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Study on Identification of People and 3D Position Measurement with Ultrasonic Sensors and Kinect sensors

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Abstract– We are developing a digital game, "Digital SUGOROKU," that enables people to understand vegetation succession. In order to realize this game, it is necessary to robustly measure 3D position of people and identify them. Using ultrasonic transmitter tags with unique identifiers, ultrasonic sensor can measure 3D position and identify tagged people. But the sensor can't measure if there is no receiver in direction of ultrasonic waves from a transmitter. On the other hand, Kinect sensor can measure 3D positions of people and tracking them with OpenNI. But the sensor can't measure if occlusion occurs due to the overlapping people. In this paper, we proposed a method for 3D position measurement and identification of people by integrating ultrasonic sensors and Kinect sensors. The evaluation results show that proposed method is more robust than methods using ultrasonic sensor and Kinect sensor separately.

1. Introduction

In recent years, global environmental problems are becoming serious. Under these circumstances, the environmental education with experience has been more required. Digital game,"Digital SUGOROKU of vegetation succession", that targeted the conservation woodlands as environmental issues have been developed. The game visualizes changes in forest ecosystems in large temporal scales by simulation. Practical study of learning environment has been advanced by using this game [1] [2].

The game is backgammon on the computer screen. An issue of Connection with virtual world and the real world had been left for the learner. Therefor we are developing a new system of the game, "Human SUGOROKU", which enables people to learn vegetation succession more realistic.

In that system, people walk on board which was placed on the floor. That person, made applicable to the plant, can experience the change of pseudo physically planting ecosystem. Figure 1 shows the overview of the system "Human SUGOROKU". The overall size of board is approximately 10m square and the size of a frame is assumed to be 1m square. The number of participants is six. Up to three people may enter in one square.

In order to realize this system, it is necessary to continue to measure the position and to identify them. Specifically, it is necessary the two technologies. First, even if there are some people within one frame which is one meter square, they can be measured position and identified. Second, it is possible to measure positions of people in large space of 10m square.

A method to measure the position has been proposed by using ultrasonic transmitter tags with unique identifiers [3] [4]. But ultrasonic sensors may become unstable due to the measurement of the directivity of the ultrasonic wave. The range which ultrasonic sensor can stably measure transmitter's position is limited. This is a problem because there is a need to measure position stable in a wide range. If we try to realize this system using only ultrasonic sensor, huge amount receivers are required. On the other hand, Microsoft's Kinect sensor can measure the position of the people by the visual information [6]. Therefore the sensor can't measure if occlusion occurs due to the overlapping people. This is a problem because there are 6 people in the game. So we intended to develop a system to measure 3D position of people and identify them if they are in a narrow range by integrating Kinect sensor and ultrasonic sensor to compensate for the weaknesses.

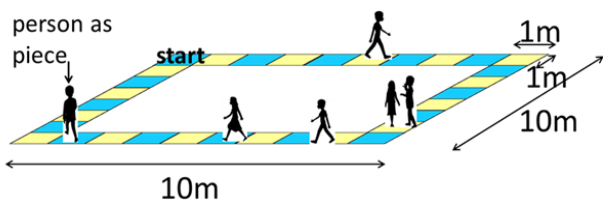


Fig.1 Human SUGOROKU

2. Position measurement and identification of the person

2.1. The identification of the person

Ultrasonic sensor is composed of transmitters, receivers and control unit. Receivers receive the ultrasonic waves emitted from the transmitters. Control unit calculate the three-dimensional position of the transmitters from the time difference until it receives from ultrasound out. Since the transmitters have unique identifiers, ultrasonic sensor can measure positions of people attached transmitters and identify them.

By using the OpenNI which is an open source library, Kinect sensor can get information of depth, and measure three-dimensional position of each part of the human body. In addition, if Kinect sensor recognizes a person, the sensor allocates the ID to the person and does the tracking.

