A Supporting System of Chorus Singing for Visually Impaired Persons using Depth Image Sensor

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Abstract— **This paper provides a study on a supporting system of chorus singing for visually impaired persons. This system is composed of an electric music baton with an acceleration sensor, a radio module, haptic interface devices with vibration motors, depth image sensor and a PC. An electric music baton transmits a signal of a conductor's motion to visually impaired players based on an acceleration of the sensor. Since a conductor has to give individual instruction to a target player, we use a depth image sensor in order to recognize the pointing direction of a conductor's music baton. The pointing direction of a conductor's music baton is estimated based on the conductor's posture. The effectiveness of our system is clarified by several experimental results.**

I. Introduction

There are many social hobby clubs for senior citizens or people with disabilities to create the "motivation for living" in Japan. One of popular hobby clubs is a chorus singing club because it does not require special skills or musical instruments. However the visually impaired persons might be difficult to participate in the chorus singing group because they cannot recognize the rhythm based on the motion of the conductor. There are only a few chorus singing groups in which visually impaired persons sing with able-bodied persons. The chorus singing group of Kanagawa Light Center [1] has been tried various methods such as getting into the rhythm using castanets or pairing a visually impaired person with an abled-bodied person in order that the visually impaired person sing a song in time to the motion of the conductor. The authors have been developed a supporting system of chorus singing for visually impaired persons [2]-[5]. This system is composed of an electric music baton with an acceleration sensor, a radio module, haptic interface devices (HIDs) with vibration motors, depth image sensor and a PC. An electric music baton transmits a signal of conductor's motion to visually impaired players based on an acceleration of sensor. The visually impaired person receives the information of the rhythm based on the motion of the conductor's baton using the vibration of the HID which is attached to the player's wrist. The similar electric music baton system was developed by Hiraiwa [6]. In this system, an oscillator array was attached to the upper arm of the player. Since this system transmits the rhythm information to the player using the oscillator array, some trainings for the player were needed to recognize the rhythm information properly. On the other hand, our system can transmit the rhythm information to the visually impaired person accurately using the HID which is attached to the player's wrist. There have been numerous studies on HIDs [7]-[9], and we used a vibration motor that could be easily obtained.

Since a conductor has to give individual instruction to a target player, we use a depth image sensor in order to recognize the pointing direction of a conductor's baton. The pointing direction of a conductor's baton is estimated based on the positions of a conductor's both shoulders.

This paper is organized on the following way: The concept of this supporting system is explained in section II. Section III explains on the recognition methods of the rhythm and pointing direction and Section IV describes the experiments and the experimental results. Conclusions and future plans are discussed in Section V.

II. The Concept and System Structure

The concept of our supporting system of chorus singing for visually impaired persons is shown in Fig.1. This system provides the two kinds of information which are rhythm of the motion of the conductor and the direction of conductor's indication to the visually impaired players. This system is composed of an electric music baton with an acceleration sensor, a radio module, haptic interface devices (HIDs), a depth image sensor and a PC. The rhythm is obtained by the acceleration of the baton's motion. The pointing direction is obtained by the conductor's posture. The conductor's posture is estimated based on the depth image of the conductor. The visually impaired players recognize the rhythm and the pointing direction based on the vibrations of HIDs.

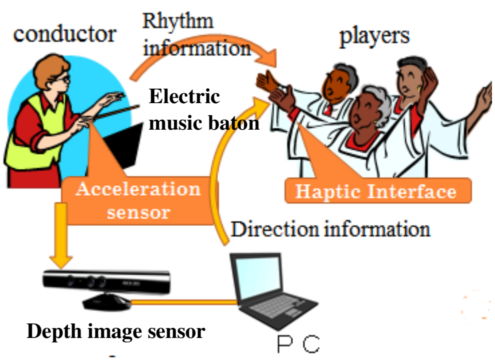
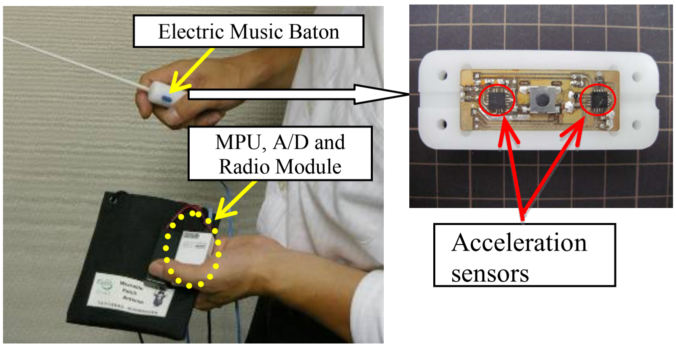


Fig. 1 The concept of our supporting system

The detail explanations of the elements of our system are shown below.

