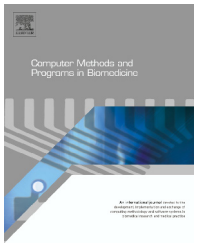
COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 122 (2015) 229–244

journal homepage: www.intl.elsevierhealth.com/journals/cmpb



An adaptive threshold based image processing technique for improved glaucoma detection and classification

*Ashish Issac, M. Partha Sarathi, Malay Kishore Dutta**

Department of Electronics & Communication Engineering, Amity University, Noida, India

ARTICLE INFO

Article history:
Received 5 April 2015
Received in revised form
14 July 2015
Accepted 3 August 2015

Keywords:
Glaucoma
Optic disc
Optic cup
Cup to disc ratio
Adaptive threshold
Fundus image

ABSTRACT

Glaucoma is an optic neuropathy which is one of the main causes of permanent blindness worldwide. This paper presents an automatic image processing based method for detection of glaucoma from the digital fundus images. In this proposed work, the discriminatory parameters of glaucoma infection, such as cup to disc ratio (CDR), neuro retinal rim (NRR) area and blood vessels in different regions of the optic disc has been used as features and fed as inputs to learning algorithms for glaucoma diagnosis. These features which have discriminatory changes with the occurrence of glaucoma are strategically used for training the classifiers to improve the accuracy of identification. The segmentation of optic disc and cup based on adaptive threshold of the pixel intensities lying in the optic nerve head region. Unlike existing methods the proposed algorithm is based on an adaptive threshold that uses local features from the fundus image for segmentation of optic cup and optic disc making it invariant to the quality of the image and noise content which may find wider acceptability. The experimental results indicate that such features are more significant in comparison to the statistical or textural features as considered in existing works. The proposed work achieves an accuracy of 94.11% with a sensitivity of 100%. A comparison of the proposed work with the existing methods indicates that the proposed approach has improved accuracy of classification glaucoma from a digital fundus which may be considered clinically significant.

1. Introduction

One of the most prominent eye diseases in today's world is glaucoma which causes irreparable damage to the eye. Glaucoma is an optic neuropathy which results in progressive damage to the optic nerve and results in loss of vision. Glaucoma is characterized by increase in the fluid pressure inside the eye. This may result in the damage to the optic nerve and loss of nerve fibers. The advancement of glaucoma may cause blindness.

Glaucoma can be classified as primary open angle glaucoma, angle-closure glaucoma, secondary glaucoma and normal tension glaucoma. In primary angle glaucoma, the drainage system of the eye becomes inefficient over time. This inefficiency of the drainage system results in gradual increase of the pressure inside the eye. The damage is slow

* *Corresponding author*. Tel.: +91 120 4392517.
E-mail address: malaykishoredutta@gmail.com (M.K. Dutta).

http://dx.doi.org/10.1016/j.cmpb.2015.08.002
0169-2607/

and painless. In angle closure glaucoma, the drainage angle of the eye is blocked. It can be progressing gradually or appearing suddenly. The secondary glaucoma is caused by physical injuries, eye abnormalities, medications and eye surgery. In normal tension glaucoma, the eye pressure remains within range but there is damage to the optic nerve. Accurate and timely diagnosis is essential for successful treatment of any disease. Computer Aided Diagnosis (CAD) may prove beneficial for screening of diseases over a large population and may be time saving as compared to the physical examination by medical professionals. It will augment and aid the clinical healthcare in the developing countries where there is shortage of trained professional ophthalmologists.

