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Binary Mask Pattern Segmentation in glaucoma detection

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***Abstract*—** Glaucoma detection is one of the most recent researches in medical field. There are several researches which mainly focus on optic cup to disc ratio to efficiently identify glaucoma. The objective of this paper is to identify glaucoma by creating a binary mask for optic cup and disc of glaucomatous eyes. The query image is segmented using these masks and identified as either normal or glaucomatous eyes. The proposed method is tested on RIM-ONE r3 database. The experimental results substantially proved that the proposed method achieved 95.29% specificity at 94.59% sensitivity with AUC of 0.869. The proposed method is also compared with existing methods and proved to work better than them.

***Keywords*—** Fundus image, glaucoma, optic disc, optic cup, mask

I. INTRODUCTION

Glaucoma is an enduring and painless eye disease which slowly damages the Optic Disc (OD) of the eye. As it is painless, it is unnoticeable in its earlier stage [1]. It is a neurological disease which occurs due to increase in fluid pressure within the eyeball [2]. Elevated pressure inside the eye damages the nerve fibers in Retinal-Nerve-Fiber (RNF) layer [3]. It starts with minor disorders and slowly it damages nerve fibers. These defects are so minor such that they usually remain unnoticeable in the earlier stages of glaucoma. In the intermediate stage, changes occur in RNF-layer with slight peripheral vision loss. In its final stage only, severe vision loss occurs which leads to blindness [4].

As it is has gradual change from the earlier stage to the final stage, it is difficult to identify glaucoma. It is necessary to capture the internal structural changes for diagnosis of glaucoma [5]. Modern imaging modality such as OCT has the capability to show detailed quantification of structural changes [6]. In glaucoma, Cup to Disc Ratio (CDR) is one of the main clinical indicators involved in glaucoma diagnosis [7]. In the initial and intermediate stage of glaucoma, the vertical CDR increases rapidly [8].

This paper introduces a binary mask for optic cup and optic disc of glaucomatous eyes. The query image is matched with the binary mask and finds whether it is glaucomatous eyes or normal eyes. The proposed method is tested on RIM-One dataset.

The remaining of the paper is organized as follows: Section II discussed the related works. Section III gives the proposed system architecture. Section IV demonstrates the proposed method with some experimental results followed by conclusion in Section V.

II. RELATED WORK

Jun Cheng et al. developed a method for CDR evaluation by using 2-D retinal fundus images [9].Here, OD is segmented and reconstructed using a Sparse Dissimilarity-Constrained Coding (SDC).This will consider both the dissimilarity and sparsity constrain from a set of reference disk with a known CDR. J liu et al. introduced a variation level set method which uses a color intensity and threshold level set [10]. Gopal Joshi et al. developed a method which makes use of anatomical evidences such as vessel bends and local image parameters [11]. Jun Cheng et al. developed a method based on super pixel classification by the use of histogram and centre surround statistics [12].

There are various research papers for segmenting optic cup and disc of stereo images. In [13], region based segmentation is used to segment optic disk and cup and CDR is calculated. In [14], super pixel classification using histograms is used for glaucoma screening. The segmented optic cup and optic disc is then used to compute the CDR for glaucoma screening. Several segmentation and boundary detection methods are introduced. In [15], fusion of multimodality, including segmentation and ellipse fitting on boundary is developed.

III. METHODOLOGY

The proposed system architecture is shown in Fig. 1. From the database, binary mask of optic cup and disc are created for glaucomatous eyes. When a query image is given, the optic cup and disc are segmented and it is matched with the already created binary mask. If the match is found, it is glaucomatous eyes. Otherwise, it is normal eyes.

