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Review of Image Processing Techniques for Optic Cup and Optic Disc Segmentation for Glaucoma Detection

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Abstract: The review paper describes various image processing techniques for optic cup and disc segmentation for automatic detection 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. This disease cannot be cured, hence detecting the disease in time is important. Current diagnosis of glaucoma relies upon examining retinal fundus image using image processing. Optic nerve head assessment in retinal fundus images is a promising method wherein optic cup and optic disc are segmented. The segmented optic disc and optic cup are then used to compute the Cup to Disc Ratio (CDR) for glaucoma screening.

Keywords: Fundus Image, Glaucoma, Optic nerve head, optic cup, optic disc, CDR.

I. INTRODUCTION

Glaucoma is a chronic eye disease in which the optic nerve is progressively damaged by the increase in the intraocular pressure inside the eye caused by a build-up of excess fluid. This pressure can impair vision by causing irreversible damage to the optic nerve and to the retina. It can lead to the blindness if it is not detected and treated in proper time. Glaucoma result in peripheral vision loss, and is an especially dangerous eye condition because it frequently progresses without obvious symptoms. This is why it is often referred to as "The Silent Thief of Sight." The intraocular pressure increases due to malfunction or malformation of the drainage system of the eye. The anterior chamber of the eye is the small space in the front portion of the eye. A clear liquid flow in and out of the chamber through a mesh-like channel and this fluid is called aqueous humor. If this channel becomes blocked, fluid builds up, causes increase in intraocular pressure. The increased intraocular pressure within the eye damages the optic nerve through which retina sends light to the brain where they are recognized as images and makes vision possible. Because revitalization of the degenerated nerve fibers of the optic nerve is impossible early detection of the disease is essential .The optic nerve head is the location connecting the optic nerve and retina. The optic nerve head consists of an optic disc, cup and neuroretinal rim (NRR) as shown in fig.1. The optic cup is the excavation of nerve fibers in the center, and the NRR are formed by nerve fibers and glial cells. Glaucomatous changes in the optic nerve head are related to decreased number of the nerve fibers. While the size of the optic cup increases, the NRR decreases. The ratio of the area of the optic cup to disc, that is cup to disc ratio (CDR) and neuroretinal rim surface are important structural indicators for assessing the presence of glaucoma. Fig. 2 shows normal eye and glaucoma affected eye.

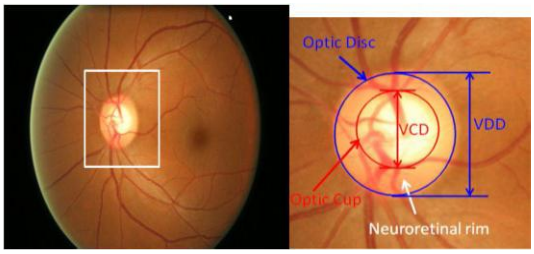

Figure 1. Fundus Image Depicting the Optic Cup, Neuroretinal rim and Optic Disc

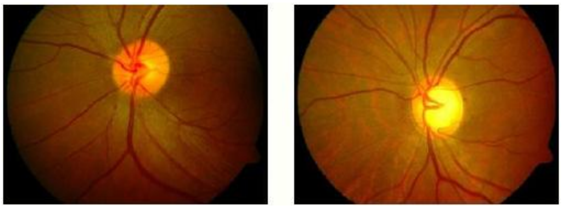

Figure 2. (a) Normal and (b) Glaucoma affected eye

II. OPTIC CUP AND OPTIC DISC SEGMENTATION

Different techniques are described in the literature for OD and OC extraction for the computation of the CDR. Before the segmentation fundus image is preprocessed. In preprocessing, techniques such as morphological operations and contrast enhancement are applied on the input image. The Color fundus image consists of red, green and blue components. The green component enhances the cup region. It appears as the region with highest brightness and hence is useful for extraction of cup .Optic disc is often present in the red field as a well defined white shape brighter than the surrounding area. Therefore Red Channel of the RGB color image is used

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for the extraction of Optic Disc region in the retinal fundus image.

Some of the techniques for image segmentation are:

The paper [1] proposed the deployment of dilation and erosion with Fuzzy c-Means (FCM) as an effective optic cup and disc segmentation. 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. The drawback of the Fuzzy C Means clustering (FCM) is, sensitive to noise and does not consider the spatial information of pixels. Table1. shows the summary of the performance analysis of the method [1].

