

Paper

Body Vibration Effects on Perceived Reality with Multi-modal Contents

Shuichi Sakamoto †1, Gen Hasegawa †1, Akio Honda †2, Yukio Iwaya †3, Yôiti Suzuki †1, Jiro Gyoba †4

Abstract To develop advanced multi-modal displays, it is important that various sensory information is presented with proper amount. Previous studies have pointed out that vibration information enhances participants' immersive experience from virtual display. Therefore, vibration information should be considered when people develop advanced multimedia systems. We have focused on the effect of full-body vibration information to peceived reality. This study examined the relation between full-body vibration amplitude and perceived reality from audio-visual contents. The sense of presence, the sense of verisimilitude, and the sense of ultra-reality were used as indicators of perceived reality. Results revealed that perceived reality increased by adding full-body vibration. Moreover, results showed that the senses of presence and ultra-reality increased monotonically according to the full-body vibration amplitude, while the sense of verisimilitude exhibited a saturating curvilinear tendency. These results suggest that body vibration is important to increase perceived reality from multi-modal contents presented by advanced multi-modal displays.

Key words: sense of presence; sense of verisimilitude; body vibration; audio-visual contents

1. Introduction

Advanced multimedia systems, such as UHDTV (Ultra High Definition Televison) and 3DTV (Three-Dimensional Television), can provide high perceptual reality. When we develop such systems, it is important that various sensory information is presented with proper amount. Recently, not only audio-visual information but also other sensory information such as touch, smell, and vibration has come to be presented easily. The potential of such information must be realized for advanced multimedia systems. Therefore, these information should be considered to develop these systems.

Here, we have focused on the effect of full-body vibration to perceptual reality from audio-visual contents. Some researchers have reported that a comprehensive model of human spatial hearing cannot be formulated without the inclusion of the human perception of self-motion and vibration information enhances perceived reality in musical scenes presented by an audio-visual display[1)2)]. However, perceived reality was treated only indirectly. Moreover, previous studies made no analytical consideration about the perceived reality.

Various indexes have been proposed and used to evaluate the perceptual reality from multimedia contents. Among these indexes, the sense of verisimilitude is used to evaluate the quality of apparent truth or reality. Our previous reports described different characteristics between the senses of presence and verisimilitude during perception of audio-visual contents[3)4)].

In this study, we investigated the effect of full-body vibration information added to audio-visual contents on perceived reality. Full-body vibration of various amplitudes was presented with an audio-visual movie that had been recorded via a camera and microphones put on a moving handcart. The perceived reality was measured using three indexes. We analyzed the relation between the vibration amplitude and perceived reality.

2. Index of Perceived Reality

Sense of reality includes many meanings. Therefore, it is difficult to ask participants directly about the amount of perceived reality. We hypothesized that perceived reality is mainly divisible into two parts: the reality obtained by the object or target and that obtained by the environment around the people. If the former reality is increased, then people might perceive

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the object or target as the real object, even if it is an imitation. If the latter reality is increased, then people might perceive it as if they were inside the environment. The importance of each reality is therefore dependent on the contents presented by the multi-modal display. Based on this hypothesis, we selected three indexes for the evaluation of perceived reality.

2.1 Sense of Presence

The sense of presence is defined as the subjective experience of being in one place or environment when one is physically situated in another place. This is the most popular index used to evaluate VR systems. Many researchers have examined cues for the sense of presence. Teramoto et al. reported that the sense of presence is used not only for evaluating the VR environment, but also for the expression of the existed “real” experience[5]. Moreover, they showed that the sense of presence is dominated mainly by the absolute amount of stimuli and that it is dominantly related to background components in a scene[3].

2.2 Sense of Verisimilitude

The sense of verisimilitude is the appearance of being true or real. We extend the meaning of this index as the existence of essence or effect, though not in actual fact. We have investigated the mechanisms of perceiving the sense of presence and the sense of verisimilitude using audio-visual contents[3)4)]. Results revealed that the sense of verisimilitude can be thought to take an appreciative role of foreground components in multi-modal contents.

2.3 Sense of Ultra-Reality

The sense of ultra-reality has been proposed by Ultra-Realistic Communication Forum (URCF), established in March 2007[6]. There are several interpretations of this index. One is that it evaluates physical reality. Using recent multimedia technologies, the physical quality of virtual environments is increasing rapidly. The sense of ultra-reality is used to evaluate the quality of contents presented by such systems and to evaluate the systems themselves. The other interpretation is that it expresses perceived subjective quality. Using the mechanism of human multi-modal perception, perceived reality can be increased even if conventional systems are used. The latter interpretation indicates that the sense of ultra-reality depends on various sensations. Some researchers have studied how people perceive the sense of ultra-reality[7].

