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Automatic Optic Disc Localization and Segmentation using Swarm Intelligence

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Abstract—The optic disc may be distinguished in eye fundus images as a rounded shape having high intensity values. An efficient localization and segmentation of optic disc in colour retinal images is a significant task in an automated retinal image analysis process. It is a challenging task to detect optic disc in all types of retinal images, that is, normal, healthy images. This paper presents an automated method to locate and segment the optic disc in all types of retinal color fundus images using histogram based particle swarm optimization techniques. The technique is tested on 235 images obtained from publicly available database DRION, and certain images obtained from an ophthalmologist. The performance analysis was done using the ground truth of DRION database. From the scatter plot, it is shown that the ground truth and detected optic disc centers have a high positive correlation. The results of the new method seem promising and useful to clinical work.

Keywords- fundus image; optic disc; particle swarm optimization; retinal images.

I. Introduction

The fundus images are used for diagnosis by trained clinicians to check for any abnormalities or any change in the retina. A healthy retinal image may contain anatomical structures like the macula, the optic disc (OD), optic cup and blood vessels. The OD is the exit point of retinal nerve fibers from the eye, and the entrance and exit point for retinal blood vessels. It is a brighter region than the rest of the ocular fundus and its shape is usually round. The location of OD is important in retinal image analysis, for example, to help locate anatomical and pathological parts in retinal images (e.g. the fovea), for blood vessel tracking, as a reference length for measuring distances in retinal images, and for registering changes within the optic disc region due to diseases such as glaucoma and the development of new blood vessels [1][2]. Figure1 shows a color retinal fundus image with fundamental features.

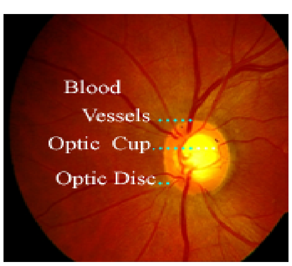


Figure1. Color Retinal Fundus Image

The organization of this paper is as follows:

Section II describes the brief survey of existing literature. Section III describes the materials used for the proposed algorithm. In Section IV a new algorithm to efficiently locate and segment an optic disc is proposed. The results are presented in Section V. Conclusions are in Section VI.

II. Literature Survey

Recently, many studies on the use of fundus images in locating optic disc have been reported. Huiqi Li et al.[3] used PCA to locate the optic disc even for retinal images having bright lesions. Boundary of the optic disc is extracted by a modified active shape model technique, but this technique is very slow. Hoover [4] utilized the geometric relationship between the optic disk and main blood vessels to identify the disk location. He described a method based on a fuzzy voting mechanism to find the optic disc location. Mendels et al. [5] and Osareh et al. [6] introduced a method for the disk boundary identification using free-form deformable model technique. Li and Chutatape [7][8] used a PCA method to locate the optic disk and a modified active shape model (ASM) to refine the optic disk boundary based on point distribution model (PDM) from the training sets. Joshi et al. used the deformable or active contour (snake) method. [9] A method based on pyramidal decomposition and Hausdorff distance based template matching was proposed by Lalonde et al. [10]. Jun Cheng et al. [11] did the automatic optic disc segmentation with peripapillary atrophy elimination. Handayani Tjandrasa et al. [12] developed a method for OD segmentation using hough transform and active contour operations. This paper presents a automatic method for optic disc detection using particle swarm optimization (PSO) technique.

III. MATERIALS AND METHODS

The images used in this paper are obtained from public databases DRION and the images obtained from Giridhar Eye Research Institute Kochi. A total of 235 images including, 5 normal images and 230 diseased images and are used in this paper for evaluation. The images are of very large variability in terms of disc size and image quality.

IV. DEVELOPED ALGORITHM

The proposed approach is composed of four steps. In the first step the preprocessing steps are explained. Next the histogram of the smoothed image using the weighted average is generated for the computation of threshold T. In the third step the particle swarm optimization technique is applied using T for the localization and segmentation of OD.

A. Preprocessing

1) Resizing

Input images are color fundus retinal images are of different size. In order to standardize retinal size, all input images are resized to 250 x 300 x 3 pixels. Thus, a drastic reduction in computational time is provided.