	Parameters	FCM with morphological operation	FCM without morphological operation
Optic cup	Sensitivity	80.63	76.71
	Specificity	99.89	100
	Accuracy	90.26	88.36
	Precision	0.999	1
	Recall	0.806	0.767
	F Score	0.892	0.868
Optic Disc	Sensitivity	87.64	86.34
	Specificity	99.75	100
	Accuracy	93.70	93.17
	Precision	0.997	1
	Recall	0.876	0.863
	F Score	0.933	0.927

Table1. Summary of Performance Analysis of method [1]

where, Sensitivity = TP/ (TP+TN)
Specificity = TN/ (TP+TN)
Accuracy = TP+TN/ (TP+TN+FP+FN)
Precision = TP/ (TP+FP)
Recall = TP/ (TP+FN)
F Score = 2*Precision*Recall/ (Precision + Recall)
TP = True Positive
TN = True Negative
FP = False Positive
FN = False Negative

The method proposed in [2] for the extraction of the optic disc contour is mainly based on mathematical morphology along with principal component analysis (PCA). The input of the segmentation method is obtained through PCA. The PCA is applied on the RGB fundus image in order to obtain a grey image in which the different structures of the retina, such as vessels and OD, are differentiated more clearly to get a more accurate detection of the OD. Then, the vessels are removed through inpainting technique to make the segmentation task easier. Next, a variant of the watershed transformation, the stochastic watershed transformation, followed to a stratified watershed, are implemented on a region of the original image. Finally the obtained watershed regions are discriminated as the optic disc region and non optic disc region. A geodesic transformation and a further threshold are used for this purpose. The validation of the method has been carried out on 5 public databases: DRIONS, DIARETDB, DRIVE, MESSIDOR and ONHSD.

The method [3] 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**.** An evaluation of the proposed procedure was performed using the set of 81 images from the STARE project, containing images from both normal and pathological subjects. The OD position was correctly identified in 79 out of 81 images (98%), even in rather difficult pathological situations.

The paper [4] presents a new template-based method for OD segmentation. 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. Firstly, an OD-containing sub-image is extracted: an OD pixel and its surrounding region (a surrounding region wide enough to include the whole OD) are selected. With this purpose, an OD location methodology is also proposed here. Then, the OD boundary is extracted in parallel from both the red and green channels of this sub-image by means of morphological and edge detection techniques. Both OD boundaries are approximated by a circumference using the Circular Hough Transform. The “better” of these results is finally selected. The algorithms were evaluated on the 1200 images of the publicly available MESSIDOR database. The location procedure succeeded in 99% of cases, taking an average computational time of 1.67 s. with a standard deviation of 0.14 s. On the other hand, the segmentation algorithm rendered an average common area overlapping between automated segmentations and true OD regions of 86%. The average computational time was 5.69 s with a standard deviation of 0.54s. This paper also

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includes a study on advantages and disadvantages involved by the use of circular, elliptical and deformable models for OD segmentation. The results of this study strengthen the hypothesis of the suitability of circular models for this purpose and show evidence that the circular approach offers good compromise between success rate, quality, and efficiency.

Author proposed an automatic method of segmenting OD and optic cup based on a statistical model technique (active shape model) [5]. Edge detection and the Hough Transform are combined with a statistical deformable model to extract the OD boundary. The method is further extended to obtain the cup boundary on a vessel-removed OD image. The advantage of using Hough Transform is its computational efficiency. But the disadvantage of Hough transform methods is that they can segment the OD from images of normal retinas that usually have a clear and consistent OD boundary, but for images of pathological retinas, these methods often fail because Hough transform are very sensitive to different types of retinal lesions and imaging artifacts around the OD boundary. Here ORIGA ^{Light} database is used to test the performance of the proposed algorithm .The table2 shows the summary of the result obtained from the proposed method.

Metrics	Proposed method for optic disc segmentation	Proposed method for optic cup segmentation
Dice mean(DM)	0.92	0.81
RAD mean	9.72%	32%
Hausdorff dist(px)	26	40

Table2. Summary of results for optic disc and optic cup Segmentation [5]

where, Dice mean=2*Area (A∩B) / {Area(A)+Area(B)}
A DM value of '1' indicates perfect match of the segmented result with the ground truth and a DM value of '0' indicates no overlap.

RAD mean= {(Area (A) +Area (B)) / Area (B)}*100

The relative area difference (RAD) indicates whether the segmentation is over or under segmented by its sign, where a negative sign denotes under segmentation and a positive sign denotes over segmentation. The absolute value of RAD represents the extent of the area difference between two areas without regarding the sign. B refers to the ground truth segmentation. The Hausdorff distance is the maximum distance of a set of points to the nearest point in the other set. The higher the Hausdorff distance between two contours, the larger the mismatch exists in terms of the matched point distance.

