Segmentation of Optic Disc and Cup in Fundus Images using Maximally Stable Extremal Regions

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Abstract**—** In procedure of clinical routine on retinal fundus, Optic Disc and Cup are often used for diagnosis many diseases such as Glaucoma, Diabetic retinopathy and Age-Related Macular Degeneration (AMD). Optic Disc and Cup are the central organ of retinal fundus which control the balance of blood vessels. Medical practitioners often used different information on these organs to diagnose such diseases. In this work, we proposed a method to automatically segment the Optic Disc and Cup from a low contrast retinal fundus image for further diagnosis by the doctor. The proposed method consists of three main steps including pre-processing, region localization and Optic Disc and Cup extraction. Firstly, Red-Channel and Morphological techniques are applied as a pre-processing step. Red-channel Method is used to enhance properties of the disc area. Then, Morphological Technique is used to remove blood vessels from the retinal fundus. Secondly, Region Localization Method using Maximal Stable Extremal Region is used to Optic Disc and Cup. Finally, Optic Disc and Cup are extracted from the retinal fundus image to calculate the disk to cup ratio.

Keywords— Retinal Fundus; maximal stable extremal region; Optic Disc; Optic Cup;

I. Introduction

A number of researchers are trying to extract the Optic Disc and Cup from the Retinal Fundus image. Optic Disc and Cup are usually used to diagnose diseases or abnormalities occurs within the Retinal Fundus such as Glaucoma, Diabetic retinopathy and Age-Related Macular Degeneration (AMD). The extraction of Optic Disc and Cup from the Retinal Fundus image are challenging, especially in the low contrast image. A number of image processing techniques has been proposed to solve this problem as followed.

Javeria Ayub et al. [1] proposed K-mean Clustering as a technique to segment Optic Disc (OD) and Optic Cup (OC) for detecting glaucoma using CDR (Cup to Disc Ratio). Canny Edge and Ellipse Fitting are techniques used to identify and smooth boundary of OC and OD. They achieved an accuracy rate of 92% with mean square error of 0.002 for CDR. Ashi Agarwal et al. [2] proposed a technique for automate detecting of optic disc from fundus images using Edge Based and Active Contour Fitting Method. Firstly, Optic Disc localization using averaging filter to remove blood vessels, Next, Maximum Intensity of an image is calculated. Secondly, Edge Detection using Sobel filter was applied together with Morphological operations to complete Optic Disc Boundary. This method provides a relatively high accuracy rate of 90%. Gibran Satya Nugraha et al. [3] proposed to segment Optic Disc and Optic Cup using Histogram Feature- Based Adaptive Threshold to find Cup to Disk Ratio. This method combined Contrast Stretching, Thresholding and Morphological Operation to help identify Disc and Cup areas. Hanung Adi Nugroho et al. [4] proposed a method using Morphological Reconstruction Enhancement and Active Contour. Red Channel is applied to enhance the object of interest. Region of Interest (ROI) is determined based on the highest value of pixel intensity. Segmentation of optic disc is undertaken using active contour. This method achieved an accuracy of 99.55%, sensitivity of 89.92% and specificity of 99.85% in segmenting optic disc. Suman Sedai et al. [5] proposed a method using Shape Regression and Circular Hough Transform to segment optic disc. That is a robust and efficient cascaded shape regression method which iteratively learns the final shape of the optic cup and disc from a given initial shape. This method achieved an accuracy for optic cup and disc with dice metric of 0.95 and 0.85 respectively.

II. Problem Analysis

Glaucoma is typically known as silent thief of sight which is characterized by elevated intraocular pressure. A patient who got this disease will slowly loss their vision which then led to permanent blindness. Glaucoma ranked second of the leading reasons of blindness worldwide. It can be diagnosed by the Cup to Disc Ratio which often known as CDR. In ophthalmology and optometry, CDR are used as a main factor to assess the progression of glaucoma. The optic disc is the location of the eye's "blind spot". This is the area where the optic nerve and blood vessels enter the retina. The optic disc can be flat or it can have a certain amount of normal cupping. But glaucoma, which

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is in most cases associated with an increase in intraocular pressure. This kind of pressure often produces additional pathological cupping of the optic disc. The pink rim of disc contains nerve fibers. The white cup is a pit with no nerve fibers. The severity of glaucoma can be identified by the size of the cup. In the final state, the cup enlarges until it occupies most of the disc area.

