Sound-Specific Vibration Interface: Its Performance of Tactile Effects and Applications

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Abstract

The tactile effects of a sound-specific vibration interface is presented in this paper. The sound-specific vibration interface generates a vibration according to a sound stream using 16 oscillators arranged in 4x4 array. By setting time frame, we were able to generate various patterns of vibrations. So, the main purpose of this paper is to analyze the effectiveness the sound-specific vibration interface. We first analyze the immersiveness of the vibration depending on the tone of sound. Second, different parts of body were evaluated to find the most suitable part of body for our sound-specific vibration interface. Next, we also assess the various patterns of vibration using four patterns for a gun-shot. In addition, we also compare the results of the vibration device with those of two other vibration interfaces: a vibrating mouse and a vibrating head-set. In the experiment, participants listened to music and played a shooting game, wearing our sound-specific vibration interface. The experiments on different patterns of vibrations lead us to conclude that a certain vibration pattern is more effective than others and our vibrations interface is more effective than other vibrating devices, especially it works best when being attached to shoulders.

1. Introduction

The sense of sight and that of hearing have been considered as methods to increase immersiveness in virtual environments so far. However, there also exist a sense of touch, taste and smell in human senses, and among those senses, the sense of touch has recently come out as an important method for increasing the immersiveness in combination with relevant visual and audio. Especially, in games or virtual realities, the sense of touch greatly helps immerse users into such applications [1]. This area of research is called Haptics [2].

There are many types of Haptic devices such as stylus force feed-back device, glove type, vibration devices, and so forth and we will only focus on the vibrations devices to which our sound specific vibration interface belongs [3][4][5][6]. In the market, there are already various devices which generate vibration [7]. A vibrating headset and a vibrating mouse are the most popular devices which embody vibrating oscillators [8]. The vibrating headset vibrates according to the low tone melody, and the vibration is known to increase the reality when watching movies [9]. However, the vibrating head-set tends to vibrate so monotonously that users get disinterested easily. The vibrating mouse reacts to user's inputs such as a button click. This vibration is also monotonous.

Fig. 1. Vibrating Headset and Vibrating Mouse

Our sound specific vibration interface is introduced and the assessment of it is illustrated in this paper. The novelty of our sound specific device is that it recognizes sounds and vibrates in various patterns which make its application more exciting and realistic.

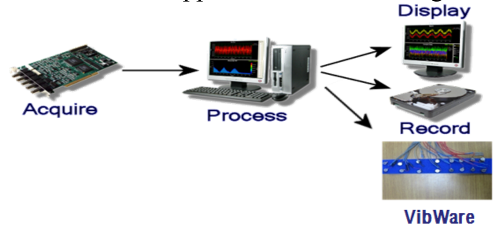

Fig. 2. Sound Analysis Process.

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2. Sound-specific Vibration Interface

The sound-specific vibration interface is in the shape of pad. There are 16 oscillators arranged in 4x4 arrays on a pad and they generate tactile effects according to a specific sound. It has an 8-bit microprocessor to control the oscillators. The microprocessor is responsible for activating and ceasing the vibrations of each oscillator.

In this paper, we distinguish sound based on two criteria. One is its tone. For example, if we can distinguish a low tone from a sound, then we will be able to generate a vibration corresponding to it. The second method to detect a sound is to match it to a previously defined or stored sound pattern.

When the vibration interface has sound input. It analyzes the sound stream by performing Fast Fourier Transform [10]. When the DSP which resides in the pad, can give distinguishable characteristics by mapping the result of FFT with the stored sound pattern or other criteria, it vibrates.

Figure 3 shows two FFT results, one from a rifle shot and the other from a gunshot. Since a gunshot and a rifle shot are easily distinguishable, the pattern can be defined ahead of playing a game, and while playing game, the sounds are constantly being analyzed. Once, a pattern matches one previously defined, it seeks and generates a matching vibration.

Fig. 3. Fast Fourier Transform of a Gunshot Sound (그림크게)

The sound-specific vibration interface consists of a vibration pad, and utilities such as a pattern editor, a visual vibration chart, and a simulation program.

