FAST SEGMENTATION OF RETINAL BLOOD-VESSELS USING DISCRETE WAVELET TRANSFORM

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ABSTRACT

Segmentation of retinal vasculature from the retinal images is used in many medicine disciplines, e.g. eye disease identification, biometrics or image registration. This article describes preprocessing of retinal images and method for fast blood vessels detection using two-dimensional discrete wavelet transform.

1. INTRODUCTION

Retinal images taken by a fundus camera are widely used by the medical community for diagnosing human diseases. Inspection of the retinal vasculature can reveal hypertension, diabetes, arteriosclerosis, cardiovascular disease and stroke [1]. Furthermore each person has a unique blood vessels tree and its segmentation may be useful for the biometric person identification and for medical registration methods. In all cases, proper blood vessels detection is crucial. Nowadays there are many different methods how to segment the retinal vasculature from the fundus images. For example, blood vessel segmentation using wavelet transform [2], region growing [3] or adaptive filtering [4] have been used. However, due to the unique properties of each technique, a single generally accepted vessel detection algorithm does not exist. Moreover usually the better segmentation method is used the more time the computation takes.

The main goal of presented method is a fast blood-vessels segmentation based on two-dimensional discrete wavelet transform (2D DWT). In this paper I will introduce a method which is composed from four main parts.

- Preprocessing
- Decomposition by 2D DWT
- Thresholding procedure
- Reconstruction with summation

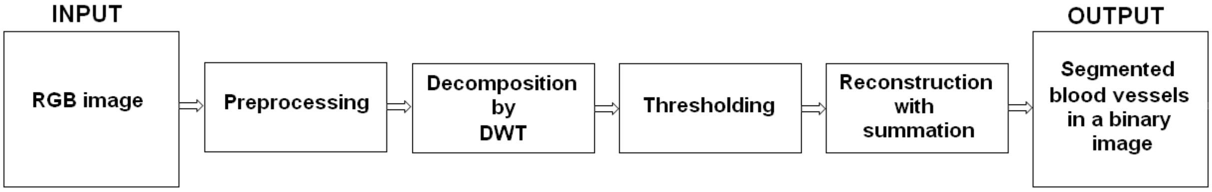

Fig 1: Block diagram of fast blood-vessels segmentation

2. PREPROCESING

The retinal images has been taken in a RGB mode by fundus camera Canon CF-60UDi with a digital camera Canon D20 (Fig 2 left). However, the best vasculature information is in the green channel (Fig 2 middle). So the first step is to separate this channel to a new image. Before applying the vessel segmentation algorithm it is necessary to denois the image (Fig 2 right). This is realized by a filter based on anisotropic diffusion [5]. The filter iteratively uses diffusion equation in combination with information about the edges. As a consequence, the homogenic (but noisy) areas are blurred and the edges are preserved. The anisotropic diffusion equation is defined as [5]:

$$I_t = div(c(x,y,t)\nabla I) = c(x,y,t)\Delta I + \nabla c \cdot \nabla I \ , \qquad (1)$$

where div is the divergence operator, ∇ is a gradient and Δ a Laplacian operator, c represented the conduction coefficient function. Index t denotes the time (iterations).