In [6] the channels of the colour retinal are separated. The blood vessels are removed, applying the contrast adjustment to enhance the low contrast image. The Fuzzy C Means combined with thresholding is applied on the red channel of the input image for the extraction of the OD and the same technique is applied on the green channel of the input image for the extraction of OC. The CDR is computed using the ratio of vertical diameter of OC and OD. The validity of this new method has been tested on 365 colour fundus images from two different publicly available databases DRION, DIARATDB0 and images from an ophthalmologist. The table3 and table4 shows comparison of Clinical CDR values with CDR values obtained in the proposed method [6].

Images	Clinical CDR(1)	Obtained CDR(2)	Difference (1)-(2)
Image 1	0.5000	0.6082	0.1082
Image 2	0.5714	0.6231	0.0517
Image 3	0.6666	0.5505	0.1161
Image 4	0.8517	0.7871	0.0646
Image 5	0.7142	0.6412	0.073
Image 6	0.4864	0.4173	0.0691
Image 7	0.7060	0.6275	0.0785
Image 8	0.9000	0.8367	0.0633
Image 9	0.6801	0.7287	0.0486
Image 10	0.9026	0.8206	0.0820
Image 11	0.4631	0.4012	0.0619
Image 12	0.6267	0.5151	0.1116
Image 13	0.5147	0.4736	0.0411
Image 14	0.7318	0.7180	0.0138
Image15	0.4265	0.3162	0.1103
Mean Difference			0.07292

Table3. Comparison between Clinical CDR and obtained CDR by the proposed method [6]

Images	Clinical CDR of DRION Database(3)	Obtained CDR(4)	Difference (3)-(4)
Image 1	0.3333	0.4000	0.0667
Image 2	0.5734	0.5316	0.0424
Image 3	0.6666	0.6080	0.0586
Image 4	0.7000	0.7543	0.0543
Image 5	0.6578	0.5816	0.0762
Image 6	0.5625	0.5045	0.0580
Image 7	0.4062	0.4995	0.0933
Image 8	0.5000	0.6020	0.1020
Image 9	0.6097	0.6696	0.0626
Image 10	0.6410	0.6610	0.0200
Image 11	0.5162	0.4011	0.1151
Image 12	0.5010	0.5362	0.0352
Image 13	0.6097	0.5215	0.0882
Image 14	0.7408	0.6943	0.0465
Image15	0.6981	0.6208	0.0773
Mean Difference			0.06643

Table4. Comparison between Clinical CDR of DRION Database and obtained CDR by the proposed method [6]

The method proposed [8] for the localization and segmentation of the optic disk (OD) in low-resolution color fundus images is decomposed into two stages. First is Locating Potential OD Areas Using a Pyramidal Decomposition (the pyramid is created using a simple Haar-based discrete wavelet transform) on the grayscale representation of the input color image and second stage uses the Hausdorff distance for searching OD contour. The key idea is that the areas identified by the pyramidal decomposition method are explored for the presence of a circular shape which is done as firstly the pyramidal candidate regions are aggregated then for each aggregated region edge detection and thresholding is performed which is followed by Hausdorff-based matching. After this the redundant solutions are eliminated. Author proposed a method of a circular transformation to capture both the circular shape of the OD and the image variation across the OD boundary simultaneously [9]. For each retinal image pixel, it evaluates the image variation along multiple evenly-oriented radial line segments of specific length. The pixels with the maximum variation along all radial line segments are determined, which can be further exploited to locate both the OD center and the OD boundary accurately. The advantage of this technique is that the parameters of the circular transformation are Fixed and even if the parameters vary within a certain range the proposed technique is stable. The proposed method was experimented over the STARE dataset, the ARIA dataset, and the MESSIDOR Dataset with OD detection accuracies of 99.75%, 97.5%, and 98.77% respectively and the OD segmentation accuracies of 93.4% and 91.7% are obtained for STARE dataset and ARIA dataset, respectively, that consists of many severely degraded images of pathological retinas.

III. CONCLUSION

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. Glaucoma is a silent disease that comes with no symptoms and warning. Glaucoma detection from Cup to disk ratio in Retina images is one of the most popular techniques for Retina analysis. This review paper depicts many works related to automated glaucoma detection by segmenting optic disc and optic cup and hence finally finds the CDR. On the basis of CDR values images are classified as normal and glaucomatous image.

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