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An approach to locate optic disc in retinal images with pathological changes

Li Xiong, Huiqi Li*

School of Information and Electronics, Beijing Institute of Technology, No. 5 Zhongguancun Street, Beijing 100081, China

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ABSTRACT

Automatic optic disc (OD) detection is an essential step for screening of eye diseases. An OD localization method is proposed in this paper, which aims to locate OD robustly in retinal image with pathological changes. There are mainly three steps in this approach: region-of-interest (ROI) detection, candidate pixel detection, and confidence score calculation. The features of vessel direction, intensity, OD edges, and size of bright regions were extracted and employed in the proposed OD locating approach. Compared with the OD locating method based on vessel direction only, the proposed method could handle the following cases better: OD partially appears in retinal image, retinal vessels are not obvious in retinal image, or there are bright lesions in retinal images. Four public databases with total 340 retinal images were tested to evaluate the performance of our method. The proposed method can achieve an accuracy of 100%, 95.8%, 99.2%, 97.8% for DRIVE database, STARE database, DIARETDB0 database, DIARETDB1 database respectively. Comparison studies showed that the proposed approach is especially robust in the retinal images with diseases.

1. Introduction

The detection of retinal structure is an important prerequisite to diagnose retinal diseases automatically. The retina contains several important structures, such as optic disc (OD), fovea, and vessels. Optic disc is the region where blood vessels and optic nerves converge. There are no light-sensing cells in OD area, so optic disc is also called blind spot. In the normal retinal images, OD is the brightest part and looks like a pale, nearly circular or vertically slightly oval disk. Correct OD detection is the basic step for computer aided diagnosis of different eye diseases, such as diabetic retinopathy [1] and glaucoma [2]. The changes of OD shape can reflect the extent of vision loss, thus various parameters of OD are used to diagnose eye diseases. For example, diameter and edge of cup, radius of OD, rim area, mean cup depth, and cup-disc-ratio are usually employed to detect glaucoma. OD detection is also a key step for the localization and segmentation of other anatomical structures such as fovea and retinal vessels. Since retinal vessels usually converge at the center of OD, vessel tracking can start from the rim of OD.

The challenges of robust OD detection includes: individual differences, fundus ocular diseases, uneven illumination, and retinal vascular occlusion. Many algorithms have been proposed for OD localization. Usually satisfactory results can be achieved in healthy retinal images. However, for the images with pathological changes, there is still no good solution. Fig. 1 shows some examples of these challenges. In Fig. 1(b), there are large areas of lesions in the image. The intensity of OD area is much darker than surrounding regions due to uneven illumination in Fig. 1(c). Only part of OD is shown in some retinal image as in Fig. 1(d). Most of the OD locating methods is effective for only one type of these difficulties.

In this paper, an improved method based on edge information is proposed to locate OD robustly in normal retinal images as well as images with pathological changes. The main contribution of this work can be summarized as three aspects. (1) Vessel edge information and OD edge are combined to detect candidate OD pixels, which successfully detect the candidate pixel of OD center in images with poor illumination or few vessel information. (2) A confidence score is proposed to locate OD center, in which a new compensation value is proposed. For images with poor illumination or few vessel information in OD region, this score will compensate the value for missing vessel edge information. (3) Comparing with the method using vessel edge information only, the improvement on candidate pixel detection and the confidence value achieves promising results in the following situations: the images with dark OD due to uneven illumination and low contrast; the retinal images with incomplete OD; the images with bright exudates, whose size and intensity are similar to OD.

* Corresponding author. Tel.: +86 1068918239.
E-mail address: huiqili@bit.edu.cn (H. Li).

