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Automatic Retina Feature Analysis for Glaucoma Detection using Cup to Disk Ratio Based on Morphology and Hough Circle Based Techniques

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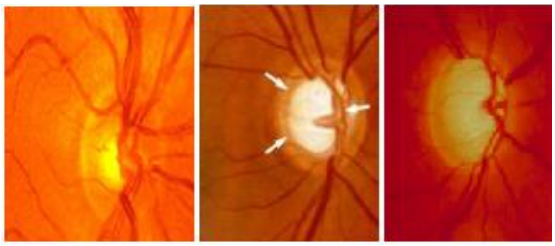
Abstract: Automated feature extraction like cup and disk of retina has great significance in automatic retina analysis and diagnosis. This leads computer aided diagnosis of the eye diseases, especially Glaucoma. The major challenge in Retina image analysis is to obtain the boundary and the area mask 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. This paper proposes a unique technique of Disk and Cup detection technique with the help of morphological and gray level processing of the image and improves the performance of disk detection using Hough circle method. This paper analyzes the performance of the techniques under the presence of noise and proposes a suitable adaptive median filtering method for suppressing the noise and detecting the accuracy of the image.

Keywords: Cup to Disk Ratio (CDR), Fundus, Glaucoma, Hough transform and Region of Interest (ROI)

I. INTRODUCTION

Glaucoma is one of the leading causes of blindness with about 79 million in the world likely to be afflicted with glaucoma by the year 2020 [3]. It is a disease of optic nerve which involves loss of retinal ganglion cells in a characteristic pattern of optic neuropathy. As blood has pressure same way eye has pressure called Intraocular pressure (IOP). When this IOP increases to certain level then it causes damage to optic nerve which leads to eventual blindness



(a)Normal optic nerve(b) Early Glaucoma (c) Advanced Glaucoma

Proposed system is divided into two distinct parts: Disk extraction and cup extraction. There are basically two types of glaucoma one is open angle or chronic glaucoma and another is closed angle or acute glaucoma, both are responsible for increasing of IOP [17]. OD segmentation methods [4] [5] have gained reasonable amount of maturity, and are capable of providing reliable OD boundaries. The cup segmentation provides an even greater challenge compared to the extraction of OD due to the fact that cup boundary is usually ill-defined than that of the disc, due to the denser vascular architecture within the optic disc. [6-16] proposed various methodologies for cup segmentation Detection of cup boundary from a Color Funds Image alone (without3D depth information) is a much more challenging work [1] [2].

The OD can be divided into two distinct regions namely, a central bright region called cup and a peripheral region called neuroretinal rim where the nerve fibers bend into cup region [4]. This is followed by calculation of CDR which is an essential part of Retina analysis. Automated Segmentation of cup and disk boundary is therefore most important part towards automated disease detection. Several past works have already provided mechanism for cup and disk detection. But most of such works fails to analyze the effect of noise in such detections. Noise is integral part of a real time scanning system. Also pure morphology driven methods fails to achieve high accuracy for retina feature extraction. Hence a curve fitting technique is better suited for the same. As Hough transform provides a good approximation about the lines and the circles present in an image, it is well suited for accurate detection of the cup and disk areas which shows strong circularity. The objective of this work is to analyse the results of both morphology and Hough based techniques for Disk and Cup area detection and compares their accuracy with standard truth image.

II. METHODOLOGY

In this paper we are using two techniques namely Color Based Detection Technique and Hough transform technique. After finding CDR value of each technique the Accuracy is compared.

A. Color Based Detection Technique

It is also called Morphological method. This method consists of following steps.

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This is followed by calculation of CDR which is an essential part of Retina analysis. In this work our focus is to develop a robust automated detection system. It is observed from the past studies that both greedy as well as heuristic based technique suffers when the retina objects are attempted to be detected over the entire image. Therefore we have developed unique pre-processing step to segment region of interest as the first stage in our detection process.

Color channel extraction: Color channel separator extracts all the three channels (red, blue and green) constituting the images is separated. Only green channel is extracted because fundus images are almost always saturated in the red channel and have very low contrast in the blue channel. This is followed by Histogram Equalization and morphological operations like dilation and erosion.

Disk Detection: The disk extractor extracts the optic disk through the two stages:

ROI extraction and disk boundary detection. In a ROI extraction first probable disk area is located by thresholding the image and selecting part of the image with highest brightness with largest area. This ROI image is then processed to detect the exact disk boundary. The process is fast as no classification is employed and entire region is processed together. Once the disk area is obtained, cup needs to be located within this boundary.

Disk Detection using Image Database:

Drishti: Drishti data set consists of 50 training images and 51 testing images so all together it's consist of 101 images. The images were tested and collected at Aravind eye hospital in Madurai, from the patients of this hospital with their consent. And these images are collected by 4 eye experts with their clinical experience.

