BIOCYBERNETICS AND BIOMEDICAL ENGINEERING XXX (2018) XXX–XXX

Available online at www.sciencedirect.com

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

Original Research Article

Automated fuzzy optic disc detection algorithm using branching of vessels and color properties in fundus images

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ARTICLE INFO

Article history:
Received 10 April 2018
Received in revised form
15 July 2018
Accepted 3 August 2018
Available online xxx

Keywords:
Optic disc detection
Fuzzy logic controller
Vessel convergence
Fundus image
Feature extraction

ABSTRACT

Optic disc (OD) detection is a basic procedure for the image processing algorithms which intend to diagnose and track retinal disorders. In this study, a new OD localization approach is proposed, based on color and shape properties of OD as well as the convergence point of the main vessels. This study is comprised of two successive fundamental steps. At the first step, an algorithm finding the approximate convergent point of the vessels is used in order to roughly localize OD. At the second step, three new features are suggested and a fuzzy logic controller (FLC) whose input membership functions are designed based on these features is proposed. The proposed method is applied to the DRIVE, STARE, DIARETDB0 and DIRETDB1 datasets and the obtained results validate the improvement in the performance by attaining success rate of 100%, 91,35%, 90% and 100% respectively and detecting OD centers and contours precisely in a reasonable execution time.

1. Introduction

Optic disc (OD) is a main anatomical region in retinal images which can be used to locate other retinal anatomic components like macula and blood vessels [1]. It is a valuable task to detect OD in the retinal images in terms of diagnosing the retinal, cardiovascular and nervous system diseases. The color and brightness features of OD look similar to hard and soft exudates which occur in diabetic retinopathy (DR). Glaucoma is diagnosed via change in cup-to-disc ratio of OD. Brain tumor, cardiovascular diseases, optic neuropathies, optic neuritis and papilledema can be approximately detected by analyzing OD shape [2].

Early diagnosis of retinal disorders and lesions like aneurysms, exudates, hemorrhages and the alteration in the size and the shape of the OD enable ophthalmologists to mitigate the effects of the diseases like DR, macular edema, glaucoma and blindness [3]. Remarkably, with respect to the information published by the World Health Organization [4],

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https://doi.org/10.1016/j.bbe.2018.08.003

the population of the people with diabetes has risen to 422 million in 2014 [5,4]. More and more, the automatic retinal image analysis software systems have a social and economic value by enabling clinical eye exams to be performed on a vast number of images in a very short time [6]. Development of automated retinal image analysis systems are especially needed in the developing countries with lack of ophthalmologists [7,8].These techniques not only save human and time resources but also provide quantitative metrics and can dramatically decrease the load on the ophthalmologists as well as reduce the inter and intra observer variability [6,9,10].

Apart from the above reasons, OD is also used as a key landmark in order to locate the other landmark points like macula and blood vessels in retinal images [3,1]. These landmarks can be used to constitute a spatial coordinate system which can be exploited to calculate the distance of edema, lesions and hemorrhages from OD and macula [3]. Detecting and omitting the OD region in the retinal images, the exudates which have yellowish color as OD can be easily detected and the diagnosis of the most of the DR cases can be succeeded [3,1,11]. The detection of OD region is also important in terms of calculating indexes at that retinal area such as arteriolar-to-venular-ratio (AVR) whose decreased value is a marker of cerebral atrophy and stroke [6,12].

In the literature, there are basically three different method types. The first type of method is based on exploiting the features of OD, such as size, color and brightness. The second method type is focused on estimating the convergence point of the vessels. The third method type models an OD template and matches this template with the most similar retinal image frame among some other candidate frames [3]. Beside this general categorization, there is still a huge literature survey on the OD detection methods. In order to summarize some of the latest state of the art methods, the analyses of these latest methods and a comparative Table 1 are described as below.

Fan et al. performed OD detection via a structured learning classifier model. The classifier was trained using a cropped OD image frame and used to generate an edge map for OD. Later, the edge map was thresholded and then circular Hough transform was applied to detect approximate OD boundary. Their proposed algorithm gave satisfactory test results on MESSIDOR, DRIONS and ONHSD datasets which have 1200, 110, 99 images respectively. This method needed a lot of various retinal images for training since it was a supervised method and failed when there was severe peripapillary atrophy [9].

Al-Bander et al. proposed a deep multiscale sequential convolutional neural network (CNN) and trained it using MESSIDOR and KAGGLE datasets which have 1200, 10,000 images respectively. Their study had encouraging results and very fast test execution time with the help of a powerful PC and GPU. This method also needed a lot of different retinal images for training as a supervised method and the trained neural network may not generalize some outlier retinal images in other retinal datasets which have different anomalies [13].

Tan et al. designed a 7-layer CNN in order to simultaneously segment fovea, OD and blood vessels. The features for each effective point of the normalized images were forwarded to the neural network which had 4 output neurons as background, fovea, OD and blood vessels. The segmentation results were not satisfactory and the study was tested only on DRIVE dataset. Additionally, the proposed method is not likely to mitigate problems like exudates and peripapillary atrophy. However, this study should also be reported in terms of its effort to detect all the retinal landmarks simultaneously via deep learning (DL) methods [14].

Díaz-Pernil et al. proposed a new OD detection method which was implemented on GPU technology. The sequence of their method was composed of AGP-color segmentator, Hamadani's binarization technique and Hough circle cloud, respectively. Their proposed algorithm provided satisfactory test results on DRIVE and DIARETDB1 datasets which in total had 129 images. The performance of this study was relatively promising but the tested retinal datasets were not enough to generalize the results. Apart from these reasons, the system was not tested on a retinal database like STARE which has different kind of lesions. Nevertheless, this study is novel in terms of the fact that it performed GPU implementation and

Table 1 – The comparative table of the latest state of the art studies.

Author	Retinal databases	Success rate	OD overlap ratio	Execution time (s)
Fan et al. [9]	MESSIDOR	0.97	0.86	
	DRIONS	0.98	0.84	1.74
	ONHSD	0.99	0.83	
Al-Bander et al. [13]	MESSIDOR	0.97	–	0.007
	KAGGLE	0.967	–	
Tan et al. [14]	DRIVE	0.8790	0.621	–
Díaz-Pernil et al. [15]	DRIVE	0.975	0.833	7.6
	DIARETDB1	0.977	0.843	16.3
Alshayeji et al. [16]	DRIVE	1	–	
	DIARETDB1	0.977	–	
	DMED	0.929	–	0.4
	STARE	0.95	–	
Dai et al. [17]	MESSIDOR	–	0.91	–
	DRIONS	–	0.908	–
	ONHSD	–	–	–

Please cite this article in press as: Nergiz M, et al. Automated fuzzy optic disc detection algorithm using branching of vessels and color properties in fundus images. Biocybern Biomed Eng (2018), https://doi.org/10.1016/j.bbe.2018.08.003