Electric music baton

We developed the electric music baton equipped with two three-axis acceleration sensors in the baton's grip. The acceleration sensor gets the acceleration of baton's motion at intervals of 10[ms]. The transmitter sends the acceleration data to the receiver. The transmitter is composed of the MPU, A/D converter and the radio module. The data logger (2.4 GHz, ASAP Systems Corporation) was used for the transmission module [10]. The electric music baton and the transmitter are shown in Fig.2. The right side of the Fig.2 shows the inside of the baton's grip.



(a) Overview (b)Inside of the baton

Fig. 2 Electric music baton and the transmitter

Haptic Interface Device (HID)

The visually impaired player wears the HID and the receiver to get the information from the electric music baton. The HID has the two small vibration motors which are used for the mobile phone. The one motor of the HID gives the rhythm and the other of it gives the pointing directional to the players based on the vibrations. The receiver is composed of the MPU, a motor driver and a radio module. The HID and the receiver are shown in Fig.3.

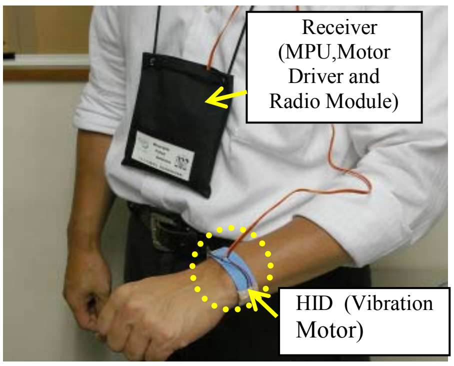
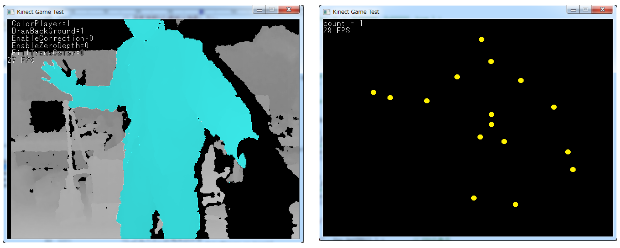


Fig. 3 HID and receiver

Depth Image Sensor

We use the depth image sensor KINECT (Microsoft Co.ltd) [11] to recognize the pointing direction of the conductor's indication. Since the KINECT is a motion capture device using the infrared projector, the posture of the person is obtained directly. The KINECT has a tracking function to get the twenty feature points of the human body. The example of the depth image and the feature points of the person of the skeleton tracking image are shown in Fig.4.



(a) Depth Image (b)Skeleton Tracking Image

Fig. 4 Depth image and the feature points of human body

The signal flow of the system is shown in Fig.5. The rhythmical signal which is obtained by the acceleration of the motion of the conductor's baton is sent to the receiver of the player. The player can recognize the rhythmical signal by the vibration of the first motor of the HID. The directional signal which means the pointing direction of the conductor's instruction is estimated based on the conductor's posture. Since the frame rate of the depth image data of the KINECT is 30 fps, the transmitter 1 sends the directional signal to the receiver at 33 [ms] intervals. The player who is indicated by the conductor can recognizes the directional signal by the vibration of the second motor of the HID.

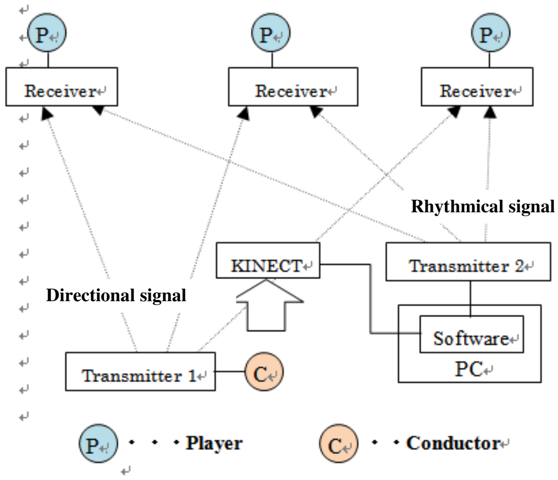
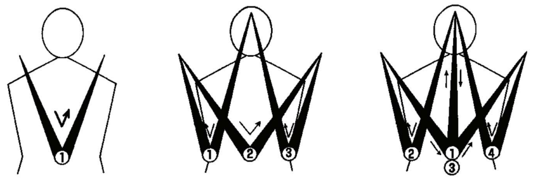


Fig. 5 Signal flow of the system

III. Recognition Method of the Rhythm and Pointing Direction

Recognition method of the rhythm

The conductor keeps beat time with the conductor's baton. We assumed that the conductor beats the simple rhythms which are shown in Fig.6. As shown in Fig.6, the feature points of the trajectory of the baton's motion are the lowest positions of it. The rhythm of the conductor's baton is estimated based on the feature points of the trajectory of the baton. As shown in Fig.7, the position of the maximum accelerations of the Z-axis is the feature points in the trajectory of the baton's motion. The rhythm of the baton's motion is determined by the jerk which is calculated by the accelerations of the Z-axis of the acceleration sensor [10],[11]. As shown in Fig.8, the jerk signal has several peaks according to the feature points of the trajectory of the baton's motion.



