Transfer of Synchronized Signal using Haptic Interface

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***Abstract*—We propose a method for using a haptic interface for vision or hearing to present alternative information to a disabled person. Till date, an acceleration sensor, wireless transfer equipment, and equipment using a vibration device have been developed. This paper describes the transfer of information, employing the characteristic efficiently, using a linear vibration actuator as the vibration device. The objective is to transmit the accent of the first beat of an important rhythm by music. In this study, a method for combining two vibration frequencies and its dependence on a vibration pattern are verified by experiment. Consequently, a method depending on a vibration pattern is adopted, the verification experiment is conducted, and the same characteristic as the case where vision is used is acquired.**

***Keywords*—Human interface, Haptic interface, Assistance of disabled person**

I. INTRODUCTION

Musical lessons are important for the development of sentiment in children. In recent years, in addition to musical lessons, at the level of elementary school education in Japan, lessons in dance have also became a required subject. The important component common to music and dance is rhythm. The most fundamental aptitude is to unite the whole rhythm. In music, a conductor plays the role of leading the whole rhythm, and in a dance performance, they unites the rhythm by uniting it with music.

However, when the vision or hearing is impaired, it is difficult to conduct a performance together with a healthy participant. Because the motion of the baton of a conductor cannot be recognized by vision when a visually impaired person participates in a musical performance, it is difficult to unite a rhythm overall. Moreover, because the music for uniting a rhythm cannot be recognized by hearing when a hearing-impaired person participates in a dance, it is difficult to unite the rhythm by depending on the vision during an intense motion. Therefore, distinct consideration and correspondence are required to overcome this impaired. Thus, it is still possible for a few pirouettes to be performed by the disabled and healthy participants together. Thus, advancements are being made in the research of a system that transmits a rhythm with an alternative haptic interface for people who have impaired vision or hearing.

We investigated first the manner in which a visually impaired person and a person with normal eyesight could participate in a musical performance together. In this study, visually impaired persons of the Kanagawa Light Center participated in a chorus circle. Methods for uniting with a practice stage producing the sound of castanets and sending a signal from a nearby source were considered for a pair composed of a visually impaired person and healthy participant. However, in the act in front of the audience, the stage from which the castanet sound was produced could not be used. Furthermore, every method of the conductor had an unreasonable gap, also producing a signal from the nearby source. Moreover, although the conductor knew the method for using black clothes and a white glove, in the Hiroshima Central School for Special Support for the disabled with a weak eyesight, the students who were completely visually disabled could not do the correspondence.

To overcome the abovementioned difficulties, we have studied an electric music baton system that transmits the baton movements of a conductor via a haptic interface device (hereinafter, a HID) [1-5]. In the study, accelerometers were built in the baton of the conductor so that acceleration data could be transmitted to the performers using radio waves. Characteristic movements of the baton of the conductor were extracted from the received data and transmitted to the performers via the HID on their wrists. Hiraiwa et al. studied a similar system [6] in which the performers wore an array of Vibrators on their arms. However, the arm proved inferior to the hand or wrist in terms of its perceptive sensitivity, so that the performers needed a certain degree of training before they could appropriately understand what they were supposed to do. In comparison, the signals from the electric music baton system developed by us in the previous study had a relatively high ability to be perceived by the HID worn on the wrist, and so the HID was not so obvious to the audience. There are numerous previous studies on HIDs [7-11]. In this study, we similarly used vibration motors, which were non-invasive and easy to put on and remove. Moreover, when using music, the transfer of the accent of the rhythm is important together with the synchronicity of time. Then, we also proposed a presentation method for the accent by the HID.

In this paper, we overview our studies on musical time synchronization and the transmission of strength. Subsequently,

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in the study, we experimentally verify the effectiveness of our developed system using tactile sense as an alternative interface for vision.

II. Electric Music Baton Sysytem COnfigurations

A. Common Method of Directing

Generally, the command used in the field of music is one that unifies it to the performance by a set [12]. The most important part of musical direction is presenting the beats. A conductor communicates different beats to the performers by the movements of the baton. "down-beats", "moving focal points", and "scoops" can be recognized based on how the baton is shaken. A part of this is to convey the number of beats by the direction in which the baton is shaken, and the timing of the rhythm changes the direction of the baton at a stretch. Particularly, for the first beat, the timing is as important as the accent of a rhythm. Therefore, using a metronome an equipment was devised so that sound could be changed and understood clearly. A motion of "moving focal points" is shown in Fig. 1.