2) Removal of Blood Vessels

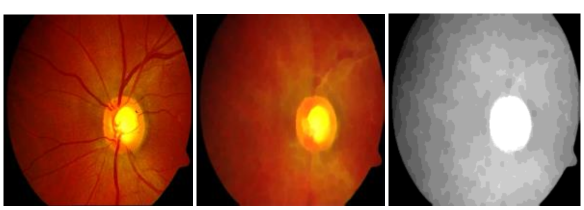
Blood vessels are removed using a morphological closing procedure,

$$I2(I,B) = A \bullet B = E(D(I,-B),-B) \quad , \quad (1)$$

where I is the input image and B is the structuring element, the smoothed, vessel free output image is I2. Here, a 11x11 symmetrical disc structuring element is used [13][14]. Figure 2 shows the vessel free image of the input image.

3) Red Channel Selection

Since the OD is often present in the red field as a well-defined white shape, brighter than the surrounding area, the red channel of the vessel free image is used for OD detection.



(a) (b) (c)

Figure 2. (a) Input image (b) Vessel free image (c) Red channel of the vessel free image

4) Histogram Segmentation

The histogram of the smoothed red component image can be divided into four regions using the weighted average of the intensity values. The weighted average can be calculated as follows.

$$X = \frac{\sum wi x i}{\sum wi} \quad , \quad (2)$$

where xi is the intensity and wi proposed weight [13].

B. Feature Extraction

The main objective of segmentation is to group the image into regions with same property or characteristics. Segmentation involves partitioning an image into groups of pixels which are homogeneous with respect to some predicate [13]. Assessment of optic disk is important in retinal screening. The optic disk is a bright pattern of the fundus image. As the optic disk is a bright pattern, and as the vessels appear dark, the gray level variation in this region is higher than in any other part of the image. The optic disc in the vessels-erased image was detected by using color connected component analysis. This paper proposes a new method for segmenting images based on PSO.

The algorithm of PSO is used to find the best values of thresholds that can give us an appropriate partition for a target image according to a fitness function.

C. Particle Swarm Optimization

The particle swarm simulates this kind of social optimization. A problem is given, and some way to evaluate a proposed solution to it exists in the form of a fitness function (4).

The swarm is typically modeled by particles in multidimensional space that have a position and a velocity. These particles fly through hyperspace and have two essential reasoning capabilities: their memory of their own best position and knowledge of the global or their neighborhood's best.

So a particle has the following information to make a suitable change in its position and velocity:

a. A global best that is known to all and immediately updated when a new best position is
found by any particle in the swarm.
b. Neighborhood best that the particle obtains by communicating with a subset of the swarm.
c. The local best, which is the best solution that the particle has seen.

Each particle, *i*, flies through an *n*–dimensional search space, *Rn* , and maintains the following information:

xi, the current position of ith particle (x - vector),

pi, the personal best position of ith particle (p - vector), and

vi, the current velocity of ith particle i (v - vector).

The personal best position associated with a particle, *i*, is the best position that the particle has visited so far. If f denotes the fitness function, then the personal best of *i* at a time step *t* is updated as:

$$p_i(t+1) = \begin{cases} p_i(t), & \text{if } f(x_i(t+1))\ f(p_i(t)) \\ x_i(t+1), & \text{if } f(x_i(t+1)) < f(p_i(t)) \end{cases} \quad (3)$$

If the position of the global best particle is denoted by *gbest*, then:

$$gbest \in \{ p1(t), p2(t), \ldots, pm(t) \} = \min\{ f(p1(t)), f(p2(t)), \ldots, f(pm(t)) \} \quad (4)$$

The velocity updates are calculated as a linear combination of position and velocity vectors. Thus, the velocity of particle i is updated using equation (3) and the position of particle i is updated using equation (4).

$$v_i(t+1) = wv_i(t) + c_1r_1(p_i(t) - x_i(t)) + c_2 r_2 (gbest - x_i(t)) \quad (5)$$

$$x_i(t+1) = x_i(t) + v_i(t+1) \quad , \quad (6)$$

where, w is the inertia weight [16], c_1 and c_2 are the acceleration constants, r_1 and r_2 are random numbers in the range [0,1] and V_i must be in the range [-Vmin, Vmax], where *Vmax* is the maximum velocity [15][16].

