Computers in Biology and Medicine 56 (2015) 1–12

Contents lists available at ScienceDirect

Computers in Biology and Medicine

journal homepage: www.elsevier.com/locate/cbm

Optic disc segmentation using the sliding band filter

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ARTICLE INFO

Article history:
Received 6 August 2014
Accepted 11 October 2014

Keywords:
Optic disc segmentation
Retinal images
Sliding band filter
Boundary extraction
Segmentation evaluation

ABSTRACT

Background: The optic disc (OD) centre and boundary are important landmarks in retinal images and are essential for automating the calculation of health biomarkers related with some prevalent systemic disorders, such as diabetes, hypertension, cerebrovascular and cardiovascular diseases.

Methods: This paper presents an automatic approach for OD segmentation using a multiresolution sliding band filter (SBF). After the preprocessing phase, a low-resolution SBF is applied on a down-sampled retinal image and the locations of maximal filter response are used for focusing the analysis on a reduced region of interest (ROI). A high-resolution SBF is applied to obtain a set of pixels associated with the maximum response of the SBF, giving a coarse estimation of the OD boundary, which is regularized using a smoothing algorithm.

Results: Our results are compared with manually extracted boundaries from public databases (ONHSD, MESSIDOR and INSPIRE-AVR datasets) outperforming recent approaches for OD segmentation. For the ONHSD, 44% of the results are classified as Excellent, while the remaining images are distributed between the Good (47%) and Fair (9%) categories. An average overlapping area of 83%, 89% and 85% is achieved for the images in ONHSD, MESSIDOR and INSPIR-AVR datasets, respectively, when comparing with the manually delineated OD regions.

Discussion: The evaluation results on the images of three datasets demonstrate the better performance of the proposed method compared to recently published OD segmentation approaches and prove the independence of this method when from changes in image characteristics such as size, quality and camera field of view.

1. Introduction

The optic disc (OD) is one of the main structures in a retinal image and its shape and appearance are important for the detection of glaucoma and assessment of white lesions related with diabetic retinopathy. The OD is also a landmark for other retinal features, such as the distance between the OD and the fovea, which is often used for estimating the location of the macula [1]. In addition, OD segmentation is an important stage for the calculation of indexes related to vascular changes, such as the Arteriolar-to-Venular Ratio (AVR) [2] as the estimation of this index requires a previous OD segmentation in order to determine the region of interest [3].

There are several works on the automatic segmentation of OD in retinal images which can mainly be grouped into four categories, namely template-based methods [4–7], deformable model methods [8–13], morphological-based approaches [14–16], and pixel classification methods [17,18]. Within the first category, Aquino et al. [4] follow a voting-type algorithm to locate a pixel within the OD as initial information to define a starting sub-image. Then morphological and edge detection algorithms are applied on the sub-image to segment the OD in the red and green channels separately. In both channels, the OD boundaries are approximated using the Circular Hough Transform (CHT) and finally the one with higher score in the CHT is selected. The method proposed by Wong et al. [5] uses a level-set approach to obtain the OD boundary, that is afterwards smoothed by fitting an ellipse. A general energy function proposed by Zheng et al. [6], which integrates priors on the boundaries of the optic disc and optic cup, as well as on the minimum rim thickness. The optic cup and disc are segmented by using an energy function in a global optimization framework with a graph cut technique. Recently, Giachetti et al. [7] proposed a multiresolution ellipse fitting method which combines a radial symmetry detector and a vessel density map to detect the OD in low-resolution image. Afterwards, the OD boundary is determined using refined elliptic contours on the mid-resolution and high-

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http://dx.doi.org/10.1016/j.compbiomed.2014.10.009
0010-4825/

resolution images. The final segmented contour is improved with a snake-based refinement algorithm.

Regarding the deformable model approaches, Lowell et al. [8] determine the OD location by finding the maximum of a correlation filter using a specialized template. Afterwards, the OD is segmented by means of a deformable contour based on a global elliptical model and on a local deformation. In the snake model proposed by Xu et al. [9], after each snake deformation, an unsupervised approach labels the contour points as edge- or uncertain-points. Then the classification result is used to refine the OD boundary before repeating the contour deformation. Li and Chutatape [10] proposed a method which extracts a point distribution model from the training set using several landmarks on OD boundaries and on main vessels inside the OD. Then this model is used by an iterative matching algorithm to locate the OD. Joshi et al. [11] modified a region-based active contour model. They improved the Chan–Vese model by using local red channel intensities and two texture feature spaces in the neighborhood of the pixels under analysis. The method proposed in [12] uses template matching and a directional matched filter to localize the OD. For OD segmentation, the authors first remove the blood vessels and bright regions using alternating sequential filtering and morphological operations. Then a fast and hybrid level set segmentation method with optimized parameters is used for extracting the OD boundary. In the method proposed by Hsiao et al. [13], the Canny edge detector and the Hough transform are used for obtaining the edge map. Afterwards, the edge map is used as an initial contour in supervised gradient vector flow snake which consists of a snake deformation stage and a contour supervised classification stage.

