Expert Systems with Applications 39 (2012) 10600–10606

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

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

A novel optic disc detection scheme on retinal images

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ARTICLE INFO

Keywords:
Optic disc
Illumination correction
GVF snake
Supervised classification
Retinal image

ABSTRACT

Robust and effective optic disc detection is a necessary processing component in automatic retinal screening systems. In this paper, optic disc localization is achieved by a novel illumination correction operation, and contour segmentation is completed by a supervised gradient vector flow snake (SGVF snake) model. Conventional GVF snake is not sufficient to segment contour due to vessel occlusion and fuzzy disc boundaries. In view of this reason, the SGVF snake is extended in each time of deformation iteration, so that the contour points can be classified and updated according to their corresponding feature information. The classification relies on the feature vector extraction and the statistical information generated from training images. This approach is evaluated by means of two publicly available databases, Digital Retinal Images for Vessel Extraction (DRIVE) database and Structured Analysis of the Retina (STARE) database, of color retinal images. The experimental results show that the overall performance is with 95% correct optic disc localization from the two databases and 91% disc boundaries are correctly segmented by the SGVF snake algorithm.

1. Introduction

Diabetic retinopathy is a chronic disease which is the primary cause of blindness in the working population of the developed world (Aquino, Gegúndez-Arias, & Marín, 2010; Manivannan, Sharp, Phillips, & Forrester, 1993; Sinthanayothin, Boyce, Cook, & Williamson, 1999; Taylor & Keeffe, 2001). Therefore, the early detection and diagnosis of diabetic retinopathy is a very important procedure from retinal images.

Optic disc detection is a very important task in retinal image analysis (Akita & Kuga, 1982; Lu & Lim, 2011). In normal retinal images, the optic disc generally appears as bright, yellowish, circular or slightly oval shape, roughly one-sixth the width of the image in diameter (Hoover & Goldbaum, 2003). Any change in the structure of the optic disc is a sign of various retinopathies especially for glaucoma (Li & Chutatape, 2004); therefore, the shape of optic disc is often used to evaluate abnormal retinal features (Ter Haar, 2005; Xu, Chutatape, Sung, Zheng, & Kuan, 2007). On the basis of the geometric relationships between the optic disc location and the vascular structure, the central macula (fovea) can be approximately located (Sinthanayothin et al., 1999; Tobin, Chaum, Govindasamy, & Karnowski, 2007).

Since the retinal blood vessels radiate from the optic nerve head, the optic nerve head is also used as a beginning point for vessels tracking (Lalonde, Gagnon, & Boucher, 2000; Sinthanayothin et al., 1999; Tolias & Panas, 1998). Furthermore, the optic disc may be identified as part of exudates regions, because the colors of the optic disc and the bright exudates are similar. It is evident that accurate optic disc identification refines the segmentation of the exudates regions (Osareh, 2004; Walter, Klein, Massin, & Erginary, 2002). The optic disc identification is fundamental for organizing a relation within retinal images, and is important to computer assisted diagnosis.

Identifying the optic disc region becomes more complicated due to the presence of retinopathy such as large exudative lesions or bright artifactual features. Sinthanayothin et al. (1999) assume that the retinal lesions have a lower variance of intensity than that of the optic disc area, in which the optic disc is approximated by identifying the largest local variation with a 80×80 window size. However, Lowell et al. (2004) had already shown that this algorithm often fails in retinal images with a large number of white lesions, light artifacts or strongly visible choroidal vessels. Besides, Walter et al. (2002) proposed another algorithm applied by shade-correction and calculated the local variation of the image for optic disc localization, in which the accurate optic disc contour

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doi:10.1016/j.eswa.2012.02.157

was determined by morphological filtering techniques and watershed transformation. The resulted contour was slightly distorted due to the outgoing vessels.

A template matching algorithm was provided by Lalonde, Beaulieu, and Gagnon (2001), which is Hausdorff-based template matching in combination with pyramidal decomposition technique. Initially, a large scale object is tracked by means of multiresolution pyramidal decomposition in the green band image, and hence the presence of small bright retinal lesions such as exudates is reduced. Then the Hausdorff distance is used to measure the matching degree between the circular template and optic disc candidate regions with different scales, the region with the highest confidence value corresponds to the optic disc location. Later on, Osareh et al. (2004) proposed another template matching algorithm to locate the optic disc. In their algorithm, the template image are obtained by averaging the color-normalized optic disc region in 25 fundus images, and then the correlation coefficient is used to indicate the best match between the template and the candidate regions. Lowell et al. (2004) showed that the template matching approach is effective, but may be highly complex.

Li and Chutatape (2004) proposed a method by applying the machinery of principal component analysis (PCA) and a modified active shape model (ASM) for optic disc identification. To create a disc space, the authors manually cropped 10 sub-images from the optic disc regions for training. Each training image is described in a vector format, and the PCA transform is employed to get the first six eigenvectors representing the training set. The optic disc is identified as the region with the minimum Euclidian distance projection, which indicates the similarity of the template vectors. However, the shape model may not be suitable to detect the various disc shapes from many pathological changes.