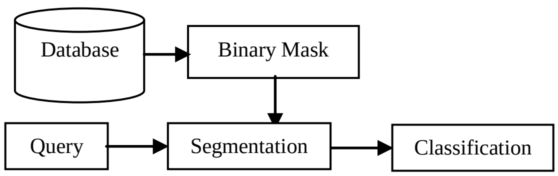

Figure 1. Proposed System Architecture

The process of creating binary mask of optic disc and cup for glaucomatous eyes is shown in Fig. 2. The idea behind this work is optic cup of the glaucomatous eyes is larger than the optic cup of normal eyes. Hence mask is created for optic cup and disc of the glaucomatous eyes. With this mask, any query image can be recognized as glaucomatous or normal. The initial binary mask is created from the first image of the database and it is called as template. The template is created by just converting the first image into gray scale image.

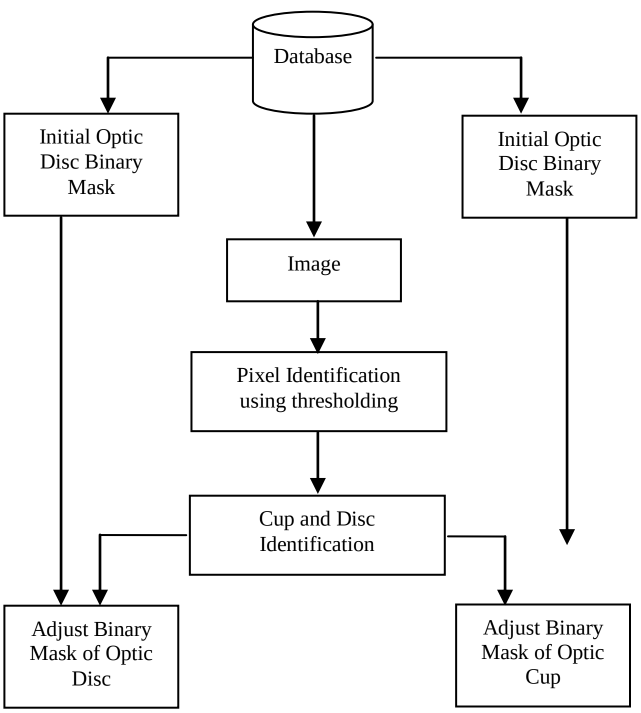

Figure 2. Binary Mask Generation for glaucomatous eyes

For optic cup and disc, two thresholds t1 and t2 are selected based on the gray value of the cup and disc respectively. From the stereo images of glaucomatous eyes, it is observed that the optic cup has higher gray values than optic disc. Hence t1 (optic cup) is selected such that it is always greater than t2 (optic disc). The steps to create binary mask of optic cup and disc for glaucomatous eyes are as follows:

Step 1: Get an image from the database

Step 2: Those pixels whose values lies above t1 are marked as binary 1. The template of optic cup is adjusted to this mask.

Step 3: Those pixels whose values lies above t2 are marked as binary 1. The template of optic disc is adjusted to this calculated mask.

Step 4: Go to step 1 to fetch the next image till the last image is reached.

As the glaucomatous eyes have larger optic cup than normal eyes, binary mask is created for glaucomatous eyes. By adjustment in step 3, we mean that logical OR is performed with the template and currently calculated mask, so that all the pixels in the optic cup or disc will be included in the mask. The process of classification of a query image to glaucomatous or normal eyes is shown in Fig. 3.

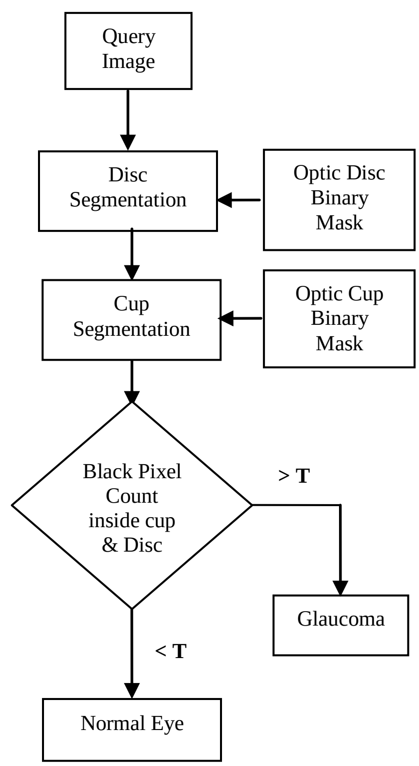

Figure 3. Classification based on binary mask

For classification of a query image to glaucoma and normal eyes, the following steps are done.