D. Optic Disc Extraction

The algorithm used to extract optic disc is based on global thresholding using PSO. From the analysis of fundus images it is known that the optic disc is the brightest part of the fundus image. It is the part with highest intensity of the histogram and to get this portion, the histogram of the preprocessed image is divided into four regions, where the last region with highest intensity represents the optic disc. To evaluate the threshold values, every agent scans the image row wise to find local best values for each row and eventually evaluates its global best for the assigned region. Among these regional global bests the agents select the most suitable candidate solution by communicating with each other. This is the threshold value or the global best. From the segmented image the green component was removed and the high intensity red component region was extracted. The binary equivalent of this extracted region represents the optic disc of the input image.

E. Optic Disc Localisation

The centroid (Y, X) of the extracted OD is used for localizing OD on the input image. The centroid (Y, X) is computed using the following equations.

$$Y = \frac{1}{m} \sum_{i=1}^{m} row_i \quad (7)$$

$$X = \frac{1}{n} \sum_{i=1}^{n} col_i \,, \quad (8)$$

where m is the number of rows and n is the number of columns.

F. Optic Disc Sgmentation

The centroid (Y, X) and the radius R of the obtained OD is used to overlay circle on the input image to segment OD of the input image. R is calculated using the following formula.

$$R = Y - ymin \quad , \quad (9)$$

where *ymin* is the minimum row coordinate.

The following figure, figure4 depicts the OD segmentation using PSO, OD extraction, OD localisation and segmentation on the input image.

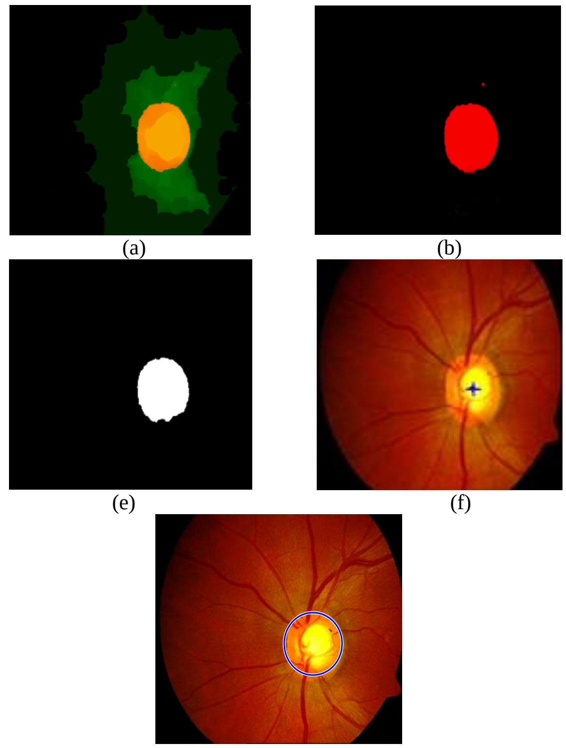


Figure 3. (a) Segmentation of image using PSO (b) Extracted high intensity red component (c) Binary OD (f) OD Localisation (g) OD Segmentation

V. Results and Discussions

The new method was tested on the publically available database DRION and images obtained from an ophthalmologist. The success rate is as follows. Among the 110 images from DRION database, 106 images with computation time 1.6673 seconds and among 125 images from the ophthalmologist, 123 images with computation time 1.6714 seconds, were successfully done the localization and segmentation of optic disc.

A. DRION database

It has 110 retinal images with each image having the resolution of 600 x 400 pixels and the optic disc annotated by two experts with 36 landmarks. The mean age of the patients was 53.0 years (standard Deviation 13.05), with 46.2% male and 53.8% female and all of them were Caucasian ethnicity 23.1% patients had chronic simple glaucoma and 76.9% eye hypertension. The images were acquired with a colour analogical fundus camera, approximately centered on the ONH and they were stored in slide format. In order to have the images in digital format, they were digitized using a HP-PhotoSmart-S20 high-resolution scanner, RGB format, resolution 600x400 and 8 bits/pixel. Independent contours from 2 medical experts were collected by using a software tool provided for image annotation. In each image, each expert traced the contour by selecting the most significant papillary contour points and the annotation tool connected automatically adjacent points by a curve. The expert traced the contour of this dataset is used as the ground truth to facilitate the performance analysis using the comparison of the centroid of this contour with the center of the extracted OD.