Position of the transmitter attached to the head and position measured by the Kinect sensor as head are the position of the person (Figure 2). If the distance between head positions measured by each sensor is below the threshold, those head positions are assumed same person's position. By identifying the person measured by two sensors, IDs allocated by the transmitter and Kinect sensor match. So it is possible to measure the position of one person in the two sensors. In this paper, the threshold is 300 mm.

2.2. Position measurement of people

Fig.3 (a) shows a configuration system for measuring the position of the person to integrate each sensor. Fig.3 (b) shows the flow of information. The system is composed of ultrasonic sensor, Kinect sensor and two personal computers for handling each sensor. One personal computer that is connected to the ultrasonic sensor is a server. Other personal computer that is connected with the Kinect sensor is Client.

IDs by each sensor are integrated. ID1, ID2 ID3 is allocated like Fig.3 (a). The person of IDi is measured at *(xi, yi, zi)* by the Kinect sensor and is measured at *(Xi, Yi, Zi)* by ultrasonic sensors. In Fig.3 (a), Kinect sensor cannot measure the position of ID2 due to the overlapping people. Ultrasonic sensors cannot measure the position of person of ID3 because receivers are not able to receive ultrasound.

Positions of people and ID information are sent from server PC to client PC by the http communication. The data are acquired by the ultrasonic sensor.At this time, the coordinates measured by ultrasonic sensors convert to the coordinate system of the Kinect sensor. IDi (Xi, Yi, Zi) is converted to IDi (x'i, y'i, z'i). As a result, the position information of each person measured by each sensor is obtained.

If hiding occurs, the ultrasonic sensors measure the position of the people. If ultrasonic wave is not received by receivers, Kinect sensor measure the position of the people. Then it is possible to robustly measure the position of the people. ID2 person is measured the position by the ultrasonic sensor, for example. ID3 person is measured the position by the Kinect sensor.

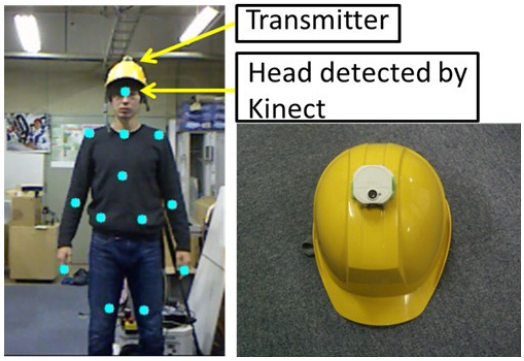


Fig.2 Measuring position

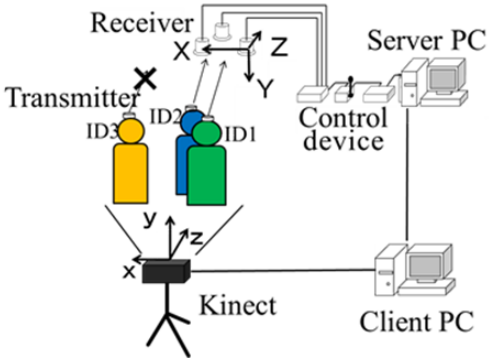


Fig.3 Configuration of measuring system

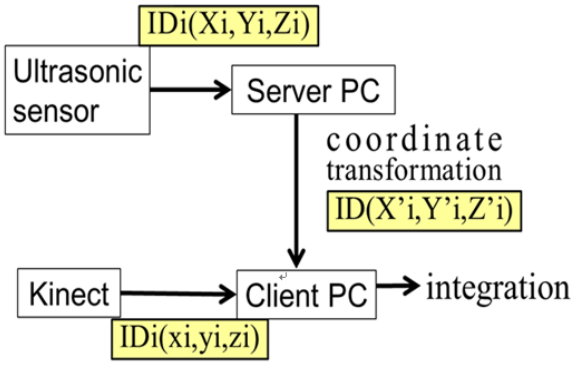


Fig.4 System diagram

3. Experiment

By integrating the sensors, the weaknesses of each sensor are complemented. Then we investigated the stability of the measurement. In preliminary experiments, the position of a person was measured considering the weakness of each sensor. We compared the stability of the measurement by using each sensor separately and the measurement by integrating sensors. In main experiment,

we investigated how much the system can measure position of two people.

