1P5-9

Proceedings of Symposium on Ultrasonic Electronics, Vol. 37 (2016)
16-18 November, 2016

Feature Extraction from RF Received Waveforms for Effective Identification of Heart Wall

心臓壁領域同定に有効な RF 受信波形の特徴

Kohei Takahashi[1†], Hirofumi Taki[2,1], and Hiroshi Kanai[1,2]
([1]Grad. School of Biomed. Eng., Tohoku Univ.; [2]Grad. School of Eng., Tohoku Univ.)
高橋航平 [1†]，瀧　宏文 [2,1]，金井　浩 [2,1] ([1] 東北大院 医工, [2] 東北大院 工)

1. Introduction

Currently, both cardiac wall motion and strain rate can be quantitatively evaluated by means of ultrasonic Doppler technique [1] or speckle tracking [2]. These assessment methods of cardiac functions require the identification of heart wall areas in B-mode images. In most cases, the heart wall is manually identified by examiner using the echo power. For clinical application, an automatic heart wall identification method is needed to eliminate the examiner-dependence and to increase the convenience. Several researches have reported image processing methods and pattern recognition methods to identify heart wall areas in B-mode images using the information of the echo power; however, the methods using only echo power would misclassify the area with low intensity inside the heart wall as chamber.

In the present study, we show the essential differences between the echo from heart wall and that from chamber. Furthermore, we propose the effective feature to identify heart wall areas except for the echo power.

2. Method

In the present study, we focus on the temporal change of scatterer distribution [3,4]. In the heart wall, major scatterers are myocardial and collagen fibers, and their distribution should be changed by local contraction and relaxation motion. On the other hand, in chamber, major scatterers are blood cells, and their distribution should be changed by blood flow. The maximum blood flow velocity is over 1 m/s [5], which is much faster than the maximum velocity of the heart wall, about 10 cm/s [6]. In addition, in left ventricular long-axis view, myocardial and collagen fibers mainly move in the axial direction. In contrast, blood cells move in the lateral and axial directions. For these reasons, the temporal change in scatterer distribution is supposed to be suitable to differentiate the heart wall from the chamber.

In the present study, we employ the cross correlation of the envelope (COE) as a feature of temporal change in scatterer distribution. COE shows the cross correlation value of signal envelopes between frames in each scan line. COE reflects temporal change in scatterer distribution because the interference effect among moving scatterers changes signal envelope.

We employ tracking method to correct the shift of signal envelope in the axial direction between frames originated from heart wall translational motion in the axial direction. By using tracking method, temporal change in scatterer distribution is more accurately evaluated, originated from heart wall contraction and relaxation motion. COE at *n*-th frame is given by

$$\mathrm{r}(n) = \frac{1}{N}\sum_{k=-N}^{N}\{\mathrm{corr}(\,\mathrm{env}(n+k, r_{n+k})\,, \mathrm{env}(n+k+1, r_{n+k+1})\,) * \mathrm{w}(k)\} \qquad (1)$$

where $\mathrm{env}(n, r_n)$ is the signal envelope cut out using a time window around a tracking point depth for the *n*-th frame r_n, corr(・ , ・) is the cross correlation function, and *w*(・) is Hanning window function. We employ the temporal averaging during (2*N*+1) frames.

3. Results

In this study, the heart of a healthy human subject was measured in a left ventricular long-axis view (frame rate: 198 Hz, sampling frequency: 20 MHz). To remove the clutter components from the surrounding tissue, a high-pass filter of MTI filter (cut-off frequency: 10 Hz [7]) was used. For calculating COE, *N* was 10 frames, that was 50 ms, and the length of time window to cut out a signal envelope was 592 μm. The tracking area was set at ±500 μm in the axial direction from the tracked point because the migration length of heart wall between frames is about 500 μm.

Figure 1 shows an illustration of left ventricular

Email: ktakahashi@ecei.tohoku.ac.jp
(taki, hkanai)@ecei.tohoku.ac.jp

long-axis view and the areas of interventricular septum (IVS) and left ventricle (LV) assigned manually in a B-mode image. Figure 2 shows the temporal changes of envelope amplitude and COE during a cardiac cycle.

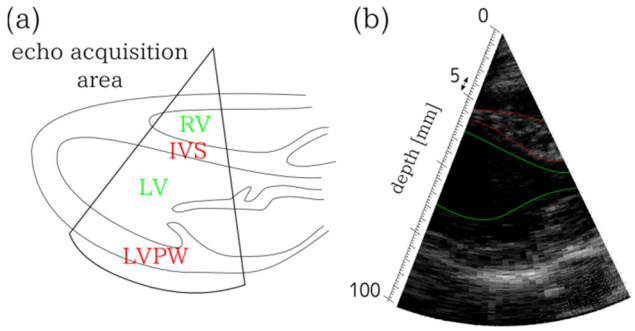

Fig. 1. (a) Left ventricular long-axis view (RV: right ventricle, LV: left ventricle, IVS: interventricular septum, LVPW: left ventricular posterior wall). (b) IVS (red) and LV (green) manually assigned in a B-mode