Step 1: Gray scale conversion of query image.

Step 2: Segment the query image using binary mask of optic disc. (Since the optic disc is larger than the optic cup).

Step 3: Segment the image obtained in the previous step using binary mask of optic cup.

Step 4: If the number of black pixels inside the segment is greater than a threshold t, identify the query image as glaucomatous eyes. Otherwise, identify it as normal eyes

Step 5: Stop.

Here the threshold ‘t’ is calculated manually by doing more iteration with query images.

IV. Experimental Results

The proposed method is evaluated on publicly available RIM-ONE r3 database [16]. The RIM-ONE database is commonly used for glaucoma diagnosis, and it has been revised several times. The final version is RIM-ONE r3 and this research is tested on this revision. It can be downloaded for free which has different fundus images (healthy eyes and eyes with different glaucoma levels). It consists of 159 images among which 85 are normal eyes, and 74 are glaucomatous eyes.

The binary mask obtained by the proposed method for optic disc and cup of glaucomatous eyes is shown in Fig. 4.

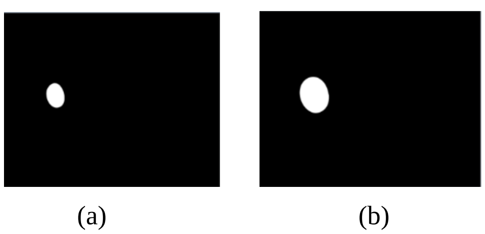

Figure 4. Binary mask of glaucomatous eyes of (a) cup and (b) disc

Fig. 5 and 6 shows the segmented images of the query images for glaucomatous and normal eyes respectively.

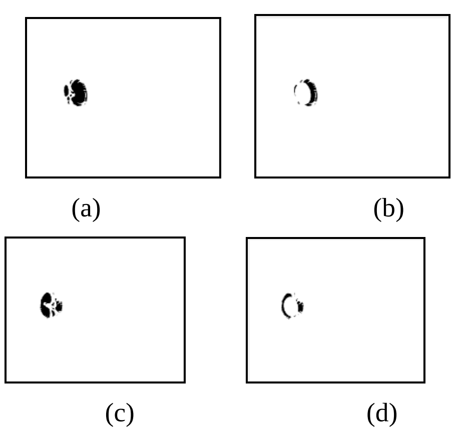

Figure 5. Results obtained for glaucomatous eyes
(a) (c) Segmentation obtained using optic disc mask
(b) (d) Segmentation obtained using optic cup mask for (a) and (c) respectively

The performance of the proposed method is evaluated using accuracy, specificity and sensitivity. In order to calculate these measures, following terminologies must be known:

- True Positives (TP)
- True Negatives (TN)
- False Positives (FP)
- False Negatives (FN)

The accuracy, specificity and sensitivity are calculated as

$$Accuracy = \frac{(TP+TN)}{N} \quad (1)$$

$$Specificity = \frac{TN}{F} \quad (2)$$

$$Sensitivity = \frac{TP}{P} \quad (3)$$

where N is the total number of fundus images, F are actual false, P are actual true. The proposed method is evaluated by plotting ROC curve.

