Automated Localization of Optic Disc in Colour Fundus Images

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Abstract: The fundamental step for developing screening systems of diabetic retinopathy is optic disc detection. The knowledge of optic disc location can be used to detect other anatomical features of the retina such as macula and fovea. Mostly OD need to be eliminated for the identification of exudates, the primary signs of diabetic retinopathy. In this work, a novel, fast and robust technique is presented for the automatic localization of OD in retinal fundus images. The proposed approach proceeded through two stages: (1) conversion of RGB to HSI colour space followed by smoothing and local contrast enhancement and (2) OD region’s center detection using thresholding and mathematical morphology. Using clinician reference (ground truth), the proposed method was validated and compared with other OD detection methods presented in the recent past. Proposed method achieved comparatively higher speed and accuracy on retinal images of variable quality (normal and abnormal) selected from four different datasets. The superior performance of the technique suggested that it could be effectively used as a pre-processing step for computer aided mass screening of retinal diseases.

Key words: Diabetic Retinopathy (DR) • Exudates • Fovea • Macula and Optic Disc

INTRODUCTION

Diabetic retinopathy, eye diseases are the primary reason of vision failure and its cruelty can lead to blindness. Fundus image and its properties are shown the Figure 1. The brightest area of retinal image is optic disc and blood vessels initiate from optic disc [1]. An optic disc can also be found as the major area. In some cases like the presence of large exudates in an image, there may be areas in the image which are bigger than the optic disc area. Therefore optic disc masking is most commonly used as a pre processing for the detection of exudates. An optic disc information be able to study cruelty of diseases like glaucoma etc.

A new, fast and robust technique is presented for the automatic localization of the center of the OD in retinal fundus images. The proposed approach proceeds through two stages. First, in preprocessing, each Red Green Blue (RGB) colour of retinal images is transformed into Hue Saturation and Intensity (HSI) space followed by smoothing by means of median filter and local contrast enhancement. In the secondly stage the OD center is detected by using Otsu’s thresholding and mathematical morphology operations like dilation and filling.

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The paper is structured as follows: Section 2, consist have the review of latest proposed methods for optic disc detection is presented, section 3 consist of the proposed technique for optic disc localization, section 4 gives experimental results and section 5 conclude the proposed work.

Various studies have been conducted regarding Optic Disc localization Colour retinal fundus images for various datasets. Below is a brief list of such literature:

Hussain et al. [2] present a technique based on top-hat operator with a radius of 25 pixels structuring element was applied to the green channel image, then smoothing image by median filter using window size of a (3×3). Finally applying hough transform to detect main circular element.

S. Sekhar et al. [3] detect optic disk and fovea. By using mathematical morphological operator followed by hough transform an optic disk is detected. The fovea is localized using its connection with an optic disk.

S. Sekhar et al. [4] localized OD by using morphological operations with Hough transform. A circular area of concern is found by dividing the observable area in the image using mathematical morphological operation. Then optic disc is detected by using hough transform.

Hussain et al. [5] and [6] use a morphological top-hat operation to the image. First they converted RGB image into HSI colour then to intensity band Contrast Limited Adaptive Histogram Equalization (CLAHE) was applied. An area thresholding method was applied to obtained binary image. To remove vessels and large peaks a closing operator followed by opening was applied. Then eroded image is subtracted from dilated image. Finally centre of the OD is detected using hough transform to the image.

S. Kavitha et al. [7] transformed original RGB image to HSV colour Next median filtering is performed for smoothing. Finally CLAHE is used to enhance local contrast. The optic disc is eliminated by using the Hough transform which is predominant to the detection of circular features. The OD is masked by using a disc of intensity value similarly to the average intensity of an image. An area enclosed by the hough circle is set to zero to eliminate the OD. Nevertheless the technique based on Hough transform does not give the best result as the Hough space is responsive to the resolution.

Akara et al. [8] and [9], transformed each RGB image into the HSI colour and then noise was removed and image was enhanced by using CLAHE to the I band. The OD is detected using the entropy of the pre-processed intensity image. For image segmentation Otsu’s algorithm is applied. The optic disc is then localized by largest connected component of circular shape.