B. Images from the ophthalmologist

The fundus images used in this experiment were taken from Giridhar Eye Institute, Kochi, Kerala. The size of the image is 576 x 768 x 3. All the images were obtained using Carlzeiss fundus camera. Out of 125 images, 5 are normal and 120 are glaucomatous.

C. Implementation

The present method was tested using 235 images obtained from the above mentioned databases and ophthalmologist. The method was evaluated by applying it to fundus images having different types of histograms. Figure 4 shows the results of histogram based PSO segmentation of real images of varying OD size and shape. Five sample images from DRION database and five sample images from the ophthalmologist and the localization and segmentation of OD on the input images are given in the following figure 4(a), 4(b) and 4(c).

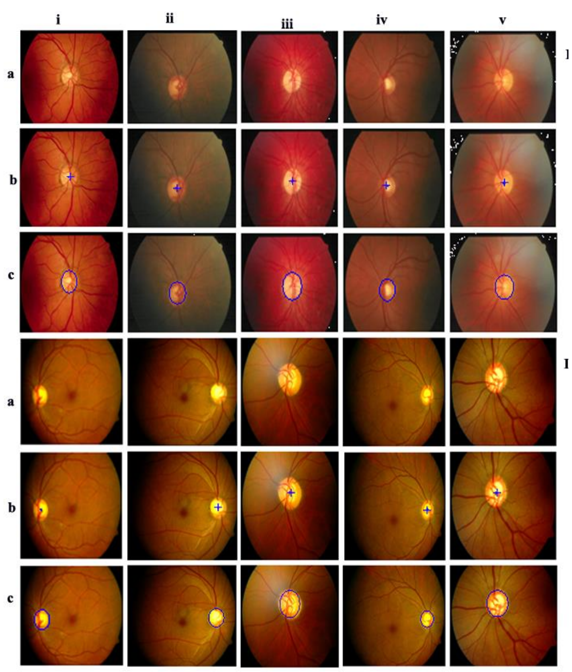


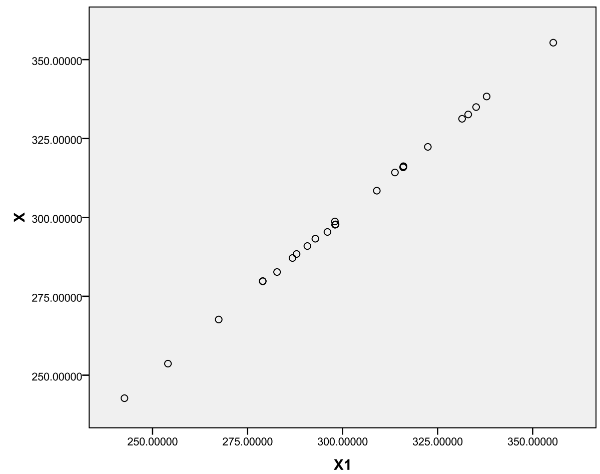
Figure 4. I–DRION database images II- Images from the ophthalmologist (a) Input Image (b) OD Localisation (c) OD segmentation

1) Performance Evaluation

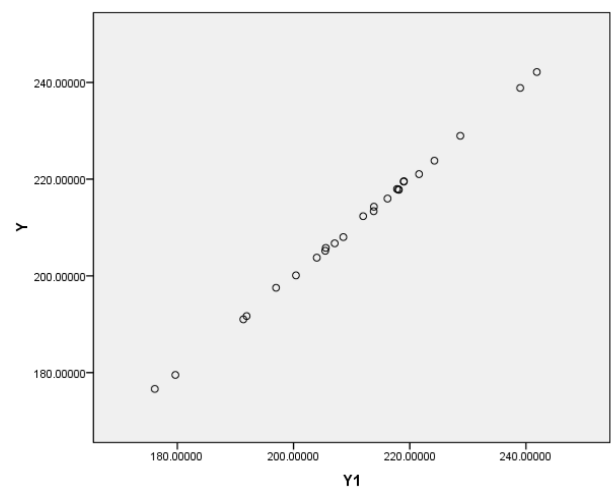
The performance evaluation is done using the following parameters.

