Locating the Optic Disc in Retinal Images Using Morphological Techniques

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Abstract. A methodology for locating the optic disc (OD) in digital retinal images is presented in this paper. Input images are intensity images (I channel of the HSI color space), resized to have a retinal diameter of 300 pixels. A shade-correction method for homogenizing the background, as well as, a set of morphological opening and closing operations for enhancing bright structures, are applied to find a pixel within OD. The methodology was evaluated on 1200 fundus images from the publicly-available MESSIDOR database, 229 of which present signs of macular edema. In 1190 of these images the distance between the methodology-provided pixel and actual OD center position remained below one standard optic disc radius. These results outperform the reviewed methodologies available in literature that were tested on this same database.

Keywords: Optic disc; fundus image; diabetic retinopathy.

1 Introduction

Diabetic Retinopathy (DR) is a retinal disease derived from complications caused by the abnormally high glucose level in blood produced by diabetes mellitus. Nowadays DR is the leading ophthalmic pathological cause of blindness among people of working age in developed countries [1], [2]. Although DR is not a curable disease, laser photocoagulation can prevent major vision loss if detected in early stages [1]. However, DR patients usually perceive no symptoms until the later stages, when visual loss develops and treatment is less effective. All diabetic patients are at risk for DR and most of them eventually develop the illness. Therefore, annual eye fundus examination in diabetic patients becomes necessary to ensure timely treatment application [3], [4], [5]. This preventive protocol involves a huge challenge for health systems due to the great number of patients needing ophthalmologic revision (the estimated prevalence of diabetes

for all age groups worldwide is forecasted to rise from 171 million in 2000 to 366 million in 2030 [2]).

DR is diagnosed by the examination of retinographies. This use of digital images of the retinal surface could be exploited for computerized early detection of DR. A robust system that enabled non-experts to filtrate cases of patients not affected by the disease using the retinographies, would reduce the specialists' workload and increase effectiveness in preventive protocols and early therapeutic treatments, resulting in outstanding economic benefits for public health system.

A successful segmentation of the optic disc (OD) in digital eye fundus images plays an important role for the development of an automated DR diagnosis system. The relatively constant distance between the OD and the fovea, can be used to help estimate the location of the latter. On the other hand, to segment the vascular tree, vessel tracking methods need an initial seed point. For this, pixels of vessels within the OD or in its vicinity have been used [7]. Likewise, finding the OD can be also used to decrease false positives in the detection of retinal exudates [6].

In this paper, a methodology for locating the OD in fundus images, focused on finding a pixel within it, is presented. The OD location methods reported in literature are based on exploiting the OD's visual appearance (this region is recognizable in fundus images as a round bright area) and its anatomical features (the OD is the entry point for the major blood vessels that supply the retina). In this way, in [11] the center of the OD is located using the vasculature origin. They determined where all the vessels converged by means of a voting-type algorithm called fuzzy convergence. Another method that uses the convergence of the vessels to detect the OD center was proposed in [12]. The four main vessels orientating from the OD were geometrically modeled using two parabolas, and the OD position was located as their common vertex. In the same way, in [14], [15], [16] a method for locate the OD is proposed exploiting the location and orientation of the vessels. While in [14] used the Hough transform to detect the circular shape of the OD, in [15], [16] a complex optimization procedure is used. Inspired by previous works, in [13] a method is presented where the OD location method is based on a vessels' direction matched filter. An OD location method using three-independent location methods and a voting procedure is presented in [19]. Finally, a method for locating the OD using template matching techniques is presented in [20].

2 Materials

To evaluate the OD location methodology described in the next section, the publicly available MESSIDOR database was used. This database[1] contains 1200 eye fundus color images of the posterior pole. 800 of these images were captured with pupil dilation and 400 without dilation, using a Topcon TRC NW6

[1] Download images section, MESSIDOR: Digital Retinal Images, MESSIDOR TECHNO-VISION Project, France [Online]: http://messidor.crihan.fr/download-en.php

non-mydriatic retinograph with a 45° field-of-view (FOV). The images were digitalized to 1440×960, 2240×1488 or 2304×1536 pixels and are 8 bits per color plane. All these images are provided in TIFF format.