3. Experiment

3.1 Stimulus

Fig. 1 shows the recording setup. A dummy head (Samrai; Koken Co. Ltd.) with binaural microphones (4101; B&K) inside its ears and a DV camera (AG-GV×100A; Panasonic) were fixed on a handcart. Binaural microphones were connected to audio inputs of DV camera via an amplifier (2639; B&K). Binaural signals were recorded at the sampling frequency of 48 kHz. Two acceleration pickups (VM-80; RION) were also fixed on both sides of the floor of the handcart to record vibration. The handcart was put on a path in Research Institute of Electrical Communication, Tohoku University. Because this pathway consists of small blocks, its surface was uneven, producing a bumpy ride. The handcart was pushed slowly by the experimenter and moved straight around 4 m. It was stopped just before hitting the fence. During this movement, audio, visual, and vibrational data were recorded digitally. The total duration of the stimuli was 9.3 s. The recorded vibration amplitude was less than 0.3 cm. **Fig. 2** shows one scene of recorded multi-modal movie.

Fig. 1 Recording setup.

Fig. 2 One scene of the multi-modal movie used in the experiment.

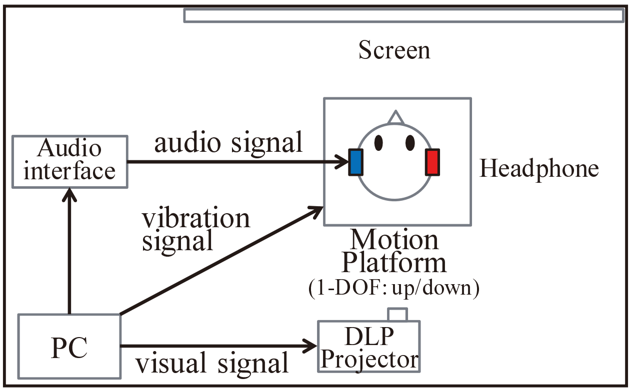

Fig. 3 Experimental setup.

3.2 Experimental Setup

Fig. 3 shows the experimental setup. Visual information was presented using a DLP projector (PDG-DHT100JL; Sanyo Electric) on a 150 in. screen (Stewart Sound Screen) set in front of participants. The field of view was 93 deg. Auditory information was presented binaurally via headphones (HDA-200; Sennheiser Electronic). The presented sound pressure level was the same as the recorded level. Full-body vibration was provided via a motion platform (D-BOX Mastering Motion). Only 1-DOF vibration (up/down) was presented during the experiment. Because of the limited frequency response of the motion platform, high-frequency components of the vibration signal were deleted using a low-pass filter ($f_c = 750$ Hz).

3.3 Experimental Procedures

Seven men (mean age=25.1 years, SD=6.1), all with normal hearing acuity and normal/corrected-normal vision, participated in the experiment.

Before the experiment, participants were asked to experience actual movement and vibration of the handcart at the place where the stimuli were recorded. They were sitting directly on the handcart at the pathway and the experimenter pushed it as he did when the stimuli were recorded. Subsequently, the experimenter took them to the experiment room and the experiment was started.

They were sitting directly on the motion platform during experiments just as they were on the handcart. The amplitude of the vibration was changed as the experimental parameter from 0 (without vibration) to 2 (twice as large as original amplitude) at 0.25 steps. Each amplitude vibration was combined to the original audio-visual movie and presented to participants four times. Therefore, 36 multi-modal stimuli were presented to each participant. The order of presentation of these amplitudes was randomized.

To choose the instructions for the sense of presence and the sense of verisimilitude, we considered that the environment itself was treated as a background component, whereas riding on the handcart in the environment was treated as a foreground component. Regarding the sense of ultra-reality, we considered that participants would feel an extended situation when they presented contents with high physical reality and subjective quality. Therefore, we gave the following instructions to participants to clarify the differences among the three indexes.

- Sense of presence: Participants rated the degree to which they felt they were now just in the place that they had experienced before.
- Sense of verisimilitude: Participants rated the degree to which they felt they were riding on the handcart.
- Sense of ultra-reality: Participants rated the degree to which they felt as if they struck the fence even though the movie stopped just before hitting the fence.

Participants rated the perceived subjective reality from 0 (low) to 6 (high). For each participant, the obtained data were normalized based on the participant's average and were converted to a z-score for comparison of the scores of each perceived subjective reality.

4. Results

Fig. 4 presents results of the experiment as a function of the vibration amplitude. Error bars denote standard errors. Compared with the no-vibration condition, all perceived subjective reality was increased by adding vibration. However, the tendency differed slightly among all indexes. The senses of presence and ultra-reality increased monotonically according to the amplitude of full-body vibration, while the sense of verisimilitude showed a saturating curvilinear tendency. The highest verisimilitude score was observed around the amplitude that was physically equivalent to that which participants had experienced before the experiment.

The results of ANOVA revealed that the effect of the vibration amplitude was statistically significant for all indexes (sense of presence $F(8, 48) = 20.29, p < 0.01$; sense of verisimilitude $F(8, 48) = 20.19, p < 0.01$; sense of ultra-reality $F(8, 48) = 23.91, p < 0.01$). Tukey's Honestly Significant Differences (HSD, $p < 0.05$) test revealed that the perceived reality of the no-motion condition was lower than those of other conditions (senses of presence and ultra-reality: 0.5 or above, sense of verisimilitude: 0.25 or above).

