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Retinal vessel segmentation employing ANN technique by Gabor and moment invariants-based features

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ABSTRACT

Diabetic retinopathy (DR) is the major ophthalmic pathological cause for loss of eye sight due to changes in blood vessel structure. The retinal blood vessel morphology helps to identify the successive stages of a number of sight threatening diseases and thereby paves a way to classify its severity. This paper presents an automated retinal vessel segmentation technique using neural network, which can be used in computer analysis of retinal images, e.g., in automated screening for diabetic retinopathy. Furthermore, the algorithm proposed in this paper can be used for the analysis of vascular structures of the human retina. Changes in retinal vasculature are one of the main symptoms of diseases like hypertension and diabetes mellitus. Since the size of typical retinal vessel is only a few pixels wide, it is critical to obtain precise measurements of vascular width using automated retinal image analysis. This method segments each image pixel as vessel or nonvessel, which in turn, used for automatic recognition of the vasculature in retinal images. Retinal blood vessels are identified by means of a multilayer perceptron neural network, for which the inputs are derived from the Gabor and moment invariants-based features. Back propagation algorithm, which provides an efficient technique to change the weights in a feed forward network is utilized in our method. The performance of our technique is evaluated and tested on publicly available DRIVE database and we have obtained illustrative vessel segmentation results for those images.

Introduction

Diabetic retinopathy (DR) is a result of long-term diabetes and it is a severe and the most common sight threatening eye disease, which causes blindness among working-age people around the world [1]. Major vision loss due to DR is highly preventable with proper screening and timely diagnosis at the earlier stages. However, DR is not painful and the diabetic patients perceive no symptom until visual loss occurs and hence they need periodical eye-fundus examination to ensure that treatment is received in time. Evaluation of the characteristics of retinal blood vessels plays an important role in the diagnosis of diseases based on vascular pathology. The various features of retinal vessels such as length, width, tortuosity and branching pattern provide new techniques to diagnose various diseases like diabetes, arteriosclerosis, hypertension, cardiovascular disease and stroke. Retinal images provide valuable information related to human eye, by which the vascular condition can be accurately observed and analyzed [2]. The only part of the central circulation that can be viewed directly and analyzed is the retinal vessel. Changes in blood vessel structure and vessel distribution, caused by diabetic retinopathy can lead to new vessel growth, which in turn instigates vision impairment. Hence retinal vessel segmentation becomes an essential tool for the detection of any variations that occurs in blood vessels. Retinal blood vessel segmentation gives the detailed information about the location of vessels which helps in the screening of diabetic retinopathy, e.g., in the detection of micro-aneurysms it helps to reduce the number of false positives [3,4]. Observations based on retinal vessel segmentation are quiet complex and hence the traditional way of diagnosis in which the ophthalmologist identifies the anomalies present in the retinal images by examining it, becomes tiresome or even impossible. As the actual size of a typical blood vessel in human retina is very small, just a few pixels wide, measurement of vascular width using retinal image segmentation process becomes critical and challenging. One of the possible solutions for these measurements is the use of computer based automated analysis of optic fundus, a technique widely accepted by the medical community. This computer based analysis helps the medical personnel to detect the changes in blood flow and vessel distribution. It also enables the

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detection of extra vessel growth. For automatic analysis of optic fundus that detects the blood vessel irregularities, segmentation of the vessels from the background is made initially and thereby further processing like feature extraction can be achieved.

In human retina, one of the most important organs is the optic nerve which acts as the convergent point of the blood vessel network. The central retinal artery and central retinal vein flow out through the optic nerve that supplies blood to the upper layers of the retina. Besides, the optic nerve acts as a channel to convey the information from the eye to the brain. In early stages, most of the retinal pathologies affects locally and does not distress the entire retina. But retinal pathology on or near the optic nerve may severely affect the vision even at the early stages because optic nerve is the most essential part for vision [5]. A few observations found in several important retinopathies are attenuation changes, focal narrowing and occlusion of retinal arteries. The diameter and shape of a retinal vessel plays a key role as indicators in ophthalmologic studies. These changes give valuable information to identify the successive stages of diseases and their response to various therapies. The optic nerve can be observed in a close view of the retinal fundus, where the optic disc is the portion of the nerve that is visible or perceivable by the eye. Fundus imaging is one of the popular clinical procedures available to record this close view observations of the retina. This fundus imaging procedure is also used for the diagnosis and evaluation of the healthy and non-healthy retinas of human eye [6]. In a healthy retina the optic nerve has a standard identifiable size, shape, color and location relative to the blood vessels. Nevertheless, in a retina containing lesions, any one or more of these properties may be deviated from its standard level and show a large variance.

