1P2-41

Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 117-118
20-22 November, 2013

Study on Movement Detection Using Precise Ultrasonic Distance Measurement - Application to Care Environments -
高精度超音波距離計測による動き検知の基礎研究 – 介護環境等への応用の検討 -

Takeo Sato, Natsuki Tobita and Mitsutaka Hikita (Kogakuin Univ.)
佐藤健雄、飛田夏希、疋田光孝 （工学院大学）

1. Introduction

We have proposed new precise ultrasonic distance measurement method, and based on it we have also invented a new movement detection technique. This technique can be installed in sensor network in the future. 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. In this paper, simulation and experimental results will be presented.

2. Measurement method

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 (Fig. 3).

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

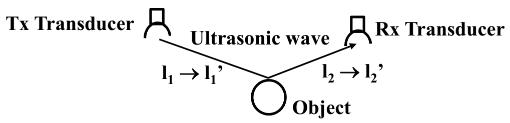
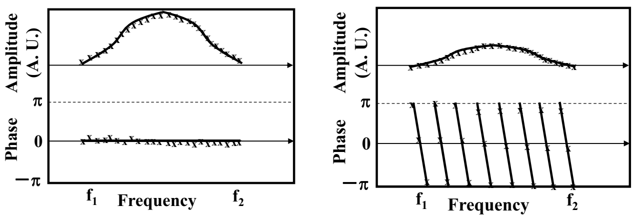


Fig. 1 Transmitting and receiving of ultrasonic CWs reflected from moving object.



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

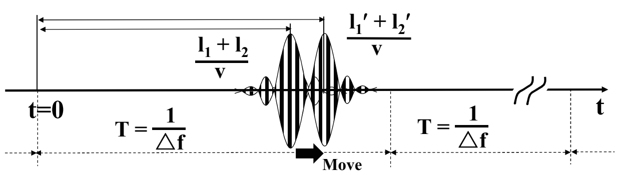


Fig. 3 Impulse responses between Tx and Rx nodes via reflecting object.

3. Simulation results

In order to check our proposal, we simulated the impulse responses between two nodes using a room model (Fig. 4). In the simulation, there are 50 reflecting objects with random reflection coefficients among the distances from 3 to 8m

----
am13033@ns.kogakuin.ac.jp

between two sensor nodes (1) and (2). The moving object, a person, is assumed to walk from 3m to 8m. The transducer has center frequency of 40kHz and bandwidth of 2.5%.

Impulse responses calculated by IFFT procedure are shown in Figs. 5(a) - (f), which correspond to the distances between two nodes via the walking person. The receiving power of ultrasonic CWs from reflecting objects decreases in proportion to the minus fourth power of distance.

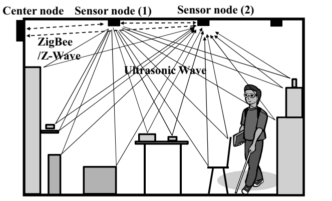
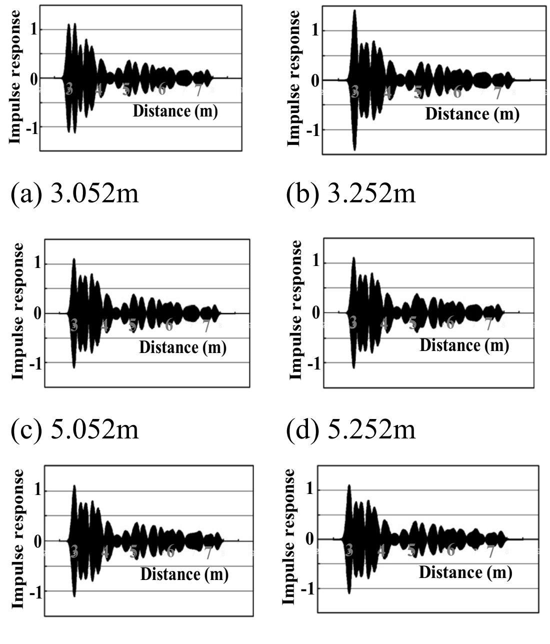


Fig. 4 Room model for simulation.

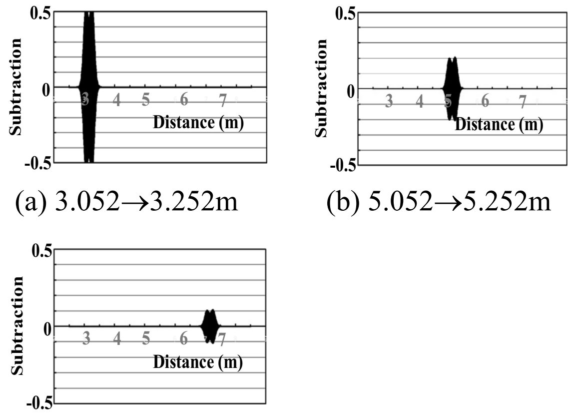


(a) 3.052m (b) 3.252m

(c) 5.052m (d) 5.252m

(e) 7.052m (f) 7.252m

Fig. 5 Simulated impulse responses.



(a) 3.052→3.252m (b) 5.052→5.252m

(c) 7.052→7.252m

Fig. 6 Movement by subtraction of two responses.

Subtracted data between Figs. 5(a) and (b) are plotted in Fig. 6(a), which correspond to movement from 3.052m to 3.252m. Reflected ultrasonic CWs from stationary objects are mutually cancelled out. The movement appears clearly as the remaining parts of subtracted two impulse responses. Same simulated results are observed in Fig. 6(b) for 5.052→5.252m movement and Fig. 6(c) for 7.052→7.252m movement.

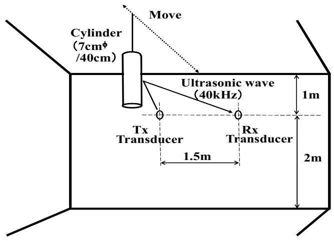
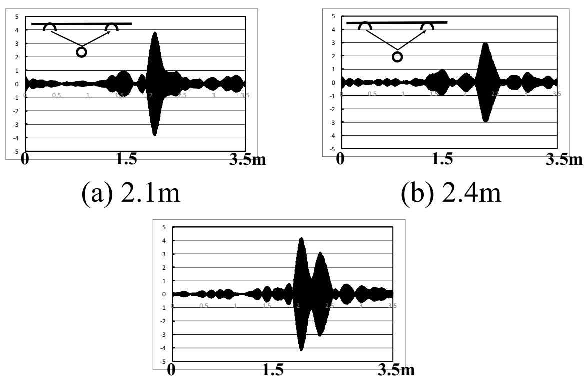


Fig. 7 Simple set up for fundamental experiment.



(a) 2.1m (b) 2.4m

(c) 2.1→2.4m

Fig. 8 Movement detection from impulse responses.

4. Fundamental experiment

In order to confirm our detection method for moving objects, we conducted a fundamental experiment. As shown in Fig. 7, Tx and Rx transducers are 1.5m apart. The reflecting object is a 40cm cylinder with 7cm$^{\phi}$ diameter. The impulse responses for distances of 2.1m and 2.4m between Tx and Rx via the cylinder are shown in Figs. 8(a) and (b), respectively. Subtracted data between Figs. 8(a) and (b) are illustrated in Fig. 8(c). Movement from 2.1 to 2.4m is clearly detected.

5. Conclusion

A new ultrasonic measurement method based on impulse responses are studied by simulation and fundamental experiment. We are planning a LabVIEW-based system to investigate precisely.

References

1. N. Tobita and M. Hikita, in Proc. of Symp. on Ultrason. Electron. Vol.32, pp.89-90, 2011.