3P5-6

Analysis of 2D motion velocity of common carotid arterial wall by estimation of phase shift and frequency of received ultrasonic echo

受信超音波信号の位相偏移と周波数の推定による総頚動脈壁2次元移動速度の解析

Akira Miyajo[1†] and Hideyuki Hasegawa[2]
(Graduate School of Science and Engineering for Research, University of Toyama)
宮條　晃 [1†], 長谷川英之 [2] （富山大院　理工）

1. Introduction

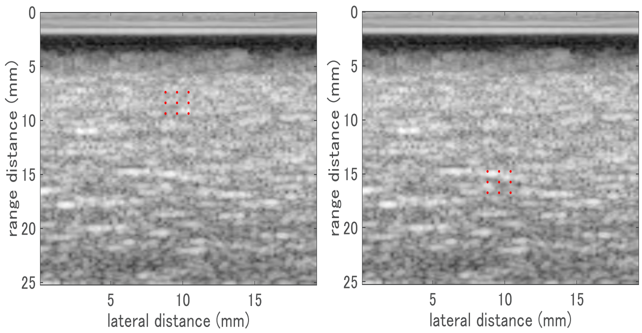
At present, the speckle tracking method [1] is widely used as 2D motion or 3D motion estimator in measurement of tissue dynamics. However, this method requires interpolation of a function, which evaluates the similarity between ultrasonic echo signals, to estimate a sub-sample small displacement. In high-frame-rate ultrasonic imaging, frame intervals could become one hundredth of that in conventional ultrasonic imaging. Therefore, the speckle tracking method requires high levels of interpolation when used with high-frame-rate ultrasound, resulting in a high computational cost. In the present study, we compared the accuracies of the speckle tracking method and our 2D motion estimator. Our motion estimator uses the Fast 2D Fourier transform for estimation of the phase shift of each component of the spectrum, and it also estimates the mean frequency of each component of the spectrum [2]. Furthermore, we analyzed displacement and velocity of common carotid wall by the proposed phase-sensitive 2D motion estimator.

2. Materials and Methods

Ultrasonic echo was measured by using plane-wave high-frame-rate imaging. In each plane-wave transmission, 24 focused receiving beams were created at intervals of 0.2 mm. One image frame consisting of 24×4 = 96 focused receiving beams was obtained by 4 emission of plane waves. The frame rate was 1302 Hz.

In the present study, the speckle tracking method and our phase-sensitive method were compared in terms of bias errors, standard deviations, and calculation time. The speckle tracking method was implemented with the normalized cross-correlation function between RF echoes as a similarity function. Subsequently, it was interpolated by reconstructive interpolation [1]. **Figure** 1 show a B-mode image of a sponge phantom. Points of interest, shown in the red points, were placed in shallow (Fig. 1a) and deep (Fig. 1b) regions, at which the lateral and axial motion velocities were estimated. The performance of the speckle tracking method and our phase-sensitive method were examined at the different sizes of the correlation window and spatial window for the Fourier transform, respectively.

Figure 2 illustrates the experimental setup. Echoes from a sponge phantom were received by a linear array ultrasonic probe with element pitches of 0.2 mm. The number of elements were 192. The ultrasonic probe was moved by an automatic stage at constant lateral and axial velocities of 2 mm/s and 1 mm/s, respectively.



(a)　　(b)

Fig. 1: B-mode image of phantom. Red points are points of interest to be tracked in shallow (a) and deep (b) regions.

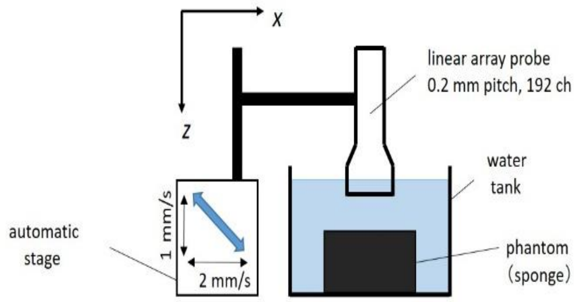


Fig. 2: Illustration of experimental setup.

3. Experimental Results

In the phantom experiment, both methods

---

1 hasegawa@eng.u-toyama.ac.jp

obtained more accurate lateral velocity estimates when the window sizes were larger. The accuracy in estimation of the axial velocity was much less dependent on the window size. The values of bias errors and standard deviations of the lateral velocities in shallow and deep regions by speckle tracking method with window size of ±2 mm (lateral)×±0.246 mm (axial) were -0.324±0.799 mm/s and -0.09±0.609 mm/s, respectively. Those of the proposed phase-sensitive method was -0.279 ± 0.339 mm/s and -0.005 ± 0.252 mm/s, respectively. The calculation time of the proposed phase-sensitive method was 97% shorter than speckle tracking method.

