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Measurement and generation of footsteps sound on Japanese traditional dance

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ABSTRACT

Our purpose is to create real sound made by human motion in the virtual reality environment. On Japanese traditional dance that is called "Nihon Buyo", the sound of footsteps is very important because dancer makes musical beats by footsteps in his performance. We tried to generate these footsteps using dancers motion for the purpose of producing the virtual reality performance of Nihon Buyo. In the real environment, the material vibration creates sound. This is the fundamental principle of physical phenomena. If we give the something power to the material, it starts to vibrate; this is most simply phenomenon of sound. So we had to create the material vibration in the virtual environment. We tried to generate the footsteps sound by motion capture data. To create the real sound in the computer environment, we have to simulate material vibration by the excitation. If we can simulate the material vibration, we could create same environment as real world in the computer environment. To generate the virtual reality footsteps sound, we used physical modeling that was the calculation of the modeling elasticity, and moreover we used Finite Element Method (FEM) to simulate the material vibration, which was wood floor vibration. At first, we measured the floor vibration of the dancers to estimate the vibration by physical modeling by the real human movement. We put on three places of contact type vibration sensor on the floor and measured it. To make the material vibration, off course, excitation is needed. For footsteps, excitation is just the motion of foot. About physical modeling, we made the DSP program that translated the movement of foot to excitation data. And the footsteps sound was generated with dancer's motion data and the elastic value of wood. As a result of estimation, it was suggested that there seemed to be the indication of correlation between the real vibration and modeling sound.

INTRODUCTION

It is said that human hearing has the capability to recognize the form of a substance in Ecological Acoustic [1, 2], which is called Hearing Shape and various experiments were conducted using the actual metal plate etc. Kunkler-Peck and Turvey investigated variously shaped real plates made of steel, wood or plexiglass [3]. And this article suggests that human hearing has an ability to get the information of substance shape. Moreover, the article of Giordano suggests that human hearing has an ability of material identification too [4]. Also about the form of a metal plate, in the article of McAdams, it was suggested that the fundamental frequency (*F0*) of the sound was also related to the perception [5].

These articles were results from the experiment using real substance which were real metal plate, real wood plate and so on, but there were no article using the substance on the virtual environment. Therefore we investigated whether there would be this feature of Hearing Shape also in the sound source generated by physical modeling even if it does not exist in the real world [6]. As a result, it was suggested that the feature of Hearing Shape existed on not only the real material sound but the virtual sound generated by physical modeling. And to investigate the *F0* perception of McAdams, we tried to make the virtual glockenspiel using physical modeling [7]. As a result, some remarkable error arises to the impression in a scale, and it is necessary to rectify this error with calculating the size of virtual plates by physical modeling.

As a next step, we paid attention to the excitation of substance vibration that was important factor of vibration. We tried the experiment to find the difference of impression according to excitation [8]. In this experiment, the motion in drum playing was analysed using the motion capture system. As a result, it was suggested that there seemed to be difference of impression according to motion that was just an excitation.

This research was an experiment for making an everyday sound by physical modeling, and investigating a difference with an actual vibration. The footstep made by a dance was examined especially this time.

PURPOSE

In recent years, simulation technology was improving rapidly and it became possible to carry out thon e simulation of the material vibration. Carrying out the simulation of the material vibration is exactly carrying out the simulation of sound. Actually, when performing the simulation of vibration, the information of excitation is needed. Especially, in case of the excitation by the human motion, it needs to measure or record the human motion to simulate the vibration of resonator.

In addition, simulation is very useful technology also on the field of archive. For example, in the case of people's footstep, it is possible to record the movement on walking and to carry out the simulation of the footstep from the excitation data instead of recording with a microphone. If there is even excitation information, vibration can be reproduced everlastingly, and furthermore, excitation information can also be used for a different simulation.