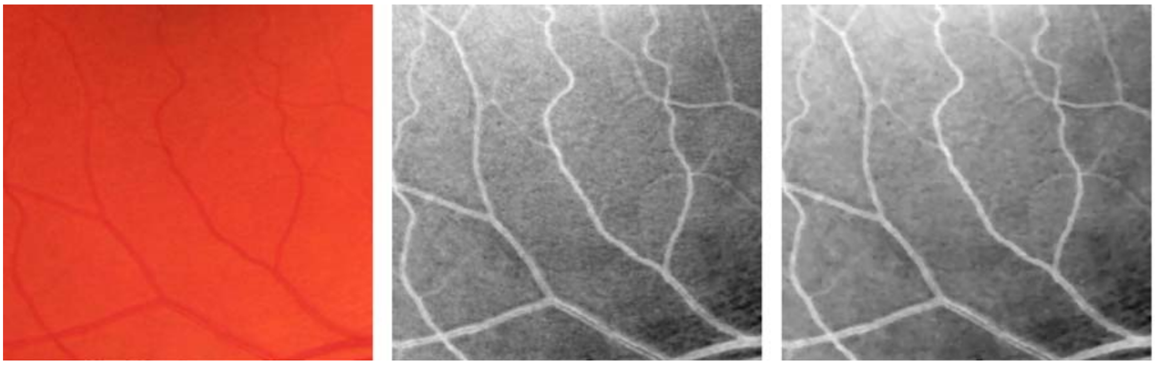

Fig 2: Original RGB retinal image on the left, G channel separated from the original RGB image in the middle, G channel image filtered by an anisotropic diffusion filter on the right

3. DECOMPOSITION BY 2D DWT

2D discrete wavelet transform [6] is based on a bank of filters, which corresponds to specific type of a wavelet. We used the Reversed Biorthogonal wavelet (RBIO3.1) as denoted in Matlab (Fig 3 left). The shape of this wavelet almost correspondents to the shape of blood vessels in the retinal image (Fig 3 right). The wavelet transform decompose the image to levels, where each level represents specific frequency band of the wavelet. We choose 3 levels 2D DWT, which is sufficient for detecting the retinal vasculature. Each level is then decomposed in three directions: vertical, horizontal and diagonal (Fig 4 and Fig 6 left).

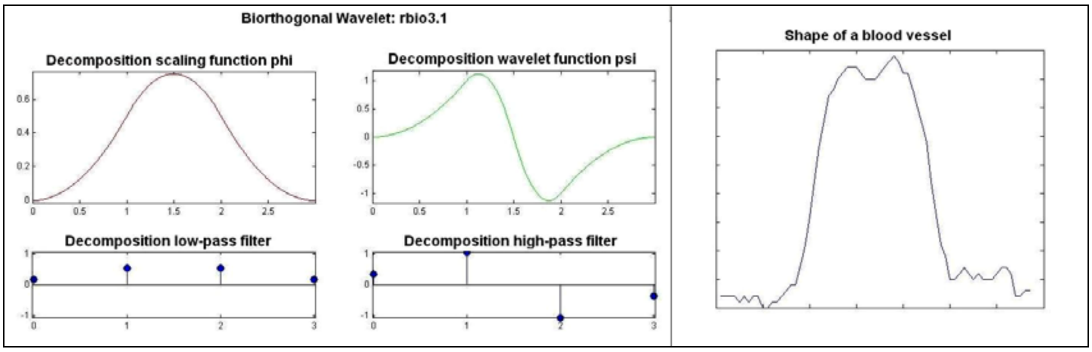

Fig 3: Biorthogonal wavelet: rbio3.1 on the left, shape of a blood vessel on the right

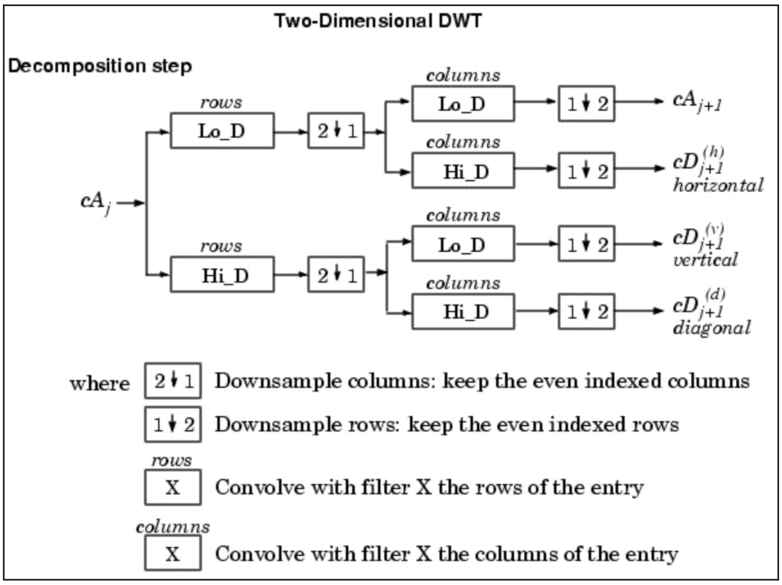

Fig 4: One decomposition level of 2D DWT [7]

