Biomedical Signal Processing and Control 25 (2016) 108–117

Contents lists available at ScienceDirect

Biomedical Signal Processing and Control

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

Blood vessel inpainting based technique for efficient localization and segmentation of optic disc in digital fundus images

M. Partha Sarathi [a], Malay Kishore Dutta [a,*], Anushikha Singh [a], Carlos M. Travieso [b]

[a] Department of Electronics & Communication Engineering, Amity University, Uttar Pradesh, Noida, India
[b] University of Las Palmas de Gran Canaria, Las Palmas de Gran Canaria, Las Palmas, Spain

ARTICLE INFO

Article history:
Received 27 June 2015
Received in revised form 29 October 2015
Accepted 30 October 2015
Available online 17 December 2015

Keywords:
Fundus image
Optic disc
Blood vessel
In-painting
Region growing
Spline interpolation

ABSTRACT

The Optic disc (OD) nerve head region in general and OD center coordinates in particular form basis for study and analysis of various eye pathologies. The shape, contour and size of OD is vital in classification and grading of retinal diseases like glaucoma. There is a need to develop fast and efficient algorithms for large scale retinal disease screening. With this in mind, this paper present a novel framework for fast and fully automatic detection of OD and its accurate segmentation in digital fundus images. The methodology involves optic disc center localization followed by removal of vascular structure by accurate inpainting of blood vessels in the optic disc region. An adaptive threshold based Region Growing technique is then employed for reliable segmentation of fundus images. The proposed technique achieved significant results when tested on standard test databases like MESSIDOR and DRIVE with average overlapping ratio of 89% and 87%, respectively. Validation experiments were done on a labeled dataset containing healthy and pathological images obtained from a local eye hospital achieving an appreciable 91% average OD segmentation accuracy.

1. Introduction

ACCURATE detection and analysis of eye pathologies and their timely treatment is essential in preventing vision loss. Automatic detection and grading of retinal diseases is an important stream of research in the recent times and holds huge potential to aid medical experts in improving the healthcare situation especially in developing countries where there is shortage of professional ophthalmologists. In recent years, several image processing algorithms have been developed to that extent, focusing on analysis of optic nerve head area in general and optic disc detection in particular. In fundus images Optic disc (OD) is the brightest object and is approximately circular or elliptical in shape. Optic disc localization is an important step in fundus image analysis to identify eye disease like diabetic retinopathy and glaucoma. Distance from OD center to retinal abnormalities like exudates and hemorrhages forms an important parameter in many ocular diseases like diabetic retinopathy. Glaucoma is a severe eye disease and analysis of optic disc is used for glaucoma diagnosis. Some features of optic disc like cup-to-disc-ratio, neuro retinal rim, blood vessels in the different regions of the optic nerve head are used to classify the images as glaucomatous or normal.

Hence, localization and segmentation of optic disc forms the significant preliminary step in most of the automatic computer assisted diagnosis (CAD) of eye diseases. The paper [1] includes 38 articles on Optic disc localization and Optic disc boundary detection.

With regard to OD localization method, Sinthanayothin et al. [2] presented a method for OD localization based on the intensity variation in the optic disc region because of blood vessels. Lalonde et al. [3] proposed OD detection method using pyramidal decomposition and Hausdorff-based template matching. Hoover et al. [4] presented a method of optic disc localization based on the fuzzy convergence of the blood vessels. Center of OD is located by Osareh et al. [5], using template matching and optic disc boundary segmentation is done by snake based approach. Mahfouz et al. [6] employed projection of image features to localize the OD. Another technique of OD center detection that uses the Geometrical model of blood vessel structure within the OD was presented by Foracchia et al. [7]. Youssif et al. [8] proposed optic disc localization method by means of a vessels' direction matched filter.

With regards to OD segmentation, some of the most common methods are summarized here. Active contours based approach is commonly used to segment optic disc contour as done in [9–11],

* Corresponding author. Tel.: +91 9891227240.
E-mail addresses: infinit47@gmail.com (M.P. Sarathi), malaykishoredutta@gmail.com (M.K. Dutta), anushikha4june@gmail.com (A. Singh), carlos.travieso@ulpgc.es (C.M. Travieso).

http://dx.doi.org/10.1016/j.bspc.2015.10.012
1746-8094/

but segmentation results are not very good because of uneven illumination and noise. Optic disc localization is required in these algorithms as preliminary step. Lowell et al. [12] employed a global elliptical parametric model combined with a local variable edge strength dependent stiffness model to identify the OD contour. Hough transform is also a popular method for OD boundary segmentation in fundus images. Fleming et al. [13] employed the Hough transform based method for optic disc boundary segmentation. Localization and segmentation of OD is presented using circular and parabolic Hough transform by Sekhar et al. [14]. Aquino et al. [15] used OD boundary detection using circular Hough transform after rough estimation of OD center and morphological processing.