From the above discussion, it clearly indicated that the optic disc and the cup segmentation is necessary to help pathologist to evaluate Glaucoma level. Thus, many researchers were attempted to extract the Optic Disc and Cup in the Retinal Fundus image. The extraction and separation of Optic Disc and Cup are challenging, particularly, in case of low contrast between Optic Disc and Cup on the image as shown in *Fig. 1*.

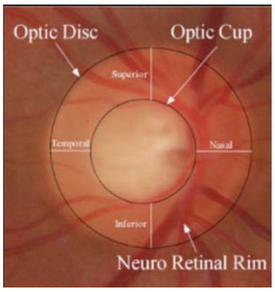

Fig.1 An example of Optic Disc and Optic Cup in a retinal fundus image.

III. Methodology

In this paper, we proposed a methodology for automatically identifying the location of Optic Disc and Cup. The proposed method consists of 3 main steps including pre-processing, region localization and Optic Disc and Cup extraction. In the first step, pre-processing, Red Channel and Morphological Methods are used for removing insignificant objects on an input image. In the second step, Region Localization Method using Maximal Stable Extremal Region is used to locate Optic Disc and Cup. In the final step, Optic Disc and Cup is extracted to calculate the disk to cup ratio.

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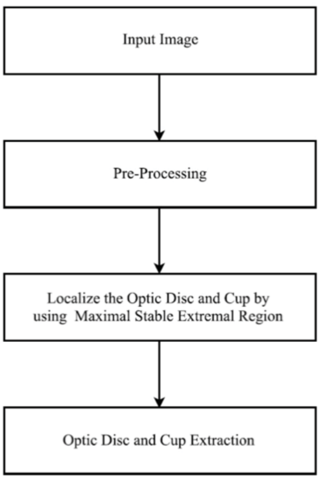

Fig 2. An overview of the proposed method.

The target result of the proposed method is illustrated in *Fig. 3*. In *Fig 3* (B) depicted the target area of Optic Disc and Optic Cup. The Optic Disc is the area that surrounded by Green Circle while the Optic Cup is the area that surrounded by Blue Circle.

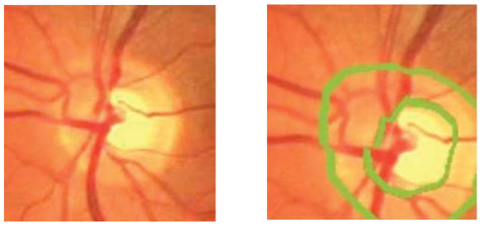

Fig 3. A target result of the proposed method.

A. *Pre-processing*

Red channel Selection:

In RGB image has three important channels which are red, green, and blue. For a 24bit RGB image, each channel has 8 bits, for red, green, and blue with conventional brightness intensities between 0 and 255. Each channel expresses each object characteristics in different intensity. In other word, it will provide different information of the observed components in three variety ways. For a Fundus image, the properties of Red channel can properly distinguish the disc from other components.

Morphological Operation:

Opening and closing are two important operators from mathematical morphology. They are both derived from the fundamental operations of erosion and dilation. Like those operators they are normally applied to binary images. The basic effect of an opening is somewhat like erosion in that it tends to remove some of the foreground (bright) pixels from the edges of regions of foreground pixels. As with other morphological operators, the exact operation is determined by a structuring element. The effect of the operator is to preserve foreground regions that have a similar shape to this structuring element, or that can completely contain the structuring element, while eliminating all other regions of foreground pixels. In this paper, multistep closing operators were used to remove all unnecessary blood vessel components. In Figure 1, it is observed that blood vessels have different shapes and sizes.

B. *Locallization*

Maximally Stable Extremal Regions (MSER):

MSER is a method for blob detection in images or thresholding. That is, all the pixels below a given threshold are identified as 'Black' and all those above or equal are identified as 'White'. Given a source image, if we generate a sequence of threshold result images where each image corresponds to an increasing threshold t, we would see first a white image, then 'black' spots corresponding to local intensity minima will appear then grow larger. These 'black' spots will eventually merge, until the whole image is black. The set of all connected components in the sequence is the set of all extremal regions. In that sense, the concept of MSER is linked to the one of component tree of the image. The component tree indeed provide an easy way for implementing MSER. In this paper, MSER was used twice. First, it was used for localizing the disc location in the given fundus image. Or, it was first used in this step. Second, it was used for separating the cup area from the extracted disc area as illustrated in the next step

