Integrating Audio and Haptic Feedback in a Collaborative Virtual Environment

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Abstract.
An ongoing study is presented here. The purpose is to design and evaluate an experiment comparing an audio/haptic/visual and a haptic/visual VR environment supporting collaborative work among sighted and blindfolded people. We want to investigate how haptic and audio functions could improve collaboration in a shared workspace. We used a 3D VR environment that supports learning of spatial geometry. The scene is a room containing objects which you can pick up and move around by means of a touch feedback pointing device called Phantom. An experiment was performed with group work in the VR environment comparing an audio/haptic/visual interface with a haptic/visual interface of the application in a laboratory. We investigate if adding audio cues improves awareness, common ground, social presence, perceived performance and work efficiency. The aim is also to conduct a quantitative and qualitative analysis of the video-recorded collaboration in order to obtain information about whether and how the added audio information changes the work process in the groups.

Keywords: HCI, Haptic, Audio, Multimodal interface, Awareness, Common ground.

1 Introduction

There are many forms of collaboration in today's information society. Visually impaired people are often disadvantaged among sighted peers in group work situations and they easily fail to contribute satisfactorily just because the information shared by the others is inaccessible to them. Besides losing the opportunity to learn, they might be excluded from normal social interaction within their peer groups. When blind and sighted people are going to collaborate, it is important to take into consideration the affordances of different interaction media and how they affect the work process in groups. The experiment presented here is based on the results from a previous evaluation of a haptic and visual interface in schools with groups including one visually impaired and two sighted pupils [4]. A number of research questions and hypotheses were derived from this earlier study about the impact that sound cues might have on the affordances that an audio/haptic/visual interface gives compared to one without audio cues.

Here haptic perception refers to an integration of both kinaesthetic sensing (i.e. of the position and movement of joints and limbs) and tactile sensing (i.e. through the skin) [1]. The Phantom used in our experiment is a haptic system that generates accurate force feedback to simulate forces (of resistance etc.) in three dimensions. The Phantom is operated with a pen-like stylus attached to a robotic arm that generates force feedback [3]. In the experiment we tested a 3D environment to support learning of spatial geometry. The scene is a room containing objects which you can pick up and move around by means of a Phantom.

This study is part of the EU-funded project MICOLE (Multimodal collaboration environment for inclusion of visually impaired children) and the aim of the project is to develop an application for collaborative learning among sighted and visually impaired pupils. Such an application must make it possible to obtain information not only by looking at things but also by feeling and hearing.

2 Background

A program for collaborative learning among sighted and visually impaired pupils in an elementary school was developed and evaluated previous to the study presented here [4]. That application, referred to as the geometry application, has a haptic and visual interface and supports construction and solving of tasks in geometry [2]. The geometry application is a 3D environment that supports collaborative learning of spatial geometry like understanding geometrical shapes such as cube and cone and the concepts of volume and area. The scene is a room viewed from above through a transparent ceiling. In the far left corner of the room there is a wooden box containing four objects with the basic geometrical shapes cube, sphere, cone and cylinder respectively. The roof, walls and the box all have different textures applied to them (Figure 1).

Fig. 1. Users carry one cube together in the geometry application with ten cubes

Apart from feeling and recognizing the different geometrical shapes, a user can also pick up and move around the objects by means of a Phantom (tiny spheres in figure 1 for two users holding the same object). In this way the users can co-operate in compiling larger objects. Since gravity is applied to all objects, the pupils feel the weight and inertia of things as they carry them around. Besides feeling and manipulating the cubes and cones etc. users can feel and also grasp each other's graphical representations in order to provide navigational guidance e.g. to a visually impaired fellow. The users can also "feel the other proxy" by means of a small repelling force, applied whenever the user's graphical representation touches that of the other person.

A task driven field evaluation of the original geometry application was conducted in schools with groups of three pupils in each. During this evaluation several problems were encountered in the prototype. The navigational guiding force was too weak. Often this problem caused some confusion when the subjects "dropped" each other during a guiding operation. It was also, to some extent, hard for the visually impaired pupils to get awareness of changes made in the environment. That is the major problem to be solved, by including audio information, in the application used in the experiment presented here.

3 Research Questions

Based on the results from the former evaluation several improvements have been made in the program. A number of audio functions have been added. The aim of the experimental study presented in this paper was to test the hypotheses that adding an audio function to the visual/haptic environment would increase the perceived awareness, social presence, perceived performance and common ground as well as the task efficiency in the collaborative work.

