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Automated detection of optic disc in retinal fundus images using gabor filter kernels

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Abstract

Identifying the position of the optic disc on the retinal fundus image is a technique that is often used in medical diagnosis, treatment and monitoring processes. Determination of the intensity of the bright colors that belongs to the optic disc on a normal retinal image by the help of image processing algorithms is a fairly easy process. However, determining the optic disc on a retinal image including the diabetic retinopathy disease is a more difficult process. The reason for this difficulty is the existence of many regions that have the same light intensity in different parts of the retina. In this study, a new method for supplying the automatic determination of the optic disc in a recursive manner is proposed. By the help of OpenCV library, automatic determination process of the optic disc on the retinal fundus images including the diabetic retinopathy disease, has been implemented. Circular regions with maximum brightness values in the retinal images that were normalized and passed through the denoising process were determined and these regions were analyzed if they are optic disc or not. This process basically consists of two steps: In the first step, the possible optic disc candidate regions were determined recursively and in the second step, by the help of Gabor filter kernels, these regions were analyzed and it's provided to decide if they are optic disc or not. This study is based on a dataset that has 89 images including diabetic retinopathy disease. Performance of this system is tested on these images and also on the images that the red, green, blue color channels and Contrast Limited Adaptive Histogram Equalization (CLAHE) retinas were obtained. Most accurate determination of the position of the optic disc is obtained with retinas, implemented process CLAHE, including the best success rate of 89.88%.

Keywords: Optic disc, diabetic retinopathy, recursively, circular region, gabor filter kernels.

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1. Introduction

As seen in Figure 1, optic disc (green circle area) or the optic nerve head is part of which optic nerve endings leaves eye. The optic disc, more than one million nerve fibers collected, is located that optic nerve connected to the retina and it is a bright disc-shaped area at which point the vessels merge. All vessels, feeding the retina, enter and exit from this point, also [1]. The diameter of the optic disc in any retinal fundus image, which bright color density and a similar structure to round or elliptical, is about 80 to 100 pixel [2].

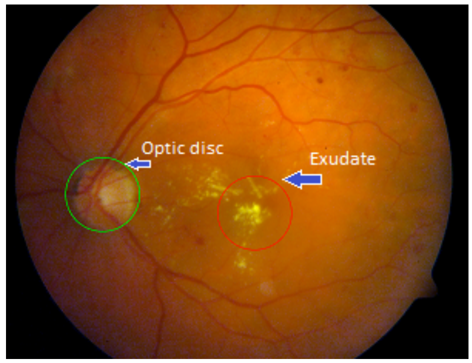

Figure 1. Original retinal fundus image from DIARETDB1 database [3]

The detection and segmentation of the optic disc is an important process in automatic retinal image analysis. As a result of nonuniform illustration of background, misclassification of cases of this area may occur. On the other hand, as a result of incorrect focus, a further deterioration may occur with formation of different ranges between retinal regions from camera. There are many regions which are important in the treatment of retinal disorders and need to be identified. These objects are: the blood vessel tree, the optic disc, the macula, the region between the macula and the optic disc and the exudates or the microaneursyms or the hemorrhages [4]. Determination of the location of the optic disc is an important step to detect diseased regions in such retina. For example, exudate (red circle area in Figure 1) is one of abnormalities in retinal disease with diabetic retinopathy and approximately and it has same color density with optic disc. The retinal images used in this work were obtained using a diabetic retinopathy database, DIARETDB1 [3]. They have 89 retinal images including normal and diseased in this dataset. Each retina is in 1112x1512 pixels.

The rest of this paper is organized as follows. In Section 2, related studies are examined. In Section 3, texture analysis and gabor filter kernels are reviewed. In Section 4, it is presented information about computer vision and OpenCV. In Section 5, it is presented information about image enhancement and image datasets. In Section 6, proposed method for find optic disc and experimental results are presented. In final section, conclusions and recommendations are presented.

2. Related Works

There are many studies on identifying the position of the optic disc. Briefly, we review here some of the methods that are relevant to our study.

