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Detection of Glaucoma Eye Disease Based on Superpixel Classification Method

Satish Thorat[1] and Manjusha Deshmukh[2]

[1]*PG Student, Department of Electronics & Telecommunication, Saraswati College of Engineering, Mumbai University*
[2]*Saraswati College of Engineering, Mumbai University*
E-mail: 1satuthorat@gmail.com, 2manju0810@gmail.com

Abstract—*Glaucoma is a chronic eye disease that leads to vision loss. Progression of the disease leads to loss of vision, which occurs gradually over a long period of time. As the symptoms only occur when the disease is quite advanced, Glaucoma is called the silent thief of sight. Glaucoma cannot be cured, but its progression can be slowed down by treatment. Therefore, detecting glaucoma in time is critical. However, many glaucoma patients are unaware of the disease until it has reached its advanced stage. Since glaucoma progresses with few signs or symptoms and the vision loss from glaucoma is irreversible, screening of people at high risk for the disease is vital. As it cannot be cured, detecting the disease in time is important. Current tests using intraocular pressure (IOP) are not sensitive enough for population based glaucoma screening. Optic nerve head assessment in retinal fundus images is both more promising and superior. This paper proposes optic disc and optic cup segmentation using superpixel classification for glaucoma screening. In optic disc segmentation, histograms and centre surround statistics are used to classify each superpixel as disc or non-disc. For optic cup segmentation, in addition to the histograms and centre surround statistics, the location information is also included into the feature space to boost the performance. The segmented optic disc and optic cup are then used to compute the cup to disc ratio for glaucoma screening. The Cup to Disc Ratio (CDR) of the color retinal fundus camera image is the primary identifier to confirm Glaucoma for a given patient. This project focuses on automatic glaucoma screening using CDR from 2D fundus images.*

Keywords: *Glaucoma screening, superpixel generation, optic disc and cup segmentation, features extractions, CDR computation.*

1. INTRODUCTION

Glaucoma is an eye disease in which the pressure inside eyes increases enough to damage the nerve fibers in optic nerve and cause permanent vision loss. The increase in blood pressure happens when the passages that normally allow fluid in eyes to drain become clogged or blocked. Glaucoma often is called the "silent thief of sight," because most types typically cause no pain and produce no symptoms until noticeable vision loss occurs. Lowering of eye pressure is determined based on how severe the optic nerve is damaged. In general, normal eye pressure ranges from 8 to 21 millimeters mercury (mmHg). Ophthalmologists tend to start treatment if the pressure exceeds 30 mmHg. The ideal intraocular pressure level for most glaucoma patients is 14 mmHg or lower. Glaucoma surgery is generally considered as a last resort when eye drops and laser treatments have been unable to lower the eye pressure sufficiently to prevent further optic nerve damage.

Optic disc (OD) is the brightest feature in a normal fundus image and it has an elliptical shape. It appears bright orange-pink with a pale centre. Orange-pink appearance represents the healthy neuro-retinal tissue. Due to pathologies, the orange-pink color gradually disappears and appears pale. Blood vessels and the optic nerves are emanating out from the OD. Its size is about one seventh of the entire image. The pale centre is consists of neuroretinal tissue and is called the cup. The vertical size of this cup can be estimated in relation to the disc as a whole and presented as a cup-to-disc ratio. The cup-to-disc ratio (CDR) expresses the proportion of the disc occupied by the cup and it is widely accepted index for the assessment of glaucoma. For normal eye it is found to be 0.3. As the neuro-retinal degeneration occurs, the ratio increases and at the CDR value of 0.8 the vision is lost completely. Since the vision loss from glaucoma is irreversible, screening of people at high risk for the disease is vital.

Glaucoma cannot be cured but its progression can be slow down by treatment so detection of glaucoma in time is important. There are three methods to detect glaucoma: (1) assessment of raised IOP (2) assessment of abnormal visual field (3) assessment of damage optic nerve head. The IOP measurement using non contact tonometry is neither specific nor sensitive enough to be an effective screening tool because glaucoma can be present with or without increased IOP. So, IOP cannot be used as a standard measure for glaucoma. A function test through vision loss requires special equipments only present in territory hospitals and therefore unsuitable for screening. Measurement of IOP and peripheral vision test requires the patients attention and assessment of glaucoma cannot be guaranteed. Assessment of damage optic nerve head is both more promising and superior to IOP measurement or visual field testing for glaucoma screening. Optic nerve head assessment can be done by a trained professional. However, manual assessment is subjective, expensive and time consuming.