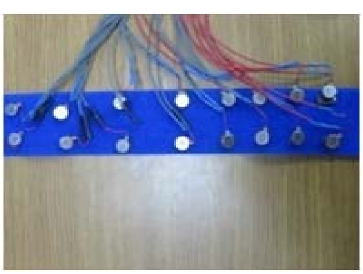


Fig. 4. Sound Specific Vibration Interface

3. Performance of Sound-Specific Vibration Interface

In this section, we performed two experiments to measure the performance of the sound specific vibration interface. The experiments were performed on two applications: WINAMP and a FPS Game [11].

3.1 Test Application

In order to perform the experiments in the latter section, we used WINAMP and our own test application. In this experiment, a gunshot sound is recorded and assigned various vibration patterns. After all the sounds are recorded and their respective vibration patterns assigned, the user can switch to the play mode. In the play mode, the sound coming out of the game or other applications is analyzed and compared to the stored sound streams. If a match is detected, the corresponding vibration is generated through the vibration pad.

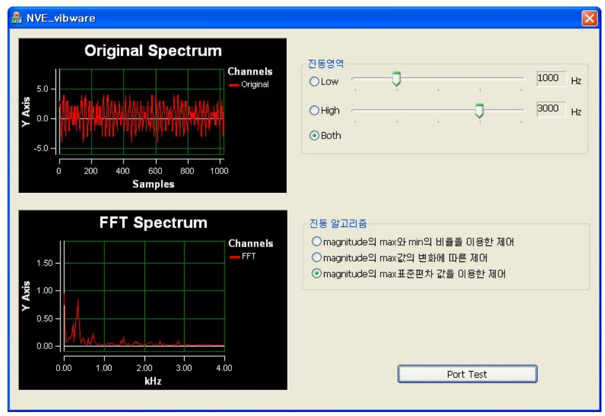


Fig. 5. Sound Specific Vibration Interface

To assess the vibrating head-set, mouse and our sound-specific vibration interface, participants' performances in the game "Sudden Attack" are compared.

3.1 Performance of vibration on Music

In the first experiment, we evaluated the sound specific vibration interface when being worn while a user listens to music. To measure the performance, we had 30 students wear our interface and grade the immersiveness it showed. The objective of this experiment is to see how much a user can be immersed into the music wearing the sound specific vibration interface.

- The experiment was performed as follows.
- Turn on WINAMP to play music
- Listen to music without the sound specific vibration interface.

- Listen to music with the sound specific vibration inter face and the device vibrates on high notes.
- The device vibrates on low notes
- Fill out the experiment questionnaires

The part of body for this experiment was a wrist. We put the sound specific vibration around a surveyee's wrist and had him / her listen to music. The surveyees were asked to grade the immersiveness at the end of the experiment.

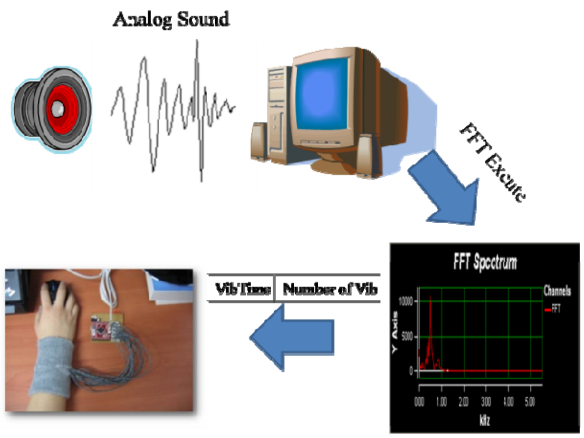


Fig. 6. Sound-specific vibration interface processing

The test application of this experiment is shown in Figure 5. The application analyzes the analog sound from a speaker performing fast fourier transform. After the magnitude on frequency domain is obtained, we consider the sound over 1.9Hz as high-pitched tone and less than 1.5Hz as low-pitched tone. If a user chooses the high-pitched tone option, the interface vibrates on the high-pitched tone and if the low-pitched tone is chosen, it vibrates on the low-pitched tone.