The whole set of 1200 MESSIDOR images includes 229 cases of retinas with presence of hard exudates and thus showing Macular Edema (ME, retinal disease closely associated to DR) signs. Therefore, the choice of this database allows evaluating the methodology under ME-related retinas where the presence of exudates may cause problems for OD location (as OD, exudates appear as bright yellowish regions in fundus images).

3 Methodology

This paper proposes a methodology for OD location in fundus images. The following process stages may be identified: resizing for standarizing retinal size of different resolution images, image preprocessing for intensity homogenization, morphological processing for enhancing bright regions and finally, the obtaining of OD location through pixels with highest intensity values.

All parameters described below were set by experiments carried out on a local database provided by the Health Ministry of the Andalusian Regional Government (Spain).

3.1 Resizing

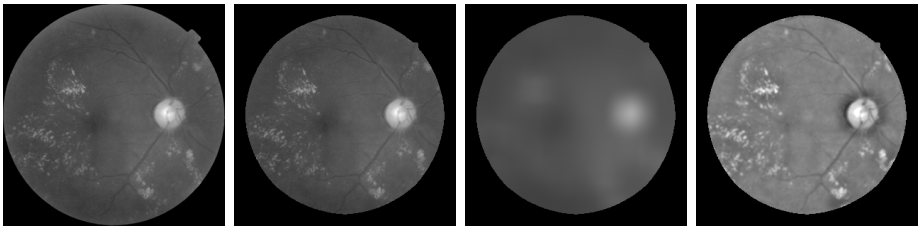
Input images, I, are intensity images obtained by finding the average of the Red, Green and Blue channels, which are extracted from the original color image.

As commented, MESSIDOR fundus images are 1440×960, 2240×1488 or 2304×1536 pixels in size, corresponding to retina diameters, D_{FOV}, of approximately 910, 1380 and 1455 pixels, respectively. In order to standarize retinal size, all input intensity images are resized to have a D_{FOV} of 300 pixels. Thus, a drastic reduction in computational time is provided (we performed test varying D_{FOV} obtaining that the application of this resizing keeps methodology perfomance in OD location). Let's denote this new resized image as $I_{resized}$ (Fig. 1, image (a)). Therefore, it should be pointed out that all parameters given below refer to retinas of 300-pixel diameter.

3.2 Preprocessing

Generally, fundus images present lighting defects at the boundary of the retina, which are mainly caused by acquisition process of the retinography. In order to remove these lighting defects, a morphological erosion using a 15-pixel diameter disc as structuring element is applied to $I_{resized}$. Thus, our region of interest is reduced to avoid processing retina edge pixels with anomalous intensity values. I_{input} stands for this resultant reduced image (Fig. 1, image (b)).

In addition, fundus images may also contain background intensity variation due to nonuniform illumination. With the purpose of removing these background



(a) (b) (c) (d)

Fig. 1: Preprocessing stage illustrated on a MESSIDOR fundus image. (a) Resized intensity image, $I_{resized}$. (b) Reduced image, I_{input}. (c) Background image, I_B. (d) Homogenized image, I_{SD}.

lightening variations, the shade-correction method proposed in [21] is applied. Basically, a background estimate, I_B, is firstly obtained by filtering I_{input} with a 69x69 arithmetic mean kernel (Fig. 1, image (c)). The difference between I_{input} and I_B is then calculated for every pixel. Finally, a shade-corrected image, I_{SD}, is obtained by transforming linearly this difference values into integers covering the whole range of possible gray-levels, [0-255] (see Fig. 1, image (d)).

