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Automatic segmentation of optic disk in retinal images

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ABSTRACT

In this paper a new algorithm is presented for automatic segmentation of the optic disk (OD) in human retinal images. In proposed method, an equiripple low pass finite impulse response (FIR) filter is designed to suppress the dominance of blood vessels and to enhance the OD region in retinal image. Desired frequency response with optimized order of the filter is achieved by choosing proper values of filter design parameters. This method computes the appropriate value of threshold to locate the OD in retinal image. Segmentation of the OD region is carried out using grayscale morphological dilation and median filtering operation. The proposed algorithm has been tested on four standard databases (DRIVE, DIRATEDB0, DIRATEDB1 and DRIONS database). The proposed algorithm detects the OD successfully with accuracies 100%, 96.92%, 98.98%, 100% on DRIVE, DIRATEDB0, DIRATEDB1 and DRIONS databases respectively. The OD segmentation sensitivity and specificity are in the range of 74.60–87.07%, 99.39–99.61% on these four databases. The proposed algorithm has low computation complexity as it takes low computation time to segment the OD over existing methods. Also it is robust to differences in image illumination and retinal anomalies. Hence the proposed method can be used for automatic screening system of retinal related diseases like glaucoma and diabetic retinopathy.

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1. Introduction

The assessment of retinal images is an investigative tool commonly used to collect important clinical information, such as for diabetic retinopathy and glaucoma evaluation [7]. Segmentation of the OD characterizes the preliminary point of several automatic computer based techniques used to help the ophthalmologist in identifying these two diseases. The Cup-to-Disc (CDR) ratio is normally used clinically to assess glaucoma progression. CDR is attained by quantifying the ratio between the vertical diameter of the OD cup and the OD rim. As for diabetic retinopathy assessment, the identification of the OD is important to trim down misclassification in the automatic detection of other lesions.

1.1. Related work

The OD is an extremely intense region inside a fundus image. In most of the research work, the OD has been identified from the features such as shape, brightness and size. A number of algorithms are introduced in state of the art for segmentation of the OD. These algorithms are broadly categorized into two components. The first component is related to the localization of the OD. Determination of place of the OD in retinal image is called as localization of the OD. The second component is related to the segmentation of the OD region. Segmentation of the OD is to extract the actual region of the OD in retinal image. These two components of automatic segmentation of the OD are discussed as follows.

1.1.1. OD localization methods

Gagnon et al. [1] proposed a method for detection of the OD, the macula and the retinal network. The OD is detected using pyramidal decomposition, Hausdorff distance based template matching and confidence assignment. Independent component analysis and structural similarity index measure were described in [2] for localization of the OD. They achieved 100% accuracy on 100 normal retinal images and 75% accuracy on 232 diseased retinal images. Average accuracy on 323 retinal images was 87.2%. Claudio et al. [3] proposed a new cascade classifier based method for the OD detection. The cascade classifiers are trained using segmented images of OD and non-OD. The OD detection in color fundus images using ant colony optimization is introduced in [4,8]. Ahmed and Amin [5] used the mean intensity value of retinal images to detect the center of the OD.

Ravishankar et al. [6] detected the major blood vessels and used the intersection of these to find the approximate location of the OD. Youssif et al. [7] proposed a method based on directional filters matched with the outgoing vessels for detection of

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the OD center. This OD detection algorithm is based on matching the expected directional pattern of the retinal blood vessels. 2-D Gaussian matched filter is used for segmentation of retinal vessels. The segmented vessels are then thinned, and filtered using local intensity, to represent finally the OD-center candidates. Fleming et al. [8] designed algorithm to detect the OD and the fovea. The approach is based on detection of main blood vessels which form approximately semi-elliptical paths enclosing the fovea. The OD was located using a circular form of the Hough transform and the fovea was detected by template matching. Rangayyan et al. [9] proposed a method based on focal point of the blood vessels in retinal image to locate center of the OD. Blood vessels are extracted using Gabor filter based approach. However the Gabor filter based approach suffers from high computationally complexity.

Chrastek et al. [10] applied an averaging filter to the green component of retinal image and positioned the OD at the point of the highest average intensity. Dehghani et al. [11] made template from three histograms, each related to one color component. They split color components (red, blue, and green) to get the histogram of each color component. The mean histogram of each color component for all retinal image samples is calculated and used as template for localizing the center of the OD. These algorithms are designed to position the OD in retinal image. They do not talk about the segmentation of the OD region.