(a)simple duple (b)simple triple (c)quadruple

Fig. 6 Trajectories of the baton's motion

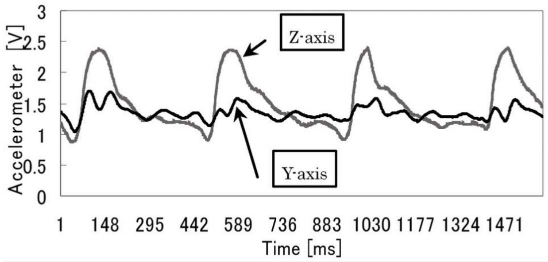


Fig. 7 Accelerations of the baton's motion

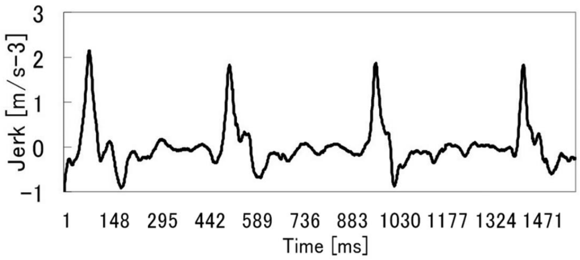


Fig. 8 Jerk of the baton's motion

<u>Recognition method of the pointing direction</u>

Since the chorus singing is organized of several parts of singing such as the alto or the soprano, the conductor has to indicate the instruction of the singing separately using the music baton. In our system, the singing part which is indicated by the conductor is determined based on the conductor's posture. The conductor's posture is estimated by the tracking function of the depth image sensor. The depth image sensor has a tracking function to get the twenty feature points of the human body such as a head or shoulders or elbows. We use the positions of both shoulders in order to determine the pointing direction of the conductor. As shown in Fig.9, the pointing direction of the conductor is the angle which is composed of the line connected the points of both shoulders and the Z-axis of the KINECT. The formulation of the angle θ is shown in (1).

$$\theta = \tan^{-1}\left(\frac{Lx - Rx}{Lz - Rz}\right) \qquad (1)$$

(Lx,Ly): Position of Left Shoulder
(Rx,Rz): Position of Right Shoulder

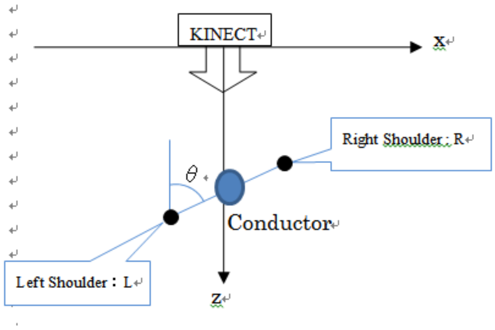


Fig. 9 Pointing angle of the conductor

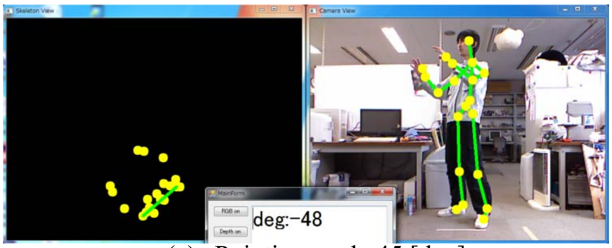
IV. Experiments and Experimental Results

The system was assessed by few experiments.

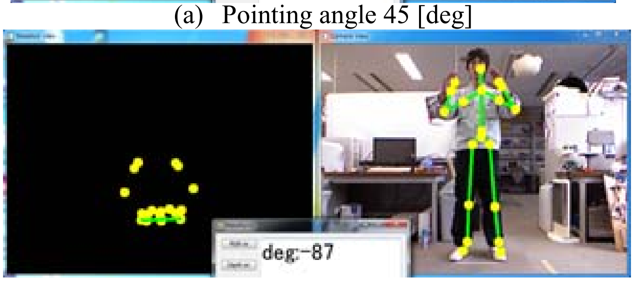
<u>Recognition test for conductor's pointing direction</u>

With this set of trials we aimed to explore the recognition accuracy of the conductor's pointing angle using the depth image sensor. In this experiment, system calculates the pointing angle of the conductor. The conductor turns to the nine kinds of directions between 0 [deg] and 180[deg] at 22.5[deg] intervals. The distance from the KINECT to the conductor is 220[cm].