2. RELATED WORK

To estimate the number of people with open angle glaucoma (OAG) and angle closure glaucoma (ACG) in 2010 and 2020[2] [3], a review of published data with use of prevalence models is taken. Data from population based studies of age specific prevalence of OAG and ACG is used to construct prevalence models for OAG and ACG by age, sex, and ethnicity. Models were combined with UN world population projections for 2010 and 2020 to derive the estimated number with glaucoma. There will be 60.5 million people with OAG and ACG in 2010, increasing to 79.6 million by 2020, and of these, 74% will have OAG. Women will comprise 55% of OAG, 70% of ACG, and 59% of all glaucoma in 2010. Asians will represent 47% of those with glaucoma and 87% of those with ACG. Bilateral blindness will be present in 4.5 million people with OAG and 3.9 million people with ACG in 2010, rising to 5.9 and 5.3 million people in 2020, respectively. So the glaucoma is the second leading cause of blindness worldwide, disproportionately affecting women and asians.

J. Meier, R. Bock, G. Michelson, L. G. Nyl, and J. Honegger is focused on a novel automated classification system based on image features from fundus photographs which does not depend on structure segmentation or prior expert knowledge [4]. Our new data driven approach achieves an accuracy of detecting glaucomatous retina fundus images. In this paper, we study image preprocessing methods to provide better input for more reliable automated glaucoma detection. We reduce disease independent variations without removing information that discriminates between images of healthy and glaucomatous eyes. In particular, nonuniform illumination is corrected, blood vessels are in painted and the region of interest is normalized before feature extraction and subsequent classification. But in this method, the features are normally computed at the image level only so selection of features and classification strategy is difficult and challenging.

M. Foracchia, E. Grisan, and A. Ruggeri presents here a new method to identify the position of the optic disc (OD) in retinal fundus images [5]. The method is based on the preliminary detection of the main retinal vessels. All retinal vessels originate from the OD and their path follows a similar directional pattern (parabolic course) in all images. To describe the general direction of retinal vessels at any given position in the image, a geometrical parametric model was proposed, where two of the model parameters are the coordinates of the OD center. Using as experimental data samples of vessel centerline points and corresponding vessel directions, provided by any vessel identification procedure, model parameters were identified by means of a simulated annealing optimization technique. These estimated values provide the coordinates of the center of OD**.**

Optic disc (OD) detection is an important step in developing systems for automated diagnosis of various serious ophthalmic pathologies. Arturo Aquino, Manuel Emilio Gegúndez-Arias, and Diego Marín presents a new template-based methodology for segmenting the OD from digital retinal images [6]. This methodology uses morphological and edge detection techniques followed by the Circular Hough Transform to obtain a circular OD boundary approximation. It requires a pixel located within the OD as initial information. For this purpose, a location methodology based on a voting-type algorithm is also proposed. The algorithms were evaluated on many images and the results were fairly good. Reliable and efficient optic disk localization and segmentation are important tasks in automated retinal screening. General-purpose edge detection algorithms often fail to segment the optic disk due to fuzzy boundaries, inconsistent image contrast or missing edge features.

James Lowell, Andrew Hunter [7] presents an algorithm for the localization and segmentation of the optic nerve head boundary in low-resolution images (about 20 /pixel). Optic disk localization is achieved using specialized template matching and segmentation by a deformable contour model. The latter uses a global elliptical model and a local deformable model with variable edge-strength dependent stiffness. The algorithm is evaluated against randomly selected images from a diabetic screening program. Ten images were classified as unusable; the others were of variable quality. The localization algorithm succeeded on all bar one usable image. But this algorithm still does not have perfect performance, owing to the variable nature of the images and the presence of distractor boundaries concentric with the desired rim, which may be located either inside or outside the rim. Noor Eliaza abdul Khalid,Noorhayati Mohamad Noor proposed the deployment of dilation and erosion with Fuzzy c-Means (FCM) as an effective optic cup and disc segmentation [8]. The cheapest way to monitor glaucoma disease is using digital fundus camera. These images are stored in RGB format which can be split into red, green and blue channels. Previous work has identified green channel as the most suitable due to its contrast. The extracted green channel is segmented with FCM. In another test, the set of images are preprocessed with dilation and erosion to remove the vernacular. The segmentation is evaluated based on the ground truth areas that are outlined by the ophthalmologists. The CDR measurements are calculated from the diameter ratio of the segmented cup and disc. The assessment shows that omitting the vernacular area improved the sensitivity, specificity and accuracy of the segmented result. But the disadvantage of the Fuzzy C means is that for noisy images it does not take into account spatial information, which makes it sensitive to noise & other image artifacts based on distribution of pixel intensity, so it is sensitive to intensity variations in the illumination. In this project, K-means clustering algorithm is used for segmentation.

