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Detection of Human Motion Using Ultrasonic Sing-Around Method
超音波シングアラウンド法を用いた人体動作の検出

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1. Introduction

Recently, the standard of body area network (BAN) has been determined[1], and it is required to handle increasing kinds of bio-information. Acceleration sensors[2] have been widely studied to detect human motion. However, these sensors provide only acceleration, and additional signal processing is requierd to know absolute the positions of body parts. We have proposed sing-around ultrasonic sensors to detect body motion[3][4]. The fundamental properties of the sing-around sensor is demonstrated in this report, and a method to use multiple sensors and to monitor the signal from every node through light transmission.

2. Proposed Detection Method of Human Body Motion Using Ultrasonic Sensors

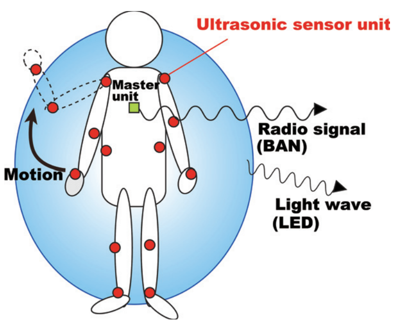

Fig.1 Conceptual diagram of detection of body motion using sing-around ultrasonic sensor units.

Figure 1 shows the system for detecting body motion using sing-around ultrasonic sensors. Output signals of sensors are remotely measrued as either radio signals or light waves. With the system, distances between the sensors and corresponding absolute positions of the body parts are estimated.

We have developed a prototype of sing-around sensor[3] as shown in **Fig. 2**. The sensor consists of two transducers for transmitting and receiving ultrasound. Output singal provides the status if the ultrasound is transmitted or not. The output signal can be measured using either an oscilloscope (direct measurement) or a photodetector (remote measurement).

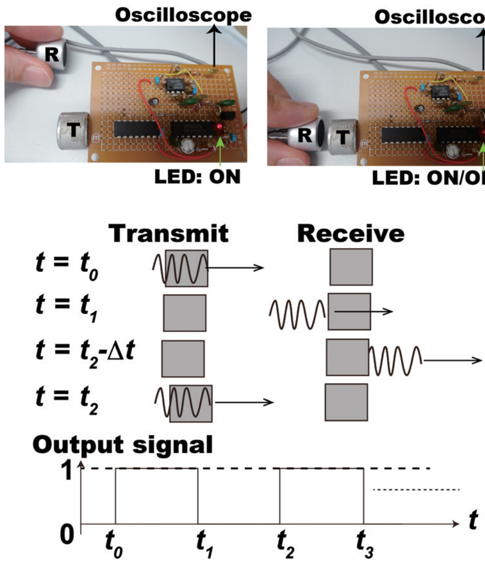

Fig.2 Pictures of developed ultrasonic sing-around sensor (top) and its operation (bottom).

First, ultrasound with the frequency of 40 kHz is transmitted from one of the transducers at $t = t_0$. At the time, output signal becomes '1.' When ultrasound is received with the other transducer, output signal downs to '0' and transmittion of ultrasound is stopped ($t = t_1$). After the receiving of ultrasound is ended, ultrasound is transmitted again ($t = t_2$). The output of this senor is a logic signal syncronized to the transmission and receiving. The distance between the two transducers is almost equal to the product of a half of time cycle and sound speed in air (= 340 m/s).

3. Operation Test of Sing-Around Sensor Unit

As a basic operation, an arm angle was estimated. The output data size sent through the BAN should be minimum, since real-time measurement is required for body motion detection. Therefore, we utilized an f-V converter to read the frequency using a low sampling rate A/D converter.

Lengths of the arm were measured by a scaler in advance (**Fig. 3**). The relationship between the output signal of f-V circuit and the actual distance was also measured. Then, the distance between shoulder and wrist was measured by the sensor. By assuming the arm shape was triangle, arm angle was estimated. **Figure 3** shows the result. From the

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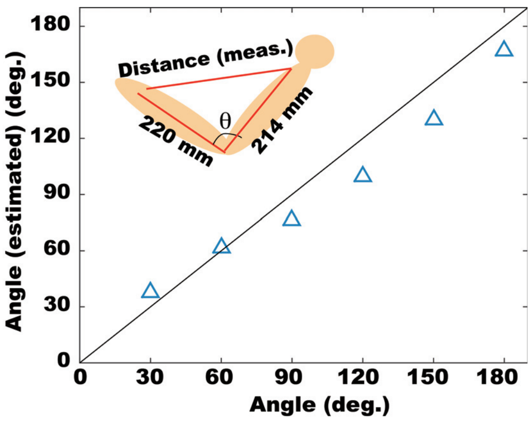

Fig.3 Experimentation of estimation of arm angle.

result, we can almost estimate the angle with the proposed method.

