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Vascular Deformation Analysis Based on *in Vivo* Intravascular Optical Coherence Tomography Imaging

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Abstract: Intravascular optical coherence tomography (OCT) has the characteristics of high resolution and fast imaging speed. Continuous images of the same section of the same vessel can reflect the deformation characteristics of the vessel wall under different blood pressure. Digital image processing may be used to segment various structures on the vascular wall and extract the deformation incorporating with biomechanical analysis. Image filtering plays a very important role in image processing. Median filter was used to filter salt and pepper noise in OCT images. Fuzzy function gray processing method was used to suppress irrelevant information and improve image clarity. Dividing point and line method was proposed to calculate the deformation and strain field.

Keywords: OCT, image processing, vascular segmentation, image filtering, deformation field, Fuzzy function.

Method

2-D strain tensor, the Lagrangian strain tensor in Polar coordinates are used to describe strain of blood vessels, defined as

$$E = \frac{1}{2}(F^T F - I) = \begin{bmatrix} \varepsilon_{rr} & \varepsilon_{r\theta} \\ \varepsilon_{r\theta} & \varepsilon_{\theta\theta} \end{bmatrix}$$

Where I is the 2×2 identity matrix. *F* is also a 2×2 matrix which denotes the deformation gradient tensor [Zhu, Friedman and Liang (2008)], defined as

Where (R, Θ) is the particle's radial and angular position in a reference configuration;

$$F = \begin{bmatrix} 1+\frac{\partial u}{\partial R} & \frac{1}{R}\frac{\partial u}{\partial \Theta} \\ r\frac{\partial v}{\partial R} & \frac{r}{R}(1+\frac{\partial v}{\partial \Theta}) \end{bmatrix}$$

(r, θ) is the particle's radial and angular position in a current configuration; *u* and *v* represent the displacements in the radial and angular directions.

In vivo pig carotid artery OCT images is noisy and has low contrast, Algorithm was designed by digital image processing method, and the image was preprocessed, including of which image denoising, smoothing, enhancement and filtering etc. It can be observed that there are more salt and pepper noises in the image. Therefore, median filter is used to

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remove the noise signal in the image. Fuzzy set function is used to transform the image gray level, which makes the useful information in the image more prominent and the image clearer. Prewitt edge operator is used to segment images, we use the luminal-intima and media-adventitia boudaries to outline the region-of-interest for registration and displaying computed strain. P denotes the Prewitt edge operator defined as

$$p_h = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \qquad p_v = \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$$

Where P_h and P_v denote Vertical and horizontal Prewitt edge operator correspondingly.

The main deformation of blood vessels is radial compression and circumferential expansion. According to the preprocessed images, we adopt a new method to calculate the displacement in these two directions. We divide the vessel boundary into *N* and *M* parts along the thickness direction and circular direction respectively

$$0 = \theta_1 < \theta_2 ..... < \theta_N < \theta_{N+1} = 2\pi$$

$$R_1 = r_1 < r_2 .... < r_M < r_{M+1} = R_2$$

Connection point (θ_i, r_i) and point $(\theta_i, r_i^{'})$. Where $r_i^{'}$ denotes the point at the adventitia boundary line. The radial compression and circumferential expansion strain are calculated by calculating the length changes of these lines before and after stress changes.

Results

The segmentation images of the luminal-intima and media-adventitia boudaries were obtained as shown in Fig. 1.

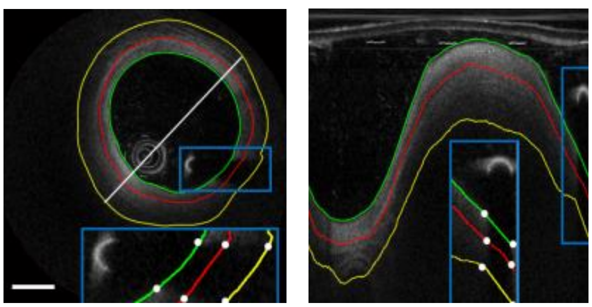

Figure 1: a) Original OCT segmentation image; b) Image segmentation in polar coordinates some computation work remains to be done

References

Zhu, H.; Friedman, M. H.; Liang, Y. (2008): Estimation of the transverse strain tensor in the arterial wall using IVUS image registration. *Ultrasound in Medicine and Biology*, pp. 1001-1014.