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Accuracy evaluation of non-contact measurement for breathing and heartbeat using airborne ultrasound
空中超音波による呼吸・心拍の非接触計測の精度検討

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1. Introduction

Non-contact measurement of vital sign is studied by various approaches. In this research, a method of non-contact measurement for breathing and heartbeat using airborne ultrasound is proposed and investigated. In previous studies, the two dimensional displacement due to breathing and heartbeat on chest surfaces of subjects without clothes was measured using a loudspeaker and two microphones [1, 2]. In this report, to measure breathing and heartbeat of subjects with clothes in non-contact, the displacement on the neck surface are measured by airborne ultrasound and the accuracy is evaluated.

2. Measurement configuration

In the proposed method, the displacement on body surface is observed by changes of time of flight measured by the pulse-echo method which is applied pulse compression using M-sequence modulated to improve SNR. Because the displacement on neck surface due to heartbeat are sufficiently smaller than the spatial resolution of the transmitted ultrasound, the displacement is calculated from the inter-frame phase difference.

To measure breathing and heartbeat of the subject in clothes, the non-contact measurement of the displacement on neck surface of the subject sitting on the chair is conducted. The measurement configuration is shown in **Fig. 1**. The pair of the loudspeaker (Pioneer PT-R4) and the microphone (ACO 7016&4116) are placed in front of the subject's neck, and a reflected wave from the neck is acquired. From the speaker, the 9th order M-sequence modulation signal allocated two sine waves of 40 kHz to one digit was repetitively transmitted. To eliminate the influence of reflected waves from the body surface other than the neck, there is sound absorbers between the transducers and the face or the chest. In addition, a contact type pulse wave sensor (BIOPAC TSD 200) was used as a reference for the heartbeat cycle. In order to evaluate the accuracy of heart rate measurement at the neck,

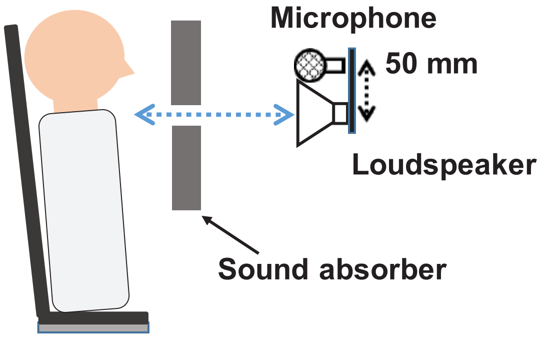

Fig. 1 Measurement configuration in a sitting position with clothes.

measurements were performed from the 5 directions about from the front to the body, the left and right sides at 45 degrees and the left and right sides at 90 degrees.

3. Measurement result

Figure 2 shows measurement results. Results from the front to the body are shown in (a), (d), (g) and (j), from the right side at 45 degrees are shown in (b), (e), (h) and (k), from the right side at 90 degrees are shown in (c), (f), (i) and (l). **Figure 2** (a)-(c) show M-mode images of cross-correlated waveforms in which the horizontal axis means the distance by using sound speed in the air. High-amplitude waves from 350 to 450 mm are reflected waves from the neck. These results correspond to results measured by the laser rangefinder. **Figure 2** (d)-(f) show M-mode images of phase differences obtained by applying quadrature detection to cross-correlated waveforms.

The examples of neck-surface displacements calculated by phase differences on white lines shown in **Fig. 2** (g)-(l). **Figure 2** (g)-(i) show displacements applied the low-pass filter of 0.8 Hz in order to extract breathing or body motion. Sometimes the breathing can be measured, sometimes mixed with the body motion. **Figure 2** (j)-(l) show displacements applied the high-pass filter of 0.8 Hz in order to extract only heartbeat and measurement results by contact type of pulse wave sensor (PWS). Heartbeats measured by the proposed method correspond to the