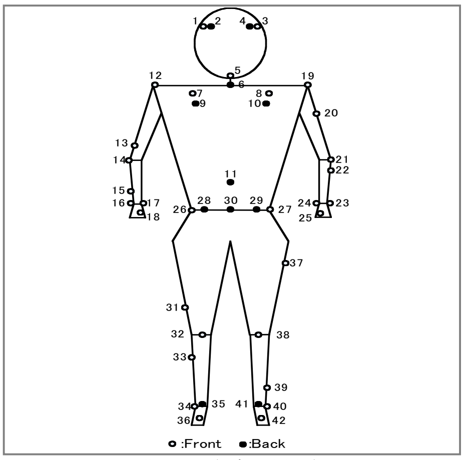
Also related with record of the sound by human motion, it is very important to record the motion data, because the sampling type's archives are only the record of acoustical vibration. Especially, about the archives of dance or music, most important thing is not recording the visual image or audio signals but recording the human skill. For the sake of preservation of human heritage, it is very important to create the system of motion archives. Simulation from the real motion like as the 3 Dimensions Computer Graphics (3DCG) animations or the Virtual Reality (VR) is very important to play back this human skill data. So this paper is about making real sounds of 3DCG, we tried to generate some footsteps using dancer's motion for the purpose of producing the virtual reality performance of Nihon Buyo.

CAPTION OF MOTION DATA

To get the real motion of human skill, we applied to Professional "Nihon Buyo" (Japanese traditional dance) dancer, Mr. Minosuke Nishikawa who is belonging to Nishikawa School, for dancing "Tomoyakko". Minosuke danced three times timing to "Tomoyakko" music. There is the greatest highlight by the footsteps in the second half portion of this dance. The sound by floor vibration by footsteps is very exciting as well as a dance. This part of "Tomoyakko" is called "Ashi-byoushi".

Recording system

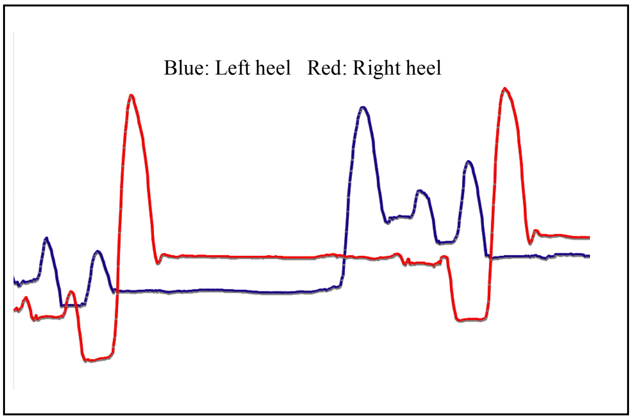
Measurement was performed by the digital optical motion capture system, MAC 3D System of Motion Analysis. Frame speed was 1/60s and shutter speed was 1/1000s. 12 infrared cameras were fixed to be able to measure the 3-dimention areas, 5m(x) ×5m(y) ×2m (z). 42 markers were attached from the head to foot on the body of dancer (e.g. Figure 1).



Source: (Mito, 2007)
Figure 1. Position of 42 markers

Recording of the motion data

After marker putting, according to music, the performer danced and the motion data of the 42 were stored in the hard disc of a computer as three-dimensional values. The Z-axis motion data of both heels was plotted as the time-series data was extracted (e.g. Figure 2) for the purpose of using as the excitation data.



Source: (Kawakami, 2010)
Figure 2. Z-axis movement of both heels (No.35 and 41 on Figure 1)

SOUND GENERATION OF THE FOOTSTEPS

In this Tomoyakko performance, the sound of footsteps is very important because dancer makes musical beats by footsteps at the last part of performance. Therefore, we tried to generate this "Ashi-byoushi" with dancer's motion.

In the real environment, the material vibration creates sound. This is the fundamental principle of physical phenomena. If we give the something power to the material, it starts to vibrate; this is most simply phenomenon of sound. But after twenty century, it became to be possible to record the acoustic signal. This is so called recording, and this is very useful technology for us in recent year. But this recording is not one of real environment but only the copy of acoustic signal. So we had to create the material vibration in the virtual environment. We tried to generate the footsteps sound with motion data.