Abramoff and Niemeijer [5] achieved the 32 features including especially the vessel orientation information that corresponds to the area of the template that was hovered over the retinal image. As they classified these properties recursively with kNN classifier, after estimating the distance to the optic disc, they estimated the area as optic disc which was belonged to the template with the lowest distance. In their study, Chaichana et al. [6] and Yavuz et al. [7] referenced the observation that optic disc is almost the most brilliant part of the fundus images and it has a rounded shape; and also the intensity channel of the image and the circumferential structure of optic disc. Foracchia et al. [8] modeled vein orientations based on the observation that the retinal vasculature spread through the optic disc. An automated method was described for locating the optical nerve in images of the ocular fundus by Hoover and Goldbaum [9]. This includes the interior surface of the eye, macula, retina etc. The optic disc detection algorithm is based on matching the expected directional pattern of the retinal blood vessels. Lalonde et al. [10] identified the location of the optic disc with the Haar Wavelet Transform method by subjecting the green channel of the retinal image to the pyramidal analysis. Liu and Chen [11] identified the location of the optic disc with Otsu method by primarily applying morphological operations to the retinal images. Morales et al. [12] determined the location of the optic disc by using the Stochastic Watersheed Algorithm after converting the retinal images to the grayscale form with Principal Component Analysis.

Digital data can be commonly used in healthcare studies to help the physician on determining the appropriate diagnosis and the treatment method. There are some studies in the literature about identifying the diseased regions on the cornea by using digital image data as similar to our study. Kaya et al. [13] used Watersheed Segmentation and thresholding methods to segment the Keratoconus region from the cornea. In another study, Kaya et al. [14] used Cropped Quad-Tree method to prepare the corneal images to the 3D imaging process as cropping the parts that will be modelled in three-dimensional forms. In their other study [15], the same authors used the digital image data in 3D simulation of the cornea before and after the operation in order to display the achievement of the treatment method by using the comparison screens. And also they obtained the thickness data by using the corneal images and then classified this data by using MLP and LR methods to identify the type and the classification of the corneal disease.

3. Texture Analysis

Texture is the most important visual cue in finding determined region on image. This process is referred to as texture classification. Texture analysis is an important and beneficial area. A successful machine vision system is performed with texture analysis. Image texture is defined as a function of the spatial variation in pixel intensities. It is performed the recognition of image regions using texture properties [16]. Texture analysis has been an active research field due to its key role in a wide range of applications. For example, in many processes, such as the detection and classification of the disease and recognition of objects in the medical field, have an important role. In general, texture analysis algorithms comprise two important steps including feature extraction and classification. The step of feature extraction is process of obtaining a set of properties associated with that region. In classification process, it is intended to identify the attributes or objects using obtained feature set.

Gabor descriptors have been used for various tasks including texture analysis and image recognition. Gabor descriptor for an image is computed by passing the image through a filter bank of Gabor filters. A two-dimensional Gabor filter is constructed by modulating an oriented sinusoidal plane wave by a Gaussian envelope. It performs a frequency analysis of a two-dimensional signal as locally. The formulation in the spatial domain can be written as follows [17]:

$$\varphi(x,y) = \frac{F^2}{\pi\gamma n} e^{-F^2\left[\left(\frac{x'}{\gamma}\right)^2+\left(\frac{y'}{n}\right)^2\right]} e^{i2\pi F x'}; \quad (1)$$

with:

$$\begin{cases} x' = x\cos\theta + y\sin\theta \\ y' = -x\sin\theta + y\cos\theta \end{cases} \quad (2)$$

Where F is the central frequency of the filter, θ is the angle between the direction of the sinusoidal wave and the x axis of the spatial domain, γ and η the standard deviations of the gaussian envelope respectively in the direction of the wave and vertical to it. γ and η parameters represent the shape factor of the gaussian surface: they determine the greater or less selectivity of the filter in the spatial domain and sometimes they're referred to as the smoothing parameters. According to the above formulation it is assumed that the angle between the wave direction and the axis of the gaussian envelope is zero. In the frequency domain the Gabor filter can be written as follows [17]:

$$\varphi(u,v) = e^{-\frac{\pi^2}{F^2}\left[\gamma^2(u'-F)^2 + n^2 v'^2\right]}; \quad (3)$$

with:

$$\begin{cases} u' = u\cos\theta + v\sin\theta \\ v' = -u\sin\theta + v\cos\theta \end{cases} \quad (4)$$

3. Computer Vision and OpenCV

Computer vision is a fundamental step, passed through various processes in a specific purpose, for making the image and machine learning more meaningful. OpenCV was designed for computational efficiency; it is an open source computer vision which has a strong focus on real-time applications. Providing a simple-to-use computer vision infrastructure is one of the goals for helping people to build fairly sophisticated vision applications quickly [18].

