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Study on Movement Detection for Care Environment Using Precise Ultrasonic Distance Measurement - Comparison between Ultrasonic Wave and Sound Wave at Upper Vocal Register -
高精度超音波距離計測による介護環境等での動き検知 – 可聴音高域を用いた場合の比較 -

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1. Introduction

New precise ultrasonic distance measurement method has been proposed [1]. We have also shown that it is possible to apply this technique to care environment to detect movement of sick or old people. Our final goal is installation of the technique to sensor network in the future. However, the experimental results at 40 kHz show that movement-detection sensitivity is extremely high due to short wavelength of 8.4 mm. Recently in large shopping malls, services using sound waves at upper vocal register, 17-20 kHz, have started to convey information about goods and attractions to customer's smart phones [2]. We investigated the feasibility using lower frequency, 17-25 kHz, to achieve less sensible and practical systems, because wavelength is 2 cm at 17 kHz.

In our proposal, ultrasonic continuous waves (CWs) at discrete frequencies within the transducer bandwidth which correspond to those of the Inverse Fast Fourier Transform (IFFT) procedure are transmitted. The relative amplitudes and phases between the received and transmitted CWs are measured in senor nodes. These data are transmitted to the center node. The impulse responses between the transmitter and receiver nodes can be calculated in the center node, which provide accurate distance information via many reflecting objects. If we subtract the impulse responses at present time from those at the preceding time, we can obtain the change of distances between objects and nodes at two different times. By this procedure, we can exclude effects of inactive objects and detect only moving objects. Therefore the sensor network including our positioning and movement detection devices will possibly be applied not only to home/office monitoring but also to care for old people, prevention of crime and watch in hospitals.

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2. Experimental results at 40 kHz

In order to detect object movement, a conventional pulse-echo method cannot be adopted in this system. Our proposed method is as follows:

(1) Tx and Rx transducers in sensor nodes alternately transmit and receive small-amplitude ultrasonic CWs (Fig. 1). The frequencies correspond to those of IFFT with spacing Δf.

(2) Relative amplitudes and phases between the transmitted CWs (Fig. 2(a)) and the received CWs (Fig. 2(b)) are measured and are sent to the center node.

(3) In the center node, the above data are compensated with intrinsic phase characteristics of the Tx/Rx transducers. Impulse responses which include distance information between the sensor nodes via reflecting objects can be obtained using IFFT.

(4) Difference between two impulse responses at different times can provide movement information of objects from one point to the other.

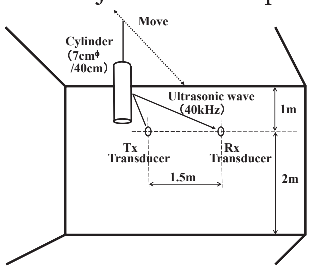
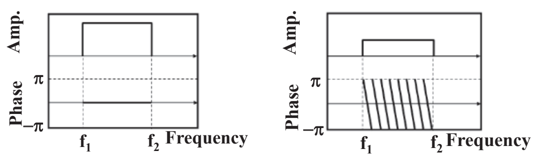
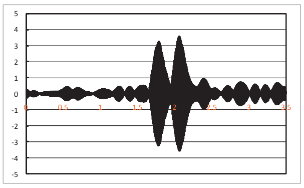


Fig. 1 Transmitting and receiving of ultrasonic CWs reflected from moving object.

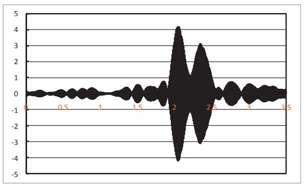


(a) Transmitting signals (b) Receiving signals
Fig. 2 Ultrasonic CWs at IFFT frequencies.

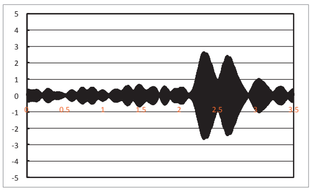
In order to confirm our detection method for moving objects, we conducted a fundamental experiment using Fig. 1's model. Subtracted data between the impulse responses at 1.8 m and 2.1 m are illustrated in Fig. 3(a). Movement from 1.8 to 2.1 m is clearly detected. Other movements of 2.1→2.4 m, 2.4→2.7 m and 2.7→3.1 m are shown in Fig. 3(b), (c) and (d) respectively. While the movements were very clear, sensitivity due to fluctuations was too high in the experiment.



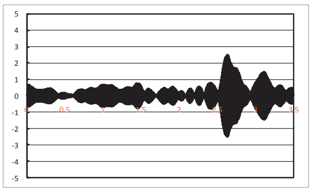
(a) 1.8→2.1 m



(b) 2.1→2.4 m



(c) 2.4→2.7 m



(d) 2.7→3.1 m

Fig. 3 Movement detection from impulse responses.

3. Feasibility check using 17 to 25 kHz

As the equal-loudness contours are shown in Fig.4, humankinds have steep degradation in hearing ability over 17 kHz. To check our new trial using the sound waves at upper vocal register, we did fundamental experiments. Using Fig.5's experimental setup, we measured the reflection and transit coefficients of sound waves for such sheet-type obstacles as cardboard, copy paper, work clothes, white shirt and sweater. The reflection and transit coefficients are shown in Fig. 6(a) and (b) respectively. Overall characteristics at 17, 25 and 40 kHz are similar, which shows the possibility to reduce the sensitivity using upper vocal register.

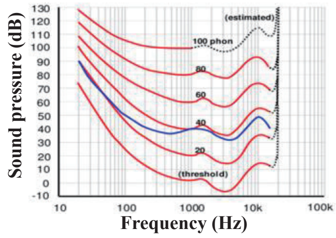


Fig. 4 Equal-loudness contours

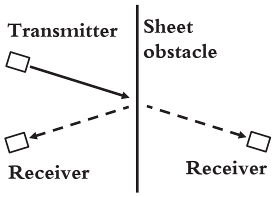
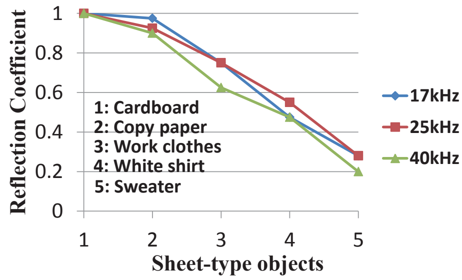
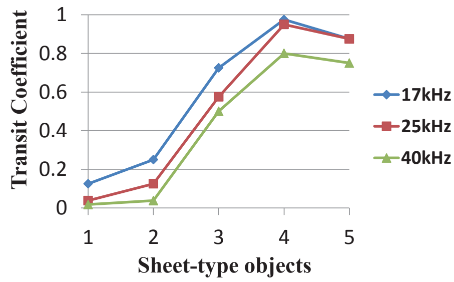


Fig. 5 Experimental setup measuring reflection and transit of sound waves for sheet-type obstacles.



(a) Reflection coefficients of sound wave



(b) Transit coefficients of sound waves

Fig. 6 Reflection and transit characteristics of sound wave for sheet-type obstacles.

4. Conclusion

A new ultrasonic movement-detection method based on impulse responses has been studied. To reduce the excess sensitivity of the previous method, we investigated the upper vocal register. The basic experiments show that more practical system will be possible using this frequency rage.

References

1. T. Sato, N. Tobita and M. Hikita, in Proc. of Symp. on Ultrason. Electron. Vol.34, pp.117-118, 2013.
2. Shoplat, NTT docomo H.P., https://www.nttdocomo.co.jp/service/convenience/shoplat/