2) Scatter plot Analysis

The statistical analysis is done using the scatter plot diagram. The ground truth x-coordinate X and the obtained x-coordinate X1 and, the ground truth y-coordinate Y and obtained y-coordinate Y1 of the centroids are plotted using the scatter plot diagram. From the scatter plot it is clear that there exists a highly positive linear relationship between both centroids. Figure 5(a) and Figure 5(b) depict the comparison between the x- coordinates X and X1 and the y-coordinates Y and Y1 of the ground truth and the obtained centroids.



(a)



(b)

Figure 5. Scatter plot diagram shows the comparison of (a) ground truth X and obtained X1 (b) ground truth Y and obtained Y1

3) Accuracy

In order to evaluate the accuracy of the new algorithm, the comparison between the ground truth centroid and the obtained centroid is used. The centroid using the ground truth boundary obtained by an expert ophthalmologist from the DRION database is used as the ground truth centroid. For the

TABLE I. COMPARISON TABLE

mage Name	*Ground Truth X*	*Obtained X1*	*Difference (X-X1)*	*Ground Truth Y*	*Obtained Y1*	*Difference (Y-Y1)*
Im1	293.2462	292.834	0.4122	219.5780	218.9893	0.5887
Im2	279.7386	278.9876	0.751	228.9630	228.7031	0.2599
Im3	355.3641	355.4261	0.062	206.7352	207.0753	0.3401
Im4	334.9644	335.1303	0.1659	213.3865	213.7809	0.3943
Im5	322.3469	322.4277	0.0808	242.1611	241.8710	0.290
Im6	308.4632	309.0022	0.5388	217.9691	217.8040	0.1650
Im7	279.8240	278.9898	0.8342	215.9897	216.1793	0.1896
Im8	316.2130	316.0045	0.2085	223.8279	224.2346	0.4067
Im9	315.8531	315.9346	0.0815	205.7907	205.5481	0.2425
Im10	288.4020	287.8909	0.5111	176.6244	176.1164	0.508
Im11	314.2352	313.7712	0.264	212.3454	211.9721	0.3733
Im12	297.6687	298.0171	0.3484	214.3045	213.8309	0.4735
Im1 3	282.6848	282.7577	0.0729	238.8594	239.0045	0.1451
Im14	295.3830	296.0165	0.6335	191.6893	191.9314	0.242
Im1 5	331.2497	331.4372	0.1875	197.5462	196.9867	0.5594
Im16	290.9223	290.7311	0.1912	191.0208	191.3622	0.3413
Im17	287.1293	286.8163	0.313	200.1131	200.4150	0.3018
Im18	338.3123	337.8987	0.4136	179.5210	179.6648	0.1438
Im18	242.7048	242.6095	0.0953	205.1935	205.4576	0.2641
Im20	253.6553	254.05	0.3947	208.0220	209.5642	0.5422
Im21	316.0102	315.9704	0.0398	217.8105	218.1223	0.3118
Im22	267.6372	267.4067	0.2305	221.0484	221.5914	0.543
Im23	298.7078	297.9794	0.7284	217.8592	218.0462	0.187
Im24	332.6179	333.0468	0.4289	203.7719	204.0013	0.2293
Im25	297.7823	298.1471	0.3648	219.4834	218.9588	0.5245
			Mean Difference of X 0.3341			Mean Difference of Y 0.3427

other images the centroid obtained from an ophthalmologist is used for evaluation. The accuracy of the new technique is evaluated using the comparison of the centroid of the obtained

OD with that of the centroid obtained using the ground truth boundary from the ophthalmologist. From the comparison table, Table I it is obvious that the mean difference of x-coordinate and the mean difference of y- coordinate are very low.

VI. CONCLUSION

The new approach for automatic optic disk localization and segmentation is effective in handling retinal images under various conditions with reasonable accuracy. The problem with retinal images is that the visibility and detection of optic disk are usually not easy. In this paper, retinal images are preprocessed and the optic disk is localized using histogram based particle swarm optimisation techniques. The new method is tested on publicly available DRION database and images from an ophthalmologist. The experimental results demonstrated that the new method performs well in locating and segmenting optic disk in colour images of large variability in terms of disc size and image quality.

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