured afterwards, as less blood will flow through the vessel afterwards and there will be a drop in pressure.

### 2.2.2 Centre line refinement using spline fitting
The orientation of a vessel segment at any point could be estimated directly from its centre line, but discrete pixel coordinates are not well suited for the computation of angles. A least-squares cubic spline (in piecewise polynomial form) is therefore fitted to each centre line to combine some smoothing with the ability to evaluate accurate derivatives (and hence vessel orientations) at any location. A parametric spline curve is required, with appropriate parameterization essential to obtain a smooth centre line. For this we used the centripetal scheme described by Lee [12].

### 2.2.3 Vessel Edge identification
The next step is to extract vessel border points from the binary retinal maps starting from the spline-smoothed centreline and the preliminary vessel widths already computed. The goal is to identify vessel edges using the information given by pixel intensity profile along vessel cross-sections. The refined centerline is smooth enough to compute reliably, most of the times, orthogonal...
segments that do not intersect each other. Hence, for each centreline pixel Cj, the perpendicular dj is computed.

\[ d_j = \sqrt{(x - a)^2 + (y - b)^2} \]  

2.2.4 Vessel Diameter Measurement

The contours refinement method proposed improves vessel width estimations in binary images since vascular boundaries are smoothed and the typical indentation of binary edges is removed. Thus, multiple diameter measurements along the same vessel will not present a high standard deviation any longer. The vessel width at point Cj lying on the spline-smoothed centre line is estimated computing the Euclidean distance between points Dj and Ej; these are the points belonging to the two refined contours and lying on segment Dj, orthogonal to centre line at Cj. We know that according to the Euclidean distance formula, the distance between two points in the plane with coordinates (x, y) and (a, b) is given by

\[ d = \sqrt{(x - a)^2 + (y - b)^2} \]  

This distance itself is the diameter of interest.

2.3 Vessel Threshold Comparator

It was found that the inferior temporal vein decreased from 0.137±0.020mm (mean and standard deviation) in the normal eyes to 0.125±0.025 mm in the glaucoma group [1]. Presuming a tube-like form, this represents a decrease of the vessel cross-section area of 16.7% compared with 28.8% for the cross-section reduction of the inferior temporal artery (diameter in normal eyes: 0.109±0.019 mm; glaucomatous eyes: 0.092 ± 0.023 mm). The discrepancy between the
decrease of artery and vein cross section might be caused by a clinically asymptomatic engorgement of the venous blood flowing in glaucoma. This observation is put as Threshold to check the threat of Primary Open Angle Glaucoma. If diameter is within the threshold limits message is displayed as “Suspect of Primary Open Angle Glaucoma”.

3. RESULTS

Algorithm is implemented using the Matlab (R2010a, The Mathworks), using only the functions offered by image processing toolbox.

![Image](image.png)

**Fig.12.** Output indicating Glaucoma suspect

Depending upon the samples collected with Probability of 0.01 the diameter variation for different ages as given by the system was as given in Figures 13 & 14.

![Image](image.png)

**Fig.13.** Diameter variation during Training for 50-65 age group

With a probability mentioned previously variation was found to follow the equation

\[ P = 98.3744 - 0.722x \]  (2)

where x is the age. This was used to decide the threshold for the respective age group
Fig. 14. Diameter variation during Training for 65-80 age group

Here the variation followed the equation

\[ P = 74.0925 - 0.4139x \]  \hspace{1cm} (3)

Where \( x \) is the age.

Fig. 15. shows the observations found by our Glaucoma classifier

<table>
<thead>
<tr>
<th>Age</th>
<th>Mean Diameter observed during training of Classifier for Superior/ Inferior temporal retinal artery (in terms of Pixel width) for patients with glaucoma</th>
<th>Threshold set for Classifier in terms of Pixel width</th>
<th>Decision if Diameter is below threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>65 to 80 years</td>
<td>45±10 units</td>
<td>50±10</td>
<td>Glaucoma suspect</td>
</tr>
<tr>
<td>50 to 65 years</td>
<td>65±10 units</td>
<td>60±10</td>
<td>Glaucoma suspect</td>
</tr>
</tbody>
</table>

Fig. 15. Table showing results of Experimentation

4. CONCLUSION

Previously Glaucoma detection has been done via optic cup to disc ratio determination and structure of optic cup[2] and [14]. Ultrasound images of the eye are analyzed to detect the structural changes in eye[13]. Our method can well be applied as an alternative method to aid the Glaucoma suspect identification.

Vessel caliber measurements not only indicate presence of glaucoma but can be useful for clinical diagnosis of 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 caliber as a bio- marker for cardiovascular diseases. Hence, the developing of a computerized system for retinal
vessel segmentation would be of great benefit to improve the efficacy of ophthalmologists work, helping them in the diagnosis of some degenerative pathologies.

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