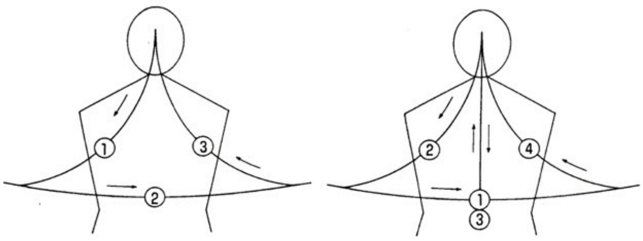

Fig. 1. Conduting technique of “moving focal points”.

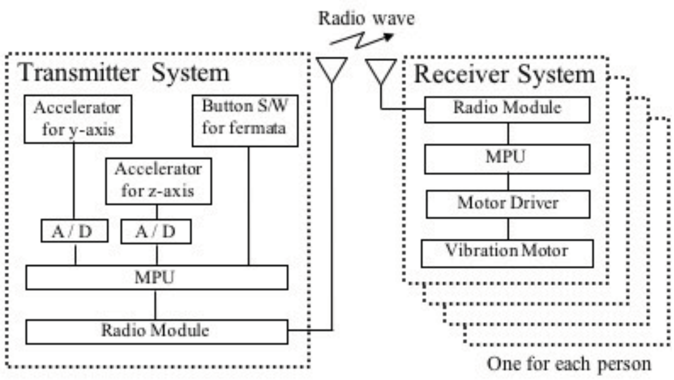

Fig. 2. System dialog of electric music baton.

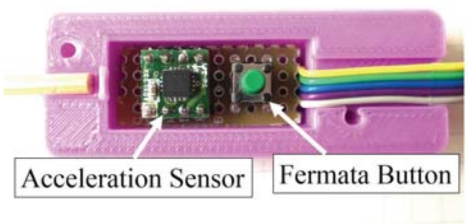

Fig. 3. Inside of the erectoric music baton.

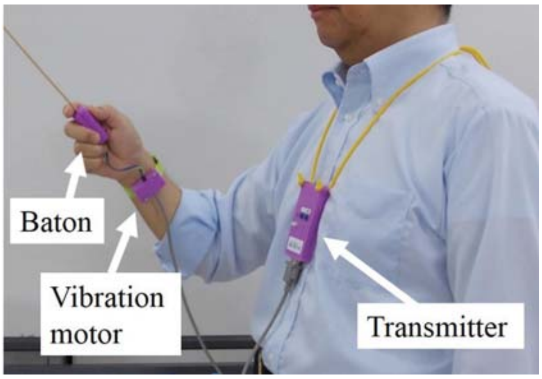

Fig. 4. External view of transmitter system.

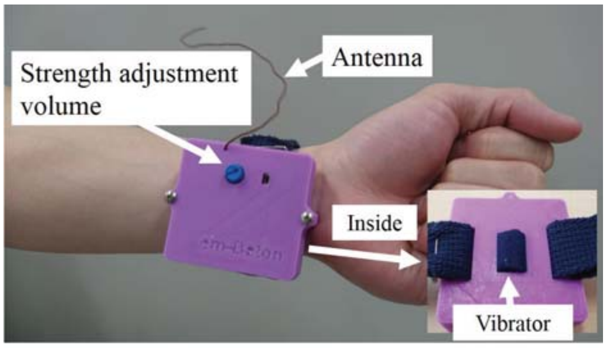

Fig. 5. External view of receiver system.

B. Overview of System

The electric music baton system consists of a transmitter system for the conductor and a receiver system for the performers, as shown in Fig. 2. The baton movements of the conductor are captured by the accelerometers built in the transmitter system and transmitted to the receiver system on the side of the performers. Subsequently, the receiver system extracts the beats and vibrates the motors. The performers receive the instructions of the conductor by the motor vibrations. The transmitter system has accelerometers built-in the baton of the conductor, as shown in Fig. 3, to measure the baton movements at a 1-kHz sampling rate. The accelerometers built in the baton are model ADXL330 accelerometers from Analog Devices. Fig. 4 presents the overall view of the transmitter system. The baton of a conductor should be sufficiently light for any conductor to be able to use it for a long time; therefore, we separated the radio device from it.