4 Methodology

An experiment was performed with group work in the improved geometry prototype comparing an audio/haptic/visual interface with a haptic/visual interface of the application in a laboratory. We used the between subjects design in this experiment. Forty participants from KTH campus were divided into pairs, where one was blindfolded. Each pair carried out two collaborative tasks in one out of two conditions: (1) a visual and haptic VR environment, (2) an audio, visual and haptic VR environment. The experiment sessions were video recorded.

There were thus one independent variable and six dependent variables. Four of the latter were subjective measures: perceived awareness, perceived common ground, perceived performance and perceived social presence. The objective dependent variables were time to perform the tasks and accuracy. The subjective measures were obtained mainly through questionnaires. Besides the quantitative analysis a qualitative analysis of the post-test interview and the video recorded collaboration will be performed in order to investigate in what ways the different modalities affect the interaction between the participants and the interaction with the system.

The prototype used in this experiment was an improvement of the original geometry application. Figure 2 shows the scene and the setting of the experiment. The virtual environment was identical with the original version except for the following improvements:

- The wooden box was moved away
- The collision detection was made more stable

- A “grip sound” was heard every time an object was lifted.
- A kind of “touch down sound” was heard every time an object touched the floor
- A “collision sound” was heard every time an object landed on top of another object
- A “contact sound” was heard every time the button on the phantom was pushed down. This “contact sound”, in stereo, was heard from one’s own avatar and it made it possible for the blindfolded participant to locate the other user’s position relative to their own position.

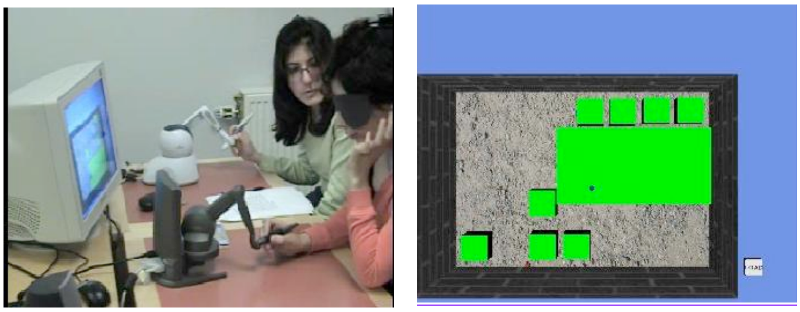

Fig. 2. Participants doing a task in the improved geometry application

The following hardware and software were used for the experiment:
- One personal computer with two dual core processors
- One computer screen
- Two phantoms (one Omni and one Desktop)
- Mouse and keyboard
- Reachin API 4.1 software
- Microsoft Visual Studio 2003 .NET software
- CamStudio for screen capturing

The blindfolded participant practiced on a training task in the experimental environment before the two real tasks, in order to get used to this type of interface. He or she practiced how to feel the shape of a cube, how to navigate in the three-dimensional environment and how to grab a cube, lift it and hand it off to the other person in the group. We made sure that he/she felt comfortable with the blindfold and got used to working in this kind of haptic environment before the real tasks were loaded. In the first task the participants were to build a table. They got eight cubes for the four legs and a flat board. Collaboration was inevitable since they were only allowed to move four of the cubes each. The second task was to make a large cube by compiling several smaller building blocks of various dimensions. The two participants solved the tasks collaboratively. Interviews and questionnaires were conducted afterwards in order to acquire information about technology use and the subject's attitudes.

5 Expectations from the Result of the Study

The data from this experiment will show if the improved multimodal interface, that includes audio cues as well as haptic feedback, will improve the groups' ability to collaborate. Firstly, we hope to show that the hypothesis holds that collaboration will take less time when audio cues provide awareness information on the changes that the two participants made in the environment. The second hypothesis was that the added audio information would improve accuracy when participants construct a composed object jointly. In this study, accuracy means the extent to which coordinated actions are either productive for the end result or disruptive. More precisely, this will be measured by coding each movement of objects by the participants either as a successful addition to the composed object that is being built or as an unsuccessful move that destroys some part that has already been built. Of course, such a successful addition can also be of two types, either the move is a successful move towards the end solution of the task or it is a successful move that is not correct in order to solve the task. We consider both types of meaningful moves.

We also hypothesized that audio cues would increase social presence and common ground as well as awareness of the other's actions that would result in fewer mistakes of mainly the first category of unsuccessful moves. Apart from the quantitative objective measures, the questionnaires focus on perceived performance, social presence, awareness and common ground. They will show if participants perceived that these aspects of the interaction with the other person and the system were improved in the sessions where audio cues were provided. Furthermore, the analysis of the data from the post-test interviews will reveal how participants reflect on their interaction with each other in the two versions of the CVE and with the system.

An in-depth qualitative analysis of the video recordings will shed light on whether and how audio cues were utilized by the pairs in order to coordinate their work.

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