3.3 Morphological Processing

The OD may be distinguished in eye fundus images as a rounded shape having high intensity values (see Fig. 1). In order to locate OD exploiting these features, a morphological processing is performed to obtain a smoothed image where the largest bright region are enhanced. Specifically, a set of morphological opening and closing operations are iteratively applied four times to I_{SD} [17]. The selected structural element is a disk whose radius r increases in each iteration ($r = 2, 4, 6, 8$). Thus, as it can be observed in Fig. 2, small bright structures that may appear in the fundus image (i.e., hard exudates), are progressively removed. Let's denote the resultant image as I_{morph}.

3.4 Obtaining the OD Location

The brightest region in I_{morph} can be assumed to belong the OD region. Thus, the pixels with the highest intensity are selected as potential OD pixel candidates. The OD is finally located through the centroid of this set of pixels. Fig. 2, image (h) shows the centroid of the brightest area in I_{morph}.

4 Experimental Results

4.1 Performance Measures

Most of the published works designed for locating the OD in fundus images are evaluated by measuring the distance between the automatically-obtained OD

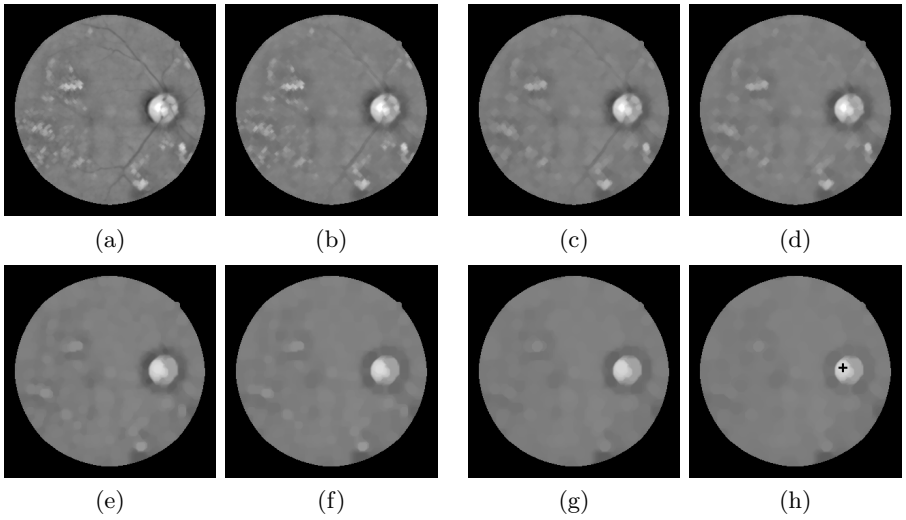


Fig. 2: Illustration of Morphological Processing stage. (a, b) First, (c, d), second, (e, f) third, and (g, h) fourth morphological opening and closing iteration. Black mark: centroid of the brightest area.

center position and the actual position of this center. This distance is usually expressed in function of the OD radius, which is taken as a reference measurement. The most extended criterion used to determine the performance is the so-called $1R$ criterion, where R stands for the OD radius. This criterion is also used in this paper to quantify the algorithmic performance of the proposed methodology on the 1200 MESSIDOR fundus images. Since OD may vary substantially in different equal-sized fundus images (according to [7] from 1/10 to 1/5 of the retinal size), R was fixed to its middle value to avoid distortion in results evaluation:

$$R = 0.15\frac{D_{FOV}}{2} \tag{1}$$

Thus, R is set to the same value for images of the same retinal size. In our case, this value was fixed to 68, 103 and 109 pixels depending on the resolution of the analyzed MESSIDOR image: 1440x960, 2240x1488 or 2304x1536 pixels, which correspond to retinas of approximately 910, 1380 and 1455 pixels in size, respectively. On the other hand, the required coordinates of the OD center position were manually obtained for each of the 1200 fundus images with the help of an ophthalmologic specialist.