Some image processing based work on segmentation of optic disc and cup for detection of glaucoma has been reported in literature. Kavita et al. [1] proposed a component analysis method and region of interest (ROI) based methods for disc segmentation. The component analysis method and the active contour are used for cup segmentation. Nayak et al. [2] proposes a method where features such as cup to disc ratio, blood vessels area ratio in inferior–superior side to the nasal-temporal side and ratio of the distance between optic nerve head and center of optic disc to the diameter of optic disc, are extracted from the images and feed as input to the classifier to classify the images as normal or glaucoma. Niemeijer et al. [3] has used regression to locate the structures in a retinal image. Bock et al. [4] has used feature extraction, dimensionality reduction and a two stage classifier for glaucoma detection. Joshi et al. [5] proposed a method for disc and cup segmentation. The optic disc is segmented using OD parameterization technique while optic cup boundaries are determined by blood vessels. Hoover and Goldbaum [6] has found the origination of blood vessels network using fuzzy convergence and located the optic nerve head. Aquino et al. [7] proposed a method which uses morphological and edge detection techniques along with the circular Hough Transform to identify the boundary of optic disc. Liu et al. [8] proposes the use of an ARGALI framework, which consists of different methods for extraction of optic disc and cup, and use them for determination of CDR. Abràmoff et al. [9] proposes a method wherein feature classification was done on stereo color fundus images and a linear cup to disc ratio was used for glaucoma estimation. Chan and Vese et al. [10] propose a method based on numerical algorithm using finite differences to detect the boundaries of objects in a given image. Liu et al. [11] proposes method for detection of optic disc and cup. For the optic disc extraction, a region of interest is selected by using pixel intensity variation method followed by variation level set method. The optic cup is segmented using a multi modal approach. The final optic disc and cup boundaries are smoothed by using ellipse fitting. Chrastek et al. [12] used a method based on morphology, Hough Transform and active contours for segmentation of optic nerve head. Acharya et al. [13] presents a method to detect glaucoma by using texture and higher order spectra features. After feature extraction, classification is performed using a variety of classifiers. Meier et al. [14] proposed some preprocessing methods and evaluated the effects of preprocessing using principal component analysis and support vector machine. Dutta et al. [15] proposed a multi threshold based method for segmentation of optic disc and cup. Also, Hough transform is used for finding the optic disc and cup radius. Yadav et al. [16] proposed a glaucoma identification method which involves the texture features of a fundus image and artificial neural network for its identification. Sharma et al. [17] proposed use of threshold and morphology to for removal of unwanted objects from the fundus images. Issac et al. [18] proposed an automatic threshold based method for detection of optic disc and cup. Marin [19] proposed a method of obtaining optic disc center and pixel region by automatic thresholding on morphologically processed fundus images. Marumatsu [20] proposed a comparison between contour modeling and pixel classification methods of optic disc segmentation from retinal fundus images. Kao [21] proposed a Gaussian shaped template for detection of optic disc and fovea in a fundus image. All these work seems to be promising but still there is a need for higher efficient algorithms in the area of image processing to develop methods which can be used for real time applications for mass screening of Glaucoma and prove beneficial for humanity especially for those countries where there is scarcity of professional ophthalmologists.

The main contribution of the paper is a fully automatic algorithm for glaucoma detection from fundus images. The proposed glaucoma identification algorithm is based on an adaptive method that uses local features from the fundus image for segmentation making the proposed method adaptive and invariant to the quality of the images and robust to noises. Unlike the existing methods where a constant threshold for segmentation of optic disc and optic cup has been used, the proposed work uses a strategic variable threshold decided from the local statistical features of the images that makes the method completely adaptive and invariant to image quality. The variable threshold increases the accuracy of the segmentation of the objects from the images and increases the accuracy of the system.

Another contribution of this work is the strategic combination of parameters like cup to disc ratio (CDR), neuro-retinal rim (NRR) area and blood vessels distribution pattern in different regions (ISNT quadrants) of the optic nerve head region as discriminatory features and use such features together to train the learning algorithms. The choice of these features has resulted into higher accuracy of performance for identification of glaucoma from the fundus image.

The rest of the paper is organized as follows: Section 2 describes the proposed methodology and the database used. Section 3 presents the imaging techniques for optic cup and optic disc segmentation. Section 4 disuses the feature selection for glaucoma identification. Section 5 discusses the experimental results and finally Section 6 draws a conclusion to the paper.

2. Proposed methodology and fundus image database used

The human eye is divided into two parts: exterior and posterior. The retinal digital fundus image deals with the posterior region of the eye which consists of the retinal surface. A retinal fundus image has blood vessels, macula and optic nerve head. The optic nerve head is the region from which the nerve fibers