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Investigation of Relationship between Accuracy of 2D Velocity Estimation and Scan Pitch of Ultrasound Image
超音波画像の走査間隔による 2 次元速度の推定精度に関する検討

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1. Introduction

In ultrasound imaging, angle-independent motion estimators were employed in some applications[1-3]. The block matching method is one of the common methods to track the tissue motion in the ultrasound imaging[4,5], and this method has an advantage such that estimation accuracy is independent on the direction of an ultrasound beam.

The lateral spatial resolution, an ability to distinguish two points in the direction perpendicular to an ultrasound beam, affects the accuracy in velocity estimation and the functional measurement of a living tissue. Although a better spatial resolution results in a better estimation accuracy, according to the sampling theorem, more sampling frequency is needed to represent the spatial information[6].

In this study, we investigate an effect of a scan pitch of an ultrasound image on the accuracy in velocity estimation. In the simulation experiment, the center frequency of an array probe is changed to simulate different situations of the lateral resolution, and the 2D velocity vectors are estimated to investigate the estimation accuracy under each condition.

2. Materials and Methods

2.1 Block matching method[4,5]

The block matching method is a method to estimate motion velocity based on an evaluation function between two successive frames. In this paper, a correlation function was used as the evaluation function. The template signal was obtained by multiplying envelope signals in the n-th frame by a spatial window centered at a point of interest (x, z). The kernel size of the spatial window was set to be $(w_x, w_z) = (6.00, 0.74)$ mm. The 2D kernel was shifted by one pixel in a search region at the $(n+1)$-th frame and, then, the best-match kernel was searched such that the normalized correlation coefficient (NCC) between envelope signals in kernels in the template and target images became maximum. Finally, the velocity vector was estimated based on the position of the best-match kernel. To find a sub-sample peak position, the reconstructive interpolation was employed[6].

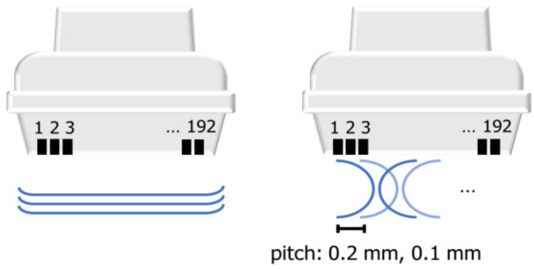

Fig. 1 (left) Transmit and (right) receive sequence used in simulation.

2.2 Simulation phantom experiment

A simulation phantom was created using the Field II simulation program[7,8]. A steady flow was simulated by moving point scatterers. Velocities of the point scatterers were set to be 200 mm/s. The diameter and center position of the flow path were set to be 6 mm and 24 mm, respectively.

Ultrasonic echoes were measured using a linear array probe, which had 192 transducer elements with an element pitch of 0.2 mm. The frequency of the array probe was set to be 5, 7.5, and 10 MHz to simulate different spatial resolutions. A plane wave was transmitted using all elements of the array probe simultaneously and, then, the element echo signals were obtained. The delay-and-sum (DAS) beamforming was applied to the element signals and scan lines of an ultrasound image were created. To investigate the effect of the scan pitch of the ultrasound image on the accuracy in velocity estimation, the scan pitch was set to be 0.2 and 0.1 mm, and the resulting number of beams became 120 and 240, respectively. **Figure 1** shows the transmit and receive sequence used in this study.

The block matching method was applied to the

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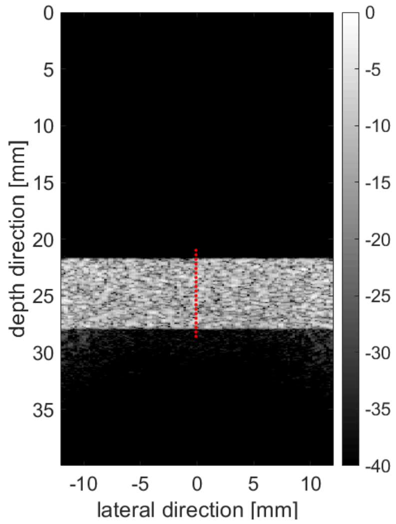

Fig. 2 B-mode image of steady flow simulation phantom. Red dots represent tracking points.

obtained beamformed signals. To evaluate the estimation accuracy of the proposed method, bias errors and standard deviations of estimated velocities were calculated. In this study, bias error b was calculated as

$$b = \frac{1}{N}\sum_{x,z,n}\frac{u(x,z,n) - u_{\mathrm{true}}(x,z,n)}{u_{\mathrm{true}}(x,z,n)}. \qquad (1)$$

In Eq. (1), variables u and u_{true} are estimated and true lateral velocities, respectively, and N is the number of points and frames of interest.

3. Results

Figure 2 shows the B-mode image obtained in this study. **Figures 3(a)** and **(b)** show velocity vectors in the simulation estimated by the block matching method with scan pitches of 0.2 mm and 0.1 mm, respectively. In Fig. 3, the frequency of the probe was set to be 7.5 MHz. **Table I** shows the bias errors obtained in the simulation experiments. In this result, a bias error of about 9% occurred when the frequency and the scan pitch were set to be 7.5 MHz and 0.2 mm, respectively. Also, when the frequency was set to be 10 MHz, velocities estimated under a scan pitch of 0.2 mm were significantly more biased than the other conditions due to insufficiency of the scan pitch. This result shows that the scan pitch must be set at 0.1 mm when using the envelope-based tracking.

Table I Bias errors and standard deviations of lateral velocities evaluated in simulation

	5 MHz	7.5 MHz	10 MHz
0.2 mm	-1.9±2.5 %	-9.1±4.1 %	-40.6±4.1 %
0.1 mm	-2.3±1.4 %	-2.9±1.4 %	-19.9±5.6 %

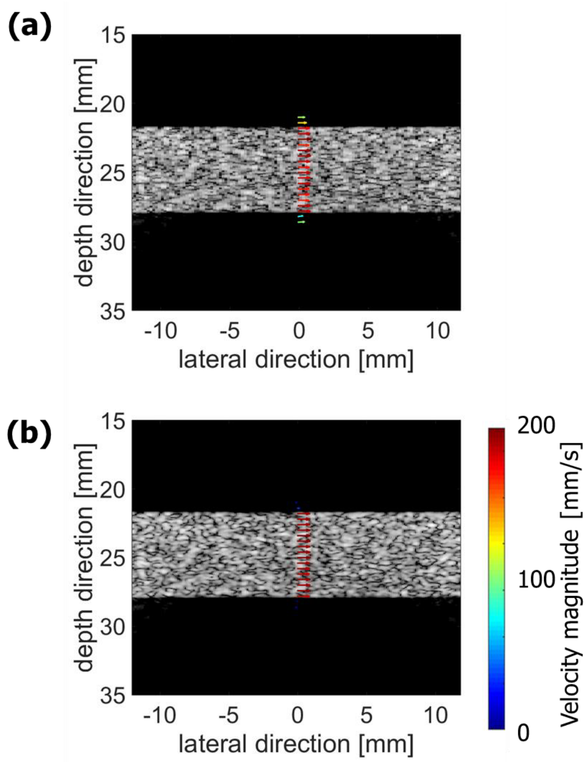

Fig. 3 Velocity vectors estimated by block matching method with scan pitches of (a) 0.2 mm and (b) 0.1 mm. Frequency was set at 7.5 MHz.

4. Conclusion

In this study, we investigated the effect of the scan pitch on the accuracy in velocity estimation. In the simulation results, the bias error was the largest when the frequency and the scan pitch were set to be 7.5 MHz and 0.2 mm, respectively.

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