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Calcification Indicator in Ultrasonography with Real Data Oversampling and a Rank Filter

リアルデータオーバーサンプリング法とランクフィルタを用いた医用超音波石灰化指標

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1. Introduction

Ultrasonography (US) has an insufficient ability in the depiction of calcifications compared with an X-ray imager [1, 2]. For the improvement of the ability of US in calcification detection, we have proposed a calcification detection method using the decorrelation of forward scattered waves [3, 4]. Since the waveform of the echo behind a calcification should be changed at the calcification location, the cross-correlation between adjacent scan lines is suppressed behind the calcification, as shown in **Fig. 1**. Therefore, the existence of a calcification can be predicted from the region with low correlation along the range direction. In this study we employ two techniques, real data oversampling and a rank filter, to improve the performance of the proposed calcification depiction method.

2. Methods

1. Real data oversampling

Since an ultrasonographic device acquires IQ data using a quadrature detector, the IQ data correspond with the real and imaginary components of the received signal only at the transmit center frequency. The so-called IQ data are really the oversampled real data with the sampling frequency of four times the transmit center frequency [5]. Therefore, we convert the IQ data to the oversampled real data. We call this process real data oversampling.

2. Correlation between adjacent scan lines

The decrease of the cross-correlation coefficient between adjacent scan lines occurs not only by the existence of a calcification, but also low signal-to-noise ratio (SNR). To suppress the effect of noise on the correlation coefficient, we employ a modified Wiener filter for the correlation coefficient given by

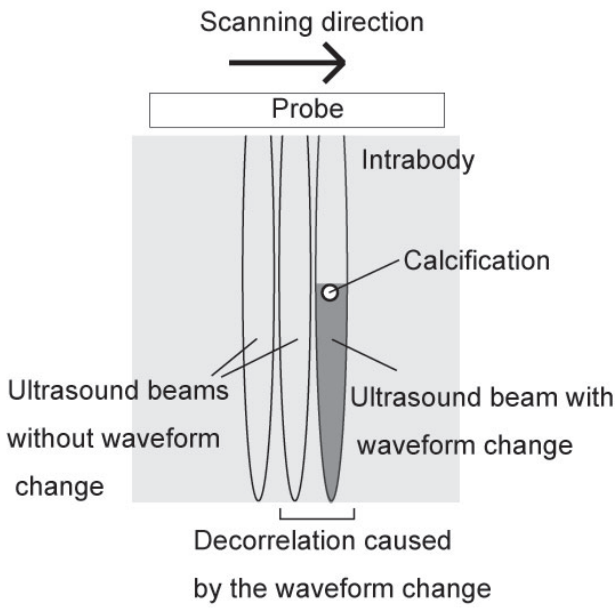

Fig. 1 Schema of the calcification indicator utilizing the decorrelation of adjacent scan lines.

$$r(x+\frac{\Delta X}{2},z) = \max_{l} \frac{\sum_{z'=z_1}^{z_2} g(x,z')g(x+\Delta X, z'+l\Delta Z_S) + \alpha n I_0}{\sqrt{\sum_{z'=z_1}^{z_2}\left|g(x,z')\right|^2 \sum_{z'=z_1}^{z_2}\left|g(x+\Delta X, z'+l\Delta Z_S)\right|^2} + \alpha n I_0}, \quad (1)$$

where n is the size of the correlation window, I_0 is the average pixel intensity in a region of interest (ROI), x and z are, respectively, the lateral and vertical components of a measurement point in a B-mode image, $g(x,z)$ is the oversampled real datum at $P(x,z)$, a position in a B-mode image, ΔX is the interval of scan lines, ΔZ_S is the scan interval for the maximization of the correlation coefficient, z_1 and z_2 are the minimum and maximum, respectively, of the z coordinates of a correlation window in front of $P(x,z)$, and α is a positive number. In this study the correlation window width was 5 mm and $z_2 = z$.

3. Rank filter for the selection of low correlation regions

Since a calcification suppresses the cross-correlation in the region behind the calcification, the region behind the calcification has significantly low cross-correlation compared with that of common soft tissue. This suggests that the low correlation regions in a ROI should be selected using the distribution of the correlation coefficients of the soft tissues in the ROI. For the elimination of the correlation coefficients influenced by calcifications we employ a rank filter. First, we choose the top 90% of the correlation coefficients in a ROI. We calculate the average and standard deviation of the chosen correlation coefficients. We then normalize a correlation profile using the average and the standard deviation.

3. Results

Experiments were conducted using a Hitachi EUB-8500 (Hitachi, Tokyo, Japan) US device, which has a function to export raw IQ data. We utilized a 7.5 MHz linear array probe, where the scan line interval is about 0.13 mm. The range interval of IQ data is 0.05 mm. **Fig. 2** shows a B-mode image of the calcification phantom used in this study. A swine fat layer 1 cm thick was located on an agar gel block. 4 wires 0.05 mm in diameter were embedded for the depth of 2 cm, and a polyethylene sheet 0.1 mm thick was positioned just behind the wires. The size of a ROI is 1 x 3.5 cm, and the center of a ROI is set at the depth of the wires. The specular echoes from the polyethylene sheet severely interferes the detection of the wires 0.05 mm in diameter, as shown in Fig. 2. The normalized correlation profile in the ROI calculated by the calcification indicator is shown in **Fig. 3**. The proposed calcification indicator depicted 3 of 4 wires 0.05 mm in diameter, and no pseudo image appeared in the ROI. This result indicates the usefulness of the proposed calcification indicator.

4. Conclusion

We examined the performance of a calcification indicator in US using the decorrelation between adjacent scan lines. The calcification indicator with a modified Wiener filter and a rank filter succeeded to depict 3 of 4 wires 0.05 mm in diameter for the depth of 2 cm, with the suppression the appearance of pseudo images. This result shows the potential of the calcification indicator to improve the calcification detection ability of US.

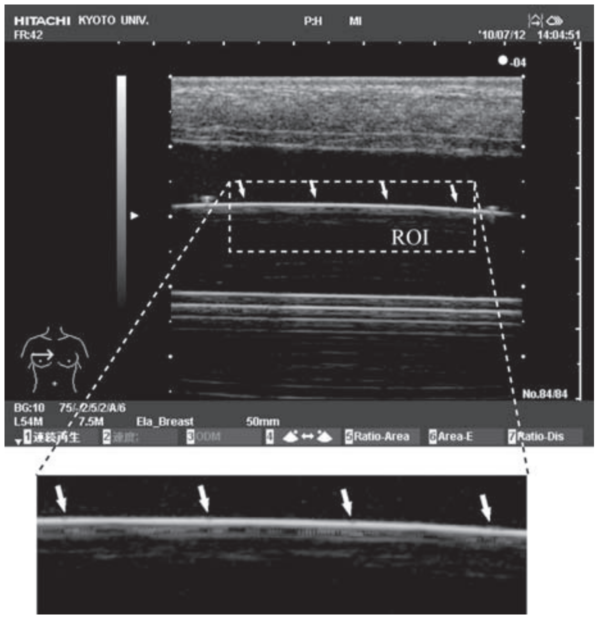

Fig. 2 B-mode image of a calcification phantom used in this study. 4 wires 0.05 mm in diameter were embedded for the depth of 2 cm, and a polyethylene sheet 0.1 mm thick was located just behind the wires. White arrows indicate the wire positions.

Fig. 3 Normalized correlation profile in a ROI calculated by the calcification indicator. μ and σ denote the average and standard deviation of the top 90% of the correlation coefficients in the ROI.

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