Comparative Study of Initial Seed Point Required Approaches with the use of Vessel Distance Hint for OD Boundary Detection

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Abstract—This paper presents a comparative study for semi-automated detection of optic disk boundary in fundus images. The study implements and measures performances of region growing, thresholding, and gradient vector flow snake (GVF-snake) approaches. The data set tested in this experiment consists of 91 fundus images, 60 clear images, and 31 faint images. The comparative results show that the thresholding method can estimate the disk boundaries of 91 test images closer to the groundtruth with the better success rate when compared to those obtained by gradient vector flow snake (GVF-snake) and region growing.

Index Terms—Boundary detection, region growing, thresholding, GVF-Snake.

I. INTRODUCTION

Finding optic disc boundary is very important for the medical purpose in the way to detect the abnormality of the patients who suffer from the disease which related to eyes or retinas. The advantages that a system for automatically detect early signs of this disease would provide have been widely studied and experienced positively by experts [22]. In this sense, the optic disc plays an important role in developing automated diagnosis expert systems for diabetic retinopathy as its segmentation is a key preprocessing component in many algorithms designed to identify other fundus features [5]. The relatively distance between the optic disc and the fovea, can be used to help estimate the location of the latter [6]. On the other hand, to segment the vascular tree, blood vessel tracking methods need an initial seed vessel point. For this, pixels of vessels within the optic disc or in its vicinity have been used [7], [13].

Optic disc segmentation is also relevant for automated diagnosis of other ophthalmic pathologies. The most well-known is Glaucoma. It is the second most common cause of blindness worldwide [31]. Image processing is a major tool that has always been chosen to solve a problem in automated ocular treatment and has been introduced to ophthalmology along with robotic surgery [28]. Biomedical engineer in cooperation with computer scientist have developed numbers of approach and algorithms using to increase efficiency rate and reduce chance of error occurrence. With the use of image processing, cataract on optic disc can be easily discovered and targeted by suitable approach and algorithm for the diagnosis of diabetic retinopathy detection [21].

In the literature very few works have been reported on locating the optic disc boundary in retinal images without the initial seed point of the optic disc. Most of the methods only locate the optic disc by using approach such as shape detection or high brightness detection in which they produce different rates of accuracy with some particular drawbacks. [6], [7], [9], [21] These techniques, however, usually fail on pathological images, where not only the optic disc that is characterized as round shape or evaluated brightness, but also other regions of fundus that has similar patterns in which it becomes harder to track the right optic disc and later originate the center point. The technique that proposed color space for optic disc detection and locate the optic disc boundary accurately using an automatically initialized snake. It then apply the used of snake and hand-labelled images to compare the performance of new color morphology methods, but the key problem showed is a comparison of color spaces for performing color morphology to remove blood vessels use for boundary location [3]. S. Sekhar et al. [32] proposed the method to locate of optic disk by means of using the morphological operations and by using the Hough transform by applying the two main processes, dilation and erosion, to find the optic disc. However, the authors mainly focused on locating the optic disc and did not address the original point of the optic disc which is hard to extend for further developments. Likewise, in [29] a detection in the curves and lines is required a limited data set and may prohibit when dealing with huge amount of datas and sometimes in multidimensional array alike retinal images.

In this work, the boundary of the optic disc is detected by exploring three initial-seed-point required techniques such as region growing, thresholding, and GVF active contour. The three approaches are applied and implemented for the comparative result in this paper. In addition, we also compare our approaches with the others which require no initial seed points to develop a comparative study. Benefits of this project will be a fundamental resources for those who wished to developed an application in ophthalmology field and to detect...
the possibilities of glaucoma in diabetic patient.

II. BACKGROUND

Digital image processing, by definition, is the use of complex computer algorithms to create, process, or modify the input digital images, and get modified digital images or some characteristics or parameters related to the digital image in return. The digital image is generally a numerical representation of a two-dimensional image, and is mostly referred to as a raster or a bitmap image. A raster image is a two-dimensional array of pixels, the smallest addressable element that represents the image on the screen. The pixel is a physical point, and it contains 8-bit value of intensity of three different color: red, green, and blue. The three colors are actually three dots which will incorporate into a point-pixel.