3.2 Sensitivity on Different Part of Body

In this section, we find the most sensitive part of body to the sound-specific vibration interface. Since our vibration interface is in the shape of a pad, it is attachable to any parts of body; however, we choose five parts of body which are seemingly the most suitable. The vibration pad was attached to the five different parts of the participants: the neck, the shoulder, upper arm, the forearm, and the wrist.

We have 30 participants randomly chosen students from University of Incheon ranging from 20-26 years old for this experiment and all the latter experiments in this paper. All subjects were novice users to our sound specific vibration interface and to a vibrating mouse and a vibrating headset. This experiment is divided into the following five stages:

1. Plays a first person shooting game without any vibration interfaces
2. An explanation on vibration interfaces is given
3. Plays the game again with the sound specific vibration interface attached to his or her body.
4. Plays the game with a vibrating mouse and then with a vibrating headset.
5. Fill out the experiment questionnaires

After playing the game, all participants graded the degree of sensitivity they felt from different parts of body, ranging from 1 to 5 with 5 being the highest score.

3.3 Effectiveness of Various Patterns

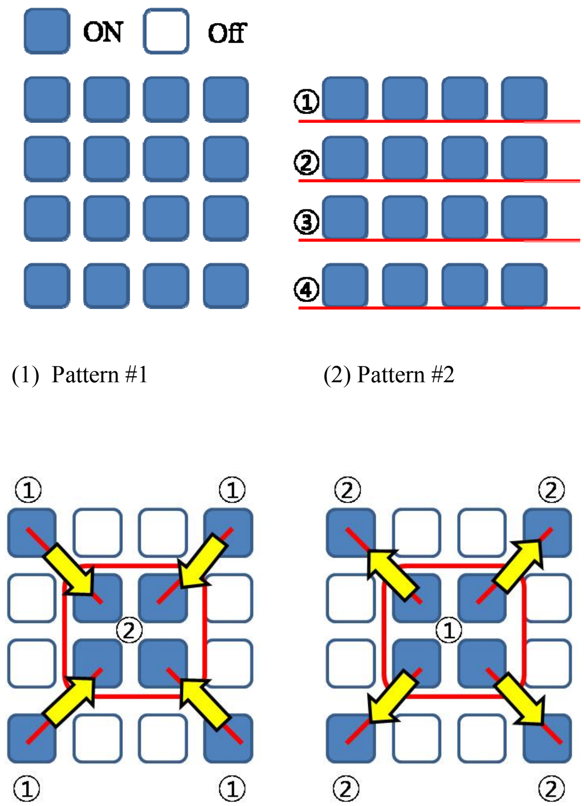
The different vibrations patterns are proposed and assessed in this section. Since we use FPS game for our experiment, we generate four different vibration patterns which will be served with a gut-shot sound. We can generate the vibration patterns because the sound specific vibration interface is composed of 16 oscillators arranged in 4X4 arrays. By controlling the sequence and timing of the oscillators, the vibration patterns are generated. The patterns are pictured in Figure 7. Each of the images has a bar at the bottom, which indicates the timing of a vibration of the pattern number in the images. The duration of the vibration is one second to coincide with the gunshot in the game.

- Pattern 1: All of the 16 oscillators vibrate at the same time for one second (see Figure7(1)).
- Pattern 2: As shown in Figure 7(2), the four oscillators in the top row vibrate first and stop. Then, the four oscillators in the next row vibrate and stop. The third row and last row vibrate in order.
- Pattern 3: The oscillators number as ① in (see Figure 7(3)) vibrates for a half-second, and ② in the center vibrates. This pattern gives users a squeezing sensation.
- Pattern 4: Figure 7(4) depicts pattern #4. The four oscillators numbered as ① in the center vibrate first and the outermost numbered as ② vibrate next. This pattern gives users an expanding sensation.

Participants give 1 to 5 points to each pattern after experiencing all four patterns of five different parts of body.

3.4 Comparison with Vibrating Interfaces

In this experiment, we also compared the sense of reality provided by the sound specific vibration interface with that of two other haptic devices. The vibrating mouse generates vibrations when a button is clicked, while the vibrating headset generates vibrations that correspond to magnitudes of sound. During the experiment, a student was asked to assess the ability of each device to immerse him or her into the game. The student was also asked to choose his or her favorite device among the three and leave feed-back about the vibration interface.