Figure 5 shows the experimental environment. Receivers of the ultrasonic sensor were placed on the ceiling. The receivers were arranged such that an equilateral triangle of sides 300mm. Three frames placed on the floor under the receivers. The frames were allocated a number as figure 5 (b). The frames were 1 meter square. There is a center of the frame 2 on the z axis of the ultrasonic sensor. Border line is parallel to axis x and axis y. Coordinate system of the Kinect sensor was rotated 90 degrees counter-clockwise X axis of the ultrasonic sensor and moved in parallel.

3.1. Preliminary experiment

Kinect sensor can't measure if occlusion occurs due to the overlapping people. Ultrasonic sensor can't measure if there are not receivers in direction of ultrasonic waves from a transmitter. Two experiments were performed to account for these.

(1) People attached transmitter to the top of the head moved in frame 1, 2 and 3. Figure 6 (a) shows the experiment method.

(2) An obstacle was put in the frame 2 in front of the Kinect sensor. A person wearing the transmitter to the top of his head moved in the frame 2. Then occlusion occurred. Figure 6 (b) shows the experiment method.

Ultrasonic sensors measured the position of the transmitter attached to the head. Kinect sensor measured the position of the head. Sampling rate is 25Hz and sampling number is 1500. We compared the stability of the measurement by using each sensor separately and the measurement by integrating sensors. In order to make the comparison, we investigated the success rate *S*. *S* is the ratio that the sensors can measure position. Each sensor cannot get value, if it cannot measure position. *S* is shown as in Equation (1)

$$S = (1 - a/b) \times 100 \qquad (1)$$

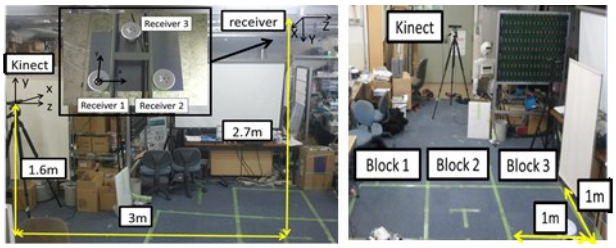
In equation (1), a represents the number of failed measurement and b represents the total number of measurements.

Table 1 shows the result of experiment (1) and Table 2 shows the result of experiment (2). The tables shows success rate *S* by only Kinect sensor, only ultrasonic sensor and the integration of the sensors. In experiment (1), *S* of ultrasonic sensor in frame 1 and 3 is lower than in frame 2. Measurement by ultrasonic sensor may become unstable if a transmitter is away from receivers. On the other hand *S* of Kinect sensor is stable in frame 1, 2, and 3. In experiment (2), S of ultrasonic sensor is stable. On the other hand S of Kinect sensor is unstable due to occlusion occur. But by integrating the sensors in both case, the sensors compensate for the weaknesses of each other, it is possible to measure the position of the person stable.

3.2. Experiment

Two people attached a transmitter on his head moved in the frames of three. They were sometimes hidden from the Kinect sensor due to overlapping. Figure 6 (c) shows the experiment method. Ultrasonic sensors measured the position of the transmitter attached to the head. Kinect sensor measured the position of the head. Sampling rate is 25Hz and sampling number is 1500. Figure 7, 8, and 9 shows the relationship between the sampling number and position of two people in x direction. Table 3 shows *S* by only Kinect sensor, only ultrasonic sensor and the integration of the sensors..

Because receivers cannot receive ultrasonic wave, there is the range which ultrasonic sensor does not measure position well. In addition, there is the range which Kinect sensor cannot measure position of the people due to overlapping. But *S* is higher by integrating the sensor. So it is possible to robustly measure position of two people by integrating the sensors.