Joshi proposed an approach for an automatic OD parameterization technique based on segmented OD and cup regions obtained from monocular retinal images. In an active contour model is presented to get robust OD segmentation [9].

This has been achieved by enhancing Chan- vese (C-V) model by including image information at the support domain around each contour point. The drawback of this method was that it does not provide better quality.Babu proposed for the measurement of CDR[10].It is considered as a parameter for the diagnosis of glaucoma and 90% accuracy is obtained The CDR ratio is an important indicator of the risk of the presence of the glaucoma in an individual. Arturo proposed to optic disc boundary using morphological, edge Detection, and feature Extraction techniques [11].It requires a pixel located within the OD as initial information. For this purpose, a location methodology based on a voting-type algorithm is also proposed. The algorithms were evaluated on many images and the results were fairly good. However this method had poor visual quality.

3. PROPOSED SYSTEM

This paper focuses on automatic glaucoma screening using CDR from 2D fundus images. In this proposed approach, preprocessing such as image filtration, color contrast enhancement are performed which is followed by a combined approach for image segmentation and classification using texture, thresholding and morphological operation. Multimodalities including K-Means clustering, Gabor wavelet transformations are also used to obtain accurate boundary delineation. We incorporate prior knowledge of the cup by including location information for cup segmentation. Based on the segmented disc and cup, CDR is computed for glaucoma screening .Fig 3.1 shows the flow chart of proposed system.

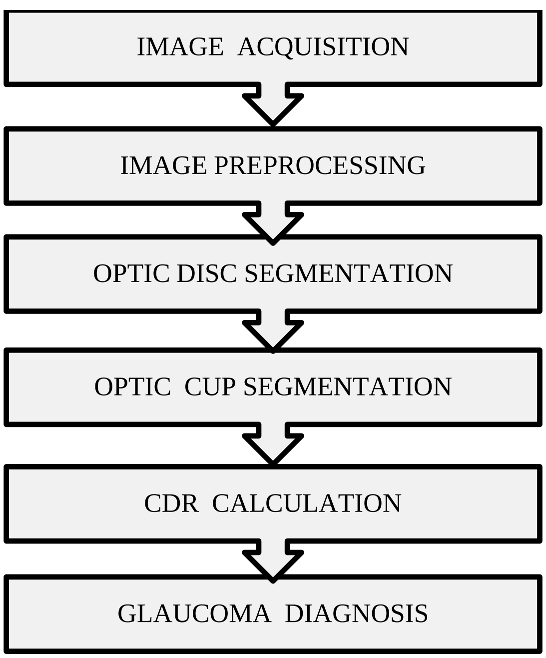

Fig 3.1: flow chart of proposed system

Using this technique, Cluster center can be applied. It aggregates the nearby pixel into super pixels. Select the pixel from an image and the centers move towards the lowest gradient position. In this technique searches for its best matching pixel from the neighborhood based on the color and spatial proximity. And then compute the new cluster center based on the found pixel. This iteration will be continue until the distance between the new center and previous one is small enough. The output of the SLIC technique is given as input to the K-means Clustering algorithm. It classifies the input data into multiple clusters. And also apply the image in gabor filter technique. It is a linear filter used for edge detection. It is used to reduce noise. By applying thresholding technique to the segmented optic disc, optic cup will be segmented. The optic disc and optic cup diameter is measured to calculate the Cup to Disc Ratio (CDR). From the CDR value, the disease condition of the patient can be identified.

A. Simple Linear Iterative Clustering Algorithm (SLIC)

The super pixel algorithm, simple linear iterative clustering (SLIC), which adapts a k-means clustering approach to efficiently generate super pixels.Despite its simplicity, SLIC adheres to boundaries as well as or better than previous methods. At the same time, it is faster and more memory efficient, improves segmentation performance, and is straightforward to extend to superpixel generation. SLIC is simple to use and understand. By default, the only parameter of the algorithm is k, the desired number of approximately equally-sized super pixels. For color images in the CIELAB color space, the clustering procedure begins with an initialization step where k initial cluster centers = li,ai,bi,xi,yi T are sampled on a regular grid spaced S pixels apart. To produce roughly equally sized super pixels, the grid interval is S= Nk . The centers are moved to seed. Locations corresponding to the lowest gradient position in a 3 X3 neighborhood. This is done to avoid centering a super pixel on an edge, and to reduce the chance of seeding a superpixel with a noisy pixel. Next, in the assignment step, each pixel *i* is associated with the nearest cluster center whose search region overlaps its location. This is the key to speeding up our algorithm because limiting the size of the search region significantly reduces the number of distance calculations, and results in a significant speed advantage over conventional *k*-means clustering where each pixel must be compared with all cluster centers. This is only possible through the introduction of a distance measure *D*, which determines the nearest cluster center for each pixel.

