Image Analysis for the Assessment of Retinal Vascular Changes

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***Abstract*—The development of an automatic telemedicine system for computer-aided screening and grading of diabetic retinopathy depends on reliable detection of retinal lesions in fundus images. The main contribution is a new set of texture features called Gabor features that do not require precise segmentation of the regions to be classified. These features represent the evolution of the textures during image flooding and allow to discriminate between lesions and vessel segments. Among several retinal vascular signs, Arteriolar-to-Venular Ratio (AVR) is a well known health biomarker and there is a strong need to develop an automated system for an accurate and reproducible estimation of AVR which requires different image analysis tools. Automatic and accurate blood vessel segmentation system could provide several useful features for diagnosis of various retinal diseases, and reduce the doctor's workload.We list publicly available databases and appropriate measurement techniques to compare quantitatively the performance of these approaches. Furthermore, we discuss on how the performance of image processing-based systems can be improved by fusing the output of individual detector algorithms. This paper presents a new supervised method for segmentation of blood vessels in retinal photographs. This method uses an ensemble system of bagged and boosted decision trees and utilizes a feature vector based on the orientation analysis of gradient vector field, morphological transformation, line strength measures, and Gabor filter responses. In this paper, we have presented an effective retinal vessel segmentation technique based on supervised classification using an ensemble classifier of boosted and bagged decision trees.**

***Keywords*—Arteriolar-to-Venular Ratio (AVR), hypertension, blood vessel segmentation, cardiovascular diseases, automatic telemedicine system, computer-aided screening.**

I. INTRODUCTION

The human eye is a unique region of the human body where the vascular condition can be directly observed. In addition to fovea and optic disc, the blood vessels contributes one of the main features of a retinal fundus image and several of its properties are noticeably affected by worldwide major diseases such as diabetes, hypertension, and arteriosclerosis. Further, certain eye diseases such as choroidal neovascularization and retinal artery occlusion also make changes in the retinal vasculature. The image may also contain other pathologies like red lesions and exudates. Manual observation of retinal blood vessel take long period of time and can be affected by inter and intra observation bias. Thus it may take time to diagnose the disease and provide relevant treatment at early stages. As the vascular network is very complex and difficult to segment manually with high accuracy. Thus computer based automatic segmentation can provide fast and easy segmentation of retinal blood vessel without any bias.

Several studies were carried out on the segmentation of blood vessels in general, however only a small number of them were associated to retinal blood vessels. In order to review the methods proposed to segment vessels in retinal images, seven classes of methods have been considered: matched filters, vessel tracking, morphological processing, region growing, multiscale, supervised and adaptive thresholding approaches. Retinal blood vessel segmentation has been widely used in various scenarios. For example, change of the retinal blood vessel appearance is an important indicator for various ophthalmologic and cardiovascular diseases, such as diabetes, hypertension, and arteriosclerosis, therefore, automatic segmentation and analysis of the retinal vasculature play an extremely vital role in the implementation of screening programs for diabetic retinopathy, the evaluation of retinopathy of prematurity, foveal avascular region detection, arteriolar narrowing detection, the diagnosis of cardiovascular diseases and hypertension, and computer-assisted laser surgery. Manual delineation is skill demanding, tedious, time-consuming, and infeasible if given a large volume of fundus image databases. The whole pipeline of the proposed method is trainable and automatic. Moreover, our method can effectively deal with the challenges of retinal vessel segmentation, as shown by our evaluations conducted using two publicly available databases (the DRIVE and STARE) and comparisons with state-of-the-art.

II. PROPOSED SYSTEM

This proposed method consist of major three things, at first the image is undergone for the process of preprocessing, then the binary conversion is carried out by the effective morphological operation. Then the second step carried out the remaining pixels in the binary images are classified by the use of GMM. i.e., Gaussian mixture model. Then the third step involves the major post-processing process, to classify the blood vessel by the segmented region using the effective feature extraction algorithm. This paper presents a new supervised method for segmentation of blood vessels in retinal photographs. This method uses an ensemble system of bagged and boosted decision trees and utilizes a feature vector based on the orientation analysis of gradient vector field, morphological transformation, line strength measures, and Gabor filter responses.