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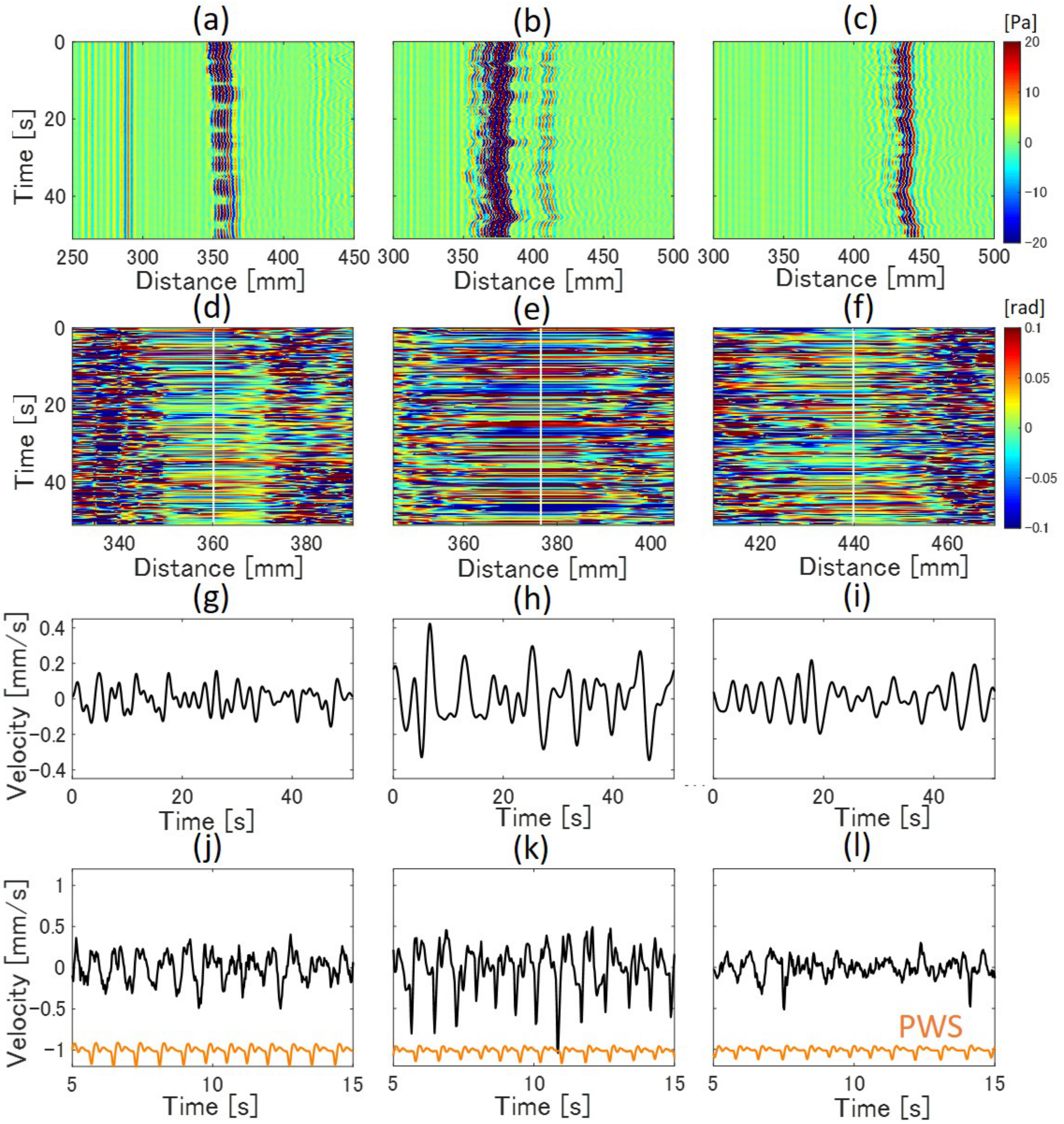

Fig. 2 Measurement results from the front to the body (a), (d), (g) and (j); from the right side at 45 degrees (b), (e), (h) and (k); from the right side at 90 degrees (c), (f), (i) and (l). (a)-(c) are M-mode images of cross-correlated waveforms; (d)-(f) are M-mode images of phase differences; (g)-(i) are displacements on white line applied the low-pass filter of 0.8 Hz; (j)-(l) are displacements applied the high-pass filter of 0.8 Hz and results of the pulse wave sensor.

results of PWS at 0 degree and 45 degrees. There are a part that heartbeat can be measured and a part that heartbeat cannot be measured. The reason why the heartbeat at 45 degree is clearer than the other is thought that the measured neck surface is close to carotid artery. These result suggest that heartbeat can be obtained by the displacement on the neck surface measured in non-contact by airborne ultrasound. Furthermore, to be clearer the waveform of heartbeat, measurement the displacement around the carotid artery is effective.

4. Conclusion

In this paper, non-contact measurement of displacement on neck surface by breathing and heartbeat using ultrasound was studied. It is suggested that heartbeat can be obtained by displacements of stretching of carotid artery. The future work is to measurement breathing clearly.

References

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