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A Survey on Optic Disc Localization Methodologies in Retinal Images

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Abstract: Optic disk segmentation is important for detecting clinical features of Diabetic Retinopathy such as microaneurysms, hard exudates, soft exudates, hemorrhages, neovascularization and macular edema. This paper examines the optic disk localization methodologies in two dimensional retinal images acquired from a fundus camera. The aim of this paper is to review and categorize the optic disc localization techniques and methodologies. The performance of the methods is compared and analyzed on two publicly available DRIVE and STARE databases. We intend to give the reader a frame work for the existing research and discuss the current trends and future direction.

I. INTRODUCTION

In normal retinal images, the optic disk (OD) generally appear as bright, yellowish, circular/slightly oval shape, roughly one-sixth the width of the image diameter[2] and it is located roughly 2.5 times of OD diameters from the temporal edge of the OD [3]. Any change in the structure of the optic disk is a sign of various retinopathies especially for glaucoma [1]. Optic disk segmentation is important for detecting clinical features of Diabetic Retinopathy (DR) such as microaneurysms, hard exudates, soft exudates or cotton wool spots (CWS), hemorrhages, neovascularization and macular edema. On the basis of the geometric relationship between the optic disk location and the vascular structure, the central macula (fovea) can be approximately located, the detection fovea is important for grading the severity of lesions like the diabetic macula edema [3]. The accurate optic disk identification refines the segmentation of the exudates regions [5] and it is used for diagnosing hypertension retinopathies [13] and diabetes [23]. Also the segmented OD act as control point for retinal image registration and used to compute central retinal artery and vein equivalent [6]. Sometimes it is used to detect blood vessels in retinal images.

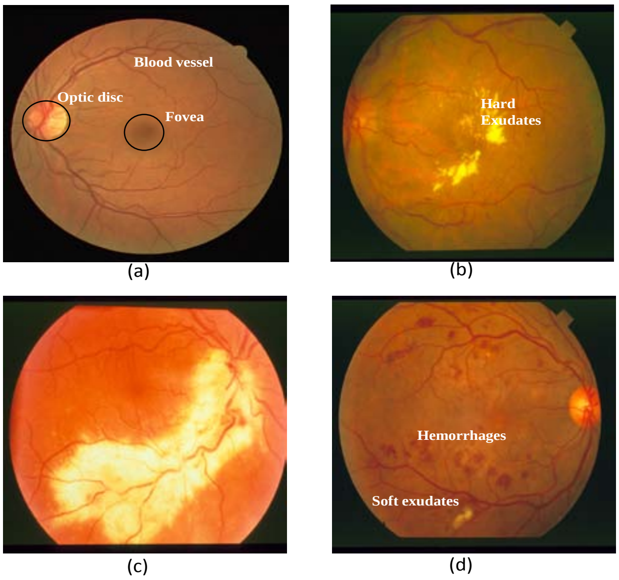

Figure.1. Retinal fundus images

(a) A non-pathological image (DRIVE). (b,c,d) Pathological images (STARE)

The manual OD segmentation can be time consuming, tedious when the image quality is poor. Therefore, extensive research efforts have been devoted to automating this process. Computer aided OD detection is also difficult or time consuming task due to several reasons: the presence of strong distracters such as vessel occlusions (Fig.1.(b)), imprecise boundaries (Fig.1.(c)), abnormal lesions like exudates (Fig.1.(d)) and peripapillary atrophy [6,19,20].

The paper reviews various OD localization methods and discusses the results obtained by various author. The remainder of this paper is organized as follows: Section 2 discusses various OD localization methods in detail. Section 3 discusses results and conclude the paper.

II. CLASSIFICATION OF OPTIC DISC LOCALIZATION APPROACHES

The optic disk localization is broadly categorized to eight groups: (1) template matching, (2) intensity based (3) Hough transform (4) Fuzzy convergences (5) Binary vasculature (6) pyramidal decomposition (7) Principal Component Analysis (8) Morphological approaches.

