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Computerized screening of diabetic retinopathy employing blood vessel segmentation in retinal images

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ABSTRACT

Diabetic retinopathy is a severe sight threatening disease which causes blindness among working age people. This research work presents a retinal vessel segmentation technique, which can be used in computer based retinal image analysis. This proposed method could be used as a prescreening system for the early detection of diabetic retinopathy. The algorithm implemented in this work can be effectively used for detection and analysis of vascular structures in retinal images. The retinal blood vessel morphology helps to classify the severity and identify the successive stages of a number of diseases. The changes in retinal vessel diameter are one of the symptoms for diseases based on vascular pathology. The size of typical retinal vessel is a few pixels wide and it becomes critical and challenging to obtain precise measurements using computer based automatic analysis of retinal images. This method classifies each image pixel as vessel or non-vessel and thereby produces the segmentation of vasculature in retinal images. Retinal blood vessels are identified and segmented by making use of a multilayer perceptron neural network, for which the inputs are derived from three primary colour components of the image, i.e., red, green and blue. Back propagation algorithm which provides a proficient technique to change the weights in a feed-forward network is employed. The performance of this method was evaluated and tested using the retinal images from the DRIVE database and has obtained illustrative results. The measured accuracy of the proposed system was 95.03% for the segmentation algorithm tested on this database.

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1. Introduction

Diabetic retinopathy is a major cause of blindness among working-age people around the world and it occurs due to the changes in blood vessel structure. Evaluation of the characteristics of retinal blood vessels based on vascular pathology plays an important role in the diagnosis of diseases like diabetes, arteriosclerosis, hypertension, cardiovascular disease and stroke. Certain features of retinal vessels such as length, width, tortuosity and branching pattern provide new techniques to diagnose these diseases. Retinal images provide valuable information related to human eye, which pays a way to analyze the vascular condition. Retinal vessels are the only part of the central circulation system which can be viewed directly and analyzed. Vascular network in retina is much affected by diseases like diabetes and hypertension [1]. Changes in blood vessel structure and also the changes due to new vessel growth lead to adult blindness, which is caused by diabetic retinopathy. Early diagnosis of changes taking place in blood vessel structure can prevent vision loss in human beings [2]. Hence retinal vessel segmentation becomes an important tool for the detection of any change that happens in blood vessels and it gives knowledge about the location of the vessels. This process helps in the screening of diabetic retinopathy by detecting the presence of microaneurysms, exudates and other red lesions [3,4]. Observations based on retinal vessel segmentation are quite complex and hence manual measurements are highly impossible. The actual size of a typical blood vessel in human retina is very small and hence measurement of vascular width using retinal image segmentation process becomes most critical. One of the possible solutions for these measurements is making use of computer based automated analysis of optic fundus. This technique is widely accepted by the medical community and this computer based analysis helps ophthalmologists to detect the changes in blood flow and also the changes in vessel distribution and extra vessel growth.

In the anatomy of human retina, optic nerve is one of the most important organs. The central retinal artery and central retinal vein that radiates through the optic nerve supplies blood to the upper layers of the retina and also act as a medium to transmit the information from human eye to the brain. The optic nerve can be properly observed in the viewing of the retinal fundus. In such a view, the portion of the nerve that is visible is called the optic disc. It is referred to the two-dimensional appearance of the portion of the nerve that is visible. In most of the retinal pathologies the entire retina will not be affected at the earlier stage. But the retinal pathology caused on or near the optic nerve may severely affect the vision of human eye, even at the earlier stages. The reason is, optic nerve is the most essential organ of human retina, which is responsible for eye sight [5]. The significant symptom of retinal problems is the changes that occur in diameter and shape of the retinal vessel. These changes give valuable information to grade the severity and classify the successive stages of certain diseases. Retinal image analysis is one of the diagnostic procedures available to study and evaluate the healthy and non-healthy human retinas [6]. In a healthy retina the optic nerve has a standard identifiable size, shape, colour and location relative to the blood vessels and in a retina containing lesions any one of these properties may be deviated from its standard level and show a large variance. In human retina, optic disc acts as the convergent area of the blood vessel network and the diameter and shape of the retinal vessels are the two prominent features of ophthalmologic study. In the computerized screening of diabetic retinopathy, these blood vessels are segmented initially and then further processing is achieved to detect the vessel irregularities.

Based on the severity of certain diseases, few morphological changes occur in retinal vessels. These changes may occur in diameter, branching angle, length or tortuosity of the retinal blood vessels. The symptom of diabetic retinopathy which can be noticed in retinal images is the variation in width of retinal blood vessels. One of the other signs of proliferative diabetic retinopathy is the unusual deviation in diameter found in blood vessels along the vein. Also the retinal micro vascular abnormalities found, seem to be the early symptom for the risk of stroke. In all these cases, the preferred centre of attention is on the prediction of variation in diameter of the retinal blood vessels. To observe these changes, initially, segmentation and then measurement of these retinal blood vessels have to be made. Another important application of retinal vessel segmentation is the automatic generation of retinal maps which is used for the age-related macular degeneration treatment and for the extraction of characteristic points of retinal vessels, used for multimodal image registration.

The main objective of this work is to detect and evaluate the changes that take place in human retinal blood vessels, due to diabetic retinopathy. This automated screening system facilitates the diagnosis of diabetic retinopathy which causes blindness, by making use of digital imaging technique, employing artificial neural network.

2. Review of related studies

Blood vessel segmentation in retinal images is attained by classifying each image pixel as vessel or non-vessel based on the local image features. In general, there are two basic approaches for blood vessel segmentation in retinal images. The algorithms used for the segmentation of blood vessels are broadly classified as pixel processing-based methods and vessel tracking methods [1]. The first group is further subdivided in literature as rule-based methods and supervised methods, where training of manually labelled images is used [7,8]. Neural network based pixel classification scheme falls under the pixel processing-based method.

Pixel processing-based methods generally consist of two phases. In the first phase an enhancement procedure is applied which selects an initial set of pixels which are further processed and ensured as vessels in the second phase [9]. The retinal vessel segmentation method presented by Mendonça and Campilho in [1] consists of three processing phases. The first phase is the pre-processing phase in which background normalization of monochromatic input image is attained initially and then thin vessel enhancement procedures are used. In the second phase, the vessel centreline candidate points are selected first and then these candidate points are joined and then validation of these vessel centreline segment