AUTOMATIC LANDMARKS DETECTION FOR RETINAL IMAGE REGISTRATION

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ABSTRACT

Registration of auto-fluorescent (AF) and near-infrared (IR) images of human retina are used for diagnosis of several eye diseases, e.g Age Related Macular Degeneration (ARMD) or glaucoma [1]. This article describes preprocessing of AF and IR images and method for automatic landmark detection, which is used for point-based image registration.

1. INTRODUCTION

Scanning laser ophthalmoscopes has been utilized for examination and diagnosis disorder of the structures in human retina over 10 years. One kind of the scanning laser ophthalmoscope, Heidelberg Retina Angiograph (HRA2), is used for angiographic examination. This device can work in several modes, eg. autofluorescent (AF) and near-infrared (IR) mode [2], which are used for examination of the optical nerve head (ONH) for early glaucoma diagnosis. Some of the diagnostic methods utilize both images, AF and IR, to increase diagnostic accuracy. For this purpose, the precise alignment of both images is needed. AF and IR images are recorded in time sequence during which the patient (or his/her eye) can move and there is a possible movement between images. Therefore the image registration should be performed first. Based on the previous results [2], where the intensity-based registration was used, our effort is to speed up the registration process utilizing the landmark registration techniques.

This paper presents a new algorithm (see Fig. 1) for automatic detection of the landmarks in AF and IR images.

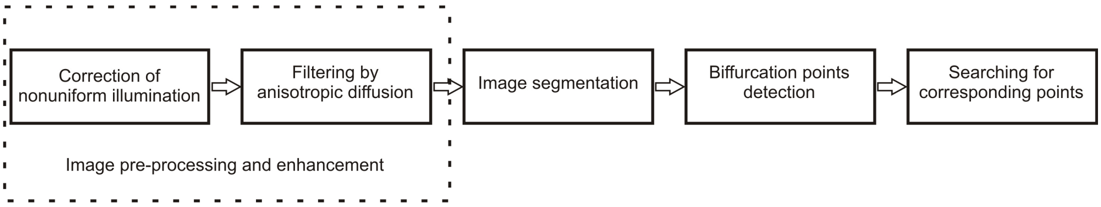

Fig 1: Block diagram of landmark detection.

2. IMAGE AND LANDMARKS PROPERTIES

In AF mode, the blue narrow laser beam is used (λ=488 nm), which excite the lipofuscin in retinal tissue that consequently emits light with a longer wavelength (around 500 nm). In IR mode, the infrared laser with wavelength 820 nm is used and the reflections are recorded. Images acquired in both modes have the same size and the same resolution.

There are several types of the landmarks, which can be utilized for registration. The main structure, which can be considered as a landmark, is the ONH. Due to the different wavelengths applied during image acquisition, the ONH is represented by different structures in AF and IR image. Only the central point of the ONH is detected for pre-registration (see next sections). The second most important landmarks types that can be used for registration are the bifurcation points of the blood vessels. There are four basic types of bifurcations, which can be recognized in retinal images:

- X shaped – mainly crossing of two vessels.
- Y shaped – normal bifurcation of vessels.
- T shaped – right-angle bifurcation of vessels.
- + shaped – right-angle crossing of two vessels.

3. IMAGE PRE-PROCESSING AND ENHANCEMENT

Image denoising, correction of nonuniform illumination and contrast enhancement is needed before apply the vessel segmentation for landmarks detection.

Image filter based on the anisotropic diffusion is used for image denoising, because there is an effort for noise reducing and preservation of the blood vessel edges. This filter iteratively uses diffusion equation in combination with information about the edges in filtered image [3]. As a consequence, the homogenic (but noisy) areas are blurred and the edges are preserved. The anisotropic diffusion equation is defined as:

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

where *div* is the divergence operator, ∇ and Δ is gradient and Laplacian operator, respectively. Index t denotes the time (iterations).