1.1.2. OD segmentation methods

Li and Chutatape [12] introduced a method based on the principal component analysis for localization of the OD and its shape was detected by a modified active shape model. They obtained accuracy of 99% for OD localization and 94% for OD boundary detection. Pre-processing techniques based on local minima detection and morphological filtering were used in [13] for detection of the OD. The OD boundary was determined using an active contour which was derived from gradient vector flow. The OD region can be segmented by computing texture features of retinal image. The texture descriptors and a regression based approach are introduced in [14] to determine the best circle that in shapes the OD. Kande et al. [15] computed the OD center using the concept of a point that has maximum local variance. Geometric active contour based approach was used to find the boundary of the OD region. Walter et al. [16] used modified variance image method to detect the OD region and OD rim. The contour of the OD was found using the watershed transform. They achieved 90% accuracy for finding the exact contours in OD. Liu and Chen [17] proposed a method based on mathematical morphology and gradient vector flow snake model to detect the OD in fluorescing retinal images.

Zhu and Rangayyan [18] used sobel operators for edge detection and Hough transform for detection of circles of OD to localize the OD and its center. They achieved 90% success rate on DRIVE database. Siddalingaswamy and Gopalakrishna [19] proposed a method based on iterative thresholding and connected component analysis to detect the approximate center of the OD. The circular shape of the OD was determined using Hough transform and morphological operations in [20–22]. Lowell et al. [23] proposed a new concept based on correlation filter to locate the OD center. Correlation peak gives approximate center of the OD and circular deformable model was used to segment the OD region. Tobin et al. [24] proposed a probabilistic approach based on vasculature related OD properties. They used two class Bayesian classifier to classify each pixel as OD or Not-OD. Welfer et al. [25] proposed a new method based on two stage morphological approach. They used a several mathematical morphological operations to detect center of the OD, the OD and OD rim. Similar morphological operators based approach was used in [26,27] to segment the OD.

There are several methods in state of the art which can detect and segment the OD in retinal images. Most of the methods are able to locate only the OD in retinal images. These methods do not discuss about the segmentation of the OD region and take large computation time to locate only the OD. Also there is a scope to improve the accuracy (Claudio et al. [3], Carla [4], Ahmad and Amin [5], Ravishankar et al. [6], Lupasu et al. [14], Zhu et al. [18], and Welfer et al. [25]) and average absolute distance (Youssif et al. [7], Rangayyan et al. [9], Deghani et al. [11] and Zhu et al. [18]) between the manually and algorithmically detected OD center. The OD segmentation method proposed by Welfer et al. [25] obtained worthy results among the methods reviewed in literature. They got superior results for the metrics used to measure the performance of the OD segmentation algorithm except average overlap between the manually and algorithmically segmented OD regions. Therefore there is a scope to improve the average overlap metric. In this paper a new algorithm is proposed for automatic segmentation of the OD in retinal image. This algorithm achieves superior accuracy for OD detection, yields better performance for OD segmentation and low computation time to segment the OD over the existing methods reviewed in literature.

1.2. Proposed approach

The proposed OD localization and segmentation algorithm is making use of equiripple low pass filter to blur the blood vessels and to enhance the OD portion. Optimum order equiripple low pass filter is designed in order to have low computational complexity and desired frequency response. Computational complexity depends up on the order of the filter. As order increases number of computations also increases ultimately the computational complexity. Order of the filter is optimized using design parameters, pass band frequency w_p, stop band frequency w_s, pass band attenuation A_p and stop band attenuation A_s and desired frequency response is achieved. Optimized order of the filter is 83 with design parameters (pass band frequency $w_p = 0.01 \times \pi rad$, stop band frequency = $0.06 \times \pi rad$, pass band attenuation $A_p = 1dB$, stop band attenuation $A_s = 60dB$). These specifications of the equiripple low pass filter are empirically obtained and then used for all the images of the four databases (DIARETDB1, DIARETDB0, DRIONS and DRIVE). These specifications give best results in suppressing the blood vessels and lesions while enhancing the OD portion in each fundus image regardless of the image FOV or the amount of image abnormality or varying spatial resolution.

Then the search of brightest pixel having maximum intensity among all pixels of low pass filtered image of retina is carried out. Threshold is computed by considering the mean intensity of square region of pixels around the brightest pixel. Square region is selected such that threshold value should not be much larger or much smaller to obtain the proper segmentation of OD portion. So it is set to $[15 \times 15]$ and applied to all images used for experimentation. This small square area improves the performance in terms segmentation accuracy as well as execution time of algorithm. The image is segmented using computed threshold value. The OD is located by determining the circular shape small cluster of high intensity pixels using compactness property of circular region [30]. Center of that region marked as the OD center. For segmentation of the OD region, square portion approximately twice the OD size in green component of retinal image around the OD center is cropped. Square portion approximately twice the OD size gives better results in further processing. Morphological dilation operation is performed to enhance the bright region of the OD. Through experimentation it is determined that the disk structuring element of radius half the actual size of the OD in retinal image is more effective for accurate segmentation of the OD. So the radius of the structuring element is set to half the actual size of the OD. Region of the OD is blunt using median filtering operation. Finally segmented

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