Analysis Of Cdr Detection For Glaucoma Diagnosis

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Abstract

Glaucoma is the second leading cause of blindness that can damage the eye's optic nerve, resulting in loss of vision and thereby cause permanent blindness. Though there is no cure, early diagnosis with adequate medication and care, it is possible to stop further impact on vision to a patient. Quantitative evaluation or description of optic disc in retinal fundus image will add as vital information for early and accurate diagnosis of disease at different stages. The proposed approach in this project is to segment the color fundus camera image and calculate the features to segment optic disc and cup separately viz., K-Means Pixel Clustering Technique and Gabor Wavelet transform. Image Segmentation will be followed by region description and feature extraction. Several structural features such as Cup to Disk Ratio (CDR), eccentricity, Compactness, Mass Deficient Coefficient etc., can be estimated from the segmented optic disc and cup. Apart from structural features, textural features can also extracted using various statistical techniques and used as vital parameter for quantitative description of the abnormal cases. If the CDR ratio exceeds 0.3 it indicates high Glaucoma for the tested patient.

Keywords - Fundus Retinal Image, Glaucoma, K-Means clustering, Gabor wavelet Transform

I. INTRODUCTION

Glaucoma is a group of diseases that can damage the eye's optic nerve and result in vision loss and permanent blindness. Some of the key facts about Glaucoma are:

a. Leading cause for blindness globally
b. Though there is no cure, right medication will help further vision deterioration
c. It is prone to affect patients of any age

According to World Health Organization (WHO), Glaucoma is the second leading cause of blindness; that contributes to approximately 5.2 million cases of blindness (15% of total blindness cases reported) and can potentially affect ~60 million people in the next decade.

Figure 1 shows the retinal image of an eye representing the ISNT nomenclature (Inferior, Superior, Nasal, and Temporal).

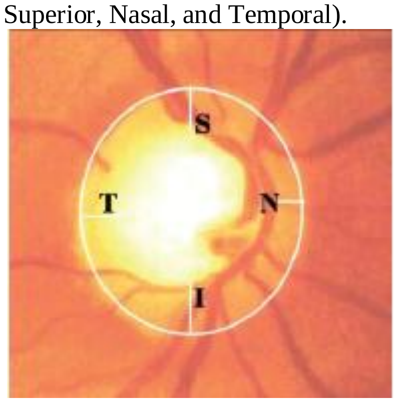

Figure 1 : Retinal image of an eye with ISNT rule

Figure 2 illustrates the neuro retinal, optic disc and cup for normal and glaucoma patient.

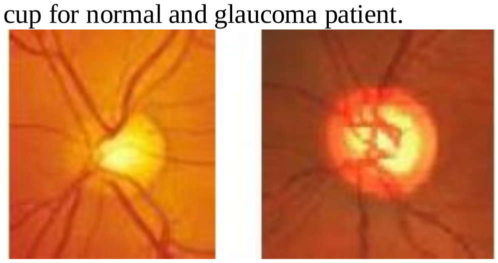

Figure 2 : (a) Normal and (b) Glaucoma affected eye

An ophthalmologist will diagnose Glaucoma by measuring the CDR (Cup to Disc Ratio) which is the ratio of the vertical height of the optic cup and optic disc. Where there is more ganglion dead cells, which shall reflect in the cup size can be used to measure the possibility of Glaucoma. If the value exceeds 0.65, it indicates for a high risk of Glaucoma and can be then tested using other techniques to confirm the disease.

Earlier various methods have been in practice for optic disc detection [4,6] however owing to challenges due to poor visibility of optic cup within the optic disc and the nervous architecture surrounding the optic cup boundary challenged the final output. One of the earliest reported methods was based on the discriminatory analysis of color intensity [7]. Variational level set based on pixel intensity was used to globally optimize the obtained cup contour [13].

As per Yuji Hatanaka's method that analyzed based on the blood vessel regions that were un-erased affected the profile the contrast of temporal side of the optic disc was high in the blue component image which affected its effectiveness [15].

In another approach by Gopal Datt Joshi, region based active contour method which avoided intensity variations due to vessels. However the cup deformation shall not be uniform due to variations in vessels [6].

In this study, we aim to find an optimized solution for optic cup detection. Post evaluating several segmentation and boundary detection methods based on image registration, segmentation, structural and textural features can also be extracted using statistical techniques such as Mahalanobis distance method, different level or severity of disease can be classified.

II. OVERVIEW OF GLAUCOMA

Glaucoma is the second leading cause of blindness that can damage the eye's optic nerve, resulting in loss of vision and thereby cause permanent blindness. Though there is no cure, early diagnosis with adequate medication and care, it is possible to stop further impact on vision to a patient. The fluid within the eye known as "aqueous humour" which flows in and out of the eye is responsible to maintain the shape of the eyeball and does not become too hard or soft. When the flow is obstructed it builds up pressure. This pressure is called as "intraocular pressure" can potentially damage the optic nerve that transmits images to the brain.