4. THRESHOLDING

The next step is to threshold [8] within each direction in each level. The main task of thresholding is to highlight high values of wavelet coefficients which almost correspond to the blood-vessels and suppress small values which correspond to noise or unimportant structures in the image. The key parameter in this process is the choice of the threshold value. A good way how to get this value is to use the histogram of the image. 88 % of the pixels in the wavelet coefficient image are noise or unimportant structures and only 12 % belongs to the blood-vessels (determined as a result of our experiments). The threshold value has been set to brightness value 30, because 88% of pixels are below this value. These pixels have been suppressed (Fig 5).

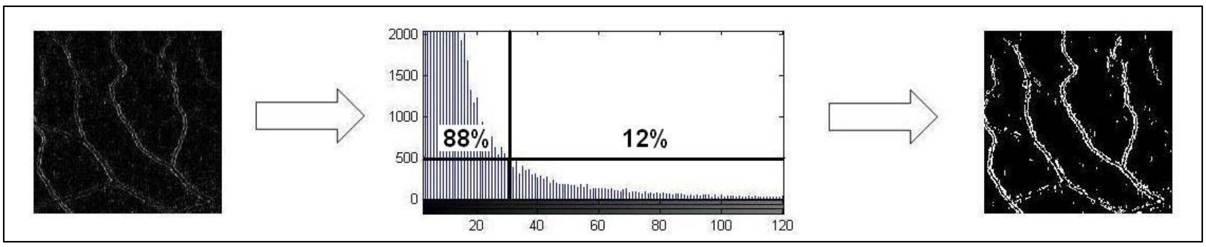

Fig 5: The thresholding procedure

5. RECONSTRUCTION WITH SUMMATION

Now it is necessary to reconstruct the final binary image. The first step is to logically add all thresholded directions in each level (Fig 6 right). So we get three images (for three levels) which reflect the segmented blood vessels. Due to the 2D DWT, before adding those images in a final image, it is necessary to interpolate them to the same size by bilinear interpolation. However the final image has to be binary. Furthermore each image includes some noise, which is necessary to remove. The possibly way how to do it is to add the three images and take away the two lower layers. This will create the final binary image, which shows the segmented vasculature from the eye background (Fig 7 right).