(1) Pattern #1 (2) Pattern #2

(3) Pattern #3 (4) Pattern #4

Fig. 7. Examples of Different Vibrations Patterns

4. Results and Data Analysis

In this section, we list and analyze the results of the experiment. Significant Analysis of Variance results are shown in Table 1, and the results of the experiment are presented in Figures 8 through 12 [12].

The ANOVA result of the first hypothesis shows that the sense of the reality given by a gunshot differs depending on whether or not the subjects wear the vibration interface, since the hypothesis is rejected by $p<0.05$.

The average score indicating the degree of immersiveness of the vibration interface when it vibrates on high-pitched tone is 3.8 and 3.9 is on low-pitched tone. We also asked the surveyees the degree of immersiveness when only listening to music without the interface, and 2.5 was given. Consequently, we can now conclude that the sound-specific vibration interface helps immerse users into music. From the ANOVA on this, we verified that the hypothesis that the interface helps users immersed into music is valid.

Table 1. ANOVA results

Hypotheses		ANOVA results
Perceived Immersiveness on 1st Experiment		F=1.39*10-11 P<0.05
The sense of the real from a gunshot is the same weather the vibration pad is in use or not		F=1.51*10-11 P<0.05
The sense of the real from a gunshot is the same regardless of types of patterns	Wrist	F=0.34, P<0.05
	Lower arm	F=0.34, P<0.05
	Upper arm	F=0.57, P<0.05
	Shoulder	F=0.017, P<0.05
	Neck	F=0.68, P<0.05
The sense of the real from a gunshot is the same regardless of types of vibrating devices		F=0.002, P<0.05

Figure 8 shows the result of the experiment.

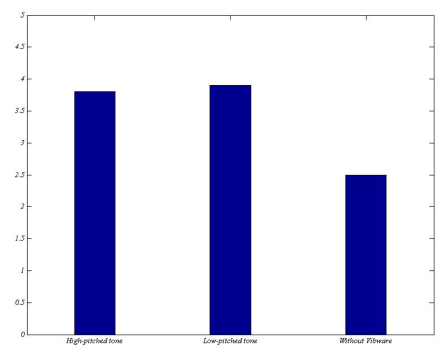


Fig. 8. Perceived Immersiveness on 1st Experiment

Figure 9 shows the results of the experiment performed on different parts of the body to find out which body part is more sensitive to the vibration interface. The results show that the shoulder is the most sensitive to the sound specific vibration interface. This sensitivity to the interface is also significant on the wrist and neck. However, the ANOVA result of hypothesis is rejected for all cases except the shoulder; therefore, even though all parts of the body, excluding the shoulder, are relatively sensitive to the vibration interface, their results are not valid.

In Figure 10, the results of different patterns are shown. The results of the ANOVA led us to conclude that pattern #4 is the most realistic when the pad is attached to the shoulder (pattern #4 > pattern #1 > pattern #3 > pattern #2). Even though the results of other parts of body are meaningless, the results still implies that the pattern #4 is the most realistic pattern on any part of the body.

In addition, the users' preferences turned out to be the vibration pad among three interfaces from the experiment. 65% of the participants chose the sound specific vibration interface as the most effective tactile interface. The reasons are as follow: the pad is attachable to any part of body, while a headset and a mouse have a designated place. The various vibration patterns of the pad are also appealing. These attributes of the pad are considered strengths of the device. Some participants claimed the mouse was even distracting when gaming. However, some other participants favored the vibration head-set because the placid vibration around the ears is pleasant.

Finally, the participants made several comments on the sound specific vibration interface.