The selection of Glaucoma patient was done on their clinical findings by clinical investigators during their visit. In selected patients there were equal number of males and females and their age between 40-80 years.

The data collection protocols are as follows

All the images collected are in PNG uncompressed format of image and are taken cantered on optic disc with a 30-degree of Field-of-view (FOV) and of dimension of 2896 X 1944 pixels.

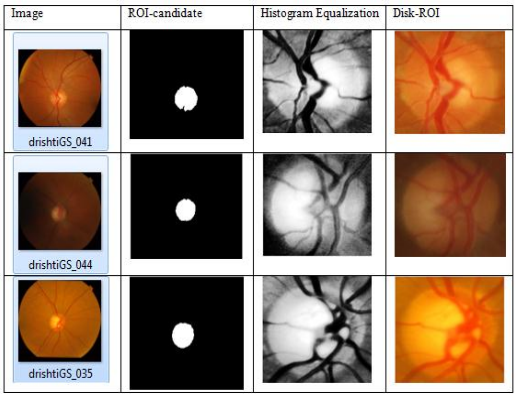
From the four experts with varying their experience of 3 year, 5 year, 9 year and 20 years respectively the ground truth data was collected.

A dedicated marking tool for Ground truth data was created for its precise marking.

The ground truth consists of the following information.

- CDR Values: For glaucoma assessment CDR acts as an important parameter, so all 4 experts marked CDR values are provided
- Segmentation Soft Map: By fusing the markings of all 4 medical experts the segmentation soft map is obtained.
- Cup boundaries and Average Optic Disc: Obtained by averaging the manual markings over many angular sectors.

TABLE I ROI EXTRACTION



B. Hough Circle Based Method

Hough circle based technique can detect the circles in a range. But due to anomalies in the ROI image, such detection is difficult. Hence Median filter based pre-processing of ROI image is performed followed by detecting the disk using Hough circles.

Hough Circles: Hough transform uses a 2D system to trace the presence of any lines represented by

$$r = x \cos\theta + y \sin\theta.$$

Matrix dimension is equal to the number of undetected parameters which are x,y and θ.

By iterating the values of r and θ in the pair (r,θ) in an image block, at (x,y) and its neighbourhood, the transform tries to find strong evidences of straight line at that pixel.

If the evidence is found then it estimates the true values of the parameters (r,θ) corresponding to that line, and then searches for the sub matrix that the parameters fall into, and increment the value of that area.

By calculating the areas with the maximum values the transform looks out for local maxima in the bounded space and extracts the lines with highest probability. By applying suitable threshold we can find the most appropriate lines.

As the circles are themselves comprising of continues lines drawn with the help of varying θ by '1' and keeping 'r' same, generalized Hough transform can easily detect the strongest circles. The strongest circle in Disk ROI is the disk boundary itself.

Hence overall proposed system is shown in figure 1

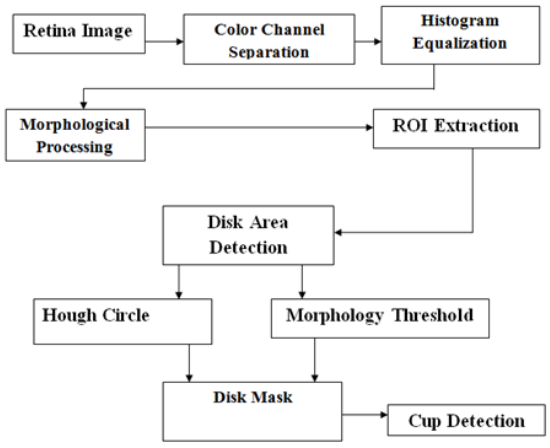


Fig 1. Conceptual Processing Block of the proposed Work

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C. Noise Analysis

Many a times, the acquired Retina image suffers from salt and pepper noise due to moisture and micro pours in the scanning lens. As such the performance of the detection is degraded. Therefore in this work we have proposed an adaptive median filter based noise removal from such images. Firstly the noisy image is median filtered with 11x11 kernels, which converts the image into a low pass image, eliminating edges and all noise values. However we want to retain the actual boundaries. Therefore we subtract the filtered and the actual noisy image. These results in high pass filtering with only noise part being left out. We binaries this image to utilize it as mask. We multiply the image with median filter image so as to obtain the actual values for noisy pixels. We make the same values in noisy pixel zero by multiplying it with inverse of the binaries high pass filtered image. Both are added to give filtered image with only noisy pixels being filtered.