Akara et al. [10] and [11], the preprocessing step are same as in [8] and [9]. The OD is detected using the entropy of the preprocessed intensity image. Otsu’s algorithm is applied for segmentation. Then binary dilation was applied so that all the neighboring pixels are also included. However the entropy filtering requires more time and memory.

V. Vijaya et al. [12] extract the OD by using propagation through radii method. In general \( r \cos \theta \), \( y + r \sin \theta \) were used to represent a circle in discrete space. The \( \theta \) lies from 0 to 360. First radiuses for all 360 degree were computed and then the mean radius is found. Next midpoint of line joining circum points is found. The mean center is the midpoints of \( x \) and \( y \) co-ordinates. The circle of best fit is drawn with mean centre as the centre and mean radius as the radius. The optic disc center is found and propagation through radii method is employed and the entire optic disc region is blackened and removed. However by using propagation through radii method the chance of detecting exudates in the proximity of the Optic Disc increases.

Huiqi et al. [13] defined candidate regions in the retinal image by clustering the brightest pixels. A different scaling factor of PCA method is applied to candidate regions to find the minimum distance among the original input image and its projection onto the disk space. An optic disc center is located at the point with the minimum distance in the candidate regions among all the scaling factors. Nevertheless, detection is time consuming.

Aliaa et al. [14] presented matched filter to match the vessels direction at the OD area. By using 2D Gaussian matched filter the retinal vessels were segmented. Thus, a vessels direction map of the segmented retinal vessels is obtained using segmentation algorithm. The optic disc center is represented by thinning and filtering vessels. The difference among the proposed matched filter resized into four different sizes and the vessels’ directions at the surrounding area of each candidates of the OD center is considered.

Akara et al. [15] first, transformed to HIS colour space from each original RGB image and then smoothing image by median filter and CLAHE was applied to improve contrast. Next a closing operator was applied and the resultant image was binarized. The reconstruction by dilation operation was applied then. The resultant image was binarized using otsu’s algorithm. The OD is then
localized by the largest connected component of circular shape. A binary dilation operation was applied to make sure that all the neighboring pixels are also included in candidate region. Nevertheless the methods based on morphological reconstruction require more time and memory.

MATERIALS AND METHODS

The Figure 2 depicted our proposed algorithm which consists of two steps. First in preprocessing step we convert RGB image to HSI colour space as the intensity band is separately used for enhancement. Next remove noise and enhanced the contrast of intensity band. In OD detection step, we converted the enhanced HSI colour space to green channel of RGB as the OD is more visible in green band. Then Otsu’s binarization and morphological operation is applied to detect the OD. This is simple and fast detection of OD in term of time and memory. The various steps involve in the proposed approach are explain below:

Pre-Processing: In pre-processing first the original retinal image’s RGB space step is transformed into HSI (hue, saturation and intensity) colour space because we make use of the intensity component in the later stages.

To reduce noise we applied a (3x3) median filter, however median filter result in blurring the image and therefore, in order to reduce the amount of blurriness, we used only (3x3) filter instead of higher order filter.

To improve image contrast, a CLAHE is applied to the intensity colour space [19]. CLAHE divides the images into related regions and on each region histogram equalization is applied. This evens out the allocation of grey values into image and thus creates hidden features more detectable.

Optic Disc Detection: In OD detection the resultant HSI components are transformed back to RGB to get the pre processed image from the green channel.

To binarize an image, the Otsu's binarization algorithm [20] is applied on green channel to split the compound regions from the smooth regions. The Otsu's binarization algorithm thoroughly searches for the threshold that minimizes the intra class variance, distinct as a weighted sum of variances of the two classes (e.g. foreground and background):

$$\sigma^2_{\omega_1}(t) = \omega_1(t)\sigma^2_1(t) + \omega_2(t)\sigma^2_2(t)$$  \hspace{1cm} (1)

where,

$$\omega_1(t) = \sum_{i=0}^{L-1} p(i)$$ and $$\omega_2(t) = \sum_{i=t+1}^{L} p(i)$$

and

$$\sigma^2_1(t)$$ = The background pixel’s variance (less then threshold)

$$\sigma^2_2(t) =$$ The foreground pixel’s variance (above threshold)

Weights $$\omega_i$$ are probabilities of two classes separated by $$\sigma^2_i$$ variances and threshold $$t$$ of these classes.