We should:

- Widen the area of vibration
- Shorten the interval of each pattern
- Be able to adjust the intensity of vibration
- Make the pad wireless

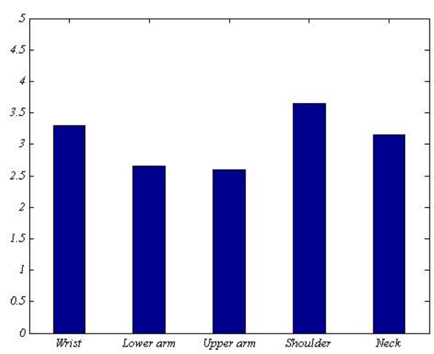


Fig. 9. Perceived reality depending on the part of body

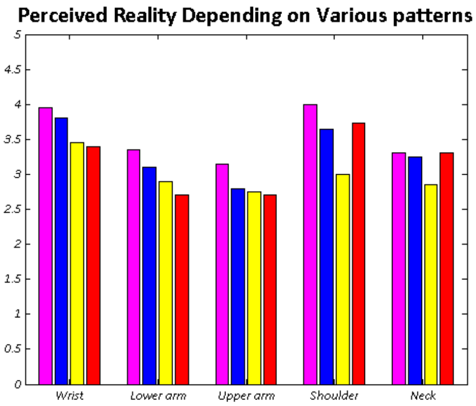


Fig. 10. Perceived reality depending on various patterns

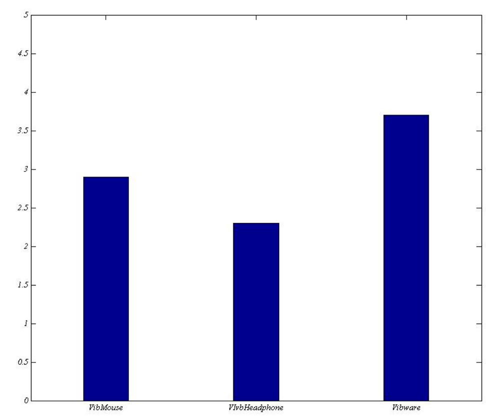


Fig. 11. Perceived reality depending on types of interfaces

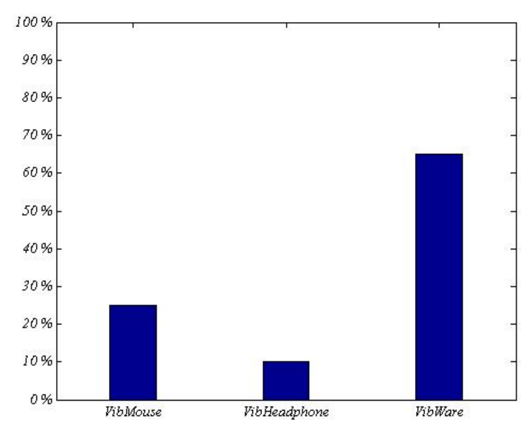


Fig. 12. Users' preferences

5. Its Potential Applications

In this section, we suggest various potential applications to which the sound specific vibration interface is applicable.

5.1 Game

The most seemingly applicable application is a game. The existing vibrating joysticks have shown its limits because the vibration is hardcoded while our vibration interface vibrates on sound out of speakers, so our vibration interface can be applied to any existing game applications or new applications easily with modifying the original structure of games.

5.2 Chatting

The sound specific vibration interface can be used to express the emotion of a user like emoticon. Thesedays young students show their emotions using emoticon on MSN or any other chatting applications. However, if we use the vibration interface to express different emotions on different patterns of vibration, this will enrich the communication between chatters.

5.3 Music Education

If we vibrate on the exact beat of music, this will be helpful to people who have been struggling with the beat.

6. Conclusion

The sound-specific vibration interface is proposed and evaluated. We performed four different experiments. First, we had the interface vibrate depending on the amplitude of the sound. Second, the interface was worn on five different parts of body to find the most suitable part of body for the device. In addition, we generated four different vibration patterns to show that different patterns can produce different immersiveness. And finally, we compare the device with a vibrating head-set and mouse.

The result showed that the sound-specific vibration interface performed the best compared to other devices and was most optimal on the shoulder. Also, different patterns of vibrations provide different degrees of reality.

For future work, we plan to develop more of the vibration patterns that will work most effectively for human body and reduce the interval between each step of vibration. Also, the prototypes of target applications will be developed.

Acknowledgement

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