A Route Guiding System for Visually Impaired Persons using a Hyper-directional Speaker

Yohei Hishida, Makoto J. Hirayama
Graduate School and Faculty of Information Science and Technology
Osaka Institute of Technology, Osaka, Japan
m1m16a16@st.oit.ac.jp
makoto.hirayama@oit.ac.jp

***Abstract*—In museums, universal designs for visitors including visually impaired persons are required. We are now developing an audio guide for visually impaired persons visiting a museum, both for hearing explanations of exhibits and for guiding his/her walking. To avoid unnecessary noises for other visitors, hyper-directional audio speakers are used. Thus, guiding audio sounds can be heard only in a small area where the target user stands. In our new system, when the target user is walking, the system rotates speaker directions for the user to continue hearing especially for route guide audio. Tracking the user's position is done by using a Kinect sensor. With our proposed system, visually impaired persons can enjoy museum tours by themselves.**

Keywords— route guiding system; visually impaired persons; hyperdirectional speaker; human movement recognition; Kinect sensor

I. Introduction

As the United Nations General Assembly prescribes in the Convention on the Rights of Persons with Disabilities, reasonable accommodation for visually impaired person is an important issue for public services in Japan [1]. However, in other research, there is a research result that accessibility is not considered for the visually impaired [2]. Currently, various systems are being researched for visually impaired person [3][4][5]. We are trying to make assisting systems for visually impaired persons using image and audio processing technologies. In this research, we make a route guiding system for visually impaired persons visiting to museums or other public facilities. A hyper-directional speaker and a Kinect image sensor are used to radiate guiding audio sounds only to a target user who needs the guide.

II. System Design

A. System Overview

Hyper-directional speakers are used in our proposed system. Directionality of the speaker is very narrow, thus it is suitable to play sounds only in small area. It can be used to play audio guide in front of an exhibits without interference to neighbor exhibits. In our previous system [6], the speaker was used to present realistic sounds from exhibition objects. In current research, it will be used not only for audio guide of exhibits but also for route guiding for visually impaired persons.

Fig. 1 shows our proposed system. A Kinect sensor with our developed software detects a target user position. When the target user is found, route guiding audio sounds are radiated from a hyper-directional speaker. The speaker is mounted on a stepping motor equipment. If he walks and moves, the system follows the position and rotates the direction of the speaker toward the user's position.

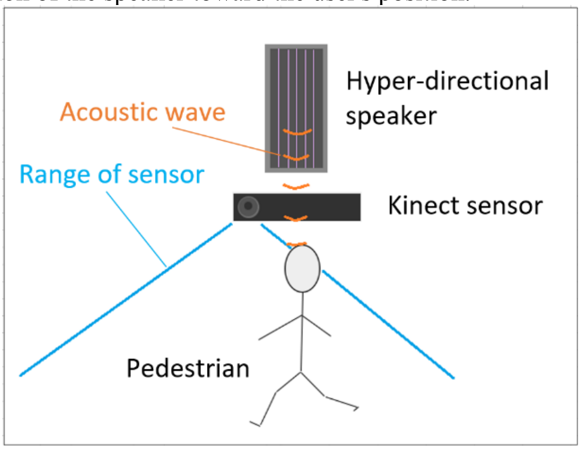

Fig. 1. A route guiding system in a museum for visually impaired persons.

B. Software and Hardware Development

Software for the system was developed in C++ with Kinect SDK in Windows environment. Detecting human position and tracking can be used withe Kinect SDK. According to the human position, control signals to a stepping motor which rotates the speaker direction are calculated and sent to the motor equipment through a D/A converter board. The speaker mounting equipment with a stepping motor are designed and developed by ourselves.

III. Parts Used

A. Hyper-directional speaker

In hyper-directional speakers, the directivity of sounds sent out is narrower than that of general cone type speakers. The beam direction is straight without spreading. Thus, the sound does not spread around, it can be delivered to a specific

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person. The attenuation of the sound pressure is small even if the distance is extended because ultrasound is used for voice transmission. Fig. 2 shows the hyper-directional speaker used this time.

Fig. 2. Hyper-directional speaker (HSS-3000[7])

B. *Stepping motor*

The direction of the hyper-directional speaker needs to be accurately adjusted to the pedestrian. Thus, a stepping motor characterized by precise rotation angle was used. Fig. 3 shows a stepping motor with a size of 42 mm, 200 steps per rotation used this time. Thus, one step is 1.8 degrees from 360 degrees / 200 steps.