The receiver system uses linear vibration actuators, the type commonly used in wearable terminals, as the transmission devices. The following clause explains the characteristic of linear vibration actuators. A part of the wrist is equipped with this vibrator. Although for a vibration, the receptive skills of the fingertip and high palm are useful, we decided to equip the high wrist with the vibrator because of advantages such as being able to hide it in the clothes. Therefore, it is expected to be seldom conspicuous on the stage at the time of a performance. Fig. 5 shows the equipped device and the in-built vibrating motor placed at the mark.

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C. Extraction of Baton Movements of the Conductor

The baton movements of the conductor or beats are extracted by the triaxial accelerometers built in the baton. The X-, Y- and Z- axes of the accelerometer indicate the back and forth, left and right, and up and down movements of the baton of the conductor, respectively. In the "downbeats," the baton of the conductor' is moved up and down and left and right, and not back and forth. We, therefore, do not use any output on the X-axis, but only outputs on the Y- and Z-axes. The accelerations of the bat conductor can be obtained from Equation (1) as a size of the synthetic vector of Y- and Z-axes.

Next, the beat timing is extracted to obtain jerk j (differentiated accelerations) from Equation (2). Fig. 6 shows an example of the actual data from the accelerometers, and Fig. 7 displays the jerk data as an operational result. The jerk data are so clearly peaked in accordance with the baton movements of the conductor that these peaks are extracted as beat timings.

$$\alpha = (A_y^2 + A_z^2)^{1/2} \qquad (1)$$

$$jeak = (\alpha_n - \alpha_{n-1}) / h \qquad (2)$$

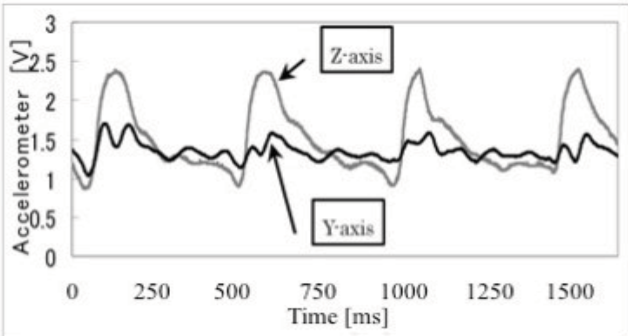

Fig. 6. Acceleration data from Y- and Z – axes.

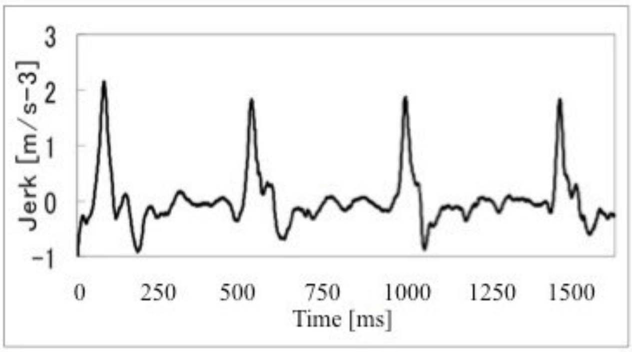

Fig. 7. Operational result data(jeark data).

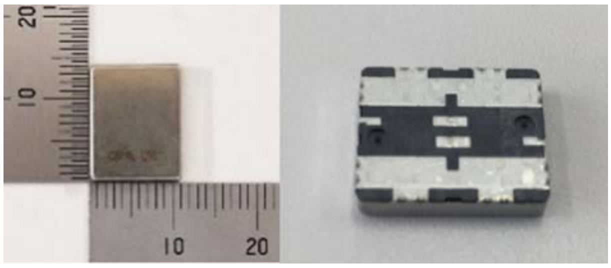

Fig. 8. View of linear vibration actuator.