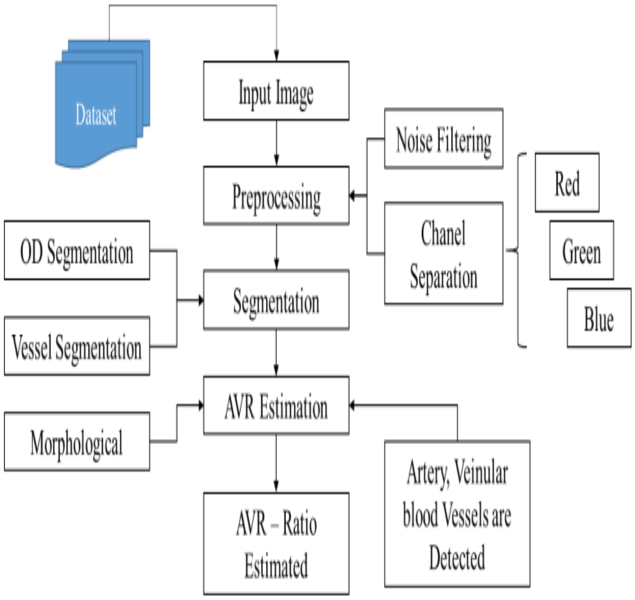

Fig. 1 Flow diagram of proposed system.

The feature vector encodes information to handle the healthy as well as the pathological retinal image. The method is evaluated on the publicly available DRIVE and STARE databases, frequently used for this purpose and also on a new public retinal vessel reference dataset CHASE_DB1 which is a subset of retinal images of multiethnic children from the Child Heart and Health Study in England (CHASE) dataset. The performance of the ensemble system is evaluated in detail and the incurred accuracy, speed, robustness, and simplicity make the algorithm a suitable tool for automated retinal image analysis. This paper presents a new supervised method for segmentation of blood vessels by using an ensemble classifier of boosted and bagged decision trees. The feature vector is based on gradient orientation analysis (GOA), morphological transformation with linear structuring element; line strength measures and the Gabor filter response which encodes information to success-fully handle both normal and pathological retinas with bright and dark lesions simultaneously. The classifier based on the boot strapped and boosted decision trees is a classic ensemble classifier which has been widely used in many application areas of image analysis, but has not been applied within the frame-work of retinal vessel segmentation for automated retinal image analysis. The obtained performance metrics illustrate that this method outperforms most of the state-of-the-art methodologies of retinal vessel segmentation. The method is training set robust as it offers a better performance even when it is trained on the DRIVE database and tested on the STARE database, thus making it suitable for images taken under different conditions without retraining.

III. STAGES OF SYSTEM

A. Input Image

The first stage of any vision system is the image acquisition stage. Image acquisition is the digitization and storage of an image. After the image has been obtained, various methods of processing can be applied to the image to perform the many different vision tasks required today.

B. Preprocessing

1. Image Filtering:

- The input images were pre-processing we are applying Gaussian filtering to our input image.
- Gaussian filtering is often used to remove the noise from the image.

2. Channel Separation:

- A channel in this context is the grayscale image of the same size as a color image, made of just one of these primary colors.
- For instance, an image from a standard digital camera will have a red, green and blue channel. A grayscale image has just one channel.

C. Segmentation

1. OD Segmentation:

We present a technique to segment the optic disc (OD) boundary from a color retinal fundus image. The technique used involves the extraction and removal of blood vessels using a top hat transform and an inpainting process. Then, a circular Hough transform is applied to the detected edges to obtain a coarse boundary of the OD and following which probable points of the optic disc are fed to a curve fitting algorithm which uses a higher order polynomial to draw the final boundary of the optic disc.

2. Vessel Segmentation:

Blood vessel segmentation of retinal images plays an important role in the diagnosis of eye diseases. In this paper, we propose an automatic unsupervised blood vessel segmentation method for retinal images. Firstly, a multidimensional feature vector is constructed with the green channel intensity and the vessel enhanced intensity feature by the morphological operation. We propose a region growing vessel segmentation algorithm based on boundary information of the image. First, the algorithm does Fourier transform on the region of interest containing vessel and affected structures to obtain its boundary information, according to which its primary feature direction will be extracted. Then combined edge information with primary feature direction computes the vascular structure's center points as the seed points of region growing segmentation. At last, the improved region growing method with branch-based growth strategy is used to segment the vessels.

D. Estimations

The AVR ratio is estimated in stage.The evaluation of the system on images of a new dataset from a local hospital shows a low failure rate and a significant correlation between the AVR calculated for distinct images of both eyes of the same patient.

IV. SIMULATION AND RESULT

The lower and upper limits of 95% CI of AVR values for each category are calculated using equations.

