AUTOMATIC DETECTION OF GLAUCOMA BASED ON CUP - DISK RATIO WITH POLAR SEGMENTATION

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ABSTRACT —This paper proposes a new method for the detection of glaucoma using fundus image. Glaucoma is a disease related with human eyes. Now-a-days detection of glaucoma is the most important research topic in medical field. It is the second leading cause of blindness in the world and it has no cure. Glaucoma has different types, they are normal tension, open angle, close angle etc. Normal tension affects the vision field and damage the optic nerve as well. The term angle means distance between iris and cornea. If the distance is large then it is referred as open angle glaucoma. Similarly if the distance between iris and cornea is short, that is referred as close angle glaucoma. Close angle glaucoma is very painful and it reduces the vision field of eye very quickly. Currently there are treatments are available to prevent vision loss but the disease must be detected in the early stage. One of the main advantage of this method is its fast processing time and accuracy. The main objective of this project is to develop an automatic detection method of glaucoma in retinal images based on Cup-Disk ratio identification and the methodologies used in this project are optic disc and optic cup localization and segmentation using Circular Hough Transform and Polar Transform.

Keywords— Glaucoma, Retinal image analysis, Optic Disk detection, Hough Transform and ROI calculation, segmentation, CDR (Cup to Disk Ratio) identification, polar transform.

INTRODUCTION

Nobody can imagine that how the world will world if we are losing our eyesight to a silent disease called Glaucoma. It has been nicknamed the "sneak thief of sight" because it often goes undetected and causes irreversible damage to the eye. Glaucoma is the term for a diverse group of eye diseases. Glaucoma is a serious ocular, chronic, irreversible neurodegenerative disease. It is one of the common causes of blindness with about 79 million in the world likely to be afflicted with glaucoma by the year 2020.It is a significant cause of blindness in the world. The incidence of glaucoma increases with age but the disease is more prevalent among individuals with a family history of glaucoma. It can occur at any age and can lead to permanent vision loss and blindness.

Glaucoma produces gradual and progressive visual field loss that results from a progressive loss of optic nerve fibers at the back of the eye. This causes damage to the eye tissues and the optic nerve, which contains more than a million nerve fibers. Optic nerve connects the eye to the brain. This important nerve is responsible for carrying images to the brain. The optic nerve fibers make up a part of the retina that gives us sight. This nerve fiber layer can be damaged when the pressure of the eye (intraocular pressure) becomes too high.

Over time, high pressure causes the nerve fibers to die, resulting in decreased vision. Vision loss and blindness will likely result if glaucoma is left untreated. Glaucoma produces gradual and progressive visual field loss that results from a progressive loss of optic nerve fibers. . If not detected in the early stage, glaucoma can result in partial or total blindness.

Clinically, the disease initially results in peripheral and subsequently central vision loss. There are usually no symptoms in the early stages of the disease. As the disease progresses, vision seems to fluctuate and peripheral vision fails. If left untreated, vision can be reduced to tunnel vision and eventually, total blindness. It is characterized by the progressive degeneration of optic nerve fibers and leads to structural changes of the optic nerve head, which is also referred as optic disk, the nerve fiber layer and a simultaneous functional failure of the visual field. Since, glaucoma is asymptomatic in the early stages and the associated vision loss cannot be restored, its early detection and subsequent treatment is essential to prevent visual damage.

The optic disk (OD) is the location where ganglion cell axons exit the eye to form the optic nerve. There have been efforts to automatically detect glaucoma from 3-D images. However, due to their high cost they are generally unavailable at primary care centers and hence a solution built around these imaging equipment is not appropriate for a large-scale screening program. Glaucoma treatments include medicines, laser trabeculoplasty (draining of fluid), conventional surgery, or a combination of any of these. Although these treatments may help to save remaining vision, they do not improve sight already lost from glaucoma.

Laser trabeculoplasty and conventional surgery also reduce intraocular pressure by draining fluid from the eye. Unfortunately early diagnosis of glaucoma with high specificity and sensitivity using standard clinical diagnostic instrumentation remains problematic. In this project the ratio between optic cup to disk is estimated by using polar segmentation which make use of early diagnosis in glaucoma detection with fast processing time.

II RELATED WORK

Glaucoma is a corporate terminus for a composite radical of circumstances that have reformist ocular pathology ensuing sight loss. Retinal nerve fiber layer defect (NFLD) is one of the most important findings for the diagnosis of glaucoma reported by ophthalmologists. However, such changes could be overlooked, especially in mass screenings, because ophthalmologists have limited time to search for a number of different changes for the diagnosis of various diseases such as diabetes, hypertension and glaucoma [1]. The texture analysis of the retinal nerve fiber layer (RNFL) in color fundus images is a promising tool for early glaucoma diagnosis. The method utilizes Gaussian Markov random fields (GMRF) and the least square error (LSE) estimate for the local RNFL texture modelling [2].