TABLE II
CDR:COLOR BASED DETECTION TECHNIQUE

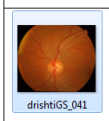
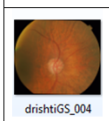
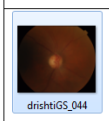
Image	Disk	Cup	CDR	Comment
 drishtiGS_041			0.307	Glaucomatous
 drishtiGS_004			0.260	Non-Glaucomatous
 drishtiGS_044			0.276	Non-Glaucomatous

TABLE III
ACCURACY:COLOR BASED DETECTION TECHNIQUE

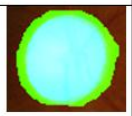
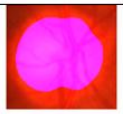
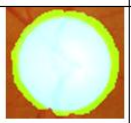
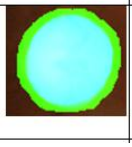
Image	Disk extraction	Cup extraction	Accuracy
 drishtiGS_018			99.90%
 drishtiGS_041			99.26%
 drishtiGS_044			100%

Table I and Table II shows Morphological technique which is used to first extract the disk ROI, and then locate the disk area by high energy based technique. Cup area within the disk is located using fast boundary segmentation method. Unlike the past works, here we have efficiently used the information from all three color channels to accurately track the ROI of the disk area. This paper shows that proposed system fares better than the existing thresholding methods which relies either on gray scale retina image or extracts the parameters from the green channel. Hence the method can be used towards automated detection of the eye diseases. This paper analyses the result with standard databases and proves that the accuracy of our system is good enough for the system to be adopted for real time retina analysis.

TABLE IV
CDR:HOUGH TRANSFORM TECHNIQUE

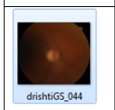
Image	Disk detection	Cup detection	CDR	Comment
 drishtiGS_060.png			0.279	Non-Glaucomatous
 drishtiGS_004			0.351	Glaucomatous
 drishtiGS_044			0.276	Non-Glaucomatous

TABLE V
ACCURACY: HOUGH TRANSFORM TECHNIQUE

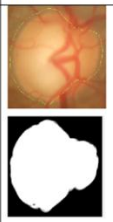
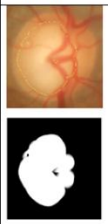
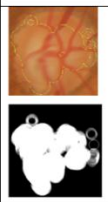
Image	Disk extraction using Hough Transform Technique	Cup extraction using Hough Transform Technique	Accuracy
 drishtiGS_060.png			96.07%
 drishtiGS_004			97.03%

TABLE IV and TABLE V shows the Hough transform technique CDR and Accuracy.. Detection of the cup area using Hough based technique did not result in acceptable result.

III.SCOPE OF THE WORK

The most important advantage of the proposed system is the speed of detection of both cup and disk area which is significant while analyzing large set of data. Many past works have proposed region growing based methods for the same. Though they claim more accuracy, they significantly affect the system performance.

The proposed system can be used as a computer aided retina scanning and retinopathy tool for detecting important retina features. This gives important edge, especially in countries like India where number of doctors per patient is very low. If the system can accurately trace the retina features, the doctors can spend more time diagnosing more patients. Our proposed system can be

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used as a prototype for disease analysis system. We have tested the system with different images from standard Drishti databases and proved that the system is adaptive in a sense that it can detect the retina features without the constraints of location of the disks and cups.. Therefore not only the proposed system is scale and intensity invariant but also rotation and gaze invariant. This work can be further extended to detect automatic cup to disk ratio which is core component of several disease detection.

IV.LIMITATIONS

Major limitation of the proposed work is that the system depends upon the intensity variations in disk area with the neighbourhood .Therefore images with lesions significant detection accuracy. Also if the retina is falsely illuminated with some other parts of retina being more illuminated than the disk area, then the system accuracy degrades. This problem can be solved by adding contour tracking along with thresholding for disk ROI detection.

V. CONCLUSION

Glaucoma detection from Cup to disk ratio in Retina images is one of the most popular techniques for Retina analysis. However detecting exact disk and cup boundary presents several challenges as the regions are distorted by blood vessels in both cup as well as the disk part of the image. Hence in this work we have presented an entirely automated technique for cup to disk ratio detection by separately identifying disk ROI and then tracking the disk region. Detection of disk and cup from the ROI image is more efficient then running the algorithm over entire image. We also have developed completely novel method for the detection not being presented so far by any other literature by combining spatial filtering with morphological processing. We have also demonstrated that with suitable processing, Hough transform can be used efficiently to detect the disk/ cup area. We have tested Cup, Disk detection techniques with Drishti Retina databases Hence the method can be used towards automated detection of the eye diseases. We also analyse the result with standard databases and prove that the accuracy of our system is good enough for the system to be adopted for real time retina analysis. The accuracy of proposed morphology based technique was 95.95% in comparison to current Hough Transform based method whose overall accuracy was observed to be 92.19%. Thus result shows that the proposed system can accurately detect the retina features irrespective of database. Hence the technique is robust. However the only limitation observed was that detection of the cup area using Hough based technique did not result in acceptable result. This can be considered as a future work for this paper.

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