Several algorithms based on retinal blood vessels for locating the optic disc have been investigated. However, the retinal vessels segmentation is a complicated job and the false vessel detection will greatly affect the subsequent operations. Hoover and Goldbaum (2003) proposed a fuzzy convergence scheme in order to decide the convergence point of vessels (optic disc location). Foracchia, Grisan, and Ruggeri (2004) identified the optic disc by means of fitting a parametric geometrical model to the main vessels. Akita & Kuga, 1982 tracked the parent–child relationship among the retinal vascular system for locating the optic disc.

General-purpose detection techniques usually fail to accurately identify the optic disc due to non-uniform illumination and vessel occlusion. On one hand, the appropriateness of the automatic localization depends deeply on whether the illumination is uniform or not, and on the other hand, vessel occlusion may lead to unacceptable contour segmentation. In order to correct these two technical defects, this paper presents a novel algorithm for automatic localization and segmentation of the optic disc in retinal fundus images. Optic disc localization is achieved by using a novel illumination correction operator, which results in a significant contrast between the optic disc and background. Besides, the boundary of the optic disc is extracted based on the supervised gradient vector flow snake (SGVF snake) model combined with supervised classification. The classifier is embedded into GVF snake deformation in order to detect the false contour points, and then the contour points will be updated to the correct edge position. Therefore, the proposed algorithm enables the resulted contour to be more robust for vessel interference and fuzzy disc boundaries.

The remainder of this paper is organized as follows. Section 2 describes the proposed optic disc detection methodology on a retinal image. Section 3 presents the experimental results. Finally, the conclusions of this paper are presented in Section 4.

2. Proposed methods

This paper proposes a new approach for optic disc detection, which can be divided into two phases: location and segmentation. The former focuses on locating the optic disc, and the latter estimates the optic disc contour. Fig. 1 shows a flow chart of the proposed scheme. Details of the presented optic disc scheme are described in the following subsections.

For our application, the optic disc is localized as the brightest area in the fundus image after illumination correction operator. The subsequent processes inspired by Xu et al. (2007) present the SGVF snake algorithm that combines GVF snake with supervised classification for optic disc segmentation.

2.1. Optic disc localization

The optic disc localization is essential to retinal image analysis. It is evident that accurate optic disc identification refines the segmentation of the exudates regions. The localization phase proposed in this paper combines the illumination correction processing stage and the estimating stage of optic disc location. The illumination correction operator works on the green band image, because the green band exhibits the best contrast in the retinal image.

2.1.1. Illumination correction

The illumination in retinal images is non-uniform due to an optical aberration, which is the result of an improper focusing of light through an optical system (Hoover & Goldbaum, 2003). Youssif, Ghalwash, and Ghoneim (2007) showed that the non-uniform illumination through the image greatly affects the accuracy of optic disc localization. In order to remove uneven background intensity, the illumination correction operator with the following equation is proposed:

$$I'(x,y) = I(x,y) - \frac{\mu_N(x,y)}{0.1 + \sigma_N(x,y)} \tag{1}$$

where $\mu_N(x,y)$ and $\sigma_N(x,y)$ are the mean and standard deviation of the pixel values within an $N \times N$ window, respectively. Since the region of interest (ROI) of the retinal image is roughly circular and the $N \times N$ window is square, the pixel number applied when the window is in the interior is more than the pixel number applied near the border of the ROI. Thus, when applying the operator to border pixels, the out-of-the ROI pixel values in the $N \times N$ window are replaced by the mean pixel value of the remaining pixels in the window. As stated in Sinthanayothin et al. (1999), yellowish optic disc appears as bright patterns in retinal images, and the grey level variation is high due to the outgoing vessels. The illumination correction operator preserves bright regions associated with the optic disc which has large local variation, and generates a significant contrast between the optic disc and background (Fig. 2(b)).

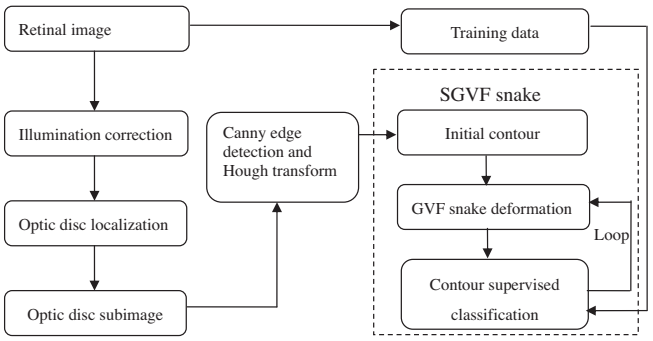

Fig. 1. Flow chart of optic disc detection process.