C. Extraction

After the candidate disc location has been identified, the ROI of the disc is registered. The ROI was rectangular subtracted from the input image. The Red channel was selected. Then, in order to erase the remained blood vessels, multistep closing operations were used. After that, image binarization technique based on the optimal threshold value was used. In other word, candidate disc area was obtained. Consequently, extraction of the candidate disc area from the ROI image was applied, called BW2. It is observed that the boundaries of extracted area are rough. Then, border smoothing technique based on Convexhull was applied. After our investigation, in this sub- step, the Green channel provides an optimal information for extracting the cup area from the disc area. Then, the Green channel was used as an input data for the second MSER deployment.

IV. Experimental Result

After applied the proposed method with the Dataset from Pattern Recognition Lab, Department of Computer Science, Friedrich Alexander University, Germany, HRF Image Database, an example of the experimental result is shown in Fig. 4.

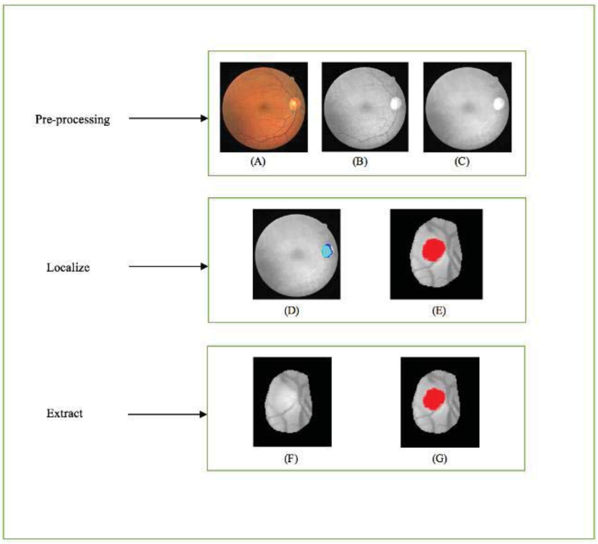

Fig. 4 In Pre-processing step, image (A) Original Image. (B) R Channel from RGB. (C) Morphological Operation. In Localize step, image (D) MSER to localize Disc from fundus image. (E) MSER to localize Cup from Optic Disc. In Extract step, image(F) Identify Optic Disc Area. (G) Identify Cup Area.

An input retinal fundus image contains a number of components such as blood vessels, Optic Disc, Optic Cup and macular. So before the Optic Disc and Cup area can be exacted, Red channel and Morphological Operation were applied to remove blood vessel and small object to bring forward the optic disc. Next, Optic disc localization to identify Region of Interest (ROI) using Maximally Stable Extremal Regions (MSER) was applied to detect Optic Disc area. Then, bounding box technique was applied to exact the Disc area. After the Optic Disc was located, once again, the combination of Red Channel and Morphological Operation are used to remove blood vessel in the Disc Area. Then, a Threshold technique was used to segment the optic disc area and remove the background. Then, this binary image was used to subtract with ROI to derive its original properties. After that Maximally Stable Extremal Regions (MSER) was used again for find Cup localize.

After the Optic Disc and the Cup area were identified. The ratio between Optic Disc and Cup (Cup to Disc Ratio) was calculated. This ratio between the area of Optic Disc and Optic Cup can be used to preliminary diagnose whether a patient exposed to Glaucoma or not. A lab scale experiment on 30 retinal fundus images of 15 non-Glaucoma cases and 15 Glaucoma cases are tested with the proposed method. The experimental result revealed the CDR ratio as shown in Table 1.

Table 1. Cup to Disc Ratio of Non-Glaucoma and Glaucoma

Non-Glaucoma				Glaucoma			
Image No.	Disc Area	Cup Area	CDR Ratio	Image No.	Disc Area	Cup Area	CDR Ratio
1	5512	1611	29.23	1	3937	1579	40.11
2	4723	1472	31.17	2	4165	2316	55.61
3	3944	1296	32.86	3	3295	1553	47.13
4	4127	1157	28.03	4	5930	3495	58.94
5	5198	1957	37.65	5	4217	1348	31.97
6	3624	947	26.13	6	4732	1963	41.48
7	4256	1614	37.92	7	3759	1264	33.63
8	5267	1584	30.07	8	2948	1464	49.66
9	3528	1069	30.30	9	5164	2486	48.14
10	7322	2374	32.42	10	6143	2745	44.69
11	4536	1474	32.50	11	3736	2385	63.84
12	3298	1036	31.41	12	4726	2684	56.79
13	5117	1699	33.20	13	5328	2584	48.50
14	4532	1567	34.58	14	3627	1837	50.65
15	3469	1615	46.56	15	4268	1747	40.93