4. Multistage Sensor System and Detection of Motion using Light Signal

To detect body motion, plural distances were measured at the same moment[4]. In the measurement, four pairs of the sensor units were separately operated and the motion of arms and legs were estimated. In that case, the number of sensing units increases as that of sensor pairs incrases. As an alternative detection system, we propose a multistage sensor system as shown in **Fig. 4**, where sevaral number of the Transmitter-Receiver pairs are relayed and forming a ring oscilator. The operation timing of each pair is remotely monitored by detecting the blinking of an LED syncronized with the signal explained in **Fig. 2** using a photodetector.

In order to know the possibility of multistage system, operation of sensors were simulated. Three pairs of sensors were considered in the calculation. The distance between these sensors were set to 10 mm (sensors 3 and 1), 16 mm (sensors 1 and 2), and 22 mm (sensors 2 and 3). **Figure 5** shows the simulation results. Output signal of receiving sensor 1 changes to ‘1’ first, since the transmitted wave from the transducer 3 arrived the earliest among the sensors. Simulation results show that the behavior of output signals are more complicated compared with single sensor unit. Therefore, algorithm which estimates distances from the output signals should be considered. In addition, output signal of the sensor shown in **Fig. 2** was possible to be remotely measured with the photodetector as indicated in **Fig. 6**.

5. Summary

We proposed a sing-around ultrasound sensor to detect human motion remotely. A possibility of the multistage sensor system has been implied and will be tested in future work.

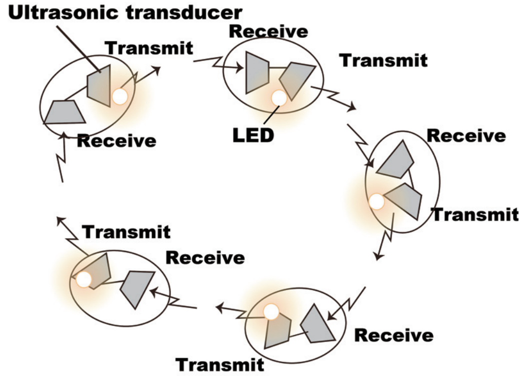

Fig.4 Conceptual diagram of sing-around system.

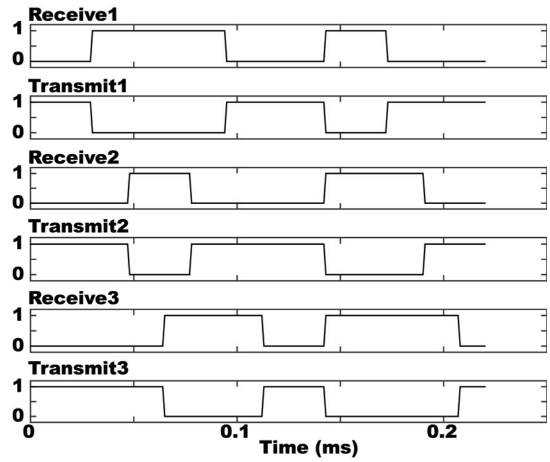

Fig. 5 Simulation results of operation of multistage sing-around sensors.

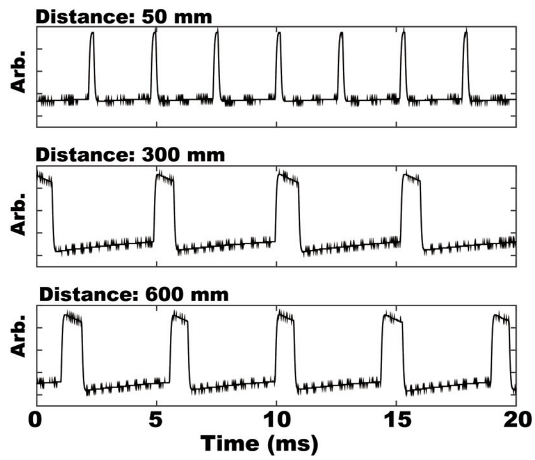

Fig. 6 Detected light wave signal.

References

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