To create the real sound in the computer environment, we have to simulate material vibration by the excitation. If we can simulate the material vibration, we create same environment as real world in the computer environment. We can create more real sound than recorded acoustic signals.

About making the vibration on the computer, every materials in the real world has elasticity, this is physical property. And modeling this elasticity is to making virtual real sound. We used the calculation of Hook's law for the modeling elasticity, and moreover we use Finite Element Method (FEM) to simulate the material vibration. On this FEM, the material graphics, so called Mesh, is rendered, and elasticity of every part of mesh is calculated. Vibration spread to all the mesh and by changing this vibration to the sound wave signal, we can listen to the virtual vibration as a sound on the computer.

To make the material vibration, off course, power is needed. This power is called excitation. For this footstep, excitation is just the motion of foot. On this modeling, we used Z-axis motion data of performers' heel as the data of excitation.

Simulation by physical modeling

Footsteps sounds were generated by Modalys which was physical modeling programming code developed at Institut de Recherche et Coordination Acoustique / Musique. This code was based on Lisp language. Modeling was taken as vibration of a plate in case of the exciter with a mass on a rectangle plate as a resonator.

In this simulation, the plate used by actual Nihon Buyo, which was called "Shosa-dai", was made into the mesh model. The rectangle plate size was 300cm(W)× 90cm(H)× 12cm(D) and the material of wood was "Hinoki". The density of Hinoki was 0.41 kg/cm^3, Young's modulus was 882.9 N/cm^2, Poisson ratio was 0.3 (coeff), Constant-loss was 0.3 (energy/freq loss), and Frequency-loss was 0.3 (global loss). The elastic parameters and size of Hinoki plate were inputted into the Lisp code (mode 80). As an excitation value, the Z-axis motion data of both heels was used after changing from the scale data to the velocity data.

The simulation was performed by the motion of the heel of each right and left, and was outputted as a sound file (16bit, 44.1kHz, Aiff format).

VIBRATION MESUREMENT

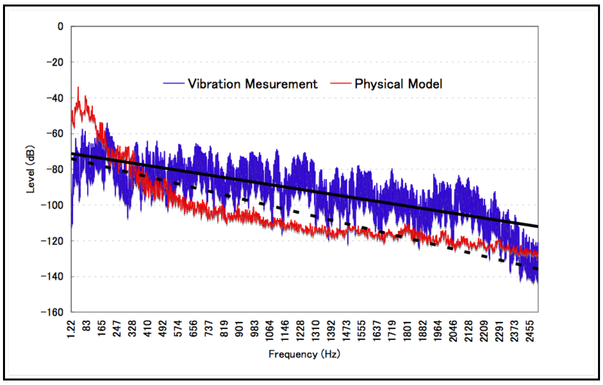
To compare the actual sound with generated sound, the real footsteps sounds of eight performers, including Mr. Minosuke Nishikawa, were recorded by the vibrometer and the microphone while dancing "Ashi-byoushi".

Three places of contact type velocity sensor (OnoSokki NP-2106) were attached on the floor (e.g. Figure 3). Duration of sensors was 1 m. 3 signals from these sensors were sent to the computer through the A/D converter (OnoSokki DS-2000) and recorded to the hard disc. Simultaneously with the vibration measurement, the acoustical signal was also recorded by the noise level meter (Ono Sokki LA-5120). All of vibration and acoustic signal by a microphone were changed into the PCM file (16bit, 44.1kHz, Wav format).

Source: (Kawakami, 2010)
Figure 3. Measurement of footsteps

Spectre Analysis

FFT analysis was performed about two sounds that were digitalised by the vibration measurement and by physical modeling. FFT was done by 2048 size and Hamming window (e.g. Figure 4).



Source: (Kawakami, 2010)
Figure 4. Spectre analysis

This result shows that the sound by floor vibration contains more complicated frequency ingredient rather than the sound by physical modeling. In this frequency bands, floor vibrations shows the frequency characteristic near white noise, but physical modeling shows the characteristic near pink noise that frequency level decreases as frequency rises.