A permanent magnet of N pole and S pole is incorporated inside the motor, and this magnet is the rotation axis. In addition, there are a plurality of coils around the magnet, and DC current is sequentially flown to each of them. The coil through which the current flows becomes an electromagnet, attracting the N pole of the permanent magnet and stopping at the position where the coil exists. When a current flows through another coil, the permanent magnet is attracted and the rotational position changes. By repeating these sequences, the rotation of the motor is realized, and it is possible to precisely control the rotation angle.

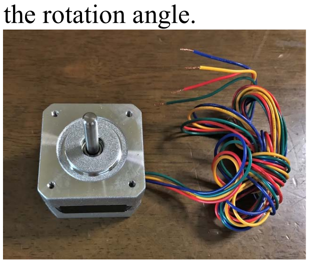

Fig. 3. Stepping motor (SM-42BYG011[8])

C. *Motor control by Arduino and motor driver*

A stepping motor was controlled by using motor driver (Fig. 4).

Fig. 4. Motor driver (L6470[9])

By using the driver, it is possible to change the current flowing through the coil in the stepping motor in detail. Thus, a larger number of steps can be secured than the original number of steps of the stepping motor, and smooth rotation can be realized.

Arduino Uno R3 was used to send signals to the driver [10]. Fig. 5 shows Arduino Uno R3 used.

Fig. 5. Arduino Uno R3

Arduino is connected to the computer. And dedicated software controls Arduino.

Arduino, driver and stepping motor are connected as shown in Fig. 6.

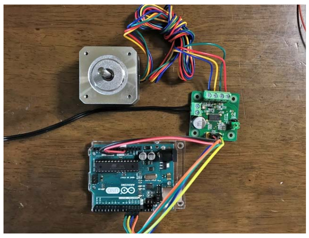

Fig. 6. Connection of each device

D. *Kinect sensor*

Kinect has a color camera, an infrared sensor, a microphone, etc. It is possible to recognize the movement, position, and voice of a person. In this our system, the 2nd generation Kinect sensor (Fig. 7) is used.

Fig. 7. Kinect sensor (Microsoft[11])

IV. SYSTEM DEVELOPMENT AND DESIGN

A. *Acquiring position coordinates of skeleton information*

In order to match the rotational position of the stepping motor with the human head, we obtain the position coordinates of the head from the skeleton information from "JointType.Head" in the Kinect library.

In addition, the data immediately after acquisition are the camera coordinate system. Thus, the camera coordinate system is converted into the Depth coordinate system by the "MapCameraPointToDepthSpace" method.

Fig. 8 shows conversion of the coordinate system. And Fig. 9 shows a pattern diagram of conversion of the coordinate system.

```
var point = kinect.CoordinateMapper.MapCameraPointToDepthSpace(joint.Position);
```

Fig. 8. Conversion of the coordinate system

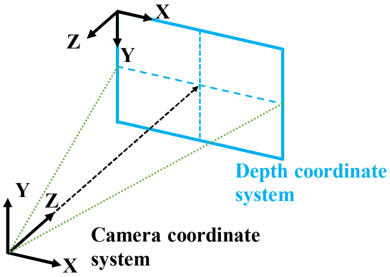

Fig. 9. A pattern diagram of conversion of the coordinate system

B. *Using the SerialPort class*

X coordinate data is sent to Arduino by "Serial Port" class. And Arduino controls the stepping motor based on the X coordinate data.

Arduino is connected to port number 3 in the environment of this computer. Thus, programming was performed in Kinect side, as shown in Fig. 10.

```
SerialPort mySerialPort = new SerialPort("COM3");
mySerialPort.BaudRate = 115200;
```

Fig. 10. Using the SerialPort class

C. *Calculation of step number of stepping motor*

The stepping motor has 200 steps per rotation, one step is 1.8 degrees from the calculation of 360 degrees / 200 steps. In this research, half step mode was used in order to smooth rotation operation. In half step mode, the angle of one step is half of that in the standard full step mode. Thus, one step is 0.9 degrees from the calculation of 1.8 degrees / 2.

Next, in Arduino, coordinate data sent to the serial port by the kinect program are acquired by "Serial.read ()". The acquired X coordinate data have been converted to the Depth coordinate system corresponding to the horizontality resolution of 512 pixels. Kinect's horizontality angle of view is 70 degrees. From this, it can be determined that the angle per pixel is 0.13671875 degrees from the calculation of 70 degrees (horizontal angle of view) / 512 pixels (horizontal resolution).

In addition, the number of steps this time can be obtained from the calculation of 0.13671875 degrees (angle per pixel) / 0.9 degree (angle of one step). However, errors due to plane and curved surfaces are not considered at this time.