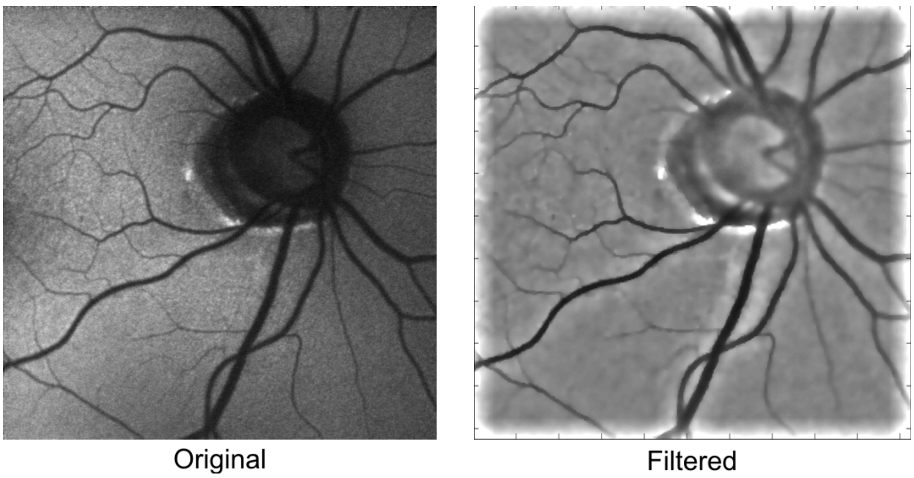

Fig 1: Original image on left, filtered and corrected of nonuniform illumination image on right.

Nonuniform illumination (also called shading) is present in both images and must be suppressed in order to achieve more accurate segmentation of the blood vessels. Normalization, correction of the brightness and contrast enhancement [4] were also applied in this pre-processing step. The original image and image after preprocessing is shown on Fig. 2.

4. AUTOMATIC LANDMARK DETECTION

4.1. SEGMENTATION AND MORPHOLOGICAL OPERATION

Segmentation of the blood vessels is based on Otsu's method [5]. This method finds an optimum value in bimodal histogram maximizing the variance between classes [5]. Otsu's method is evaluated in nonoverlaping sub-images (32x32pix), but only threshold level higher than 0.4 is used for segmentation. If the threshold level is smaller, it means that the sub-image contains only background pixels with no significant blood vessels. Final threshold level is multiplied by constant 1.10 to get more stable results.

The width of the extracted blood vessels is approximately from 4 to 8 pixels. Therefore, the vessels are thinned to 1 pixel width line using morphological operation based on Parallel Thinning Algorithm [6], see Fig 3.

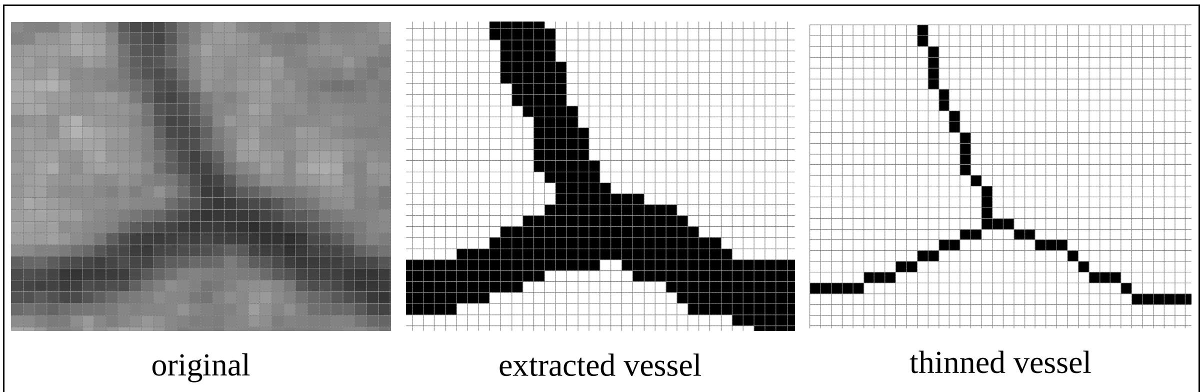

Fig 3: Extraction of blood vessels.