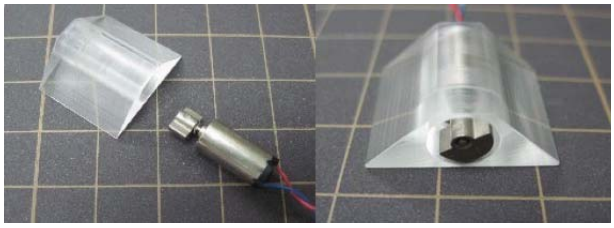

Fig. 9. View of vibration motor.

D. Haptic Interface Device

The electric baton system that we have developed uses linear vibration actuators (LD14-002 from NIDEC COPAL, Japan), as illustrated in Fig. 8. In addition to the vibration motors, the HID includes pin-type devices, used in already widely accepted electronic Braille devices or haptic displays and in invasive electrode probes. Our system is intended for use by numerous individual performers with one conductor. Moreover, the performers of the abovementioned chorus requested that such a device be easily and continuously available at the lowest possible price. Therefore, we decided to use an eccentricity type vibration motor (VM-612 from S.T.T, Japan) as shown in Fig. 9, commonly used in cell phones and smart phones. Because the system was controllable only by the ON–OFF control of the vibrating motor, it could be made simple, but some problems still existed. First is the problem of the time taken for a vibration to occur. The acceleration sensor is attached to the vibrating motor and confirms the state of the voltage seal-of-approval and that the generated vibratings are measured by the oscilloscope, as displayed in Fig. 10. We attempted to find an approach for setting the seal-of-approval voltage value in two steps, similar to the right of Fig. 10. We also tried to obtain the method for testing the seal-of-approval of the bias voltage beforehand, similar to the left of this Fig., in a previous research to shorten the time for the vibrating generation. However, it was difficult to perform this below 20 ms, i.e., for the time required for the vibrating generation as the time for synchronization, we referred to the preliminary experiment. Then, we decided to adopt the linear vibration actuator, which began to be used at a wearable terminal. The linear vibration actuator is set by the frequency of the pulse signal. The internal weight moves, and the vibration is generated by setting a stopper. The acceleration sensor is attached to the linear vibration actuator, and it confirms that the input pulse signal and state of the vibrating generation were measured by the oscilloscope, as shown in Fig. 11. It unites with an input pulse, and a vibration occurs below 1 ms, satisfying the requirements of this study.

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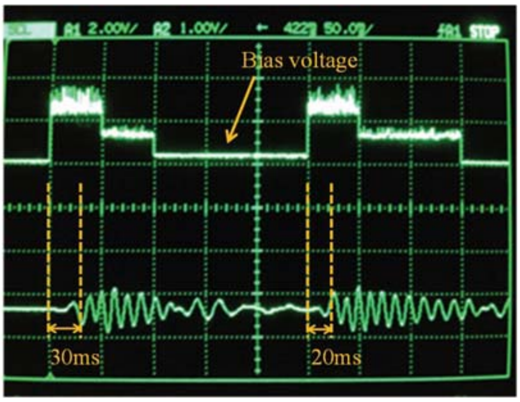

Fig. 10. Improvement of the rise-up time by voltage control.

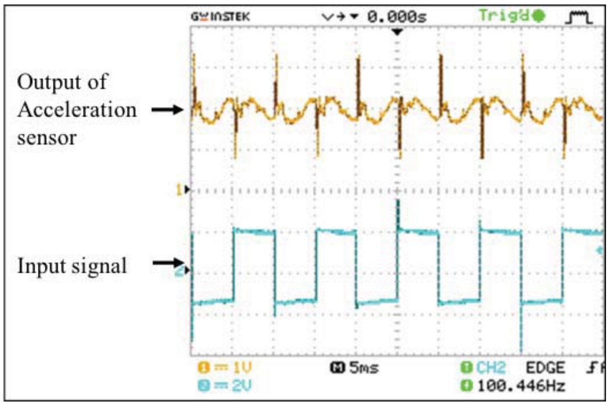

Fig. 11. State of an input pulse signal and the vibration outbreak.

III. EXPERIMENT OF HAPTIC SENSE USING LINEAR VIBRATON ACTUATOR

A. Experiment on vibration frequency discerment

1) Objective of the Experiments: The linear vibration actuator generates a vibration corresponding to an input pulse. Therefore, it is possible to achieve variable vibration frequencies with a pulse frequency. Then, to investigate the possibility of transmitting the accent of a rhythm by changing the vibration frequency, a frequency discrimination experiment is conducted. This is equivalent to the pitch discernment by hearing.