(a) (b)

Fig.5 Experiment environment

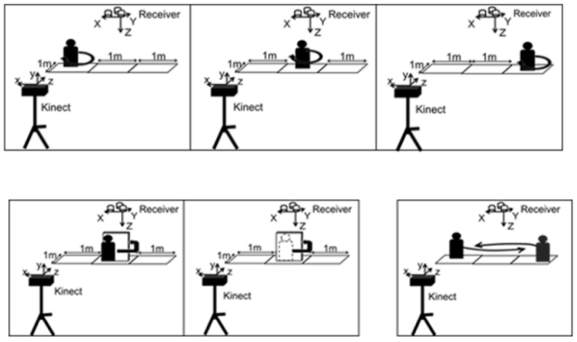


Fig.6 Experiment method

Table 1 Success rate of measuring in each block

Block	Ultrasonic sensor[%]	Kinect[%]	Both sensors[%]
1	76.8	98.2	98.5
2	94.4	98.5	98.6
3	73.4	97.8	98.0

Table 2 Success rate of measuring with obstacle

Block	Ultrasonic sensor[%]	Kinect[%]	Both sensors[%]
2	95.2	46.9	95.6

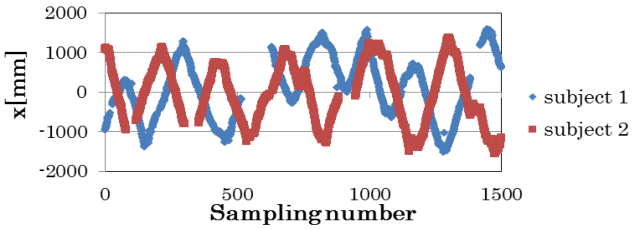


Fig.7 Result of x direction measured by ultrasonic sensor

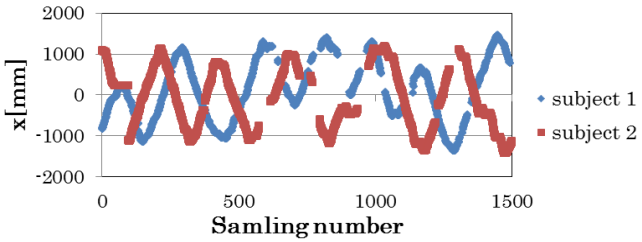


Fig.8 Result of x direction measured by Kinect

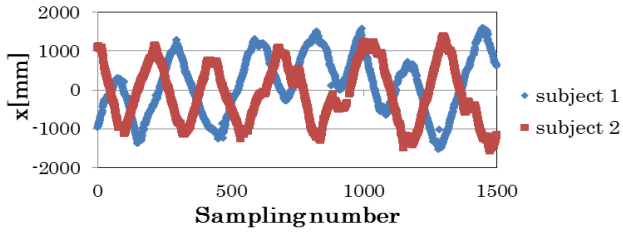


Fig.9 Result of x direction measured by both sensors

Table 3 Success rate of measuring each person

subject	Ultrasonic sensor[%]	Kinect[%]	Both sensors[%]
1	84.1	81.9	95.6
2	85.0	79.2	97.9

4. Conclusion

This paper describes a method for 3D position measurement and identification of people by integrating ultrasonic sensors and Kinect sensors for developing "Human SUGOROKU". Ultrasonic sensor can measure 3D position and identify tagged people. Kinect sensor can measure 3D positions of people and tracking them with OpenNI. Preliminary experiment shows that ultrasonic sensor can't measure if there are not receivers in direction of ultrasonic waves from a transmitter, and Kinect sensor can't measure if occlusion occurs due to the overlapping people. By combining the Kinect sensor and ultrasonic sensors, we made it possible to measure positions of people and identify them. Both sensors measure the position of the heads and identify person by the distance difference. Then it is possible to robustly measure the position of the people. When people are dense, ultrasonic sensors measure the position. When ultrasonic wave is not received, Kinect sensor measures the position.The experiment results show that the proposed method is more robust than methods using only ultrasonic sensor or only Kinect sensor.

The proposed method robustly measure position of people in three squares. In the future, in order to realize "Human SUGOROKU", we will extend this system. We will develop a system which can measure the positions of people and identify them in a wide range of approximately 10 meters squares.

Acknowledgments

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