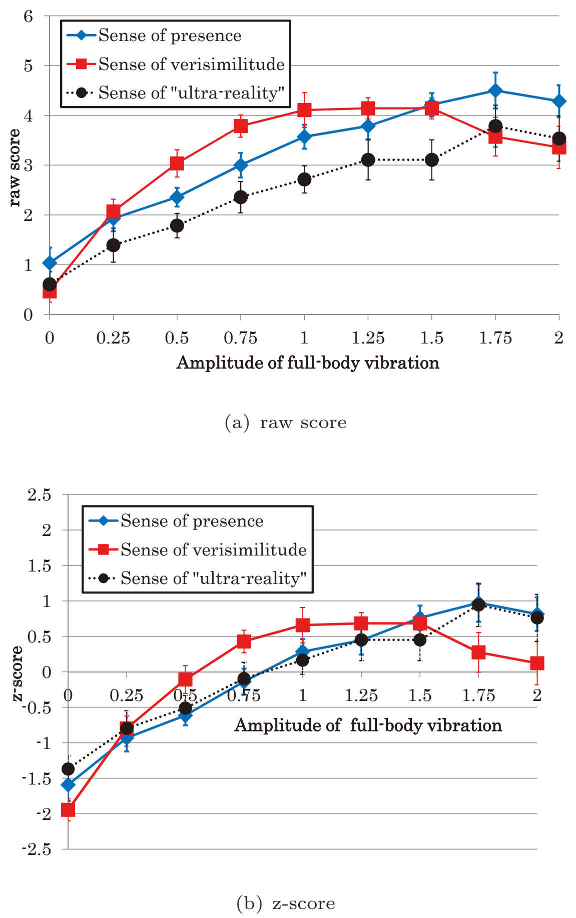

Fig. 4 Perceived reality as a function of amplitude of full-body vibration

5. Discussion

This study investigated the effect of vibration on perceived reality in multi-modal contents. The experiment results revealed higher perceived reality when vibration was included with the audio-visual movie. This tendency was observed among all indexes. These results suggest that vibration information is useful to enhance perceived reality regardless of the kind of perceptual reality. Such results were reported from previous studies[1)2)]. Therefore, it is important to add appropriate vibration information to advanced multimedia systems, such as UHDTV and 3DTV for increasing perceptual reality. However, it is noteworthy that the scenes we used as stimuli included vibration information originally. Moreover, immediately before the experiment, participants experienced the actual scene, including the vibration. Therefore, they easily recalled the "real" situation and compared it with the virtual environment. If the scene which people have not experienced is presented, it is unknown whether presented vibration information increases perceptual reality or not. It should be clarified. The effect of vibration using contents that did not originally include vibration information should also be investigated.

The tendency of perceived reality as a function of amplitude of full body vibration differed slightly among the indexes we used. Sense of presence and ultra-reality increased according to the amplitude, while the highest score of the sense of verisimilitude was observed around the amplitude of original vibration, which was recorded and which had been experienced. Previous studies indicated that the sense of presence was dominated by the absolute amount of the stimulus, whereas the sense of verisimilitude might be affected by prototype of contents[3)4)]. Our findings correspond to those of previous studies.

Although the sense of presence and ultra-reality increased at the range of the experiment, it would be saturated when the vibration amplitude increased further. Ozawa reported that the highest score of the sense of presence was observed at higher sound pressure levels than the actual recorded level[8)]. However, the score of the sense of presence becomes saturated for reasons that might differ from the reasons why the score of the sense of verisimilitude becomes saturated. As described in the previous section, the sense of verisimilitude is important in the evaluation of foreground components and is affected by the contrast between foreground components and background components[3)]. Therefore, the perceived sense of verisimilitude decreased when the absolute amplitude of the vibration exceeded that of the prototype for these participants.

To develop advanced multimedia systems, various sensory information must be presented with proper amount. Our study has shown the importance of full-body vibration. Actually, advanced motion simulator presents accurate vibration information, which increased participants' immersive impression. Spatiotemporal consistency must be examined in future studies.

6. Conclusion

We examined the effect of vibration information included in multi-modal contents on the perceived reality. More specifically, this study investigated the relation between the amplitude of full-body vibration presented via the motion platform and perceived reality in multi-modal contents. As the index of perceived reality, we used the sense of presence, the sense of verisimilitude, and the sense of ultra-reality. Results revealed that the perceived reality increased when full-body vibration was added to an audio-visual movie. In paticular, the senses of presence and ultra-reality increased monotonically according to the intensity of full-body vibration, whereas the sense of verisimilitude showed a saturating curvilinear tendency. These results suggest not only that audio-visual information but also that body vibration has manifold effects on perceived reality depending on its intensity. To develop advanced multimedia systems, we conclude that not only audio-visual information, but also vibration information should be presented with proper amount to increase perceived reality.

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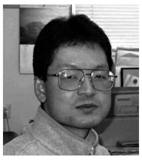

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