Towards a Tool for Automatic Retinal Vessel Quantification in Early Detection of Silent Brain Infarction

Iñigo Barandiaran, Odei Maiz, Ivan Macia,Jurgui Ugarte, Pere Toram, Xoxe Vazquez

Vicomtech Foundation, Mikeletegi N57, CP:20009, San Sebastian (Spain)

ibarandiaran@vicomtech.org

Abstract: Retinal vessel quantification is an important component of retinal disease screening protocols. We provide an initial description of an application for retinal screening that performs automatic vessel quantification for early detection of silent brain infarction.

© 2013 Optical Society of America

OCIS codes: 100.2960, 170.4470 ,170.4580

1. Introduction

Retinal imaging allows studying different aspects of the microcirculation in-vivo, whose role in vascular or metabolic diseases is less clear than that of macrocirculation [1]. Image analysis tools with state-of-the-art vascular morphometry techniques applied to large populations have allowed to establish correlations between patterns of retinal microcirculation and different cerebrovascular and cardiovascular diseases and metabolic disorders [2]. One of the most popular retinal biomarkers is the arterio-venular ratio (AVR), representing the quotient between the averages of several arterioles and venules widths. Alternatively, the AVR is also represented as the quotient of the central retinal artery equivalent (CRAE) and the central retinal vein equivalent (CRVE), as proposed in [6].

We describe our initial implementation of a software tool for automatic retinal vessel quantification to evaluate the usefulness of retinal fundus imaging as a diagnostic technique to identify silent cerebral infarction in 50 years or older population, with no known stroke episodes. This would allow to non-invasively assess the risk of infarction, take preventive measures, develop screening programs for the population at risk and get more insight into the disease.

The paper is structured as follows: Section 2 gives a brief overview of some approaches dealing with retinal microvasculature analysis in fundus images. Section 3 presents the image processing mechanisms for retinal vessels measurement integrated in our approach, as well as a brief description of implementation details. Finally, section 4 gives a small discussion about implemented approach and addresses next lines of research and development.

2. Background

The quantification of retinal biomarkers such the AVR, CRAE or CRVE in large populations requires automated tools for vessel segmentation and analysis in order to perform studies on large populations. An in deep review of current existing methods for retinal vessels segmentation mechanisms can be found in [5]. Approaches for retinal vessel segmentation can be roughly categorized as those based on supervised [7] and unsupervised [3] techniques. Supervised techiques rely on hand segmented and labeled images and requires an off-line training process prior to new image segmentation. Segmentation process becomes a classification process with two different classes: pixels that belong to vessel structures and those that belong to background. In opposite, approaches not depending on a training stage rely on different specialized image processing and analysis techniques specialized for vascular structures.

In general, algorithms based on supervised classification report better segmentation results at the cost of higher computation times, and at the risk of trainning classifiers with high generalization error, thus good results are reported only in images with good correlation with those used during training. On the other side, unsupervised techniques use to be less computationally demanding but they are also prone to error due to the need of several user parameter tuning.

Our vascular extraction implementation is based on the approach proposed in [3], which uses an unsupervised and fast segmentation mechanism which avoids the need of off-line training steps. We are interested in low complexity and fast approaches that could allow the clinicians to be able to carry out large screening programs.

3. Methods

Figure 1 depicts the image processing pipeline integrated in our approach. Following, all procesing steps are described in detail. After image acquisition, we first perform a field of view (FOV) detection, representing a region-of-interest for

Fig. 1. Image processing pipeline for vessel caliber quantification.

the following processes. A bilatering image filtering performs an image smoothing while preserving most significant vessel contours which prevents missing very small caliber vessels while removing undesired image noise. Next, we apply an isotropic undecimated wavelet transform (IUWT), as described in [3]. This transformation applied to several wavelet scales acts as a contrast enhancer, increasing the difference between structures of different luminance value. Once vessel segmentation is performed, we apply a thresholding operation and a connected component analysis for removing spurious small connected components, representing the minimun length of a vessel candidate to be measured. We use a segmentation threshold of 15%-20% of the lowest luminance value inside the region of interest (FOV). This value oversegments the images, ensuring that most of the vessel tree is retained. The centerline is obtained by reducing vessel regions to one-pixel-wide skeletons using a thinning algorithm. Afterwards, a branch detector is applied in order to identify and separate vessel bifurcations and vessels segment, and obtained vessel segments are approximated with B-spline curves for regularization purposes and for obtaining curvatures and sections. Finally, we use Full Width at Half Maximum(FWHW) algorithm to estimate vessel caliber along such sections. Figure 2 shows partial results of the implemented image pipeline.

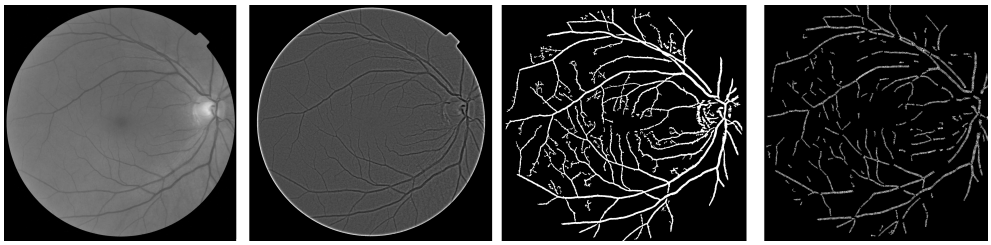

Fig. 2. Resulting images of processing pipeline

We measured the computation time needed by our implementation for performing a retinal vessel quantification from a fundus image, by using the REVIEW public dataset (http://reviewdb.lincoln.ac.uk/). Total computation time, as measured on an Intel Quad Core 2.4Ghz CPU is between 1 for REVIEW VDIS dataset and 4 seconds for REVIEW HRIS dataset, depending only on input image resolution. It is worth noticing that we do not perform any image subsampling or image reduction for computational cost saving.