Glaucoma is a disease characterized by elevated intraocular pressure (IOP). This increased IOP leads to damage of optic nerve axons at the back of the eye, with eventual deterioration of vision. CDR is a key indicator for the detection of glaucoma. The ratio of the size of the optic cup to the optic disc, also known as the cup to-disc ratio (CDR), is one of the important clinical indicators of glaucoma, and is currently determined manually by trained ophthalmologists, limiting its potential in mass screening for early detection [3]. An automatic detection method of Glaucoma in retinal images were also developed [4]. The ratio of the optic cup to disc (CDR) in retinal fundus images is one of the primary physiological parameter for the diagnosis of glaucoma. The K-means clustering technique is recursively applied to extract the optic disc and optic cup region and an elliptical fitting technique is applied to find the CDR values. The blood vessels in the optic disc region are detected by using local entropy thresholding approach. The ratio of area of blood vessels in the inferior superior side to area of blood vessels in the nasal-temporal side (ISNT) is combined with the CDR for the classification of fundus image as normal or glaucoma by using K-Nearest neighbour, Support Vector Machine and Bayes classifier [5].

A novel method is proposed for the early detection of glaucoma using a combination of magnitude and phase features from the digital fundus images [6]. The pressure inside the normal eye is below 21mm of Hg. When the pressure inside the eye(s) increases more than 21mm of Hg, the optic nerve is damaged. By measuring the colour pixels in the affected area the observation shows that the person is suffering from Glaucoma or not [7]. Detection of the ratio of optic cup to disk radius is a significant diagnostic task, a major role is being handled by the computer assistance. The optic disk has been found by using red color space image as the optic disk is brighter considering to the other macula region and the contours are identified by means of morphological reconstruction techniques [8].

The major challenge in Retina image analysis is to obtain the boundary and the area mask of cup and disk. Automated detection of cup and disk area demands sophisticated morphological and image processing applications to make the boundary more prominent and hence detectable with higher accuracy [9]. Manual grading and analysis of the RetCam image is subjective and time consuming. A system for intelligent analysis of iridocorneal angle images, which can differentiate closed angle glaucoma from open angle glaucoma automatically [10].

III . PROPOSED METHOD

Early detection of Glaucoma through automated retinal image analysis helps in preventing vision loss. Optic disk (OD) and optic cup (OC) segmentation from retinal images is the preliminary step in developing the diagnostic tool for early Glaucoma detection. The proposed methodology is aimed at contributing to the development of computer assisted system for Glaucoma screening. There are other published methods of OD and OC (Optic Cup) segmentation available in literature but this methodology is computationally fast, produces higher accuracy, robustness and tolerant to vast variety of images which make it suitable for integration with Glaucoma detection system.

Fig 3.1 Retinal fundus image

3.1 PROPOSED METHODOLOGY

This work presents an automated Optic Disc and Optic Cup localization and segmentation technique. For the segmentation of OD boundary, the first step is to approximate the OD center. Optic Disc appears as the brightest spot in the retinal fundus images but the presence of artifacts can create multiple bright spots. Pathologies in fundus images can take shape of OD while actual OD could lose its brightness. The shape of the OD varies from circular to elliptical. This information about the shape of the OD can be used for the detection of OD. The proposed methodology preprocesses the image to remove vessels and enhance the OD boundary using morphological operations. CHT is used for both OC and OD localization. Spatial to polar transform is applied to convert circular region of interest. This polar segmentation uses a novel segmentation algorithm to segment both optic disk and optic cup. Finally ratio between these two are calculated. If the ratio between Optic Cup and Optic Disk is less than 0.3 then the image is not glaucomatous. Otherwise if the ratio between OC to OD is greater than 0.3 then the image is noted as glaucomatous.

3.2 PREPOCESSING

Varying conditions during image capture, noise, uneven illumination and contrast variations are the added challenges of automated optic disc detection and segmentation. In order to handle these images autonomously, preprocessing has to be applied.

3.2.1 Histogram Matching

Histogram matching is the first step in preprocessing stage**.** Histogram matching or histogram specification is the transformation of an image so that its histogram matches a specified histogram. The well-known histogram equalization method is a special case in which the specified histogram is uniformly distributed.

Histogram Matching has been applied to for normalizing the image variations. The histogram of properly illuminated image is taken as reference and the other image's histograms are matched with it which resulted in normalized illumination and color tone. Red channel was chosen as it

3.2.2 Background Normalization

Background normalization is then performed by subtracting the image with the estimate of background. The estimate of background Ibg is calculated by filtering the image with a large arithmetic mean kernel such that the filtered image doesn't contain any visible structures. Original image is also morphologically opened using a 'disk' shaped structuring element with a size 1/100th the size of the original image to obtain I-open. Background normalized image I-normalized is the difference of opened image and the background estimate.

$$I_{normalized} = I_{open} - I_{bg} \quad (1)$$

3.3 OPTIC DISK LOCALIZATION

OD localization from preprocessed images is done by applying CHT (Circular Hough Transform). This step requires a radius search range of min radius and a max radius. Max and min radius are approximated to be 1/30th to 1/10th of the image width. The output of the transform contains all the circles that are present in the given range. The circle with the highest score is kept.

