Designing Auditory Displays to Facilitate Object Localization in Virtual Haptic 3D Environments

Koen Crommentuijn
Department of Human-Computer Interaction
School of Computer Science and Communication
Royal Institute of Technology
SE-100 44 Stockholm, Sweden
kjcr@csc.kth.se

Fredrik Winberg
Department of Human-Computer Interaction
School of Computer Science and Communication
Royal Institute of Technology
SE-100 44 Stockholm, Sweden
fredrikw@csc.kth.se

ABSTRACT
Five different auditory displays were designed to aid blind users in finding objects in a virtual haptic 3d environment. Each auditory display was based on a different principle and incorporated different methods for representing spatial information. Results from an evaluation with seven visually impaired persons reveal to what extent these methods facilitate object localization in a virtual haptic 3d environment.

Categories and Subject Descriptors
H.5.2 [Information Systems]: User Interfaces - *Auditory (non-speech) feedback, Haptic I/O.*

General Terms
Design, Human Factors.

Keywords
Auditory display, haptics, object localization, visually impaired users.

1. INTRODUCTION
With the development of haptic devices, such as the PHANToM Desktop[1], visually impaired persons have gained the means to explore virtual 3d environments. But when no visual representation is used, the task of finding objects in virtual space can become time consuming and frustrating. Every inch has to be scanned in order to know what is there and when a virtual environment is dynamic, many events and changes will go unnoticed to the user.

Researchers and software developers within the haptic community have proposed a variety of haptic tools to aid users in localizing objects (e.g. [1, 5]). The use of an auditory display for the same purpose has received less attention. Because so far only a few auditory displays have been investigated, this research set out to implement and compare new methods to facilitate object localization in virtual haptic 3d environments.

2. AUDITORY DISPLAYS
An auditory display uses non-speech sound to convey information to a user. In this case the information should represent or lead to the position of objects in a virtual 3d environment. One way is to use a x,y,z-coordinate space and sonify the x, y and z values for objects that need to be located (cf. [2]). The first of the five auditory displays investigated is based on this principle

Another way is, to sonify a virtual environment in relation to the position of the cursor (point of interaction). From the cursor the direction and/or distance to objects can be sonified. The second of the five auditory displays investigated uses discrete cues (e.g. up-right-front) to represent direction combined with an increasing rhythm when closing in on an object to represent distance. The third auditory display uses 3d surround sound to create a natural audio-haptic virtual environment. Like Pitt & Edwards [4], the cursor here acts as a virtual microphone through which one can listen to the continuously playing virtual sound sources placed in virtual space. The fourth auditory display uses 3d surround sound to (primarily) represent direction combined with an increasing rhythm when closing in on an object to represent distance.

Yet another way to sonify a virtual environment is to use the direction in which the cursor is pointing (cf. [3]). The direction to an object is thus represented by the position of the pen (kinesthetic) in combination with audio feedback. The fifth auditory display is based on this principle and also incorporates a guiding tone when pointing near to an object to help the user to point directly at the object. The distance is again represented by an increasing rhythm.

Haptic magnetism, a haptic aid to find objects, was chosen to be implemented along with the auditory displays to evaluate how a haptic aid works. With haptic magnetism enabled, objects exert small attractive forces upon the haptic device, pulling the hand of a user towards the objects.

3. EVALUATION
All audio methods have been implemented in a 'simple' virtual haptic 3d environment (see figure 1). The environment was bounded by a large box in which three to eight cubes were present.

The virtual environment could be explored with a PHANToM Desktop. When touching a cube and simultaneously pressing the button on the stylus, the cube could be dragged. Audio was played over a pair of headphones. No visual representation was given to the user.

The evaluations involved questions about the number of objects and the layout of the virtual environment as well as tasks to move the cubes into specific positions (e.g. move all cubes to the left

ASSETS'06, October 22–25, 2006, Portland, Oregon, USA.
ACM 1-59593-290-9/06/0010.