There are various techniques in image processing that can be applied in order to detect, modify, or segment the images i.e., extracting the expected features. The basics of techniques applied in this study are described below.

1) Region Growing: Region Growing is a simple region-based image segmentation method used to partition an image into regions which, in this case, is applied to extract the optic disc from fundus images. The basic explanation of the mechanism of Region Growing is that it examines neighboring pixels of initial seed points and determines whether the pixel neighbors should be added to the region using the pre-defined criteria. The process is then iterated until the criteria is no longer satisfied, in the same manner as in general data clustering algorithms. This is also classified as a pixel-based image segmentation method since it involves the selection of initial seed points.

2) Thresholding: Thresholding is a technique used in image segmentation, one of the processes in digital image processing, to convert the image into binary image in which the value of each pixel is either 0 or 1, represented by the colors of black and white. The conversion process is to compare each pixel value of the original image to that of a thresholding value, which can be automatically found, often the mean value, or from some threshold selection algorithm. If the pixel value is greater than the thresholding value, assuming it is an object which should be brighter than its background, then it is set to 1, otherwise it may be the background, and is set to 0.

3) GVF Snake: Gradient vector flow snake or GVF Snake is an extension of the well known method snakes or active contours. The difference between traditional snakes and GVF Snake is that, GVF Snake converge to boundary concavities and they do not need to be initialized close to the boundary. The core step of Snake algorithm is to minimize the sum of internal and external energy, which both are represented in the form of vectors. Therefore, the external energy and internal energy are both supposed to minimal when the snake is at the object boundary position. In this study, we have tried using GVF Snake to find optic disc boundary.

III. METHODOLOGY

Fundus or retinal images are often taken by using fundus cameras in hospitals and research centers. We have obtained many free retinal databases from the internet which will come into use during the course of the experiment. The resolution of these images depends upon the quality of the camera used. Most of the new cameras used today produce images of quality that is enough for image processing. This experiment uses the data set of 91 Retinopathy of Prematurity(ROP) images, which is classified into 60 clear images and 31 faint images.[10]

In this study, the experiment flow is designed as indicated in the figure[1] on page[2]. The detail explanation of each process is given below:

4) Image Classification: In this study, since quality and clarity of images has significant effect on performance and accuracy of many algorithms, all images that are tested are manually classified into 2 classes, clear images, and faint images. This classification should also point out each approaches drawbacks regards to quality of source images.

5) Preprocessing: Fundus images taken by the fundus cameras usually contain noises, illumination spot, or non-uniform features with the brightness centering on the optic disc and decreasing outwards to other regions. This often makes it complicated to extract optic disc from the images as they usually have similar color to the background. Therefore, preprocessing is needed for the ease of feature extraction. The common characteristics of the preprocessing technique used in this study is to apply Canny operator to intensify the contrast between the areas of interest and the background. The techniques are often performed on the green channel of RGB color images, which exhibits the area of interest better in terms of contrast than the other channels.
6) Applying Techniques: In this phase of the study, each fundus image in this experiment are applied with all three approaches. For all approaches, initial seed point is chosen to be the point in the image where the sum of the distance from it to all main vessels are minimum.

- **Region Growing:** Firstly, Canny operator is applied to remove noise in the image, and to enhance the edge of optic disc, making it more suitable for region growing function. Then, apply region growing on the result image.

- **Thresholding:** For each point in the image, we compute shortest distance from it to all main vessels. To get the boundary, we include all points that such a distance is less than the threshold value to be the boundary of the OD. To select the threshold for an image, we find the average of the short distance from each pixel to the main vessels and also find the standard deviation. The threshold is then set to be difference between average value and the standard deviation.

- **Active Contour(GVF Snake):** Firstly, we apply Canny operator to remove noise and to enhance the edge of optic disc, Then, apply the GVF Snake function.