For example, if the value of the X coordinate is 100 pixels, it will be 13.671875 degrees from the calculation of 0.13671875 degrees * 100 pixels to find the angle per 100 pixels. In addition, the number of steps this time can be obtained as 15.1909722 ≈ 15 steps from the calculation of 13.671875 degrees / 0.9 degrees. TABLE 1 shows an example of step number calculations.

TABLE I. EXAMPLE OF STEP NUMBER CALCULATION

pixel X	Rotation Angle(degree)	Number of steps	Number of steps(Integer)
0	0	0	0
16	2.1875	2.430555556	2
32	4.375	4.861111111	5
64	8.75	9.722222222	10
128	17.5	19.44444444	19
256	35	38.88888889	39
512	70	77.77777778	78

D. *Connecting devices*

Fig. 11 shows the connecting devices.

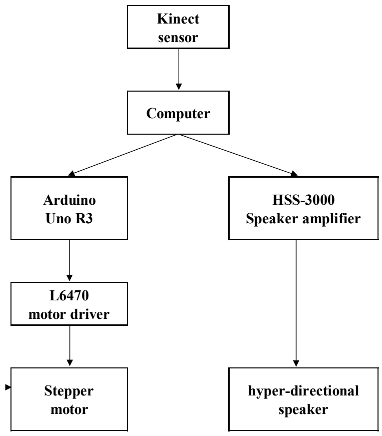

Fig. 11. Connecting devices

V. ATTACHING SPEAKER TO STEPPING MOTOR

There are plural fixing screws on the backside of the hyper-directional speaker, fixation with the stepping motor was performed using the metal fitting as shown in Fig. 12.

Fig. 12. Fixed by the bracket

Fig. 13 and show the fixed state.

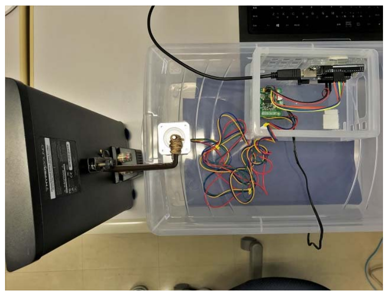

Fig. 13. Fixing of stepping motor and speaker

Fig. 14 shows a pattern diagram of rotation angle calculation.

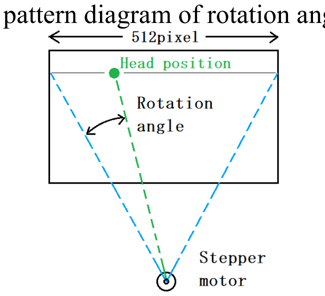

Fig. 14. Calculation of rotation angle

VI. USING THE SYSTEM

A. Experiments

We conducted experiments to listen to voice guidance while walking. The produced system is installed at a height of about 160 cm and a pedestrian crosses the front from left to right. About the guidance voice, I used the voice "Seminar room is here". In this research, a normal student became a subject. Fig. 15 shows the setting of the experiment.

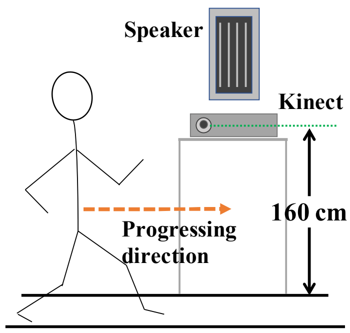

Fig. 15. The setting of the experiment

B. Experimental result

As an experimental result, it was confirmed that the rotational position of the stepping motor fluctuated according to the change in the position coordinates of the person. Moreover, while the direction of the speaker followed the subject, we confirmed that the voice guidance that "Seminar room is here" is sent by hyper-directional speakers.

C. Evaluation

From the opinion of the subject such as " Sound is clearly heard " and the experimental result, we recognize that the conversion of the position coordinates detected by kinect and the rotational position of the motor were done correctly.

D. Future works

However, in this research, we limited the guidance to cross the front of the Kinect sensor from left to right, so the same guidance was given to the subjects even if the subjects advanced in the opposite direction.
Also, it was only voice guidance such as "Seminar room is here".

From these facts, we recognize that it is necessary to realize detailed voice guidance such as "It is the opposite direction" or "It is 10 meters away", recognizing the change of position coordinate of the person.

Next, the subject was a normal student. We recognize that our proposed system needs to be evaluated for accessibility by visually impaired persons. Experiment with visually impaired persons will be done.

VII. CONCLUSION

We produced a voice guidance system in which the direction of the speaker follows the pedestrian and conducted experiments with a normal student.

We are currently improving and developing to create a voice guidance system that is easy for visually impaired people.

When our system will be used in museums or other public facilities, it will contribute to increase accessibility for visually impaired persons.

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