4.2. LANDMARK DETECTION

The thinned lines were used for detection of bifurcation based on summation of closest pixels (3x3 pixels large window). If the sum of closest pixels is greater than 3, corresponding pixel is marked as possible bifurcation. The result from this operation was used for decision about the landmark shape:

- Single bifurcation with no closest possible bifurcations – Y or X shaped bifurcation.
- Bifurcations with closest points marked as possible bifurcation too – 4-points neighborhood (vertical and horizontal direction) is scanned to decide whether bifurcation point is T or + shaped.

4.3. SEARCHING FOR CORRESPONDING POINTS

The method for landmark detection, described above, is used for both, AF and IR images. Because these images have slightly different structure, the number of detected landmarks can be different and different bifurcations are detected in AF and IR image. But only few corresponding points are enough for point-based registration (depends on used transformation). These corresponding points must be determined before registration process.

The detection of the ONH is utilized for pre-registration and for searching of the corresponding points. In the image of the extracted vessels and ONH (by Otsu's method), the blood vessels are deleted using morphological erosion and ONH is emphasized by morphological dilatation. Erosion deletes only these structures, which has width less than 10 pixels, others structures (mainly parts of the ONH) are subsequently thicken by dilatation. This image is used for masking out the landmarks detected inside ONH. This mask is also used for detection of the central point of the ONH using two orthogonal projections of this image. These central points (in AF and IR image) are set as the center of new coordinate systems and the positions of landmarks are recomputed relative to these new systems. This can be considered as a kind of pre-registration, using only translation transformation.

To detect the corresponding landmarks, the distances between landmarks in AF and IR images are computed. For each point in one image, the closest point determined iteratively, but this minimum distance must be less than 40 pixels. By this selection, the number of corresponding landmarks is around 10 for one set of AF and IR image, which is enough for Euler 2D transformation (three points are minimum).

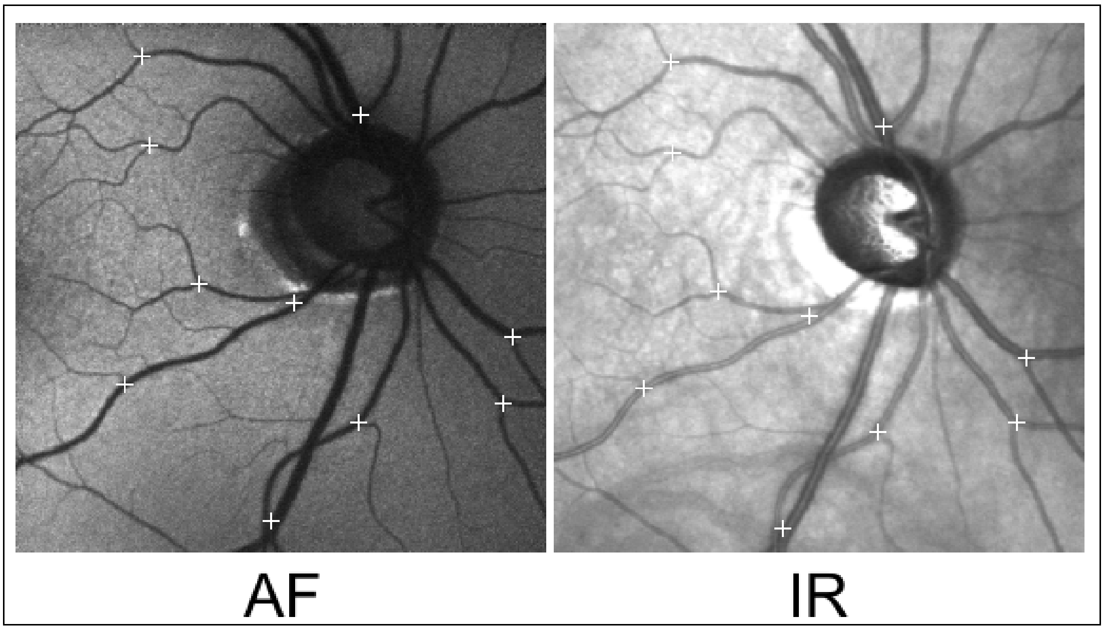

Fig 4: Detected corresponding points in AF and IR image.