[1] www.sensable.com

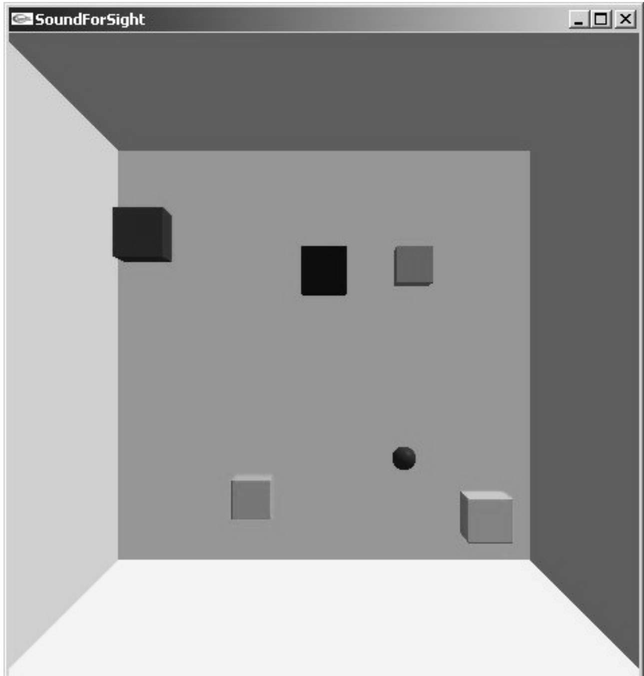

Figure 1: Visual representation of the virtual environment.

wall). The moving tasks provided the users with an interesting challenge which could easily be timed. Three visually impaired persons (2 male, 1 female) tried all 5 auditory displays during an evaluation. Four visually impaired persons (2 male, 2 female) tried only 2 pre-selected auditory displays, to obtain a more detailed evaluation. Except one female who had low vision (10/100), all participants were blind. The age of the participants varied from 26 to 59.

4. RESULTS

4.1 Coordinate Sonification

Sonifying the x,y,z-coordinates of objects did not successfully aid users in finding them. The characteristics of sound (pitch, panning, high-pass filter) that were mapped to the position of an object lack resolution and don't provide absolute values. The implemented auditory display did give the users a global impression, but left a too large area to search for the objects.

4.2 Discrete Directional Cues

Using discrete cues to represent the direction of objects is useful. It takes some time for a new user to recognize and make use of the cues, but they then provide an unambiguous direction. Integrating discrete directional cues into an auditory display can be difficult though. An environment with more then a few objects needs a well designed algorithm in order to present all the discrete directions without confusing the user.

4.3 Distance by Rhythm

An increasing rhythm to represent the distance between the cursor and an object appeared intuitive. Users easily perceived when they moved the cursor nearer to an object. Using rhythm to represent distance can be a valuable option when combining it with another method to represent direction.

4.4 Virtual Microphone

Positioning virtual sound sources at the location of virtual objects creates a natural/realistic auditory space. The use of such a method is very intuitive and requires little cognitive effort by the user. The time to find-and-touch objects was on average the shortest with the implementation of this auditory display. It should be noted however that the fine movement necessary to go from being close to touching an object took a relative long time. Providing more support for the final fine movement should improve the performance of this auditory display.

4.5 Pointing

For a visually impaired person, the principle of pointing is less obvious, because it is based on a visual cue. But the results show that with some practice and explanation the users were able to successfully use the stylus of the PHANToM Desktop as a pointing device. It took some time and 'luck' to discover all the objects present, but when an object was discovered, users had little trouble to move closer and touch it.

4.6 Haptic Magnetism

The users reacted positively to haptic magnetism. Some tasks were completed amazingly fast, but some similar tasks took a long time to complete or were not completed correctly. It was reported that haptic magnetism, despite the attractive forces being weak, from time to time interfered with the desired movement of the user. Users also reported that when they felt the haptic magnetism, they let it pull the stylus toward the virtual object. The haptic magnetism is thus not used to extract the direction or distance to an object, but used in a more passive way. Since haptic magnetism is only felt within a certain range of an object, a supporting method giving a more global overview would be useful.

5. REFERENCES

[1] Magnusson, C. & Rassmus-Gröhn, K. *Audio haptic navigational tools for non visual environments*, First ENACTIVE Workshop, Pisa, Italy, 2005.

[2] Mereu, S. & Kazman, R. *Audio Enhanced 3D Interfaces for Visually Impaired Users*, Proceedings of CHI '96, Vancouver, Canada, 1996.

[3] Müller-Tomfelde, C. *Interaction Sound Feedback in a Haptic Virtual Environment to Improve Motor Skill Acquisition*, Proceedings of ICAD '04, Sydney, Australia, 2004.

[4] Pitt, I. & Edwards, A. *Navigating the Interface by Sound for Blind Users,* In D. Diaper & N. Hammond (Eds.), People and Computers VI, Proceedings of the CHI '91 Conference (pp. 373-383). Cambridge University Press, 1991.

[5] Sjöström, C. *Virtual Haptic Search Tools – The White Cane in a Haptic Computer Interface*, Presented at AAATE 2001, Ljubljana, Slovenia, 2001.