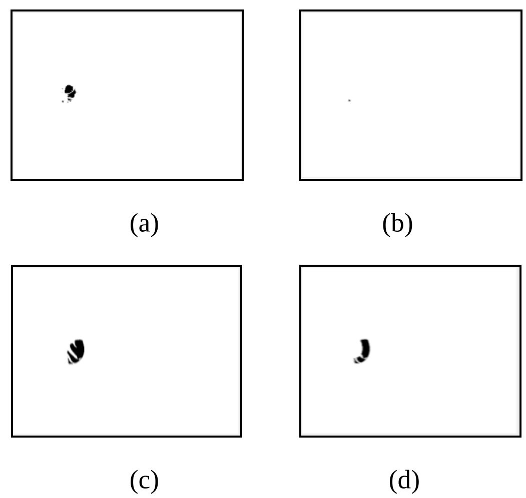

Figure 6. Results obtained for normal eyes
(a)(c) Segmentation obtained using optic disc mask
(b)(d)Segmentation obtained using optic cup mask for (a) and (c) respectively

From the Fig. 5 and 6, it is evident that number of black pixels obtained for glaucomatous eyes is larger than the normal eyes. And for some normal eyes, the segmented image has negligible blackpixels. Table 1 shows the results obtained for the proposed method for RIM-ONE database.

Table 1 Results obtained for the proposed method

	No. of Images	No. of Images identified as Glaucoma	No. of images identified as Normal
Glaucomatous	74	70	4
Normal	85	4	81

From the Table 1, it is observed that the proposed method correctly identified more than 92% of the query images. The ROC curve obtained for the proposed method is shown in Fig. 7.

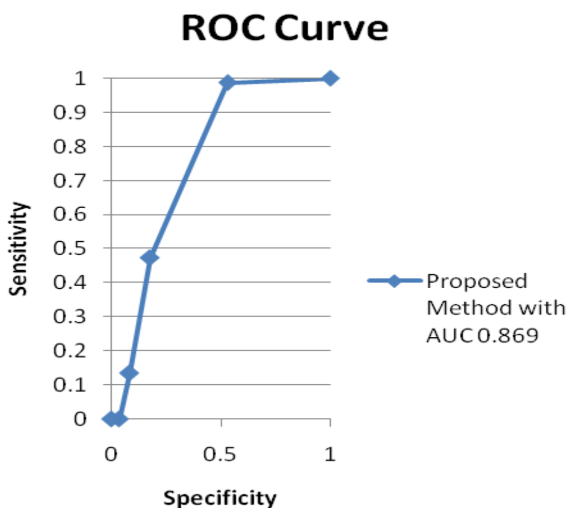

Figure 7. ROC obtained for the proposed method

The proposed method is compared with other existing methods [17-19]. In [17], polar map based approach is used for glaucoma detection. Methods [18] and [19] used geometric feature extraction and block based segmentation respectively. Table 2 shows the comparison of the proposed method with the existing methods.

Table 2 Performance Comparison of the Proposed Method with Existing Methods

Method Used	**Accuracy (%)**	**Specificity (%)**	**Sensitivity (%)**
Existing Polar Map Based Approach [17]	82	84	82
Proposed Block based Approach [18]	78	72.9	83.8
Proposed Geometrical Feature Extraction [19]	91.2	98.82	82.43
Proposed Binary Mask method	**94.97**	**95.29**	**94.59**

From the Table 2, it is observed that the proposed method achieves higher accuracy than other existing methods. Also, AUC of the proposed method is compared with AUC of the existing methods. The comparison of AUC is shown in Table 3.

Table 3 AUC Comparison of the Proposed Method with Existing Methods

Method/ Measure	**AUC**
Method [17], 2016	89.64
Method [18], 2018	86.31
Method [19], 2018	86.5
Proposed Method	86.9

The proposed method achieves higher AUC than method [18] and [19] but has lesser AUC when compared to method [17].

V. CONCLUSION

In this paper, the fundus images of eyes are identified as normal or glaucoma using binary mask. A common binary mask for optic disc and optic cup for glaucomatous eyes are created from the database. The query image is segmented using optic disc and cup subsequently and the glaucomatous eyes are identified from the segmented image. The proposed method is tested on RIM-ONE r3 database. The experimental results proved that the proposed method achieved 95.29% specificity at 94.59% sensitivity with AUC of 0.869. The performance of the proposed method is evaluated by comparing it with recent methods and proved to have higher accuracy than the existing methods.

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