4. Image Enhancement and Image Datasets

In the first phase of the study, an image enhancement process is applied to all RGB (Red, Green, Blue) fundus image. In this process, each retina in RGB color space has been light intensity equalization process namely normalizing that is used to eliminate that may occur any effects of intensity changes on image. Another image enhancement process is Contrast Limited Adaptive Histogram Equalization (CLAHE) which proved itself to be effective in image analysis. CLAHE is an adaptive contrast histogram equalization method where the contrast of an image is enhanced by applying contrast limited adaptive histogram equalization on small data regions rather than the entire image [19]. Normalized RGB retinal fundus images are allocated to red, green and blue color channels to use in the study.

Thus, there were obtained 5 retinal datasets which have each containing 89 retinal images. These are normalized RGB retinal fundus images, red, green and blue channels of normalized RGB retinal fundus images and CLAHE retinal fundus images.

5. Proposed Method

The main objective of this paper is automated detection of optic disc using gabor filter kernels. In particular recursively, we investigated the presence of the candidate of the optic disc and making the analysis. Several studies conducted for the same purpose in literature. The methodology of this study is different from others since it is an original work. The proposed method is based on texture analysis with gabor filter kernels and was tested on 89 images in the DIARETDB1 database. Main steps of proposed method are following:

- Preparation of the retinas
- Testing regions with texture analysis

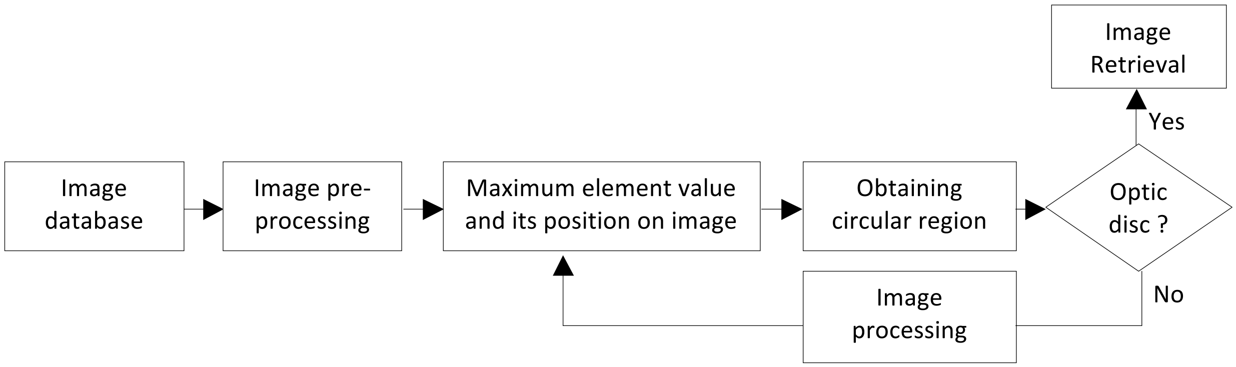

Figure 2. The block diagram of the proposed method

5.1. Preparation of the retinas

After image enhancement and image dataset processes, they were obtained five regions that random optic disc and without any region namely non-optic disc area from the images that retina of each group. These images are stored into a system to be compared in the analysis. It was studied with square and circular structures by trial and error method and it was seen to be a more successful outcome with a circular structure.

Table 1. Used regions for test: a) 5 pieces of any other region; b) 5 pieces of optic disc region

Region 1	Region 2	Region 3	Region 4	Region 5
a)				
				
b)				
				

5.2. Testing regions with texture analysis

A copy of the retinal image is created which is named temp image for avoid deterioration of the original retinal image before starting analysis. Image processing is performed on this temp image.