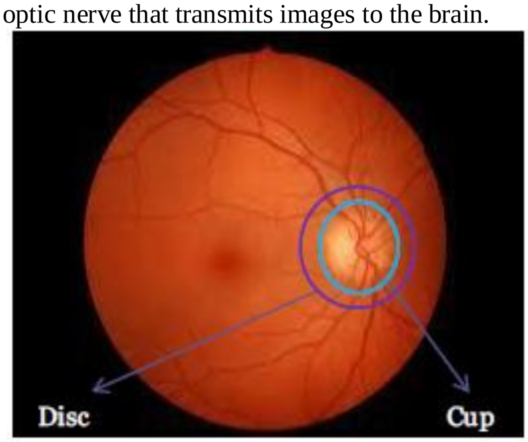

Figure 3 : Classification of cup and disc

III. METHODOLOGY

In order to extract the optic disc and cup, a region of interest around the optic cup and disc must first be delineated. The disc and cup extraction can be performed in the entire image localizing the ROI (region of interest) would help to reduce the computational cost as well as improve the segmentation accuracy. The shape deformation within the optic disk (OD) is an important indicator for the detection of glaucoma. The disk parameters are estimated using the OD and cup boundaries.

The ROI is segmented to calculate the cup and disc area, boundaries and also structural and textural features . To localize the boundary exactly morphological feature is applied. The optic disc region is usually of a brighter pallor or higher color intensity than the surrounding retinal region.

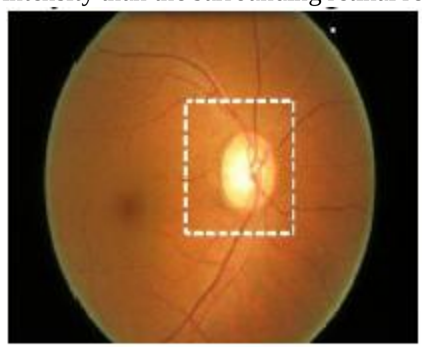

Figure 4 : Retinal fundus image with the defined ROI by masking

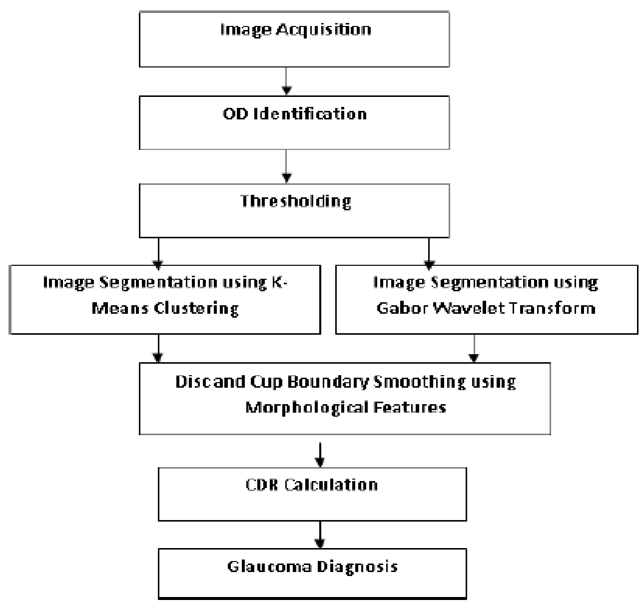

Figure 5 : Workflow of Glaucoma diagnosis using CDR calculation

IV. K-MEANS CLUSTERING

K-means is one of the simplest learning algorithms that solve the well-known clustering problem. The procedure follows a simple and easy way to classify a given data set through a certain number of clusters (assume k clusters) fixed a priori. The main idea is to define k centroids, one for each cluster. These centroids should be placed in a cunning way because of different location causes different result. So, the better choice is to place them as much as possible far away from each other. The next step is to take each point belonging to a given data set and associate it to the nearest centroid. When no point is pending, the first step is completed and an early groupage is done. At this point we need to re-calculate k new centroids as barycenters of the clusters resulting from the previous step. After we have these k new centroids, a new binding has to be done between the same data set points and the nearest new centroid. A loop has been generated. As a result of this loop we may notice that the k centroids change their location step by step until no more changes are done. In other words centroids do not move any more. Finally, this algorithm aims at minimizing an *objective function*, in this case a squared error function. The objective function

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2$$

where $\left\| x_i^{(j)} - c_j \right\|^2$ is a chosen distance measure between a data point $x_i^{(j)}$ and the cluster centre c_j is an indicator of the distance of the *n* data points from their respective cluster centres.

Optic Disc and Cup Segmentation

To calculate the vertical cup to disc ratio, the optic cup and disc first have to be segmented from the retinal images. The green plane of the registered image is extracted to choose mean value for background blood vessel, cup and disc are replaced for segmenting the image. Using concatenate function, the images are mapped in a set of 4 iterations to execute for the above set of mean values. The identified mean value is replicated with the mean value within each of the array and then the distance matrix is calculated.

Optic Disc Smoothing

The disc boundary detected from the above step may not represent the actual shape of the disc since the boundary can be affected by a large number of blood vessels entering the disc. Therefore morphological features is applied to reshape the obtained disc boundary.