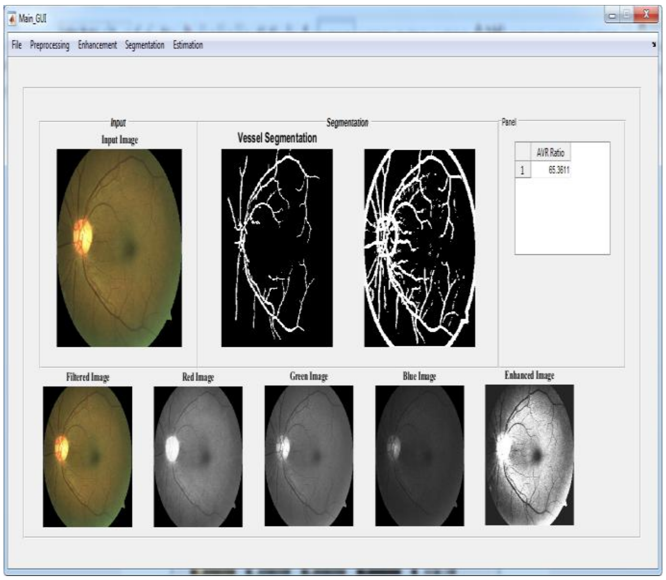

Fig. 2. AVR Estimation

$$\text{Lower 95\% limit} = \bar{x} - 1.96 \times \frac{\sigma}{\sqrt{n}}$$

$$\text{Upper 95\% limit} = \bar{x} + 1.96 \times \frac{\sigma}{\sqrt{n}}$$

where x is the mean AVR value, s represents the standard deviation and n is the number of subjects in each category.

The AVR values for the categories of subjects with diabetes, diabetic retinopathy, hypertensiveretinopathy and vascular retinopathy are compared in this table.

As can be observed in this table, the mean AVR value of 0.66 (95% CI: 0.64 - 0.68) in the nonpathological subjects with normal BP is higher than other group with pathological and/or high BP with mean AVR value of 0.62 (95% CI: 0.61 - 0.63), which shows evidence that the measurements obtained for AVR are consistent with the expected association of the AVR value with the risk of systemic diseases and hypertension.

Table 1shows the mean of AVR values and 95% confidence interval for each category ofsubjects.

Table.I

AVR FOR DIFFERENT PATHOLOGICAL CONDITIONS

Pathological status	Number of subjects	AVR (Mean ± SD) [95% CI] Right eye	Left eye	Average of both eyes
Diabetes	58	0.61 ± 0.08 [0.59 - 0.63]	0.62 ± 0.06 [0.60 - 0.63]	0.62 ± 0.06 [0.60 - 0.63]
Diabetic retinopathy	21	0.63 ± 0.10 [059 - 0.67]	0.60 ± 0.06 [0.58 - 0.63]	0.62 ± 0.07 [0.59 - 0.65]
Hypertensive retinopathy	63	0.61 ± 0.09 [0.59 - 0.63]	0.62 ± 0.07 [0.60 - 0.63]	0.61 ± 0.06 [0.60 - 0.63]
Vascular retinopathy	69	0.61 ± 0.08 [0.59 - 0.63]	0.62 ± 0.07 [0.60 - 0.63]	0.61 ± 0.06 [0.60 - 0.63]
Pathological or high BP	102	0.62 ± 0.08 [0.61 - 0.64]	0.62 ± 0.07 [0.61 - 0.64]	0.62 ± 0.06 [0.61 - 0.63]
Non-pathological and normal BP	28	0.66 ± 0.06 [0.64 - 0.69]	0.65 ± 0.08 [0.62 - 0.68]	0.66 ± 0.06 [0.64 - 0.68]

BP: Blood Pressure

CI: Confidence Interval

V. CONCLUSION

As we concluded, this process is deals with the development of automated retinal image analysis methods for the assessment of signs related with the changes in vessels calibers caused by several pathologies such as diabetes, hypertension, cerebo-vascular and cardiovascular diseases. Among several retinal vascular signs, Diabetic is a well-known health biomarker and there is a strong need to develop an automated system for an accurate and reproducible estimation of retinal blood vessel segmentation and classification, which requires different image analysis steps, namely vessel segmentation, Feature Extraction, and classification. Finally, our method was shown to better handle the challenges in retinal vessel segmentation. This is because it is able to extract scale and rotational invariant features and RF is well-known for strong generalization capability.

REFFERENCES

[1] K. Kotliar, E. Nagel, W. Vilser, S.-F. Seidova, and I. Lanzl, “Microstruc-tural alterations of retinal arterial blood column along the vessel axis in systemic hypertension,” Investigative Ophthalmol. Visual Sci., vol. 51, no. 4, pp. 2165–2172, 2010.