Yu et al. [16] proposed optic disc boundary detection method based on directional matched filtering and level set model. Joshi et al. [17] presented optic disc boundary segmentationbased on image information in multidimensional feature space. Line operator was also used for automatic OD detection in fundus image by Lu et al. [18]. Walter and Klein et al. [19] proposed optic disc localization method by intensity based thresholding and employed the watershed transformation to the gradient image for OD contour detection. Watershed transformation was also used by

Reza et al. [20] for optic disc Segmentation. Sandra et al. [21] presented an automatic segmentation of OD based on mathematic morphology along with principal component analysis.

The literature investigation discloses that segmentation of the optic disc is a seriously challenging issue. The reason for this is the uneven emergence of the Optic disc in various subjects.

Intensity-based segmentation techniques for OD localization and segmentation do not effortlessly solve the issue of variation in the color of fundus image, random intersections of retinal blood vessels with optic disc region. Active shape models based OD segmentation technique faces the parametric models for vascularization and impossibility of making a point-to-point connection in training contours. Training-based methods of optic disc segmentation suffer due to presence of anomalous brighter spots due to pathologies.

The main contribution of this work is a novel algorithm for efficient OD localization and segmentation. This is done by blood vessel removal using a strategic inpainting based method for accurate segmentation of Optic disc using adaptive threshold based region growing approach. One more important contribution of this paper is to apply a double windowing based method for accurate OD localization and center detection which is used as the initial seed for the region growing approach. After OD center is detected, blood vessels have been successfully inpainted in the optic nerve head region. The inpainting algorithm is another original contribution of this paper. In addition, Intensity adjustment is done in optic disc region, which will help the region to grow in an efficient manner.

Another highlight of this paper is that an adaptive threshold based region growing approach has been devised and employed for accurate segmentation of OD. Adaptive threshold has ensured that the algorithm performed successfully on varied test databases like MESSIDOR and DRIVE as well as local dataset unlike other existing algorithms. The experimental results obtained are discussed and compared with respect to other state of art methods with two algorithms in particular [15,16]. The proposed work illustrates a pipeline for optic disk detection and segmentation which is observed to work on most of the fundus images acquired under different settings and from different imaging equipments. It is therefore to be seen in the context of a desire to standardize the initial screening process for various ophthalmological pathologies.

Further the paper is organized as follows. Section II presents the details of Database of fundus images used. The next section explains the method of preprocessing of fundus image, stepwise explanation of OD center, blood vessels inpainting followed by segmentation of optic disc boundary from the fundus image. Section IV details the experimental results of optic disc segmentation obtained. Section V presents a detailed discussion, analysis and comparison of results with other established algorithms. Finally section VI concludes the paper with a brief summary and future scope.

2. Digital fundus image database used

Standard and labeled database of MESSIDOR database and DRIVE database have been used for testing the proposed algorithm. Labeled information is available for this standard fundus image database. In addition to this some fundus images used for this work were collected from the Venu Eye Research Centre, New Delhi, India. In this work total 144 images were used for experimentation from Venu Eye research centre from patients aged 18 to 75. All images were used anonymously and had an ethical clearance from the hospital committee. The Fundus camera with inbuilt software is used to take pictures of the inner surface of the eye in the JPEG format and had a resolution of 2544×1696 pixels.

MESSIDOR [27] is a publically available database, contains 1200 color eye fundus images captured by the Hôpital Lariboisière Paris, the Faculté de Médecine St. Etienne and the LaTIM–CHU de Brest (France). These images are of 45 degree field of view (FOV) in which 800 images with pupil dilation and 400 without pupil dilation. MESSIDOR images are of size 1440×960, 2240×1488, or 2304×1536 pixels in size in TIFF format.

DRIVE [28] is publically available database contains 40 fundus images of size 565×584 pixels and are provided in TIFF format. These images were acquired by a Canon CR5 non-mydriatic 3CCD camera. Fundus images of DRIVE Database are of 45 degree field of view (FOV)

3. Methodology

The objective of this work is to design and develop a new method for automatic and efficient OD segmentation. The proposed method is based on region growing approach. Center of OD is detected automatically which is considered as seed point to grow region. Blood vessels are inpainted in the optic nerve head region for accurate OD segmentation. In addition, Intensity adjustment is done in optic disc region after blood vessels inpainting, which will improve the region growing process.

Hence the proposed method of optic disc segmentation from fundus image is further divided into two subsections which deal with OD localization, and OD boundary detection, respectively. OD boundary detection includes blood vessels inpainting followed by intensity adjustment and region growing considering OD center as a seed point. Fig. 1 shows the flow chart of proposed OD localization and segmentation method.

3.1. Optic disc localization

Optic Disc comprises of a bright disc where the optic nerves terminate. Inside the bright disc lies the Optic Cup, this is even brighter, having higher intensity. Hence in this paper the strategy adopted is to detect the bright intensity regions in the fundus image.

As shown in Fig. 2(a), initially a Kaiser window was run with a mask of size $P \times N$ along the rows, where P is 1/10th of M and is the approximate diameter of OD [16]. M and N are number of columns and rows of the image, respectively. The row corresponding to maximum response is taken as the x-coordinate of OD center. Another hat shaped window as shown in Fig. 2(b) of size $P \times P$ is then passed through all the columns of the marked row. The maximum response thus obtained gives us the y-coordinate of the OD center. Fig. 2(c) represents the output after passing the Kaiser and Hat