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Nordahl, Rolf; Serafin, Stefania; Nilsson, Niels Christian; Turchet, Luca

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Enhancing realism in virtual environments by simulating the audio-haptic sensation of walking on ground surfaces

Rolf Nordahl *   Stefania Serafin †   Niels C. Nilsson ‡   Luca Turchet §

Aalborg University Copenhagen
Lautrupvang 15, 2750 Ballerup, DK

ABSTRACT

In this paper we describe an experiment whose goal is to investigate the role of physics-based auditory and haptic feedback provided at feet level to enhance realism in a virtual environment. To achieve this goal, we designed a multimodal virtual environment where subjects could walk on a platform overlooking a canyon. Subjects were asked to visit the environment wearing an head-mounted display and a custom made pair of sandals enhanced with sensors and actuators. A 12-channels surround sound system delivered a soundscape which was consistent with the visual environment. Passive haptics was provided by having a physical wooden platform present in the laboratory. Subjects reported of having a more realistic experience while auditory and haptic feedback are present. However, measured physiological data and post-experimental presence questionnaire do not show significant differences when audio-haptic feedback is provided.

Keywords: audio-haptic feedback, realism, presence.

1 INTRODUCTION

In the academic community, foot-based interactions have mostly been concerned with the engineering of locomotion interfaces for virtual environments [3]. However, to our knowledge the use of footwear augmented with sensors and actuators has not been investigated yet when combined with visual feedback in a virtual reality experience. While active haptic feedback at feet level has not been investigated yet in a virtual reality environment, passive haptics is known to significantly enhance presence [1]. Passive haptics has also been combined with redirected walking in [2].

In this paper, we are interested in investigating whether realism in a virtual reality environment is increased by enhancing the simulation with interactive auditory and haptic feedback provided at the feet. To achieve this goal, we engineered a pair of shoes enhanced with sensors and actuators. While wearing the shoes, subjects are able to hear and feel the surfaces they are stumpling upon. Our hypothesis is that this enhanced simulation has an impact on the perceived realism of the simulation and also sense of presence reported by the subjects in the environment.

We start by describing the technology developed, and we then present one experiment whose goal is to evaluate the ability of auditory and haptic feedback to enhance realism and presence in the simulated virtual environment.

2 A MULTIMODAL ARCHITECTURE

We have developed a multimodal architecture with the goal of creating audio-haptic-visual simulations of walking-based interactions. The system requires users to walk around a space wearing a pair of shoes enhanced with sensors and actuators.

The architecture consists of a pair of custom made shoes enhanced with sensors and actuators. On top of the shoes, markers are place to track the position of the feet by using an Optitrack motion capture system by Naturalpoint. Auditory feedback is provided using a surround sound system composed by 12 Dynaudio BM5A speakers, and visual feedback is provided by a nVisor SX head-mounted display (HMD), with 1280x1024 resolution in each eye and a diagonal FOV of 60 degrees. In the following, we describe the relevant hardware and software components of the architecture.

2.1 Haptic shoes

In order to provide auditory and haptic feedback during the act of walking, a pair of custom made shoes with sensors and actuators has been recently developed [5]. The particular model of shoes chosen has light, stiff foam soles that are easy to gouge and fashion. Four cavities were made in the tickness of the sole to accommodate four vibrotactile actuators (Haptuator, Tactile Labs Inc., Deux-Montagnes, Qc, Canada). These electromagnetic recoil-type actuators have an operational, linear bandwidth of 50–500 Hz and can provide up to 3 G of acceleration when connected to light loads.

As indicated in Fig. 1, two actuators were placed under the heel of the wearer and the other two under the ball of the foot. The sole has two FSR pressure sensors (I.E.E. SS-U-N-S-00039) whose aim is to detect the pressure force of the feet during the locomotion of a subject wearing the shoes. The two sensors were placed in correspondence to the heel and toe respectively in each shoe. The analogue values of each of these sensors were digitalized by means of an Arduino Diecimila board (http://arduino.cc/) and were used to drive the audio and haptic synthesis.

3 SIMULATION SOFTWARE

We developed a multimodal physics-based synthesis engine able to reproduce auditory and haptic feedback at feet level, to simulate the act of walking on different surfaces. An interesting characteristic of this engine is its ability to physically simulate both auditory and haptic feedback. The footstep synthesis engine, is able to render the sounds of footsteps both on solid and aggregate surfaces. In this particular experiment, the engine was tuned in order to simulate the audio and haptic sensation of walking on a creaking wooden plank. This particular material was chosen to match the visual feedback provided to the subjects. The environment was enhanced with visual feedback in order to render, through the use of a commercial game engine, the visual sensation of exploring a canyon. In particular, in our simulation the Unity3D game engine has been used (http://unity3d.com/).