2) Methodology: The vibration that performs continuation of 125 Hz as a fundamental vibrating is shown in Fig. 12, and it serves as a candidate for comparison. The vibration frequency is varied from 50 Hz to 200 Hz per 25 Hz for comparison. A linear step experiment and scale step experiment, which performs the variation of the comparison vibration, which is 81.89 Hz (Sound-E) as the fundamental tone and is equivalent to the chord of C-E-G, so that it may become the same as that of a pitch of the vibration frequency are conducted. An arm of a subject is equipped with the linear vibration actuator. The fundamental vibrating and a comparison vibration decide whether it is felt at the same frequency. When "same" when vibration frequency is the same is answered; however, when the vibration frequency is different, the rate of correction is totaled by considering the cases where "different" is the correct answer. There were seven test subjects, males and females of 20 years of age.

3) Results: The experimental result and a scale step for the experimental result of a linear step are shown in Fig. 13. In this diagrammatic chart, the ordinate is the percentage of correct answers and the horizontal axis is the frequency. At a linear step, the reference vibration of Fig. 14 is 125 Hz, and E (81.89 Hz) is considered as the reference vibration at the scale step. At a linear step, because 75 Hz, 100 Hz, 125 Hz, and 150 Hz are over 80% of the percentage of correct answers, it can be said that discernment is possible. In comparison, at the scale step, as show in Fig. 14, G (48.69 Hz) and C (130 Hz) are able to identify over 80% of the percentage of correct answers. However, the discernment of the remaining answers is difficult.

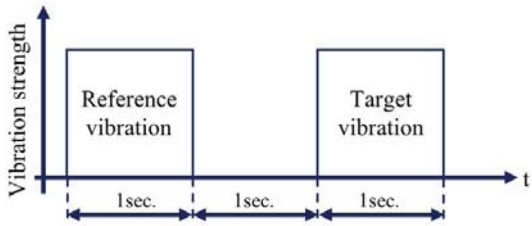

Fig. 12. Time-chart of vibration pattern of 1st experiment.

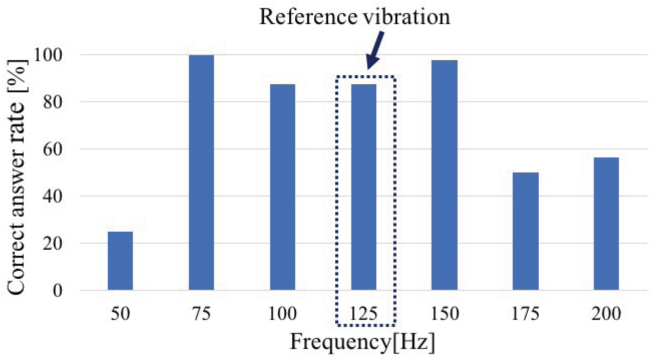

Fig. 13. Experiment with linear step frequency.

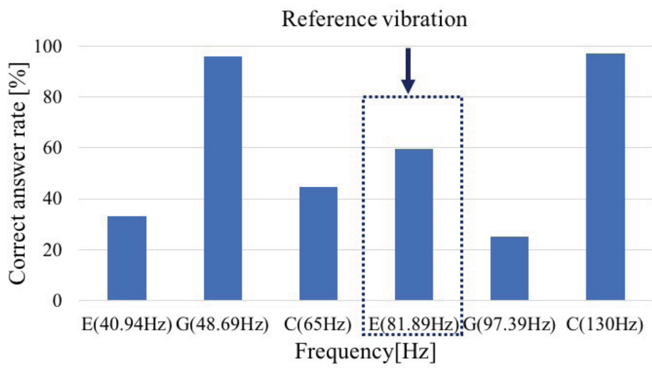

Fig. 14. Experiment with musical scale step frequency.

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B. Experiment on vibration separation recognition

1) Objective of the Experiments: The beep sound currently used with home appliances displays how to transmit information with the pattern of a sound of the same frequency. Therefore, we aim to generate a beat that has an accent to have an vibrating pattern similar to a beep sound in a vibration, and the other beat is identified. However, the continuation time of the vibration generation to the timing of the present beat is approximately 50 ms to 100 ms. Therefore, non-vibrated time is inserted between vibrations because it is investigated whether it is possible to express a pattern in time within the above limit. Moreover, if there is sufficient non-vibrated time, an vibrating discernment recognition experiment will be conducted for investigating whether it can be recognized as a separate vibration. This is equivalent to a visual flicker experiment.