[2] A. Kochkorov, K. Gugleta, C. Zawinka, R. Katamay, J. Flammer, and S. Orgul, “Short-term retinal vessel diameter variability in relation to the history of cold extremities,” Investigative Ophthalmol. Visual Sci., vol. 47, no. 9, pp. 4026–4033, 2006.

[3] E. Nagel, W. Vilser, and I. Lanzl, “Age, blood pressure, and vessel diameter as factors influencing the arterial retinal flicker response,” Investigative Ophthalmol. Visual Sci., vol. 45, no. 5, pp. 1486–1492, 2004.

[4] S. Roychowdhury, D. D. Koozekanani, and K. K. Parhi, “Screening fundus images for diabetic retinopathy,” in Proc. Conf. Record 46th Asilomar Conf. Signals, Syst. Comput., 2012, pp. 1641–1645.

[5] S. Roychowdhury, D. Koozekanani, and K. Parhi, “Dream: Diabetic retinopathy analysis using machine learning,” IEEE J. Biomed. Health Informat. , no. 99, Dec. 2013, doi: 10.1109/JBHI.2013.2294635.

[6] R. Perfetti, E. Ricci, D. Casali, and G. Costantini, “Cellular neural net-works with virtual template expansion for retinal vessel

segmentation," IEEE Trans. Circuits Syst. II: Exp. Briefs, vol. 54, no. 2, pp. 141–145, Feb. 2007.

[7] M. Fraz, P. Remagnino, A. Hoppe, B. Uyyanonvara, A. Rudnicka, C. Owen, and S. Barman, "An ensemble classification-based approach applied to retinal blood vessel segmentation,"IEEE Trans. Biomed. Eng. , vol. 59, no. 9, pp. 2538–2548, Sep. 2012.

[8] D. Marin, A. Aquino, M. Gegundez-Arias, and J. Bravo, "A new su-pervised method for blood vessel segmentation in retinal images by us-ing gray-level and moment invariants-based features," IEEE Trans. Med. Imag., vol. 30, no. 1, pp. 146–158, Jan. 2011.

[9] M. Fraz, P. Remagnino, A. Hoppe, B. Uyyanonvara, A. Rudnicka, C. Owen, and S. Barman, "Blood vessel segmentation methodologies in retinal images a survey," Comput. Methods Programs Biomed.,vol. 108, no. 1, pp. 407–433, 2012.

[10] A. Hoover, V. Kouznetsova, and M. Goldbaum, "Locating blood vessels in retinal images by piecewise threshold probing of a matched filter re-sponse," IEEE Trans. Med. Imag. , vol. 19, no. 3, pp. 203–210, Mar. 2000.

[11] R. Rangayyan, F. Oloumi, F. Oloumi, P. Eshghzadeh-Zanjani, and F. Ayres, "Detection of blood vessels in the retina using gabor filters," in Proc. Canadian Conf. Electr. Comput. Eng. , 2007, pp. 717–720.

[12] A. Mendonca, and A. Campilho, "Segmentation of retinal blood vessels by combining the detection of centerlines and morphological reconstruction," IEEE Trans. Med. Imag. , vol. 25, no. 9, pp. 1200–1213, Sep. 2006.

[13] M. Miri, and A. Mahloojifar, "Retinal image analysis using curvelet trans-form and multistructure elements morphology by reconstruction," IEEE Trans. Biomed. Eng., vol. 58, no. 5, pp. 1183–1192, May 2011.

[14] K.A.Vermeer,F.M.Vos,H.G.Lemij,andA.M.Vossepoel,"Amodel based method for retinal blood vessel detection," Comput. Biol. Med., vol. 34, no. 3, pp. 209–219, 2004.

[15] B. Lam, and H. Yan, "A novel vessel segmentation algorithm for patholog-ical retina images based on the divergence of vector fields," IEEE Trans. Med. Imag., vol. 27, no. 2, pp. 237–246, Feb. 2008.

[16] M. D. Abrmoff, M. K. Garvin, and M. Sonka, "Retinal imaging and image analysis," IEEE Trans. Med. Imag. , vol. 3, pp. 169–208, Jan. 2010.

[17] CDC, (2011, Mar.). Diabetic retinopathy. Atlanta, GA: National for chronic disease prevention and health promotion [Online]. Available: http://www.cdc.gov/visionhealth/pdf/factsheet.pdf

[18] H. M. Pakter, S. C. Fuchs, M. K. Maestri, L. B. Moreira, L. M. Dei Ricardi, V. F. Pamplona, M. M. Oliveira, and F. D. Fuchs, "Computer-assisted methods to evaluate retinal vascular caliber: What are they measuring?" Investigative Ophthalmol. Visual Sci. , vol. 52, no. 2, pp. 810–815, 2011.