In the group of mathematical morphology algorithms for OD segmentation, Reza et al. [14] threshold the green component in order to obtain a binary image with isolated bright parts. Then, morphological opening is used to detect the connected components and to remove the small ones. Afterwards, extended maxima operator and minima imposition are used for extracting the OD and exudate boundaries. In [15], an adaptive mathematical morphology approach is used in two stages. In the first stage a coarse detection of OD boundary is obtained and in the second stage the results are improved. The method described in [16] uses principal component analysis in the first stage to obtain a grey image with an improved representation of the OD. After removing the vessels, a variant of watershed and stochastic watershed is applied. Finally, a geodesic transformation is used to discriminate the watershed regions as OD or non-OD regions.

In the pixel-based classification category, Abràmoff et al. [17] use a feature selection and a k-nearest neighbor classifier. The final step is the classification of each pixel into rim, cup, or background. Recently, Cheng et al. [18] proposed a method which classifies each superpixel as disc or non-disc region using histograms with enhanced contrast and texture features. Superpixels are local and coherent regions that provide local image information. Superpixel classification is used for initialization of the disc boundary followed by a deformable model for getting the final contour.

Since the intensity inside OD is variable and the OD region can be degraded by different types of retinal lesions, OD segmentation is challenging and still an open task mainly for reducing the processing time and, in pathological images, for improving the performance. In this paper, we propose a new method for OD segmentation that can be classified as a template-based solution. Our main motivation was the development of a fully automatic method that is able to produce useful results even in the presence of severe pathological conditions and showing a great independence from image acquisition settings. In this method the response of a filter suitable for the enhancement of bright circular regions, the sliding band filter (SBF), is used for estimating both the OD centre and the OD boundary. For high resolution images, the sliding band filter (SBF) is used twice. The first SBF is applied on downsampled images to estimate the optic disc centre (ODC) that is then used for defining a region of interest where the second SBF is afterwards applied for fine boundary extraction. The parameters of the second SBF are set adaptively based on the image size and camera field of view (FOV). This OD segmentation approach is evaluated on the images of three public datasets.

The proposed method is a fully automatic algorithm which segments the optic disc independently of image characteristics such as size and camera field of view. Our solution is robust to variations of contrast and illumination, the presence of exudates and peripapillary atrophy caused by diabetic retinopathy, risk of macular edema, and the blurredness of images due to severe cataracts. From now on we shortly call this approach the SBF-based OD segmentation, or simply SBF-based method.

This paper is organized as follows. Section 2 presents our approach for OD segmentation. The results in images of three different datasets are presented in Section 3, where a comparison with the manual segmentation is also included. Finally, Section 4 summarizes the conclusions.

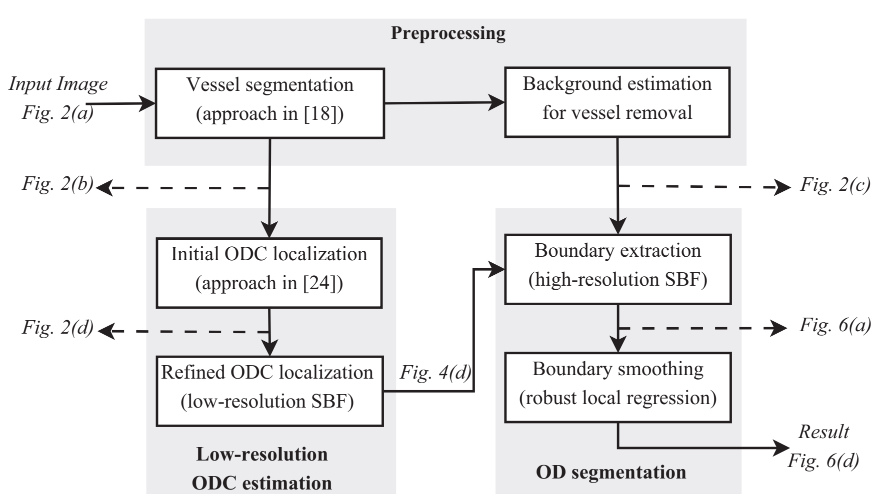

Fig. 1. Block diagram of SBF-based for optic disc segmentation.