Figure 3 shows the B-mode image of a common carotid of a healthy subject. **Figure** 4 shows the estimated lateral velocities at red points in **Figure** 3, which are estimated by the proposed phase-sensitive method. A characteristic change in velocity was observed around the carotid bifurcation.

Then, the velocities of the two red points in **Figure 5** were estimated. **Figure** 6c shows the change in thickness of the posterior wall, which is obtained by temporal integration of the difference in velocities shown in **Figure** 6b. Thickness of posterior wall became thin by approximately 25 μm. This value corresponded to the value reported in the previous paper [3], which was estimated by a 1D motion estimator.

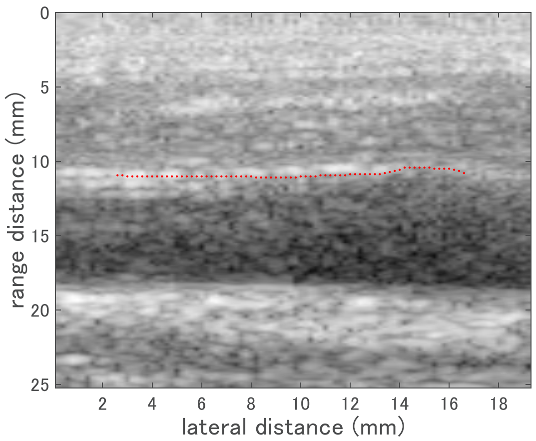


Fig. 3: B-mode image of carotid artery. Red points are points of interest to be tracked, which are assigned in anterior wall.

4. Conclusion

Through the phantom experiments, the proposed phase-sensitive method has shown better performance in terms of bias errors and standard deviations than the speckle tracking method. In the in vivo experiment, complicated movement was observed around the carotid bifurcation, which cannot be observed with a 1D motion estimator.

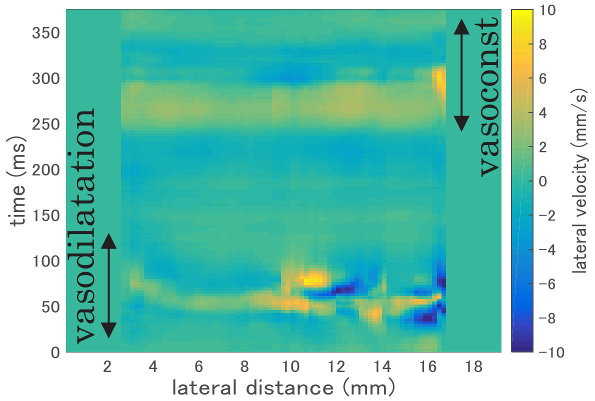


Fig. 4: Estimated axial motion velocities at red points in Fig. 3.

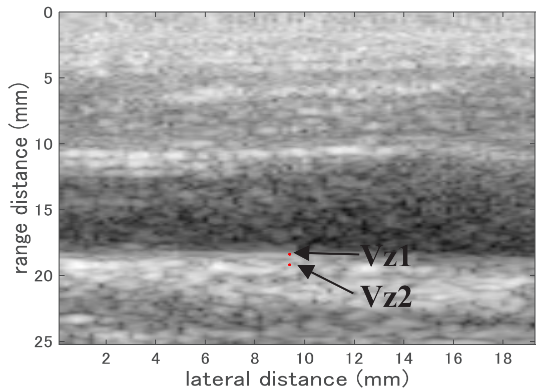


Fig. 5: B-mode image of carotid artery. Two red points are points of interest to be tracked, which are assigned in radial direction of posterior wall.

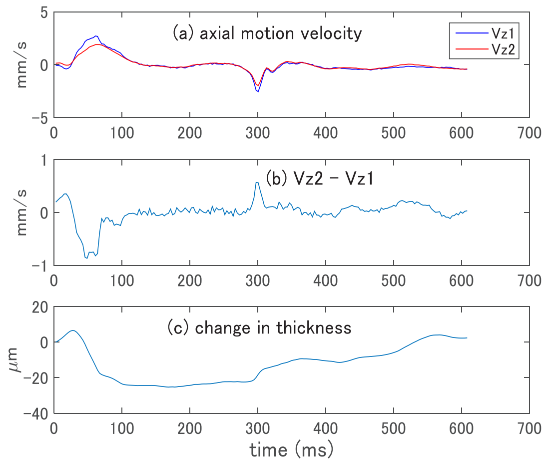


Fig. 6: (a) Axial motion velocities at points Vz1 and Vz2. (b) Velocity differences between Vz1 and Vz2. (c) Change in thickness between red points in Fig. 5.

References

1. I. Cespedes, *et al.*, Ultrason. Imaging, vol. 17, pp. 142-171, 1995.
2. H. Hasegawa, Appl. Sci., vol. 6, pp. 195-1-19, 2016.
3. H. Hasegawa, *et al.*, IEEE Trans, UFFC, vol. 53, pp. 52-63, 2006.