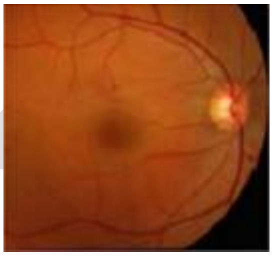

Fig 3.2 OD localization using CHT

3.4 OPTIC DISK AND OPTIC CUP SEGMENTATION

For the precise segmentation of the Optic Disc, a region of interest (ROI) is extracted from the original image ''I_orig''. The size of ''I_roi'' from ''I_orig'' is calculated as described by following equation

$$roisize = r + buff \quad (2)$$

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Where, r is the radius of the circle approximated by the CHT and buff is the number of extra pixels that are not part of the OD. ROI is centered on the circle center approximated by the CHT. ROI contains Optic Disc pixels surrounded by non-OD pixels. The next task is to find precise boundary between OD pixels and non-OD pixels. Direct thresholding techniques does not yield good results as the gray level distribution of the OD and non-OD regions is not uniform and applying a global threshold fails. Applying a local threshold on a neighborhood of pixels also does not return good results because of the circular nature of the OD. To overcome these issues, a novel OD segmentation technique is proposed that makes use of Polar Transform.

Polar transform can be defined as a 2D coordinate system where every point is calculated using distance from a reference point and an angle from a reference direction. Polar transform has been used a lot in automated segmentation of iris from image as is done.

For OD segmentation, the ROI image is calculated and ROI's pixel coordinates are converted from Cartesian to Polar coordinates. The origin point is the center of the ROI image. Due to this transformation, the OD is now straightened. Next this straightened OD is divided in to sub-tiles. Morphological erosion by reconstruction is applied on each tile followed by morphological dilation by reconstruction. At this step, since precise boundary of the Optic Disc is needed, morphological opening and closing is avoided to remove the structures in the retina that are to be used as the end boundary points to distinguish between Optic Disc pixels and the rest of the image. Opening by reconstruction preserves the shape of the components.

After application of opening by reconstruction, each tile is then thresholded using adaptive thresholding. If the output tile is successfully thresholded in to two regions, it is forwarded to the next step as is. If not, then a blank tile (all black) is forwarded. The tiles are then combined and Polar to Cartesian transformation is applied. Similarly, for Optic cup segmentation the same procedure is followed. Ellipse fitting is then performed using ellipse equation in which the boundary obtained via thresholding is used to draw an ellipse over it. This gives the precise OD boundary and the Optic Cup.

3.5 ELLIPSE FITTING

Finally, ellipse fitting is performed by using ellipse equation in which the boundary obtained via thresholding is used to draw an ellipse over it. This gives the precise OD boundary and the Optic Cup of fundus image.

3.6 CLASSIFICATION OF OPTIC DISK PIXELS

	Algorithm predicted pixel $\in$ OD	Algorithm predicted pixel $\notin$ OD
Actual pixel $\in$ OD	True Positive (TP)	False Positive (FP)
Actual pixel $\notin$ OD	False Negative (FN)	True Negative (TN)

IV. EXPERIMENTS AND RESULTS

The methodology is evaluated on publically available datasets of fundus of eye. Among which one input is taken for detecting glaucoma. The following figures gives the description regarding outputs obtained at each stage.

4.1 HISTOGRAM MATCHING

Initially, a reference image is taken for histogram matching. Histogram of input image and the reference image is matched to obtain accurate output.