EVALUATION

The evaluation of impression for two types of sound that are the generated sound by physical modeling, and the floor vibration was conducted in order to measure the effect of physical modeling

Methods

Each sound was taken into the movie of the dance made by computer graphics in order to consider the difference in the impression of the measured footstep and the footstep made by physical modeling. The stimulus shown to the subjects was the last part of "Ashi-byoushi" which took about 40 seconds.

The measure used for the evaluation experiment was based on three expression words, "aesthetic", "volume", and "brightness", which words were 3 factors of timber. Subjects marked on three expression words "aesthetic", "volume", and "brightness" in seven steps after appreciating each stimulus. Subjects were 10 healthy persons (f:6, m:4, yr=20.5±0.6).

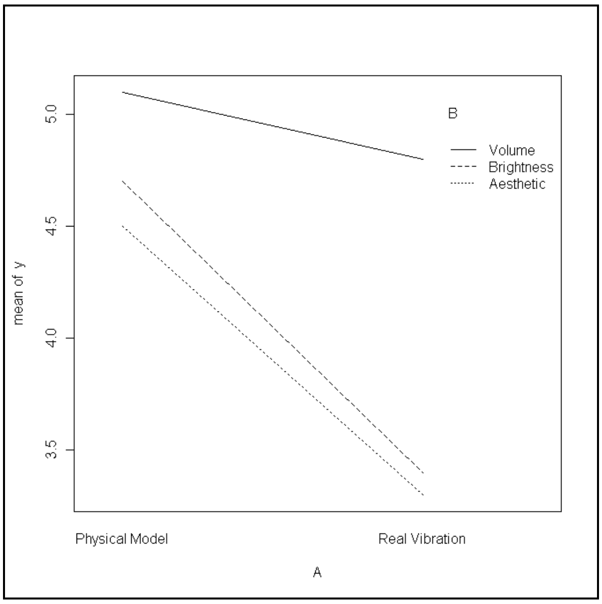
Analysis and results

All data of ten persons were analysed by two-ways ANOVA (group A: 2 types of sound, group B: 3 expression words). Table 1 is the result of ANOVA and Figure 5 is the result of the interaction after ANOVA.

Table 1. The result of ANOVA

	Df	Sum Sq	Mean Sq	F value	P value
A (Sound)	1	13.067	13.067	7.230	0.009 **
B (Words)	2	12.900	6.450	3.569	0.035 *
A*B	2	3.033	1.517	0.839	0.437
Residuals	54	97.600	1.807		

There seems to be the significant difference in group A ($F(1,54)=7.230$, $p<0.01$) and group B ($F(2,54)=3.569$, $p<0.05$), but not seems to be the significant difference in the interaction between A and B ($F(2,54)=0.839$, ns).



Source: (Kawakami, 2010)
Figure 5. Interaction plot

Figure 4 shows that there is the significant difference between physical model and the real vibration on the expression words "aesthetic" and "brightness". But there is not the significant difference on "volume".

From these results, it was suggested that both stimuli do not have difference impression of "volume". On the contrary, about "aesthetic" and "brightness", both have different impression so that spectrum structure shows.

CONCLUSION

Although the footstep generated by physical modeling was estimated in this experiment, it was suggested that the impression difference with an actual footstep is large. As this reason, the elasticity of wood was quite more complicated than metal materials, and a reality could not be made by this program. However, a significant difference was not seen about the impression of "volume". As this reason, it is thought that the motion of an actual heel was used as data of the excitation. It is thought that excitation information is important and this excitation information has contributed to the impression greatly for impact sound like vibration, especially like as this experiment. Also from this conclusion, when hearing vibration of a substance, it is considered that we get not only the material information but also the change of the external energy that makes vibration.

Although record of the act by motion capture probably developed increasingly from now on, a possibility of generating sound at the time of reappearance was suggested using the information on these motion data as excitation data.

ACKNOWLEDGMENT

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