7) Evaluation and Results: In this study, evaluation was conducted using pixel based technique, in which each pixel of the detection result is compared to the groundtruth image. From the experiment, the number of pixels that are true positives (TP), true negatives (TN), false positives (FP) and false negatives (FN) can be obtained.

\[
\text{Sensitivity} = \frac{TP}{TP + FN} \quad (1)
\]

\[
\text{Positive Predictive Value} = \frac{TP}{TP + FP} \quad (2)
\]

This study uses Sensitivity and Positive Predictive Value (PPV) as the performance measure. Sensitivity is the measure of the proportion of positives which were correctly detected, while Positive Predictive Value (PPV) is the measure of the proportion of correct data from the whole retrieved data.

### IV. RESULT & DISCUSSION

From the data set of 60 clear images and 31 faint images, the experiment result is as below:

Region Growing approach gives the result of 44.67% sensitivity and 26.69% PPV for clear images, while giving 74.10% sensitivity and 3.66% PPV for faint images. Thresholding approach gives the result of 62.43% sensitivity and 68.19% PPV for clear images which both are the highest among all approaches, while giving 47.71% sensitivity and 49.12% PPV for faint images. GVF Snake 2D approaches gives 55.93% sensitivity and 18.51% PPV for clear images, while giving 40.68% sensitivity and 9.33% PPV for faint images (see table I).

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>PPV</th>
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<tbody>
<tr>
<td><strong>Region Growing</strong></td>
<td>46.67%</td>
<td>26.69%</td>
</tr>
<tr>
<td><strong>Thresholding</strong></td>
<td>62.43%</td>
<td>68.19%</td>
</tr>
<tr>
<td><strong>GVF Snake 2D(Active Contour)</strong></td>
<td>55.93%</td>
<td>18.51%</td>
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This can be explained that when the edge of the OD is unclear, the region growing approach grows from the inside of the OD and also spurs out to the background resulting very poor PPV. The situation is better when the boundary of the OD is clear. The same scenario happens with GVF snake, without clear boundary the GVF snake also grows freely to outside.

### TABLE I: Average precision and recall

With a good hint from the shortest distance to the vessels, we can see that most initial seed point required methods work noticeably better than without seed-point required methods (Morphological Operator and Circular Hough Transform) for both Sensitivity and PPV. This implies that the point what gives the minimum sum of shortest distance from it to the main vessels that we used as the seed of the OD is quite useful in getting the location of the OD.

According to the result, it is obviously seen that thresholding approach gives relatively high PPV not only in clear images but also in low quality images. On the other hand, region growing gives quite high sensitivity while has relatively poor PPV compares to other approaches.

(See image Result Image B in figure [2] on page [4])
Numerical experiments

Y. Nakaguroa, S. S. Makhanov and M. N. Dailey, Detection of optic disc in various detection software that requires optic disc detection. Department of Computer Science, University of Bristol, Bristol, BS8 1UB, U.K. b Bristol Eye Hospital, Bristol, BS1 2LX, U.K.


In this work, we experiment on three approaches(region growing, vessel distance thresholding, and the GVF snake) of OD detection which requires the initial seed input. We compare the results with other approach which requires no seed point. In our experiment, we pick the seed point of the three methods to be the point whose shortest distance sum to the main vessels in the image is minimum. We found that thresholding approach seems to performs best in both clear and faint images compares to other approaches regards to highest sensitivity and PPV in clear images and the highest PPV in faint images. The major drawbacks that region growing and active contour approach have is that under the constraint of low quality images, the algorithm will overgrow the region (which often enclose the whole optic disk), resulting in relatively low PPV.

It is observed that most result of thresholding approaches gives the result that is very closed to the actual optic disc, therefore, this approach could be a base resource for development in various detection software that requires optic disc detection.

V. CONCLUSION

Fig. 2: Results on sample faint images: Red: Region Growing; Green: Thresholding; Blue: GVF Snake 2D; Black: Optic Disc(OD) boundary

REFERENCES