2) Methodology: An arm of a subject is equipped with a linear type vibrator, and the time for which the vibration is separated is obtained and felt for two to answer, causing the non-vibrated time to increase from 0 ms per 8 ms to 64 ms with 125 Hz vibrations, as shown in Fig. 15. The time for which the vibration felt enforcing one to answer is obtained, decreasing the non-vibrated time from 64 ms per 8 ms to 0 ms conversely similarly. There were six test subjects, males and females of 20 years of age.

3) Results: The result of the experiment is presented in Table 1. The threshold value at the time of increasing the non-vibrated time from 0 ms was set as 16 ms. Moreover, the threshold value at the time of decreasing it from 64 ms was set as 24 ms. In this experiment, 8 ms, which is the single cycle time of 125 Hz of vibrating frequency, was used as the variable step. Therefore, the difference in the threshold value results from the variable direction. However, it is set as the non-vibrated time of 24 ms required for the discernment, which is the threshold value at the time of reduction.

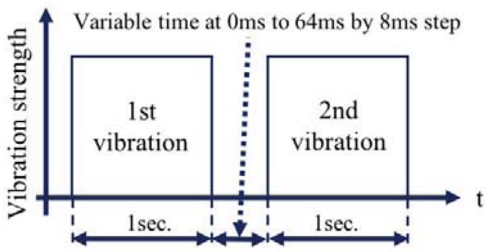

Fig. 15. Time-chart of vibration pattern of 2nd experiment.

TABLE I. RESULT OF THE EXPERIMENT

Variable direction	Threshold time
Increment (0ms to 64ms)	24ms
Decrement (64ms to 0ms)	13ms

C. Enforcement Verification Experiment

1) Objective of the Experiments: It was planned to express at the beginning the accent of a beat by combining the vibration frequency. However, because the discernment rate is low, a method for using the expression generated by an vibrating pattern is adopted. In this experiment, it is verified whether the effect of vision in this method is the same.

2) Methodology: Six subjects are divided into two groups, each of three participants. The timing of the rhythm is divided into groups recognized visually and recognized with the HID. In the recognition with vision, a yellow LED lights up according to the timing of a beat, and red LED lights up by a beat with an accent. Using a linear type vibrator, for the timing of the rhythm, as shown in Fig. 16, a 125 Hz vibration is applied for the recognition with the HID for 76 ms. For the beat with an accent, 24 ms are provided for a 125 Hz vibration. No further vibration is given after the 24 ms. A vibration is again given for 24 ms. Moreover, it screens to intercept the information from the vision. For controlling the timing of beat by a microcomputer, a subject strikes castanets to the timing of the beat with an accent, and records the time gap with the beat. This experiment is conducted six times, changing the combination of the six subjects. The experiment setup is presented in Fig. 17.

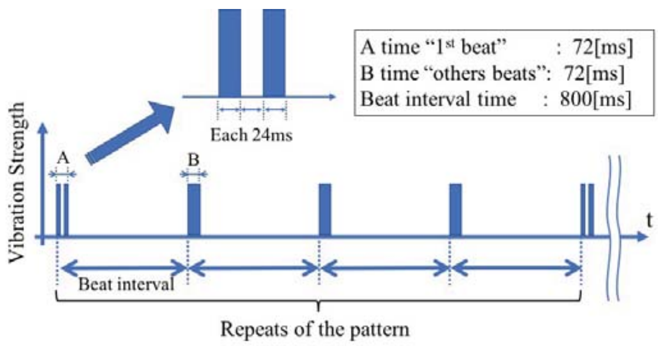

Fig. 16. Time-chart of vibration pattern of enforcement experiment.