As OD is round, therefore its selection desires to be made exact to the biggest one among the regions whose shapes are round. Circularity ($C$) of the shape of an area is defined by the value of compactness. $C$ as defined in the equation (2).

$$C = \frac{\text{Area}}{\text{Perimeter}^2}$$  \hspace{1cm} (2)

where the area is number of pixels in the region and the total no of pixels around the border of each region is the perimeter.

To remove false detected area, we applied area filtering. Area filtering is used for identification of the target area on the basis of its properties. It was tested and analyzed that area smaller than 150 pixels are not OD area.

To include boundary of an OD, a morphological dilation is applied. A disc-shaped structuring element ($s$) of radius 11 is used in dilation operator. An image $I$ dilation with structuring element $s$ is specified by $I \oplus s$. where $I$ is the image after otsu’s binarization and $s$ is the structure element. The structuring element $s$ is placed with its origin at ($x$, $y$) and the new pixel value is determined using the rule:
\( g(x,y) = \begin{cases} 1 & \text{if } s \text{ hits } I \\ 0 & \text{otherwise} \end{cases} \)

Next filling is performed. Filling used to seek for regions enclosed by closed contour. Hence optic disc is detected in the retinal image. The optic disc’s center is the severity of the binary image obtained from thresholding.

**RESULTS AND DISCUSSION**

In this work, 240 retinal images are used, obtained from Al-Shifa Trust Eye Hospital Kohat, Pakistan and available online databases i.e. DIARETDB0 [16], DIARETDB1 [17], DRIVE [18]. From Al-Shifa Trust Eye Hospital 50 images are selected (10 are normal and 40 are abnormal). DIARETDB0, 80 images (20 normal and 60 contain signs of diabetic retinopathy), from DIARETDB1, 70 images (5 are normal and 65 shows abnormality), from DRIVE, 40 images. The image size varied from 565 x 584 to 1500 x 1152 while the FOV coverage varied between 35 and 50. All images were JPEG compressed.

<table>
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<th>Test databases</th>
<th>Test Set</th>
<th>Correctly detected</th>
<th>False detected</th>
<th>Accuracy</th>
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<tr>
<td>DIARETDB1</td>
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<td>97%</td>
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<tr>
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<tr>
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<tr>
<td>Total</td>
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<td>234</td>
<td>6</td>
<td>98%</td>
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The proposed algorithm is tested for detection of an optic disc’s center on the databases: DIARETDB0, DIARETDB1, DRIVE and Al-Shifa Trust Eye Hospital Kohat, Pakistan.

The proposed technique achieved a success rate of 98% as optic disc was detected correctly in 234 out of 240 images selected from the DIARETDB0, DIARETDB1, DRIVE and Al-Shifa Trust Eye Hospital Kohat dataset.

This evaluation considers two things, namely correct detection i.e. the number of images where optic disc area was correctly detected and secondly false detection i.e.

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Fig. 3: (a) Input RGB image (b) Intensity image (c) Image after median filter (3x3) on I band (d) Image after applying CLAHE on I band (e) Preprocessed OD (f) OD detection using otsu’s binarization (g) after area filtering (h) after dilation and (i) after morphological filling. (j) OD center (k) Abnormal input RGB image, (l) OD.Center. (m) OD and other area detected, (n) after area filtering
Fig. 4: (a) to (l) Optic Disc’s center detection in retina images from DRIVE, DIARETDB0 and DIARETDB1 datasets while (m) and (n) shows retinal images with wrongly detected optic disc’s center in Al-Shifa Trust Eye images

the number of images where non optic disc area was detected as optic disc. In Table 1 the efficiency of the proposed technique is shown by comparing it with its counterparts and Table 2 shows comparison of methods [7] and [8] with the proposed technique on the selected databases.

The percentage detection rate of proposed method is relatively superior than others. The results of each step of the proposed method are shown in Figure 3.

Figure 4 shows Optic disc center in original RGB normal and abnormal image in Al-Shafa Eye Trust Hospital retina images and available databases like DIARETDB0, DIARETDB1 and DRIVE dataset.

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REFERENCES