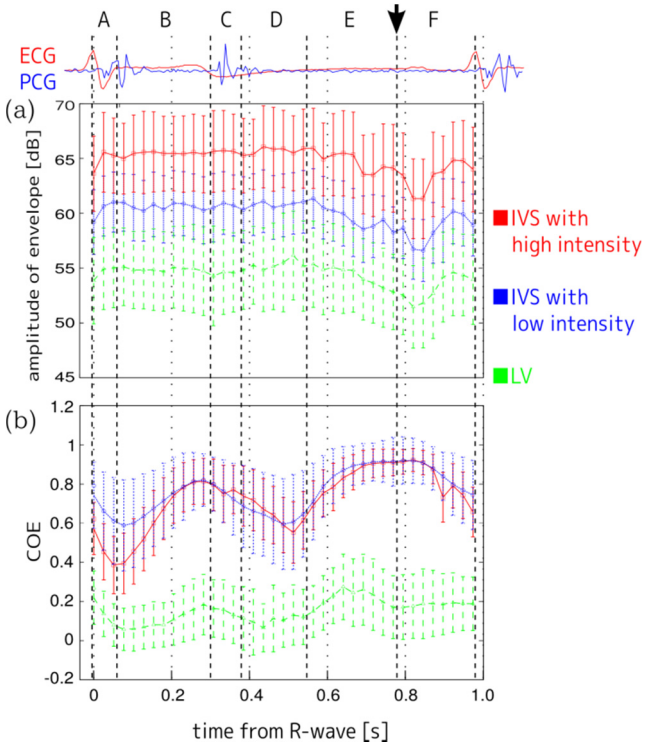

Fig. 2. Time changes of features. (a) Envelope. (b) COE. Red, blue, green lines denote in the area of IVS with high intensity, IVS with low intensity, and LV, respectively. Periods A, B, C, D, E and F denote the isovolumetric contraction phase, ejection phase, isovolumetric relaxation phase, rapid filling phase, slow filling phase and atrial systole phase.

COEs in IVS shows a similar tendency in spite of the difference of intensity. In addition, the temporal change of COE in IVS was much larger than that in LV, and COE in LV was low during a cardiac cycle. In IVS, COE was low in the early ejection phase and the rapid filling phase, when the heart wall contracted and relaxed. In contrast, COE was high in the else phase. This result shows that COE may be suitable to evaluate the changes of scatterer distribution.

Figure 3 shows the B-mode image with envelope and with COE of the frame when the COE difference between IVS and LV was the largest, at the time of black down arrow in Fig. 2 (b). Figure 3 shows the areas with high COE located at the areas with high echo intensity. In addition, the areas with low intensity in the heart wall had high COE. These results show the effectiveness of COE as a feature for identification of the heart wall.

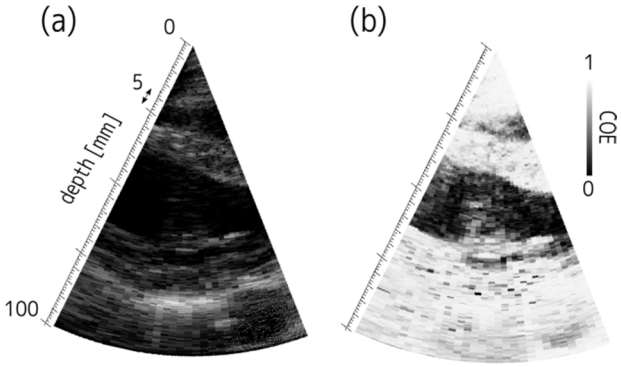

Fig. 3. B-mode images with feature at the time of black down arrow in Fig. 2 (b). (a) Envelope. (b) COE.

4. Conclusion

In this study, we proposed a new feature that is useful to differentiate the heart wall from the chambers in ultrasound images. The results show a high potential of the feature in identifying heart wall areas.

References

1. G. R. Sutherland, *et al.*: J. Am. Soc. Echocardiogr. 17 (2004) 788.
2. J. D'hooge, *et al.*: IEEE Trans. UFFC. **49** (2002) 281.
3. H. Takahashi, H. Hasegawa and H. Kanai: Jpn. J. Appl. Phys. **52** (2013) 07HF017.
4. K. Nakahara, H. Hasegawa and H. Kanai: Jpn. J. Appl. Phys. **53** (2014) 07KF09.
5. L. Hatle and B. Angelsen: Doppler Ultrasound in Cardiology (Lea & Febiger, St. Louis, MO, 1982).
6. L. Kapusta, *et al.*: Ultrasoud Med. Biol. 26 (2000) 229.
7. H. Takahashi, H. Hasegawa and H. Kanai: Jpn. J. Appl. Phys. **54** (2015) 07HF09.