4.2 Design Considerations

The methodology proposed in this paper iteratively applies a set of morphological opening and closing operations with a structural element whose size increases in each iteration (see Subsection 3.3). This technique is described in [17] and was

Method	ME Risk=0 (971)	ME Risk≠0 (229)	Total (1200)
I_G (RGB) Preprocessing [12]	96.70	96.51	96.66
I_G (RGB) Preprocessing [21]	98.97	96.94	98.58
I_I (HSI) Preprocessing [21]	**99.38**	**98.25**	**99.17**

Table 1: Performance comparison between different input monochrome images and preprocessing techniques. Results are expressed in %.

also used by Sanchez *et al.* in their methodology to detect hard exudates [18]. In that work, it was applied to find OD candidate pixels to the green channel of the RGB fundus image, I_G, with the luminosity normalized by means of the methodology proposed in [12]. However, in this paper, intensity channel of the HSI color space, I_I, and the preprocessing technique proposed in [21] have been used.

In this respect, we have performed tests to find the input image and the preprocessing that provides the best performance for our methodology. Table 1 shows the results. It can be clearly observed that the configuration used in this paper renders better performance than that applied in [18].

4.3 Results and Comparison to other Methods

Many methods for OD location in fundus images have been reported in literature. However, most of them are evaluated on their own fundus images databases, which are not publicly accessible. Therefore, our algorithm could not be tested on them and performance comparison can not be thus carried out under identical conditions. For the sake of rigorousness, we have compared our approach to OD location algorithms that were tested on the MESSIDOR database. Table 2 shows performance comparison results in terms of $1R$ criterion, with the methods published by [19] and [20] (notice that these are the most recent reviewed methodologies). The values in the table are presented for the whole set of MESSIDOR database (1200 images), as well as on sets of not ME-related (971 images) and ME-related (229 images) pathological retinas, as reported by their authors.

An overview of the OD location results on retinas without signs of ME (ME risk=0) shows that the three methodologies' performance is comparable and higher than 99% (all of them provided a pixel located at a lower distance than $1R$ in 963 of the 971 images). However, when the results are analyzed on ME pathological retinas (ME risk≠0), the values reached in [20] and in this work (both, 98.25%) are higher than that obtained in [19] (96.50%). When performance is compared between these both most accurate methodologies, our approach renders better overall performance than that proposed in [20]: it is slightly higher on the total 1200 images, with a much lower needed average computational time.

Method	ME Risk=0 (971)	ME Risk≠0 (229)	Total (1200)	Average time
Aquino *et al.* [19]	**99.38**	96.50	98.83	1.67s
Yu *et al.* [20]	99.28	**98.25**	99.08	4.7s
This work	**99.38**	**98.25**	**99.17**	1.53s

Table 2: Performance comparison with other methodologies in literature. Results are expressed in %. Last column: average computational time to process a single image in seconds.

5 Conclusions

A method for locating the OD in retinal digital images is presented in this paper. Firstly, a background homogenization to correct nonuniform illumination is performed in resized intensity images (channel I of HSI color space). Then, morphological operations are applied in order to enhance the bright region of the OD. Finally, the OD is located through the centroid of the brightest area.

This methodology was tested on the 1200 fundus images of MESSIDOR database that includes more than 200 fundus images with ME signs. Regarding the evaluation criterion, the so-called criterion $1R$ was used: the OD is successfully located if the distance between the estimated OD location and the actual OD center is lower than one OD radius.

Table 2 shows a performance comparison between our proposed methodology and those proposed by [19] and [20] (to the best of our knowledge, these are the most recent published methods that were tested on the same database used in this paper). An overview of the location results shows that our proposed method reaches better overall performance than [19] and [20], also providing the shortest computational time.

Therefore, the demonstrated effectiveness, together with its simplicity and fast implementation, make this proposed automated OD location method a suitable tool for being integrated into a complete prescreening system for early DR detection.

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