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A generalized method for the detection of vascular structure in pathological retinal images

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ABSTRACT

Variations in blood vasculature morphology of retinal fundus images is one of the dominant characteristic for the early detection and analysis of retinal abnormalities. Therefore the accurate interpretation of blood vasculature is useful for ophthalmologists to diagnose patients that suffer from retinal abnormalities. A generalized method to detect and segment blood vasculature using retinal fundus images has been proposed in this work using (i) preprocessing for quality improvement of retinal fundus images, (ii) initial segmentation of vasculature map to find vascular and non vascular structures, (iii) extraction of relevant set of geometrical based features from the vasculature map and intensity based features from original retinal fundus image that differentiate vascular and non vascular structures efficiently, (iv) supervised classification of vascular and non vascular structures using the extracted features, and (v) joining of candidate vascular structures to create connectivity. The proposed method is evaluated on clinically acquired dataset and different publically available standard datasets such as DRIVE, STARE, ARIA and HRF. The clinically acquired dataset consists of 468 retinal fundus images comprising of healthy images, images with mild, intermediate and severe pathologies. Test results of the proposed method shows average sensitivity/specificity/accuracy of 85.43/97.94/95.45 on the 785 retinal fundus images. The proposed method shows an improvement of 14.01% in sensitivity without degrading specificity and accuracy in comparison to the recently published methods.

1. Introduction

Retinopathy is one of the leading causes of blindness affecting over 12 million people in India [1]. Multiple retinal abnormalities such as diabetic retinopathy, hypertensive retinopathy, glaucoma and age related macular degeneration manifest in the retina overtime. Retinal images also provide considerable information on pathological changes caused by a number of systemic conditions such as diabetes, hypertension, and cardiovascular diseases. Studies reveal that the prior detection and management would have prevented 80 percent of these cases from going blind [2]. The ophthalmologists visualize various symptoms of the above mentioned retinal abnormalities in retinal fundus images and analyze them in order to confirm the type of retinal abnormality. These symptoms may

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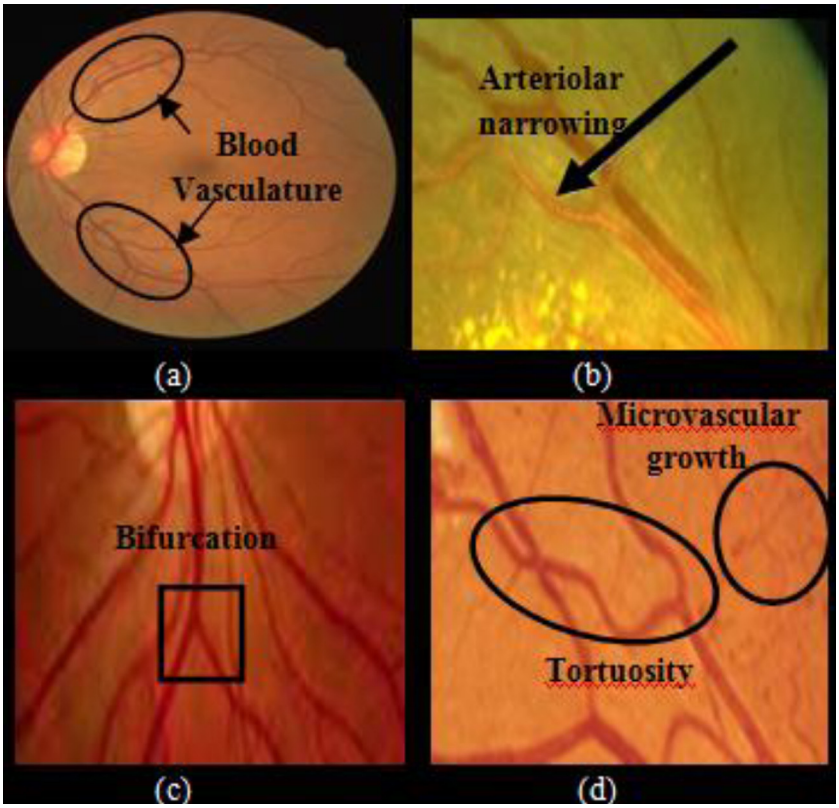

Fig. 1 – (a) Healthy retinal fundus image; (b) retinal fundus image showing variations in arteries of retinal blood vasculature; (c) retinal fundus image depicting bifurcation; (d) retinal fundus image with tortuosity and microvascular growth.

be visualized as (i) the variations in geometrical structure of retinal blood vasculature, and (ii) the appearance of lesions with the progression of disease. The initial manifestations of retinal diseases can be seen as the deviations in retinal blood vasculature from its normal appearance. Fig. 1(a) is an example image to depict the normal appearance of retinal blood vasculature. The deviations in normal retinal vasculature appear as changes in (i) the widths of arteries and veins, (ii) bifurcation related parameters, (iii) tortuosity measures, and (iv) microvascular growth of the blood vasculature, etc. Fig. 1(b) depicts the contraction in the width of arteries which is termed as arteriolar narrowing. Likewise, Fig. 1(c) shows the reduction in bifurcation angle in between parent and its two daughter branches. The reduction in bifurcation angle in pathological images can be confirmed by the standard range of bifurcation angle for healthy retinal blood vasculature. Lastly Fig. 1(d) highlights the tortuosity and microvascular growth in a pathological image. Tortuosity is abnormal twists and turns in retinal blood vasculature, whereas microvascular growth is the appearance of new minute blood vascular structures across the retinal surface called as neovascularization.

1.1. *Motivation*

Estimation of the above mentioned variations in retinal blood vasculature aids in recognizing the detection and progression of various retinal abnormalities. In addition, early estimation may help the ophthalmologists in prevention of vision loss and spreading of various systemic abnormalities in patients by providing necessary diagnostic treatments and preventive planning. This estimation requires the subjective and quantitative observation of the changes in the retinal blood vasculature for efficient diagnosis, assessment and management. However, a large number of patients undergo routine examination in eye hospitals, where huge numbers of retinal images are acquired from the patients. The screening of these patients requires manual marking of retinal vasculature which becomes tiresome and is a time consuming process. Also in the manual labeling and segmentation, accuracy in assessment of retinal blood vasculature and related parameters is highly dependent on the ability and experience of the expert. Therefore, there is a need to design an automated extraction system of retinal blood vasculature to assist ophthalmologists, which would be helpful to reduce the cost associated with the expert graders and eliminate the inconsistency associated with manual labeling.

Another significant task associated with retinal blood vasculature is its reliable exclusion for the accurate and efficient detection of various retinal lesions and other anatomical structures. The detection process of lesions such as microaneurysms, hemorrhages, drusen, exudates, etc., may produce false positives if blood vasculature is not properly eliminated from the retinal fundus image. False appearances occur because retinal vasculature presents similar contrast with lesions and thus interfere in its extraction. Therefore, the precise exclusion of retinal blood vasculature will highlight the