4 EXPERIMENT DESIGN

We performed an experiment whose goal was to investigate the role of auditory and haptic feedback in enhancing presence and realism in the simulated virtual environment. Subjects were asked to stand on a physical wooden plank while experiencing the environment. The experiment was designed as within-subjects experi-

*e-mail:rn@create.aau.dk
†e-mail: sts@create.aau.dk
‡e-mail:ncn@create.aau.dk
§e-mail:tur@create.aau.dk

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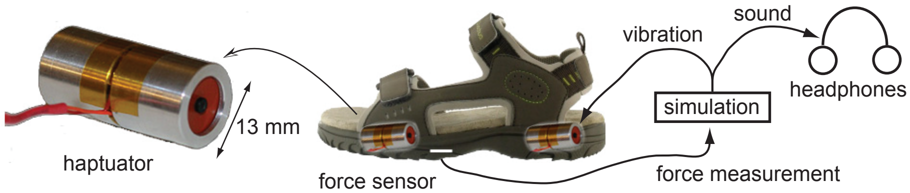

Figure 1: The developed haptic shoes used to provide auditory and haptic feedback in the multimodal architecture.

	Trials NF-F			**Trials F-NF**		
	Mean	**Max.**	**Min.**	**Mean**	**Max.**	**Min.**
NF	90±13.96	99.2±14.92	81.9±14.45	89.2±15	97.2±14.28	83.7±15.83
F	87.5±11.17	96.9±8.68	78.6±11.89	93.3±14.17	101.6±14.71	86.2±15.12

Table 1: Heart-rate results of the experiment. Legenda: NF-F: trials in which the no feedback condition was presented first and the feedback condition afterwards; F-NF: trials in which the feedback condition was presented first and the no feedback condition afterwards.

ments, where half of the subjects experienced the condition without audio-haptic feedback (named NF in the following) first and the one with audio-haptic feedback (named F in the following) afterwards, while the other half experienced the condition with audio-haptic feedback first and the one without audio-haptic feedback afterwards.

Before starting the experiment, each participant was asked to wear an HMD and the haptic shoes previously described, together with a wireless Q sensor device developed by Affectiva (www.affectiva.com), which, placed around the wrist, allows to measure skin conductance and temperature.

NF-F		F-NF	
NF	F	NF	F
29.46 ± 0.80	30.27 ± 1.09	30,51 ± 0,95	29,92 ± 0,79

Table 2: Mean skin temperature (degrees celsius) for the two condition-orders NF-F and F-NF, experiment with passive haptics.

NF-F		F-NF	
NF	F	NF	F
1,69 ± 2,15	1,71 ± 1,68	1,54 ± 1,87	1,29 ± 1,37

Table 3: Mean skin conductance (microSiemens) for the two condition-orders NF-F and F-NF, experiment with passive haptics.

4.1 Participants

Twenty participants (15 men and 5 women, aged between 20 and 34 (mean=23.05, standard deviation=3.13) took part to the experiment. Participants were primarily recruited from the campus of the Media Technology Department of the Aalborg University Copenhagen; however no restrictions on background were imposed. All participants reported normal, or corrected to normal, hearing.

5 Results

5.1 Measuring physiological data

Table 2 shows the results of the measured temperature. Table 3 shows the results pertaining to the measures of skin conductance and skin temperature. Table 1 shows the results for the heart-rate measurements.

The results obtained by measuring physiological data did not show significant differences between the two conditions.

5.2 Realism and audio-haptic feedback

As a final analysis of the experiments' results, it is interesting to discuss the observations provided by the subjects when the experiments were completed. Specifically, we asked subjects if they had noticed any difference on the two conditions and, in affermative case, if they could elaborate on the differences noticed and how they affected their experience. When asked whether they had noticed a difference between the two trials, 13 of the participants mentioned that they had noticed the change in the haptic and/or auditory feedback provided by the shoes. All of the participants who noticed the difference expressed a preference towards the added feedback.

6 Conclusions

In this paper, we have described an experiment whose goal was to assess the role of auditory and haptic feedback delivered at feet level to enhance sense of presence and realism in a multimodal virtual environments. While quantitative results obtained while measuring physiological data and performing a post-experimental presence questionnaire do not show significant differences among the two conditions, subjects were actually able to perceive the differences among the experiences.

In the future, we are interested in further investigating the role of auditory and haptic feedback provided at feet-level, also as a mean to provide useful information such as indications for navigation in virtual environments or feedback for actions in entertainment systems.

References

[1] B. Insko. *Passive haptics significantly enhances virtual environments*. PhD thesis, Citeseer, 2001.

[2] L. Kohli, E. Burns, D. Miller, and H. Fuchs. Combining passive haptics with redirected walking. In *Proceedings of the 2005 international conference on Augmented tele-existence*, pages 253–254. ACM, 2005.

[3] A. Pelah and J. Koenderink. Editorial: Walking in real and virtual environments. *ACM Transactions on Applied Perception (TAP)*, 4(1):1, 2007.

[4] M. Slater, M. Usoh, and A. Steed. Depth of presence in immersive virtual environments. *Presence: Teleoperators and Virtual Environments*, 3(2):130–144, 1994.

[5] L. Turchet, R. Nordahl, A. Berrezag, S. Dimitrov, V. Hayward, and S. Serafin. Audio-haptic physically based simulation of walking on different grounds. In *Proceedings of IEEE International Workshop on Multimedia Signal Processing*, pages 269–273. IEEE Press, 2010.

[6] M. Usoh, E. Catena, S. Arman, and M. Slater. Using presence questionnaires in reality. *Presence: Teleoperators And Virtual Environments*, 9(5):497–503, 2000.