Fig 4 shows detected points in AF and IR image. Only corresponding landmarks are displayed and used for consequential image registration.

4.4. IMAGE REGISTRATION

Detected landmarks were used for rigid registration of AF and IR images. The parameters of Euler 2D transformation (translation and rotation) are found by Lavenberg-Marquart optimizer using Iterative Closest Point method [7]. The open source library ITK (www.itk.org) was used for registration and image transformation. One result is shown on Fig. 5.

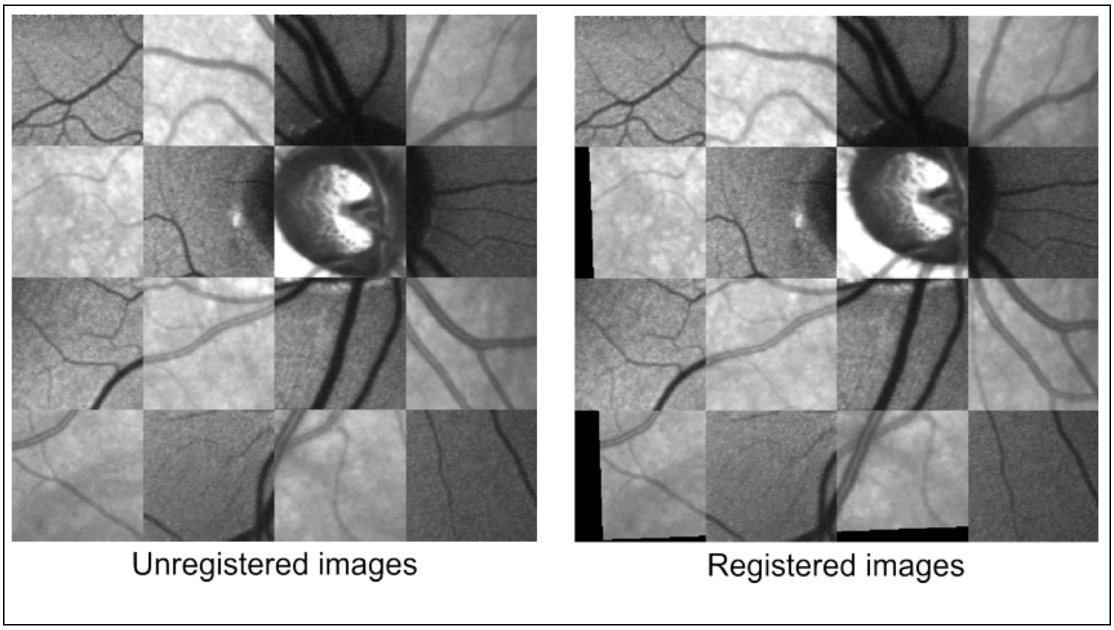

Fig 5: Result of registration process based on sets of landmark.

5. DISCUSION AND CONCLUSION

The presented algorithm for automatic landmark detection was tested on several images (size 512x512 pixels) from our database and the results are satisfactory. The algorithm is optimized to run fast. Complete registration process of one AF and IR image including image pre-processing, vessels extraction, landmark detection with point matching and registration takes approximately 15 seconds on common PC (CPU at 1.83 GHz). In compare with intensity-based method [4], which takes 1 - 2 minutes, the landmark based registration method are faster and they can be used as pre-registration for intensity-based methods.

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