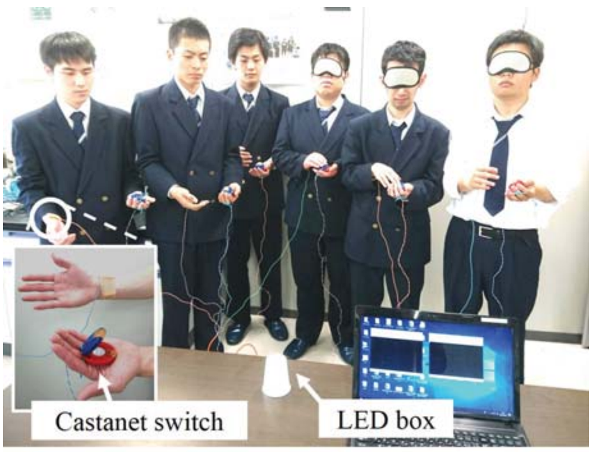

Fig. 17. View of enforcement experiment.

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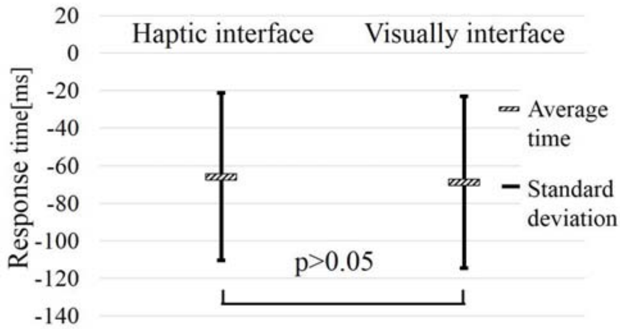

Fig. 18. View of enforcement experiment.

3) Results: The result of an experiment is shown in Fig. 18. Vision and a tactile sense strike the castanets before timing the presentation. In the case of vision, the average number of hours is -68.8 ms and standard deviation is 45.6. In the case of tactile sense, the average number of hours is -65.8 ms and standard deviation is 44.5 When t-testl is performed about both the results, it yields $p = 0.43$ therefore, the difference between the results is not significant.

IV. CONSIDERRATION

An approach for using a combination of two vibration frequencies as information presentation for synchronization by a haptic interface was verified by a vibration frequency discernment experiment. Consequently, the capability to identify the difference between two vibration frequencies as discernment capability of a wrist was based on 125 Hz at a linear step; when for 50 to 200 Hz it was made as a 25 Hz unit for the object frequency, the recognition rate was 80%. However, beyond the frequency range, the recognition rate became 50% or less. Moreover, although the recognition rate was only with a specific high frequency, the case where a standard frequency of 81.89 Hz was used, a pitch step was performed. The same frequency was recognized to be different in many cases. A possibility is that this standard frequency and fundamental frequency were too low for the high linear step. Numerous experiments/opinions are incomprehensible when these the experiments of both did not concentrate considerably on a subject.

Vibration separation recognition was performed as a next experiment. In this experiment, non-vibrated time was in the middle of the same vibration frequency. We clarified by the experiment that to recognize the separation of vibration insertion of no-vibration was required. The result value was close to the visual experimental result of the flicker test, as a well-known visual example. It is thought that this is not because of the characteristic of the receptor but because of the discernment capability over a stimulus within a brain. Moreover, there were numerous opinions that this approach is more intelligible than the method of using two vibration frequencies. Therefore, we adopted this method.

Finally, verification of the conditions near a music performance was performed. The difference in the reaction time for the timing presentation by vision and haptic in this experimental was 3 ms. A difference of this level is satisfactory for a musical timing synchronization. Moreover, both the reaction times have a negative value. In the rhythm of a constant cycle with periodicity, since this reason is predicted from front timing, it is. Therefore, the results by vision and haptic sense have the same characteristics. The technique of this study is useful as an information presentation method accompanying a haptic interface as a visual alternative organ for synchronization.

V. CONCLUTION

We proposed a method to use a haptic interface as an alternative information presentation for those who have an impediment in vision or hearing. In this study, transmission of the accent of the first beat by a musical rhythm, combination of two vibration frequencies, and the dependence of the method of on the vibration pattern were verified by experiment. As a result, the method depending on the vibration pattern was adopted in this research. Accordingly, it was shown clearly that it could be discerned from two vibrations by inserting a no-vibrating time of 24 ms or more in the middle of vibration. Finally, a verification experiment examined the use of a vibrating pattern, and the accent of rhythm was recognized similar to vision.

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