A. Method based on template matching:

The template matching method assumes the optic disc to be approximately circular and consisting of bright pixels, based on these assumption the templates are created. Then a running window of size N×N is applied on the intensity-plane of the image and for each new position of the running window the correlation between the running window and the template is calculated. The pixel with the highest correlation is selected as the location of the OD-center.

A template matching approach was employed by Osareh et al. [5] to approximately locate the OD. Initially, the images were normalized by applying histogram specification, and then the OD region from 25 color-normalized images was averaged to produce a gray-level template. The normalized correlation coefficient was then used to find the most perfect match between the template and all the candidate pixels in the given image.

Instead of creating an image as template, Dehghani et al.[16] construct three histograms as template, each corresponding to one color component. At the first step they apply an average filter with the size of 6 × 6 pixels to reduce the noise. Then, a window with the typical size of the optic disc (80 × 80 pixels) is used to extract the optic disc of each retinal image. In the next step, the color components (red, blue, and green) of each optic disc are separated to obtain the histogram of each color component. Finally, the mean histogram of each color component for all retinal image samples is calculated as template.

B. Method based on intensity:

The algorithms based on intensity variations are simple, fast and reasonably robust for normal images with less intensity variations. These algorithms may fail when the OD is obscured by blood vessels (see Fig.1.(b)) and distracters like exudates, CWS and bright artifacts [20]. To localize the OD from the intensity image a certain threshold must be set. The threshold value is selected by identifying the brightest two percent of the image. The selected threshold is used to create the binary image.

Sinthanayothin et al. [3] have assumed 80x80 pixels as the size of OD and intensity variations of the neighboring pixels were used to localize the OD. The point with highest pixel variance was treated as OD centre. Walter et al. [21] developed an algorithm to identify OD using pixel brightness, discrete distance function and watershed transform in Hue Saturation, Luminance (HSL) color space.

C. Method based on the Hough transform:

The Hough transform technique is able to find geometric shapes in an image. The optic disc has an approximately circular shape, therefore the Hough transform can be used to detect the optic disc. With the optic disc radius fixed in Hough parameter space, the search for a circular object becomes a two-dimensional problem. This method finds the circular shape with fixed radius in a thresholded edge image of the fundus. To detect edges of all possible orientations at each pixel various edge detection kernels such as Sobel, Canny, Prewitt, Roberts and Log edge operators are used. The maximal response of the kernel for each orientation is retained. On this edge map of the retinal surface a single threshold is applied to obtain a binary edge map. Finally the Hough transform technique is applied to the edge pixels in the edge map to accumulate evidence of circles with fixed radius in the image. The circle with the highest magnitude of evidence is chosen as the optic disc [25].The Hough transform was used by many authors to detect OD [6,22,23,24].

D. Method based on multiple fuzzy convergences and equalized brightness:

This method identifies the optic nerve as the focal point of the blood vessel network. In order to determine the focal point the retinal vessel network must be detected. Then the fuzzy convergence is applied on these vessels, followed by a hypothesis generation to draw a conclusion whether the found location can be determined as OD-location or not [th1].

Hoover et al. [2] developed an algorithm using fuzzy convergence to identify OD after the application of illumination equalization. This algorithm detects the ONH using brightness characteristics of the ONH.

E. Method using binary vasculature:

Normally, the eye fundus image vessels tend to not be affected by diabetic signs, and can be detected even when such signs exist in the image.

Foracchia et al. [27] have described an algorithm by modeling geometrical directional pattern of the main vessels. Initially, the vascular skeleton was extracted to measure the diameter, centre point and direction of the vessel. The main blood vessels modeled using parabolas were used to identify the centre of the disk [25,27].

Youssif et al. [15] used directional pattern of the retinal blood vessels to localize the center of optic disc. Hence, a simple matched filter was proposed to match the direction of the vessels at the optic disc vicinity. The retinal vessels were segmented using a simple and standard 2D Gaussian matched filter. Consequently, vessels' direction map of the segmented retinal vessels was obtained using the same segmentation algorithm. Then, the segmented vessels were thinned and filtered using local intensity to represent the optic disc center candidates. The Gaussian matched filter was resized in four different sizes, and the difference between the output of the matched filter and the vessels' directions was measured. The minimum difference provided an estimate of the optic disc–center coordinates

Mendonca et al. [9] describes a method for automating the localization of the OD in color eye fundus images, by combining information extracted from the vascular network with intensity data obtained from the red (R) and green (G) channels of the RGB representation. The distribution and variability of vessels around each image point are estimated using the concept of entropy of vascular directions, which associates high values of this measure with the occurrence of a large number of vessels with multiple orientations. This information is then combined with the highest image intensities, with the goal of localizing pixels where both entropy and intensity are maximized.

