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Basic investigation on effects from movement induced by pulsation on a method for estimation of average speed of sound

Miku Iida[1‡], Ryo Nagaoka[2*], Masaaki Omura[2] and Hideyuki Hasegawa[2]
([1]Graduate School of Science and Engineering, Univ. of Toyama; [2]Faculty of Engineering, Univ. of Toyama)

1. Introduction

In the image reconstruction of ultrasound images, a distance from a scattering point to each ultrasound element is calculated and the received signal is corrected using the calculated propagation time. In this correction, the longitudinal sound of speed (SoS) in living tissue is assumed to be a constant value. However, the assumed value may be different with the correct value because the SoS varies depending on the properties of the tissue. To solve this problem, we proposed a method for estimating the mean SoS distribution[1)].

We also applied this estimation method to data obtained from the carotid artery measurements using plane wave transmission and evaluated reconstructed images, and the improvement of intima continuity in the lateral direction was observed[2)].

As the focused wave transmission requires more time to measure an object from one end to the other, the frame rate is lower than that of the plane wave based imaging. In this study, we investigated the effect of motion induced by pulsation on the estimation method for the carotid artery measurements using ultrasound imaging with focused beams.

2. Principle

2.1 Estimation method of average SoS

The method of calculating value of estimated SoS is same as the method proposed by our previous papers, and coherence factor(CF)[1,3)] and signal to noise ratio(SNR) [1,4,5)]were also used as evaluation index.

CF is the value evaluating a phase dispersion of echo signal after delay correction $e_k(m,n)$ at the spatial point(m,n)[6,7)]. The closer the estimated SoS is to true, the more the echo signals are aligned in phase, which means the dispersion approaches 0 and CF approaches 1. Conversely, the further away from the true value the estimated SoS is, the closer CF approaches 0.

$$CF(m,n) = \frac{\left|\frac{1}{K}\sum_{k=0}^{K-1} e_k(m,n)\right|^2}{\frac{1}{K}\sum_{k=0}^{K-1}|e_k(m,n)|^2} \qquad (1)$$

E-mail: [‡]m23c1003@ems.u-toyama.ac.jp,
[*]nryo@eng.u-toyama.ac.jp

where, k is the element number and K is the total number of elements.

SNR is the value representing the signal to noise ratio of echo signal after delay correction $e_k(m,n)$ at the spatial point (m,n)[4,5)]. Power of noise S is the mean squared error between signals of channels y_i and the linear model $ax_i + b$ and then we decide a coefficient of a and b by minimizing the Eq. (2)[8)]. Finaly, we calculated SNR as shown in the Eq. (3). As well as CF, the closer the estimated SoS is to true, SNR approached 1. Conversely, the further away from the true value the estimated SoS is, the closer SNR approaches 0.

$$S = \sum(y_i - ax_i - b)^2 \qquad (2)$$

$$SNR(m,n) = \frac{a^2}{S_{min} + \gamma \cdot (a)^2} \qquad (3)$$

2.2 Procedure of the estimation

CF and SNR were calculated (thereafter referred to as CF) by using the value of corrected echo signals $e_k(m,n)$ in delay-and-sun(DAS) beamforming at 5 m/s intervals from 1450 to 1600 m/s. The CF weighted distribution $s_{CF}(m,n)$ was obtained, by multiplying by the distribution of CF $CF(m,n)$ and corrected echo signals $e_k(m,n)$. And then we calculated the average of CF weighted rf signals distribution $\overline{s_{CF}(m,n)}$. A median value of average of CF weighted rf signals distributions $s_{CF,med}$ was chosen as the threshold value. The SoS when CF was the largest among the values larger than the threshold value was determined as the estimated SoS. The average SoS were estimated at

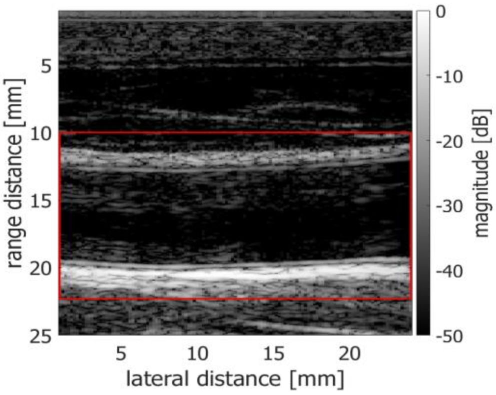

Fig.1 Region of estimation of SoS

the points of 500 × 121 in the depth and lateral directions. The red square in **Fig. 1** represents the range of estimation of SoS. The range of 500 points was set from 10 to 22.30 mm (sample points: 406 to 905) which included the region from anterior wall to posterior wall of the carotid artery. Finally, a median filter was applied. This estimated SoS distribution was used to reconstruct the image.

