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Robust and accurate optic disk localization using vessel symmetry line measure in fundus images

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ABSTRACT

Accurate optic disk (OD) localization is an important step in fundus image based computer-aided diagnosis of glaucoma and diabetic retinopathy. Robust OD localization becomes more challenging with the presence of common pathological variations which could alter its overall appearance. This paper presents a novel OD localization method by incorporating salient visual cues of retinal vasculature: (1) global vessel symmetry, (2) vessel component count and (3) local vessel symmetry inside OD region. In the proposed method, a new vessel symmetry line (*VSL*) measure is designed to demarcate the lines that divide the retinal vasculature into approximately similar halves. The initial OD center location is computed using the highest number of major blood vessel components in the skeleton image. The final OD center involves an iterative center of mass computation to exploit the local vessel symmetry in the OD region of interest. The proposed method shows effectiveness in diseased retinas having diverse symptoms like bright lesions, hemorrhages, and tortuous vessels that create potential ambiguity for OD localization. A total of ten publicly available retinal image databases are considered for extensive evaluation of the proposed method. The experimental results demonstrate high average OD detection accuracy of 99.49%, while achieving state-of-the-art OD localization error in all databases.

1. Introduction

Optic disk (OD) localization is an important aspect of fundus image analysis in computer-aided diagnosis of glaucoma and diabetic retinopathy [1]. The optic disk appears as a bright and relatively circular structure in normal fundus images (Fig. 1). Accurate OD localization ensures efficient optic disk and cup segmentation which is crucial for deriving cup-disk-ratio (CDR) based glaucoma risk index [2]. In diabetic retinopathy affected images, the optic disk region can be easily confounded with the bright exudates. Hence, the optic disk is identified and discarded to enhance the exudate detection performance [3]. Moreover, OD also acts as a landmark in the localization of fovea and macula [4].

Various methods have been proposed in the literature for OD localization using retinal anatomical structures. The methods can be broadly grouped in two categories, i.e. appearance based methods and model based methods. The appearance based methods are designed based on the shape

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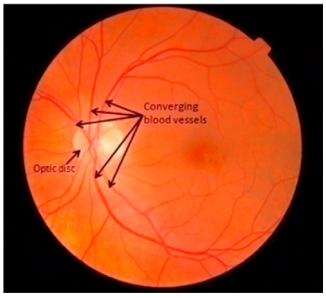
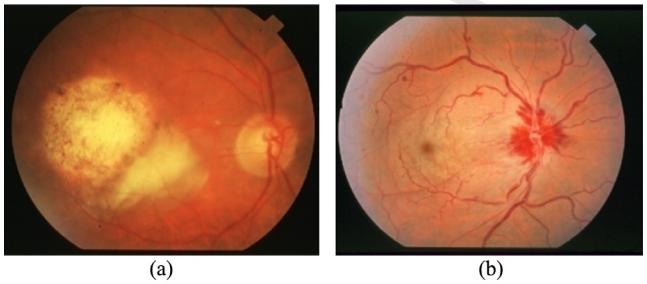


Fig. 1 – Healthy retina containing bright and circular OD with converging blood vessels.

and brightness characteristics of OD. Sinthanayothin et al. proposed a method based on the fact that the OD has the highest image variance due to the bright OD pixels and the dark retinal blood vessel pixels within the OD region [4]. Walter and Klein detected the OD assuming that OD is the brightest region within a retinal image [5]. Multiple line operators in specific directions are designed by Lu and Lim to capture circular brightness structures [6]. The effectiveness of the appearance based methods is reduced in images having non-uniform illumination and pathological images causing changes in OD appearance due to the interference of large exudates and bright artifactual features.

It is observed that blood vessels are most stable anatomical structures in the pathological fundus images (Fig. 2). Thus, model based OD localization techniques which uses blood vessel map tend to be more reliable even in the presence of retinal pathologies. Hoover and Glodbaum exploited the fuzzy convergence property of blood vessels at the OD center [7]. This method reported an overall accuracy of 89% and several failure cases arise due to the convergence of vessels around a bright lesion. OD is localized as the common vertex of two parabolas fitted with the major blood vessels in [8]. Youssif et al. developed an OD detection algorithm based on matched filtering which matches the directional pattern of the retinal blood vessels [9]. Mahfouz and Fahmy identified the OD by locating the peak of the 1-D projections with an accuracy of 92.59% [10]. The working parameters of [8], the filters of [9], size of the projection windows of [10] need to be tuned separately for different databases. Circular transformation is used to locate the OD based on its shape and image variations across the OD boundary in [11]. The images having very low image variation across the OD boundary reported incorrect OD localization in this method.



(a) (b)

Fig. 2 – (a) Retinal image having lesions of higher brightness and larger size than OD. (b) Retinal image where OD is completely covered by hemorrgages.

Welfer et al. [12] proposed a new adaptive method for automatic localization and segmentation of the optic disk using mathematical morphology. Soares et al. [13] performed OD localization based on the cumulative sum field computed from retinal vessel orientations. This method reports an average accuracy of 99.15%. Zhang and Zhao suggested an OD detection method based on vessel distribution and directional characteristics along with global Hough transform [14]. Main limitations of the model based methods are that they are complex and require high computation time. Moreover, complete and accurate vasculature favors the model based techniques, since very high detection accuracy is achieved when manually labeled vessels are utilized. Giachetti et al. applied fast radial symmetry transform as the principal cue to locate optic disk centers and reported high detection accuracy of 99.66% in MESSIDOR database [35]. Bekkers et al. proposed a template matching approach to recognize a curved geometry on the position-orientation domain [36]. Dashtbozorg et al. presented an automatic approach for OD center detection and segmentation using a multiresolution sliding band filter (SBF) which is suitable for the enhancement of bright circular regions [37].

In this paper, we propose a robust and accurate approach for OD localization by incorporating three salient visual cues derived from retinal vasculature symmetry and convergence characteristics. Our contribution in the paper can be summarized as follows: first, we explore the global symmetry of the segmented vessel map to select lines which divides it into approximately similar halves. Second, we observe that highest number of major blood vessel components converge inside the OD region (vessel component count). We formulate an algorithm to locate the initial OD center on the global symmetry line by designing two semi-annular masks. Third, despite the fact that the retinal blood vessels usually exhibit a random pattern in fundus images [15], we observe local symmetry and dense vessel distribution inside the OD region. This visual cue helps us to detect the final OD center location by an iterative computation of center of mass. The proposed method's performance is evaluated by using 10 publicly available databases such as DRIVE, STARE, HRF, ROC, E-OPHTHA-EX, DIARETDB0, DIARETDB1, MESSIDOR, DRIONS-DB, and DRISHTI-GS. The high average detection accuracy of 99.49% is achieved despite the presence of large number of pathological fundus images. Further, the parameters used in the method are simple to select and they are consistent for the fundus images in all databases.

The organization of the paper is as follows: The proposed OD localization method is formulated in Section 2. The materials used for evaluation of the proposed method and analysis of the obtained results are discussed in Section 3. Finally, some concluding remarks are noted in Section 4.

2. Proposed optic disk localization method

For OD localization, we have selected the green channel (Fig. 3 (a)) of the RGB color image (Fig. 2(a)) as it provides best contrast and clinical information of retinal structures. The proposed OD

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