Optic Cup Smoothing

After the cup boundary detection, morphological feature is again applied to eliminate some of the cup boundary's sudden changes in curvature.

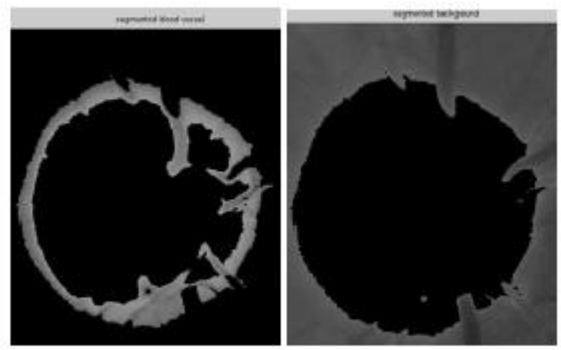

Figure 6 : Segmented blood vessel & background using K-Means clustering

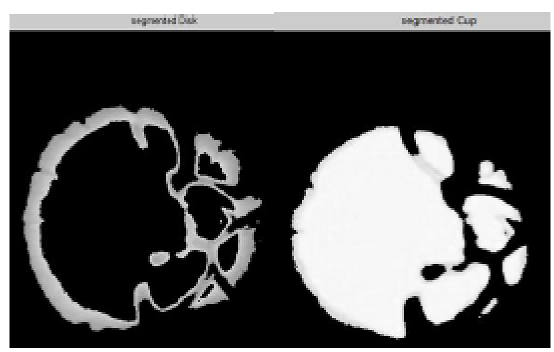

Figure7 : Segmented disc & cup using K-Means clustering

V. GABOR WAVELET TRANSFORM

The problem with cup and disc segmentation is that the visibility of boundary is usually not good especially due to blood vessels. Normally matched filters are used for blood vessel enhancement but the drawback is that MFs not only enhance blood vessels edges they also enhance bright lesions. On the other hand, Gabor wavelets can be tuned for specific frequencies and orientations which is useful for blood vessels. They act as low level oriented edge discriminators and also filter out the background noise of the image. Since vessels have directional pattern so 2-D Gabor wavelet is best option due to its directional selectiveness capability of detecting oriented features and fine tuning to specific frequencies.

Table 1 : Parameter value for tuning Gabor Wavelet

PARAMETER	VALUE
Dilation	3
Elongation	4
Rotation Angle	15°
R_0	[0,3]

$$\Phi_G(\mathbf{x}) = \exp(j\mathbf{R}_0\mathbf{x})\exp(-\frac{1}{2}|\mathbf{A}\mathbf{x}|^2) \qquad (1)$$

$$\hat{\Phi}_G(\mathbf{x}) = (detA^{-1})^{1/2}\exp(-\frac{1}{2}(A^{-1}(\mathbf{R}-\mathbf{R}_0)^2)) \qquad (2)$$

Where R0 is a vector that defines the frequency of the complex exponential and A= $\begin{bmatrix} \epsilon^{-1/2} & 0 \\ 0 & 1 \end{bmatrix}$ with elongation €≥11 is a 2 x 2 positive definite diagonal matrix which defines the wavelet anisotropy and elongation of filter in any desired direction. For each pixel position and considered scale value, the Gabor wavelet transform MΦ (b, a) is computed for θ spanning from 0° up to 165° at steps of 15° and the maximum is taken. Table-1 shows the selected values for tuning of Gabor wavelet.

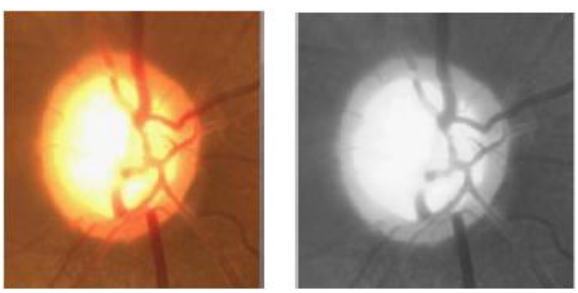

Figure8: Gabor Wavelet Based Enhanced Retinal image

Table 2 : Classification of structural features

Images	Normal	Glaucoma1	Glaucoma2	Glaucoma3
Area	11315	9503	6031	5002
Perimeter	360	490	405	358
Max. Width	117	117	98	81
Max. Height	122	116	82	82
Eccentricity	0.959	1.0086	1.1951	0.9878
FormFactor	1.0971	0.4994	0.4621	0.4904
CDR	0.3	0.69	0.66	0.69

As stated in the above table, if the formfactor is greater than 1 the patient is still in the safe zone and not affected by Glaucoma. On the other hand if it is less than 1, it can be confirmed as Glaucoma affected patient.

Eccentricity is the ratio of the maximum width to maximum height. Formfactor is the compactness which is calculated as (4 x π x Area) / (Perimeter)2

CONCLUSION

I hereby present the result of the study aimed at Glaucoma detection using K-Means clustering segmentation and Gabor Waelet Transform of this fundus image to obtain the accurate boundary delineation. The output is checked for structural features like CDR (Cup to Disc Ratio), eccentricity, compactness to confirm Glaucoma for a given patient.

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