B. K-Means Clustering

K-Means algorithm is an unsupervised clustering algorithm that classifies the input data points into multiple classes based on their inherent distance from each other. The algorithm assumes that the data features form a vector space and tries to find natural clustering in them. The points are clustered around centroids μiAi = 1…k which are obtained by minimizing the objective.

$$\sum_{J=1}^{K} \sum_{I=1}^{X} = \left\| X_i^{(j)} - c_j \right\|^2 \quad (1)$$

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

- Compute the intensity distribution (also called the histogram) of the intensities.
- Initialize the centroids with k random intensities
- Repeat the following steps until the cluster labels of the image do not change anymore.
- Cluster the points based on distance of their intensities from centroid intensities replicated with the mean value within each of the array and then the distance matrix is calculated

C. Gabor Filter

Gabor filter is a linear filter used to detect the edge. It is used to reduce noise. Gabor filter can be

tuned for specific frequencies and orientations which are useful edge detection. They act as low level oriented edge discriminators and also filter out the background noise of the image. Since that have directional pattern so 2-DGabor filter is best option due to its directional selectiveness capability of detecting oriented features and fine tuning to specific frequencies.

D. Cup Segmentation

In cup segmentation, use thresholding or binarization for optic cup segmentation process. This process will convert the image into a B/W (Black & White) image where it can easily segment the optic cup from disc region.

E.CDR Calculation and Diagnosis

After obtaining the disc and cup, various features can be computed. We follow the clinical convention to compute the CDR. It is ratio between the Vertical Cup Diameter (VCD) &Vertical Disc Diameter (VCD).

$$\text{CDR} = \text{VCD}/\ \text{VDD} \quad (2)$$

The computed CDR is used for glaucoma screening. CDR value exceeds 0.6 shall be recommended for further analysis of a patient to the ophthalmologist. When CDR is greater than a 0.6, it is severe glaucomatous, when CDR is between 0.4 to 0.6,it is moderate glaucomatous and when CDR is less than 0.4 it will be considered as a healthy one.

4. RESULTS

Data set

Images and database are collected from Shivam Eye care clinic, Navi Mumbai. The images were acquired using a Canon CR5 non–mydriatic 3 CCD camera with a 45 degree field of view (FOV).Each image was captured using 8 bits per color plane at 768 by 584 pixels. The FOV of image is circular with a diameter of approximately 540 pixels. For this database, the images have been cropped around FOV. For each image, a mask image is provided that delineates the FOV. The VISUCAM NM/FA fundus camera is the perfect combination of a non-mydriatic fundus camera with superior image quality and an easy-to-use camera for fluorescein angiography.

Table 1: Comparison of Clinical CDR with our results

Images	Clinical Method(CDR)	Proposed Method(CDR)
1	0.66	0.68
2	0.68	0.65
3	0.60	0.64
4	0.37	0.38
5	0.40	0.41
6	0.42	0.43
7	0.54	0.52
8	0.68	0.69

Table 1 shows the comparative results between clinical method and proposed method. It shows that values of CDR of proposed method are equivalent to the values of CDR of clinical method. When CDR is greater than a 0.6, it is severe glaucomatous, when CDR is between 0.4 to 0.6,it is moderate glaucomatous and when CDR is less than 0.4 it will be considered as a healthy one.

5. CONCLUSION

In this paper we presented super-pixel classification based optic disc and cup segmentations for glaucoma screening. This project is presented and evaluated for glaucoma detection in patients using multimodalities including simple linear iterative clustering (SLIC) algorithm, K-Means clustering, and Gabor wavelet transformation of the color fundus camera image to obtain accurate boundary delineation. It is important to have a good disc segmentation because the CDR computed from wrong disc is not very meaningful for doctors. The algorithm for locating optic disc in retinal images is an efficient k-means clustering algorithm. It is an effective method to detect of optic disc in retinal images. Reliant on the results that are obtained from the proposed algorithm it is seen that the optic disc is detected accurately. With the help of proposed algorithm in this project, workload of doctor's can be reduced. A weak color change would increase the challenge in cup segmentation. This project utilized the prior knowledge of cup location by using location feature to boost the performance.

Using structural features like CDR (Cut to Disc Ratio), the ratio value exceeds 0.6 shall be recommended for further analysis of a patient to the ophthalmologist. This shall help in patients worldwide by protecting further vision deterioration through timely medical intervention. The result by the proposed methods is good enough for screening purposes in polyclinics and eye centers, according to discussions with clinicians and ophthalmologists.

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