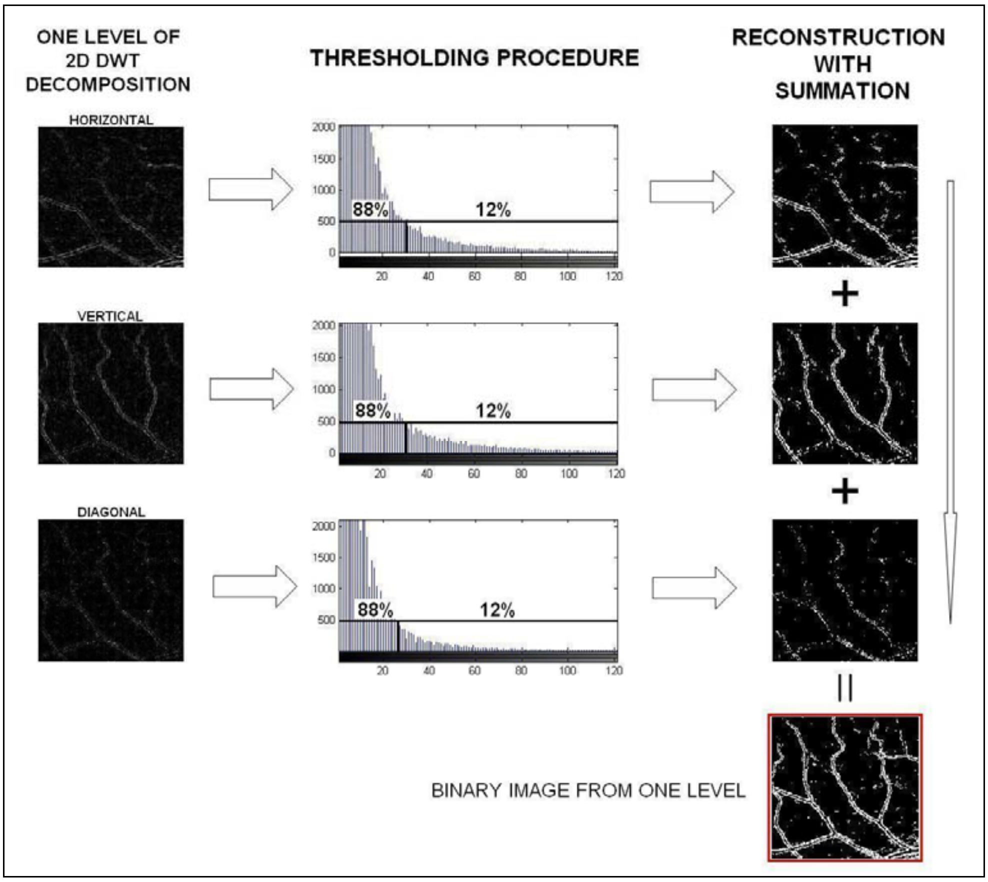

Fig 6: Three directions of one level 2D DWT decomposition on the left, thresholding procedure in the middle, adding procedure on the right

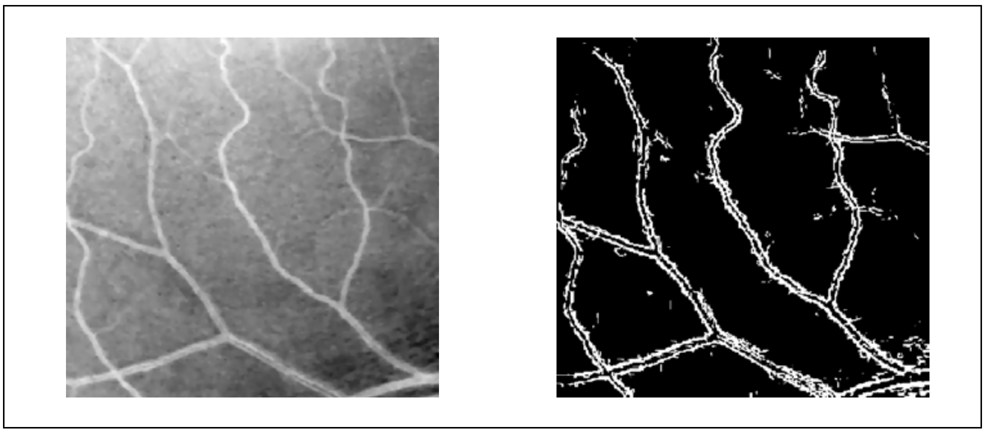

Fig 7: Input image on the left, segmented blood vessels on the right

6. CONCLUSION

The two-dimensional discrete wavelet transform can be used for the segmentation of retinal vasculature from the fundus images. The algorithm was implemented in Matlab and evaluation time was measured. For the presented image (size 655×633 pixels) the whole computation time was 2.7 seconds on Intel Pentium 4 (2.66 GHz, 1024 MB SDRAM), which is fast enough for practical application. The DWT decomposition has been set at level 3. However the quality of the segmentation is not as good as other slower segmentation methods. Nevertheless, this method may be used for more complex blood vessels segmentation methods as a utility. In future research I would like to develop the properties of this method, especially improve the threshold method for a better segmentation of small and low-contrast blood-vessels.

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