3. Experimentations

We measured 100 frames of data from the carotid artery of a healthy male at a center frequency of 7.5 MHz with 64 transmitter channels and 192 receiver channels. **Fig. 2** shows a M-mode image at lateral position of 12 mm. The estimation method was for the average SoS applied to 7 to 12 and 77 to 82 frames with the pulsation and 61 to 66 frames without the pulsation. The images reconstructed using the estimated average SoS distribution were evaluated.

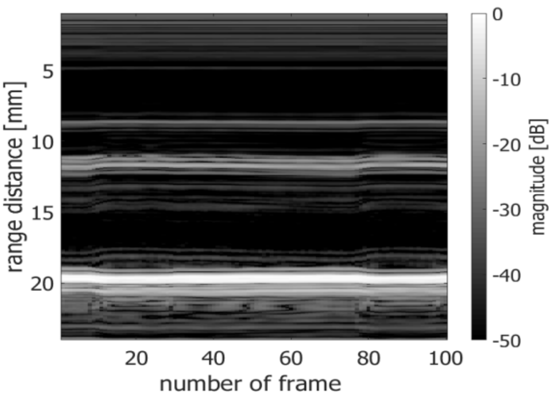

Fig.2 M-mode image

4. Results

The images were reconstructed using the estimated average SoS distribution, and contrast was calculated. The contrast was calculated using the region at depths of 8 to 9.97 mm without correction of the average SoS and the region at depths of 19.93 to 21.89 mm with the correction in the posterior wall of the carotid artery. **Table I** shows the results of calculating the average and standard deviation contrast in 61 to 66 frames when not beating and in 7 to 12 (pulsation 1) and 77 to 82 (pulsation 2) frames when beating in DAS images and in images reconstructed using CF and SNR. Although the degree of the improvement by the proposed method was low, the contrast values were slightly improved in the without pulsation. However**,** the contrast value was not improved with pulsation using SNR. Meanwhile the contrast values were slightly improved in both the cases with and without pulsation using CF.

Table I Result of contrast

	DAS [dB]	CF [dB]	SNR [dB]
Without Pulsation	16.31 ±0.004	16.35 ±0.011	16.32 ±0.022
With pulsation1	15.92 ±0.042	15.94 ±0.042	15.92 ±0.038
With pulsation2	16.09 ±0.087	16.10 ±0.119	16.07 ±0.104

5. Conclusion

We evaluated the effect of pulsation on the average SoS estimation method for the carotid artery measurements using ultrasound imaging with focused beams. The contrast was calculated for several frames in each of the cases with and without pulsation, and the average and standard deviation of the contrast were calculated and slightly improved in both of without and with pulsation using CF.

Therefore, these results indicated that images reconstructed with the average SoS estimated using CF had less effect from motion due to pulsation in this method.

In the future, we also plan to evaluate the effect of motion on the estimation method in numerical simulation experiments. Additionally, we will investigate the more proper evaluation index for the estimated results.

References

1) F. Sannou, R. Nagaoka and H. Hasegawa, Jpn. J. Appl. Phys. **59**, SKKE14 (2020).
2) R. Nagaoka, M. Omura, and H. Hasegawa, J. Med Ultrason. **51**(3), 549 (2024).
3) H. Hasegawa and R. Nagaoka, J. Med. Ultrason. **46**, 297 (2019).
4) H. Hasegawa and R. Nagaoka, Jpn. J. Appl. Phys. **58**, SGGE06 (2019).
5) H. Hasegawa and R. Nagaoka, Ultrason. Imag. **42**(1), 27 (2020).
6) K. Abe, M. Arakawa and H. Kanai J. Med. Ultrason. **46**, 27 (2019).
7) P-C. Li and M. Li, IEEE Trans Ultrason. Ferroelectr. Freq. Control. **50**, 128 (2003).
8) S. J. Miller, *The Method of Least Squares* (Mathematics Department Brown University, Providence, RI, 2006) p.1.