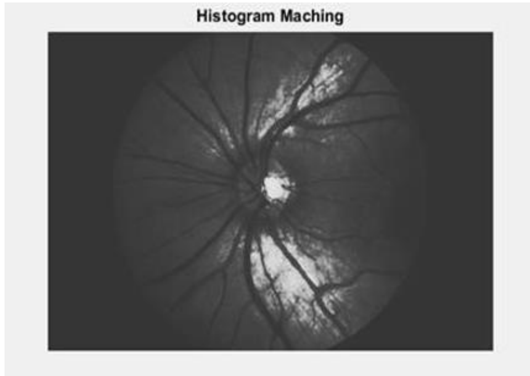

Fig 4.1 Histogram matched output

4.2 BACKGROUND NORMALIZATION

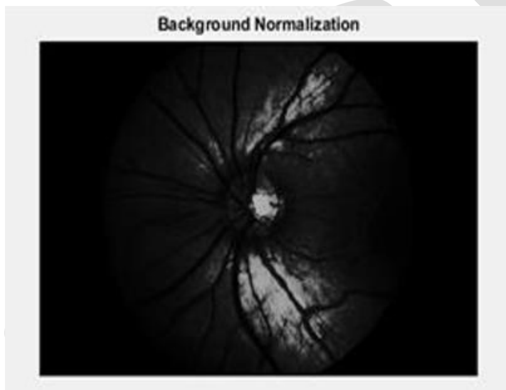

Fig 4.2 Background normalized image

Fig.4.2 gives the background normalized image. By completing this preprocessing stage an output of Background normalization is then performed by subtracting the image with the estimate of background. The estimate of background Ibg is calculated by filtering the image with a large arithmetic mean kernel such that the filtered image doesn't contain any visible structures.

4.3 OUTPUT

The final output of glaucoma detection is shown in figure 4.3. This image provides accurate Optic Disk and Optic Cup and the ratio between these two outputs are taken by using mathematical approach.

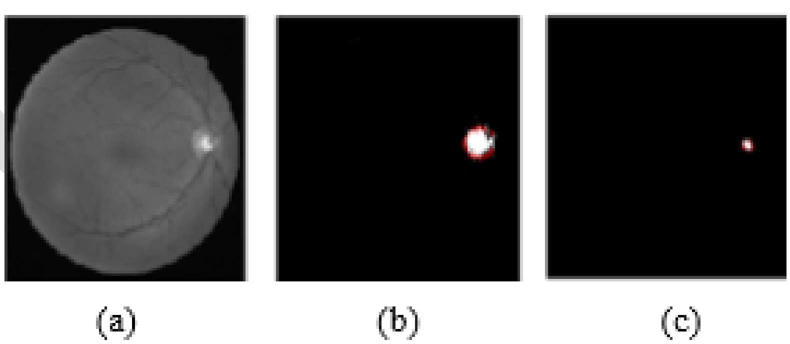

Fig a) input image b) Optic Cup c) Optic disk

4.4 COMPARISON CHART

The given table 1.1 gives the detailed results of corresponding authors for their experiment with the detection of glaucoma by using various methods. By seeing the table we can understand that the proposed work perfoms in a better way by means of sensitivity , specificity , time and accuracy.

Table 1.1 Comparison with existing methods

Author Name	Sensitivity	Specificity	Accuracy	Time(Sec)
A. Basit and M. M Franz 2015 [1] (Morphological Operations)	0.891	0.991	This parameter is not Considered	This parameter is not Considered
Sopharak and Uyanonvara 2008 [2] (Mathematical Morphology Method)	0.213	0.938	This parameter is not Considered	14.92
M. Abdullah ana M Fraz 2016[21] (Circular Hough Transform and grow – cut Algorithm)	0.812	0.991	0.961	52.2
Karthekeyan Sakthivel and Ragurajan narayanan 2015[10] (Local Binary Pattern and Dugman's Alogorithm)	0.952	0.951	This parameter is not Considered	2.4
Archana Nandibewoor S B Kulkarni 2013 [3] (MATLAB Software tool)	0.962	0.961	0.952	This parameter is not Considered
Niladri Halder1and Diby4endu Roy 2015 [15] (RGB color conversion method)	This parameter is not Considered	This parameter is not Considered	0.901	This parameter is not Considered
Shruti P Y and Sharangouda.N 2015 [16] (Morphological Operations and Hough Transform)	This parameter is not Considered	This parameter is not Considered	0.961	This parameter is not Considered
Proposed Methodology **(Circular Hough Transform and Polar Transform)**	**0.833**	**0.998**	**0.993**	**1.6**

V.CONCLUSION

An advanced technique that identifies the optic cup and optic disk is presented in this paper. It determins the radius by segmenting out the optic cup and optic disk and then calculating the ratio between them in fundus of the macula. The main feature which has been considered here for identifying the vision impaired disease glaucoma is the Cup- to- Disk Ratio (CDR), which specifies the change in the cup area. Increase in the intra ocular pressure (IOP) results in increase in the area of the cup and this results in dramatic visual loss. In this paper increase in cup area is analyzed by examining the CDR value. The CDR was calculated by taking the ratio between the area of optic cup and disc. If the CDR > 0.3 indicates the suspection of glaucoma and if the CDR ≤ 0.3, is considered as normal image. A novel segmentation technique which makes us of polar transform is used for segmentation of optic cup and optic disk. The proposed methodology out performs all the previous methods in terms of its time, efficiency and requires less computational resources. This will greatly enhance the development of detection systems of different ophthalmic diseases like glaucoma and now these systems can be deployed on mobile devices thus greatly increasing its usability. This proposed method can be used as an adjunct tool by the physicians to cross check their diagnosis and hence can be an efficient tool for early detection of Glaucoma.

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