From the information in Table 1, the performance of the proposed method is calculated using Confusion Matrix. Confusion Matrix is a predictive value evaluation performed by as compared to the results really sought by people. True Positive (TP) is what the program predicts is true and people say it is true. True Negative (TN) is what the program predicts is not true and people say it is not true. False Positive (FP) is what the program predicts is true, but people say that is not true. False Negative (FN) is what the program predicts is not true, but people say that actually.

Accuracy is the value that tells how accurate the program is. Can be calculated from

$$\frac{(TP + TN)}{(TP + TN + FP + FN)} \tag{1}$$

Recall or True Positive Rate (TPR) is the value that tells how complete the program is or the probability of prediction. This value can be calculated from

$$\frac{(TP)}{(TP + FN)} \tag{2}$$

True Negative Rate (TNR) or Specificity is the value that tells how program can correctly identify the non-comply cases. This value can be calculated from

$$\frac{(TN)}{(TN + FP)} \tag{3}$$

False Positive Rate (FPR) is a value that tells how program falsely reject the null hypothesis. This value can be calculated from

$$\frac{(FP)}{(TN + FP)} \tag{4}$$

False Negative Rate (FNR) is a value that tells how program falsely reject the alternative hypothesis. This value can be calculated from

$$\frac{(FN)}{(TP + FN)} \tag{5}$$

Precision is a value that tells how much program is actually predicts. This value can be calculated from

$$\frac{(TP)}{(TP + FP)} \tag{6}$$

Table 2. Confusion Matrix Result of the proposed method.

Decription	Value
Recall	0.85
Precision	0.92
Accuracy	0.80
TNR	0.33
TPR	0.67
FNR	0.15

Table 2 showed the value of Recall, Precision, Accuracy, TNR, TPR and FNR which calculated using Eq. 1 – Eq. 6. The figure revealed that the proposed method can perform reasonably well with the rate of 0.85, 0.92, 0.80, 0.33, 0.67 and 0.15 respectively.

V. CONCLUSION

In this research, the methodology for automatically identifying the position of Optic Disc and Cup on low contrast Retinal Fundus image was proposed. The proposed method consists of 3 main steps including pre-processing, region localization and Optic Disc and Cup extraction. In the first step, Red Chanel and Morphological Methods are used for removing noises. In the secondly step, Region localization using Maximal Stable Extremal Region to locate Optic Disc and Cup. In the third step, Optic Disc and Cup extraction for finding its area on fundus image. The proposed method achieved: accuracy rate of 80%, precision of 92%, and recall of 85%. In future work, we plan to improve the segmentation methods to improve the segmentation methods to increase an accuracy and computational time performance.

VI. ACKNOWLEDGEMENT

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VII. REFERENCES

[1] J. Ayub et al., "Glaucoma detection through optic disc and cup segmentation using K-mean clustering," *2016 International Conference on Computing, Electronic and Electrical Engineering (ICE Cube)*, Quetta, 2016, pp. 143-147.

[2] A. Agarwal, A. Issac, A. Singh and M. K. Dutta, "Automatic imaging method for optic disc segmentation using morphological techniques and active contour fitting," *2016 Ninth International Conference on Contemporary Computing (IC3),* Noida, 2016, pp. 1-5.

[3] Segmentation of the Optic Disc and Optic Cup Using Histogram Feature-Based Adaptive Threshold for Cup to Disk Ratio Gibran Satya Nugraha, Indah *Soesanti MATEC Web Conf. 75 05003 (2016)*

[4] H. A. Nugroho, Ilcham, A. Jalil and I. Ardiyanto, "Segmentation of optic disc on retinal fundus images using morphological reconstruction enhancement and active contour," *2016 2nd International Conference on Science in Information Technology (ICSITech)*, Balikpapan, 2016, pp. 362-366.

[5] S. Sedai, P. K. Roy, D. Mahapatra and R. Garnavi, "Segmentation of optic disc and optic cup in retinal fundus images using shape regression," *2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Orlando, FL, 2016, pp. 3260-3264.