At various stages of the disease, the vascular network in retina is very much affected and hence various morphological changes occur in retinal vessels. We can substantially observe enough geometrical changes in diameter, branching angle, length or tortuosity in the retinal blood vessels due to diseases. The segmentation and measurement of retinal blood vessels can be used to grade the severity of certain diseases. The sign of risk level for diabetic retinopathy is the variation in width of retinal vessels within the fundus. One of the most important tools for the prediction of proliferate diabetic retinopathy is the abnormal variation in diameter along the vein. Moreover, the various retinal microvascular abnormalities predicted are seen to be the early symptoms for the risk of stroke. In all these cases, the desired focus is on the variation in diameter of the vessel and not in the exact diameter of the vessel. An alternative application of retinal vessel segmentation is biometric identification using distinctive retinal vascular network for each individual.

This research paper is organized as follows: Section “Overview of retinal vessel segmentation” reviews various other vessel segmentation methods, Section “Methodology” describes and illustrates the methods of our proposal for vessel segmentation, Section “Experimental results analysis” presents its results and compares the performance with some of the techniques previously published and Section “Discussion and conclusion” puts forward the discussion and concludes this work.

Overview of retinal vessel segmentation

Segmentation of vessels in retinal images is achieved by classifying each image pixel as vessel or nonvessel based on the local image features. In two-dimensional images, the techniques adopted for identifying vessels are based on specific properties of the vascular segments. There are two basic approaches that are generally considered for the identification of general vascular segments, which also play a key role in retinal vessel segmentation applications. The algorithms used for the segmentation of blood vessels are broadly classified as pixel processing-based methods and vessel tracking or vectorial tracking methods [2]. Supplementary methods used for vessel segmentation in retinal images can be classified into two groups. The first group consists of rule-based methods and the second group consists of supervised methods, where training of manually labeled images is used. Neural network based pixel classification scheme falls under the second category [7,8], which is followed in this paper.

Pixel processing-based methods normally consist of two phases. In the first phase, an enhancement procedure is implied and it selects an initial set of pixels, which is further ensured as vessels in the second phase [9]. The retinal vessel segmentation method presented in Ref. [2] consists of three processing phases. In the first phase, background normalization of monochromatic input image is performed and later thin vessel enhancement procedures are used. In the second phase, the vessel centerline candidate points are selected and subsequently these points are connected and based on vessel length, the validation of centerline segment candidates is achieved. In the third phase, vessels with different widths are enhanced and processed using binary morphological reconstruction technique and vessel filling is achieved using region growing process. Soares et al. have proposed an algorithm, where retinal blood vessels are detected using Gabor wavelets by representing each pixel by a feature vector and then by using Bayesian classifier with Gaussian mixtures, each pixel is classified as either a vessel or nonvessel pixel and thus segmentation is achieved. The concept of matched filter detection was proposed by Chaudhuri et al. [10], where twelve rotated versions of 2-D Gaussian shaped templates are used to search vessel segments along all possible directions. The resultant image produced is the binary representation of the retinal vasculature. Likewise, segmentation of retinal vessels are also obtained by matched filtering approaches using global [11] or local thresholding strategies [12]. Also for the purpose of vessel borders extraction, differential filters based on either first-or-second order derivatives are used. A two stage region growing procedure was proposed by Martinez-Perez et al. where features derived from image derivatives are used in the segmentation of retinal vessels [13,14]. As stated in Ref. [15], the edge detection, matched filtering and region growing procedures can also be collectively used for the automated detection of retinal blood vessels. Jiang et al. have proposed a technique of adaptive local thresholding based on the use of verification-based multithreshold scheme combined with classification procedures in Ref. [16], used for the detection of vessels in retinal images. A technique used for the segmentation of vessel like patterns in retinal images that combines morphological filters and cross-curvature evaluation was proposed by Zana et al. in Ref. [17]. In this approach, vessel segments alone are considered as image feature and hence using morphological filters simplifies the computation of cross-curvature. An algorithm for retinal vessel segmentation based on the classification of pixels using simple feature vector was proposed by Niemeijer et al. in Ref. [18]. A new method of segmentation of blood vessels in retinal images was proposed by Staal et al. in Ref. [19]. This supervised method is called primitive-based method and this algorithm is based on the extraction of image ridges used to compose primitives that describe the linear segments called line elements. The pixels those are assigned to the closest line element partitions the image in the form of image patches and are classified using a set of features from the corresponding line and image patch. In addition, a technique based on neural network is used to identify the retinal blood vessels, where the inputs are obtained using principal component analysis and then edge detection technique is used.

Vessel tracking methods use the concept of measuring some local image properties to locate the vessel points which are used for tracing the vasculature. In these types of algorithms, both the