Tobin et al. [30] proposed a method based on spatial filtering and Bayesian classifiers to extract local features from the retinal vasculature, obtaining a confidence image map. The point with the highest confidence value in this confidence image map represents the optic disk center.

Niemeijer et al. [14] defines a set of features based on vessel map and image intensity, like number of vessels, average width of vessels, standard deviation, orientation, maximum width, density, and average image intensity, measured under and around a circular template to determine the location of the optic disc.

Youssif et al. [15] proposed to detect the optic disk using directional filters matched with the outgoing vessels

F. Method based on pyramidal decomposition:

A resolution pyramid is created using a simple discrete wavelet transform. At the fifth level of the resolution pyramid, the small bright pixels belonging to exudates have disappeared. Pixels belonging to the optic disc are, however, still visible. Expecting the optic disc to be a bright circular object in the fundus image, the optic disc candidates are the pixels with a high intensity value compared to the mean intensity value of the ROI in the low resolution image. Each candidate pixel in the image at the fifth level of the pyramid corresponds to a region of many pixels in the original image.

To pinpoint one pixel within such a region as a candidate OD-center, the original image is smoothed and the brightest pixel within the region is selected as a candidate.

Lalonde etal. [26] have proposed a pyramidal decomposition method with Hausdorff distance based template matching. Possible areas which might contain the OD were first found using pyramidal decomposition and Haar discrete wavelet transform with green band of the RGB image. They have reported the accurate identification of OD without OD boundary in all 40 images. The circular pattern was placed around the detected OD region. Lowell et al. [6] have showed similar results with less complex methods than pyramidal decomposition and template matching.

G. Method based on Principal Component Analaysis:

Principal Component Analysis (PCA) was used for extracting different features present in the fundus images which includes OD and vessels [1,3,28]. PCA transforms the possibly correlated variable in to uncorrelated variables called as principle components.

Li and Chutatape [1] extracted basic features present in the fundus image using PCA. To create a disc space, manually cropped 10 sub-images from the optic disc regions for training. Each training image is described in a vector format, and the PCA transform is employed to get the first six eigenvectors representing the training set. The optic disc is identified as the region with the minimum Euclidian distance projection, which indicates the similarity of the template vectors. However, the shape model may not be suitable to detect the various disc shapes from many pathological changes.

H. Morphological approaches:

Welfer et. al [13] introduces a new adaptive method based on mathematical morphology to identify some important optic disk features namely, the optic disk locus and the optic disk rim.

Park et al. [29] proposed to locate the optic disk according to its morphological properties (i.e. circular area with large local intensity variability).

III. RESULTS AND CONCLUSION

Results obtained by various optic localization methods are presented in Table.1.

Table.1 Obtained result of optic disk localization on DRIVE and STARE databases

Method	Drive	Stare
Youssif et al.[15]	100	98.77
Osareh et al.[5]	-	58
Foracchia et al.[27]	-	98
Tobin et al.[30]	-	87.7
Park et al.[29]	90.25	-
Dehghani et al.[16]	100	91.36
Sinthanayothin et al.[3]	60	50
Walter et al.[21]	80	75
Hsiao et al.[12]	100	90
Mahfouz et al.[7]	100	92.59
Lu et al.[17]	97.5	96.3
Qureshi et al.[13]	100	-
Mendonca et al.[9]	100	98.8
Welfer et al.[10]	100	-

The review presents a detailed review of algorithm and results used for the automated localization of OD using fundus photographs. Most of the methods provide better results on DRIVE database compare with STARE database

Even though many techniques and algorithms have been developed, there is still room for improvement in OD localization methodologies.

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