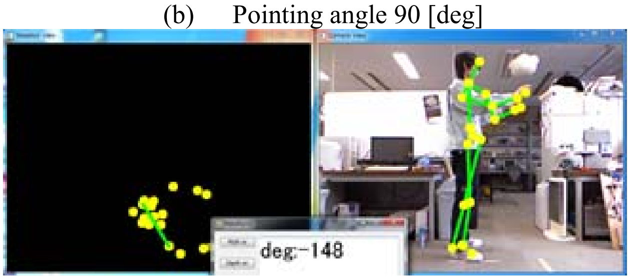
The examples of the tracking image of the conductor are show in Fig.10(a)-(c). The left images of the Fig.10(a)-(c) show the line which is connected the both shoulders of the conductor. The calculated angles are the absolute values.



(a) Pointing angle 45 [deg]



(b) Pointing angle 90 [deg]



(c) Pointing angle 180 [deg]

Fig.10 The examples of the conductor's pointing direction

Fig.11 shows the experimental results of the conductor's pointing direction. As shown in Fig.11, we considered that the effective range of the conductor's pointing angle is between 20[deg] and 150[deg]. The reason of the failure to understand the angle was that the positions of conductor's both shoulders were not recognized by the KINECT.

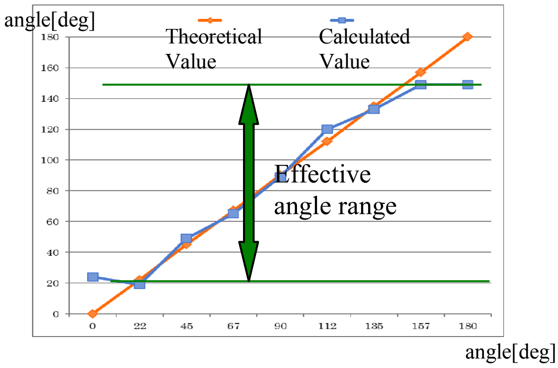


Fig.11 Experimental results of conductor's pointing angle

Performance test

We conducted a performance test to evaluate the recognition of the conductor's pointing person. Three subjects without physical disabilities (aged from 21 to 23 years, men) are participated in the test. In the test, all subjects close his eyes. The conductor keeps 104 times of simple double beat for a target subject using an electric music baton. The system calculates the pointing direction of the conductor and sends the vibration signal to the target subject. When the subject felt the vibration from the HID he holds out his right hand. The scene of the performance test is shown in Fig.12. Each subject was tested two times.

The recognition rates which mean the accuracy rates of the pointing direction of the conductor are shown in Table 1. The average accuracy rate of the pointing direction of the conductor is 78.0[%]. The reason of the failure to understand the direction was that the subject did not feel the vibration of HID.

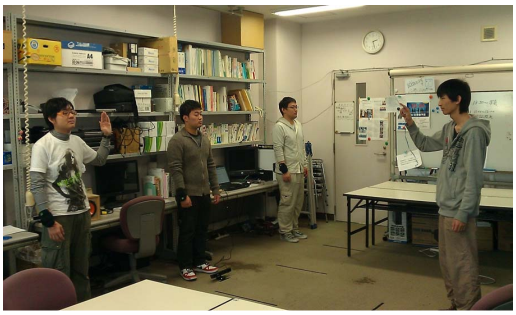


Fig.12 Scene of the performance test

Table 1 Recognition rates of the performance test

Subjects	1 st [%]	2 nd [%]	Average[%]
A	74.0	87.0	80.5
B	67.3	78.8	73.1
C	76.9	83.7	80.3
Average	72.7	83.2	78.0

V. CONCLUSIONS

We developed the supporting system of the chorus singing for visually impaired persons. This system is composed of an electric music baton with an acceleration sensor, a radio module, haptic interface devices, depth image sensor and a PC. Since a conductor has to give individual instruction to a target player, we use a depth image sensor in order to recognize the pointing direction of a conductor's music baton. The pointing direction of a conductor's music baton is estimated based on the positions of a conductor's both shoulders. The effectiveness of our supporting system was clarified with several experiments. The effective range of the conductor's pointing angle using the depth image sensor is between 20[deg] and 150[deg]. The average accuracy of the pointing direction of the conductor is 78.0[%]. The experiments gave us a new practical experience and design ideas for improvement. In our future work, we intend to explore further the practicality of the system by various experimental scenarios.

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