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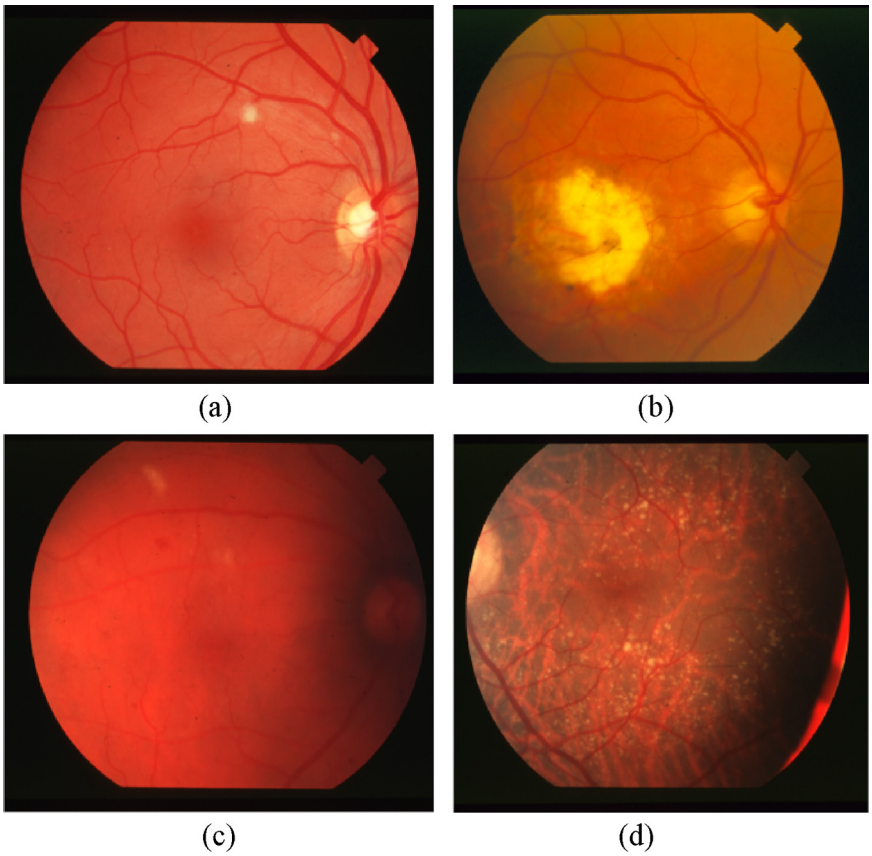

Fig. 1. Examples of retinal image. (a) Healthy retinal image; (b) image with large area of lesions; (c) image with dark OD; (d) image with incomplete OD.

2. Related work

Many methods have been proposed to detect OD, which can be generally classified into three categories: methods based on intensity, methods based on template matching, and methods based on vascular structure.

In early studies, the methods to locate OD center are mainly based on intensity. In these methods, OD is located by finding the largest bright area [3], the pixel with highest average intensity in a certain neighborhood area [4], or the bright region with maximum variance [5–7]. These methods can usually obtain correct location in normal fundus images. In the images with pathological changes, lesions such as hemorrhages, drusen, and exudates may influence the localization results, because the intensity and shape of these lesions may be similar to OD. Sometimes uneven illumination makes the OD's features look less prominent. Hence, an illumination correction operation was performed by Hsiao [7]. It is hard to acquire correct OD location by solely using the feature of intensity. Many improved methods have been proposed. For example, a line operator was designed to detect circular brightness structure by Lu [8]. In [9], a circular transformation was proposed to describe circular shape of OD and image variation across OD boundary to detect OD location and OD boundary. Besides, OD center was located by a voting to the candidate pixels detected by the maximum difference, maximum variance and maximum gray-level in low-pass filtered image [10].

Template matching is another widely used method. This method commonly consists of two steps: selecting candidate pixels (usually according to intensity, vascular structure etc.) and matching the given templates. In [11] candidates of OD center were determined by pyramidal decomposition and Hausdorff distance was employed for circular template matching to edge image. A template of Laplacian of Gaussian with a vertical channel in the middle was proposed in [12], in which the vertical channel corresponds to the major vertically oriented vessels. A PCA-based model called "disc space" was proposed by Li [13] to locate OD. For every pixel in the candidate region, the model is applied in different scales (0.8–1.2) and Euclidian distance to its projection onto the "disc space" was calculated. The point with the smallest value was determined as the OD center. In [14], binary circular template and Pearson correlation coefficient were employed to detect the OD candidate matching in CIElab lightness image. Approximate Nearest Neighbour Field [15] was used to find the correspondence between a chosen OD reference image and an input image.

Due to uneven illumination or pathology, there is large variation in the shape, color, intensity, and size of OD. It is hard to achieve stable results using the above intensity-based or template-based methods. It is observed that optic disc is the entrance region of blood vessels. The vascular geometric structures are utilized to locate the OD center [16–20]. Fuzzy convergence was proposed by Hoover [16] to determine the origination of retinal vessel network. Fuzzy segment model is set to create convergence image via voting type. A geometrical model of vessel structure was presented by Foracchia [17], which suggests that vessel path follows a similar directional parabolic course in all fundus images, and the vertex is defined as the origin of retinal vessels, namely OD center. A point-distribution-model (PDM) was trained to describe the position of the main anatomical structures including optic disc, macula, and vascular arch by Niemeijer [18]. The OD center was detected by fitting the PDM model to a testing image. In [19], OD center was determined by information of vessel which is extracted by curvelet transform. Two main vessels were detected using adaptive mathematical morphology in [20] and the OD center was located on the point of intersection.