As seen in Figure 2, in this process, it was obtained x, y coordinate information on retinal image with minmaxLoc function by utilizing the OpenCV library. (The minmaxLoc function finds the maximum element value and its position on image.) A circular region that has a 120-pixel-radius was determined and accepting coordinate information as the center of the region. This region is converted to gray mode and after that the texture analysis was conducted with the gabor filter kernels. It is controlled if the region is the optic disc or not. If the test result assumes that this region as optic disc, this coordinate and the radius of 120 pixels information is saved in the system for optic disc information related to the retina. Otherwise, by obtaining the average pixel value in 40-pixel-radius for that region and it is assigned to all pixels in this region. This radius value is determined by trial and error method. Providing that not the optic disc and with the condition to go beyond the boundaries of the image, this all workflow is repeated. Otherwise, this process is terminated. All these procedures were applied to the whole retina in retinal dataset.

a-1) Step 1 a-2) Step 2 a-3) Step n

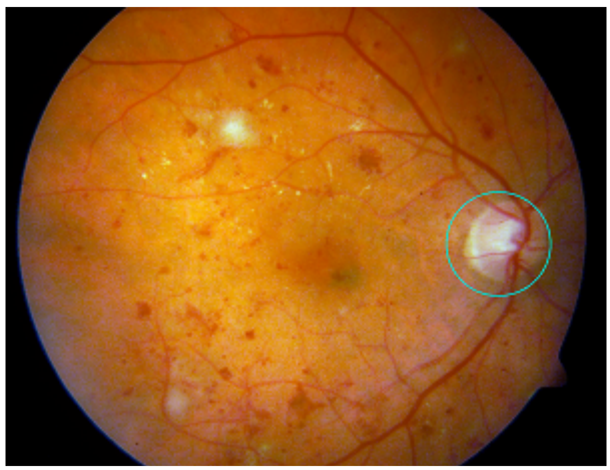

Figure 3. a) The steps of obtaining the optic disc; b) Determination of the optic disc in retinal image(the area within the green circle)

We can say that we have achieved successful results for identification and accuracy on localizing the optic disc region. Obtained success rates are presented in Table 1. As seen in Table 1, the number of retinas the location of which detected correctly is 73 out of 89 and the success rate is 82.02% in image set of RGB color space. The number of retinas at the location of which detected correctly is 71 out of 89 and the success rate is 79.78% in image set of red channel. The number of retinas at the location of which detected correctly is 72 out of 89 and the success rate is 80.90% in green channel image set. The number of retinas at the location of which detected correctly is 41 out of 89 and the success rate is 46.06% in blue channel image set. The number of retinas at the location of which detected correctly is 80 out of 89 and the success rate is 89.88% in CLAHE retinal image dataset.

Table 2. Obtained success rates

Image Datasets	accurate detection	false detection	Not Found	Accuracy
RGB color space retinal image dataset	73	0	16	82.02%
Red channel retinal image dataset	71	1	17	79.78%
Green channel retinal image dataset	72	0	17	80.90%
Blue channel retinal image dataset	41	0	48	46.06%
CLAHE retinal image dataset	80	1	8	89.88%

6. Conclusion and Future Work

Detection of the optic disc in diseased retina such as diabetic retinopathy is a very important step. Because, these regions are candidate for be exudate in computer vision and machine learning systems. Therefore, the determination of these regions must be done. On the other hand, it is an important issue for analyzing the diseases of the optic disc region, too.

In literature, there are many studies on determining of the optic disc. It is intended to identify the optic disc recursively by our study unlike other studies. The circular optic disc region, obtained by the location information by utilizing library OpenCV, were tested whether it's optic disc or not with texture analysis with which type of gabor filter kernels. Circular region information, assumed that the optic disc has 120-pixel-radius, was recorded in the system. The best success has been achieved in CLAHE retinas by the analysis with created dataset.

In our next study, it is considered to provide the best algorithm for successful classification by obtaining the feature vectors that best describes the image (optic disc). The good degree of feature vectors required for classification in this process must be obtained.

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