3.1. User Application

The pipeline described in section 3 is currently integrated in a user-friendly application. The application is able to process fundus images either in batch mode or interactively. In the interactive part, clinicians are able to analyze both eyes of the patient simultaneously in order to evaluate differences or correlations between them. Moreover, a disc-shaped region of interest can be defined by the clinician in order to limit vessel quantification to that region. According to [8] only retinal vessels comprised in a region at some specific distance from the center of the optic disc are reliable. The application is being tested and validated by a group of primary care clinicians lead by Dr. Xoxe Vazquez Dorrego, head of the Oftalmology Service at Hospital Municipal de Badalona (Spain).

4. Conclusions and Future Work

This paper presents an application for automatic retinal vessel segmentation and quantification. Retinal vessel features such as arteriolar to venular ratio (AVR) or vessel bifurcations are important, clinically validated biomarkers that are

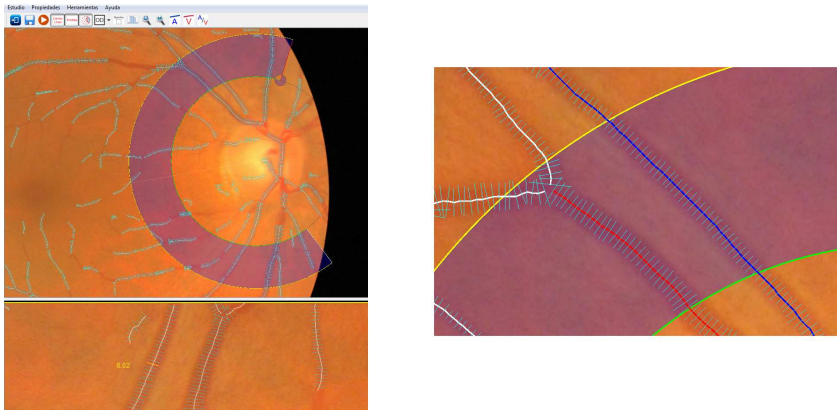

Fig. 3. (Left) Retinal vessel segmentation with ring-shaped ROI and panoramic retinal image reconstructed along the ROI. (Right) Arteriole(red) and venule(blue) quantification detail.

closely related with disorders such as hypertension or diabetic retinopathy. Our current implementation is able to process very fast high resolution fundus images, thus allowing clinicians to run large off-line studies involving many patients. However, the integrated processing pipeline is not fully optimized and used to generate wrong measures when some artifacts or features were present in the images, such as a strong central light reflex (CLR) in some vessels. The use of FWHM is both fast and unstable, thus a more robust mechanism such as the one proposed in [4] should be integrated in the future, as well as a mechanism for CLR identification and removal. Finally, we plan to extend our current approach by adding new segmentation and quantification mechanisms for the detection of some retinal lesions such as soft/hard exudates or micro-aneurysms. In addition, some retinal landmarks are to be identified in future works such as the position and diameter of the optic disc, and the position of the macula.

References

1. Liew G., Wang JJ., Mitchell P., Wong TY. “Retinal vascular imaging: A new tool in microvascular disease research.” Circulation: Cardiovascular Imaging, Vol(1):2, 156–161 (2012).
2. Nguyen TT.,Wong TY. “Retinal Vascular Manifestations of Metabolic Disorders.” Trends in endocrinology and metabolism, Vol(17):7, 262–268 (2006).
3. Bankhead P., Norman C., Graham J., Curtis T.“Fast retinal vessel detection and measurement using wavelets and edge location refinement.” PLoS ONE. doi:10.1371/journal.pone.0032435 (2012).
4. Dinesh K.,A liahmad B.,H ao H.“Retinal vessel diameter measurement using unsupervised linear discriminant analysis.”, ISRN Ophthalmology, Vol(2012), doi:10.5402/2012/151369 (2012).
5. Fraz MM.,Remagnino P.,Hoppe A.,Uyyanonvara B.,Rudnicka AR.,Owen CG.,Barman S.“Blood vessel segmentation methodologies in retinal images–A survey.” Computer methods and programs in biomedicine, Vol(108):1, 407–433 (2012).
6. Hubbard L.,Brothers R.,King W.,Clegg L.,Klein R.,Cooper, L.,Sharrett A.,Davis M.,Cai, J.“Methods for evaluation of retinal microvascular abnormalities associated with hypertension/sclerosis in the atherosclerosis risk in communities studies.” Ophthalmology, Vol(106):12, 2269-2280 (1999)
7. Ricci E., Perfetti R.“Retinal blood vessel segmentation using line operators and support vector classification.” IEEE Transactions on Medical Imaging, Vol(26):10, 1357–1365 (2007)
8. Ortiz D., Cubides M., Suárez A., Zequera M., Quiroga J., Gomez J., Arroyo N.“Support system for the preventive diagnosis of Hypertensive Retinopathy.” EMBC, 5649–5652 (2010)