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# Iterative Design of an Audio-haptic Drawing Application

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**Abstract**

This paper presents the ongoing design and evaluation of an audio-haptic drawing program that allows visually impaired users to create and access graphical images. The application is developed in close collaboration with a user reference group of five blind/low vision school children. The objective of the application is twofold. It is used as a research vehicle to investigate user interaction techniques and do basic research on navigation strategies and help tools, including e.g. sound fields, shape creation tools and beacons with pulling forces in the context of drawing. In the progress of the development, the preferred features have been implemented as standard tools in the application. The final aim of the application in its current form is to aid school work in different subjects, and part of the application development is also to create tasks relevant in a school setting.

**Keywords**

Haptic, auditory, force-feedback, blind, low vision, iterative design, interface, drawing

**ACM Classification Keywords**

H5.1 [Information interfaces and presentation (e.g., HCI)]: Multimedia Information Systems.

H5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces -- Auditory (non-speech) feedback, Haptic I/O, User-centered design

H.5.3 [Information interfaces and presentation (e.g., HCI)]: Group and Organization Interfaces – Computer Supported Cooperative Work

### **Introduction**

Getting access to 2D graphics is still a large problem for users that are severely visually impaired. Using a haptic display in combination with audio feedback is one way to enable access. General guidelines to create and develop haptic applications and models are collected in [1]. Applications making practical use of non-spoken audio and force-feedback haptics for visually impaired people are e.g. applications supporting mathematical display [2], [3] & [4], games [5-7] and audio-haptic maps [5;8]. As described in [9] and [10], there are indeed people who are blind who have an interest in hand drawing. In [11], a CAD application is presented that enables users to create drawings with the help of audio and keyboard. In [12], a study on a haptic drawing and painting program is presented.

### **Iterative design process**

User-centered design is a design philosophy that focuses on the end users needs and wishes for a products functionality [13]. This is motivated by that fact that it is very hard for designers to foresee the needs and wishes of others, and is especially important when the end users are people with impairments.

In the current work our target group involves children with visual impairments. This presents special problems since the number of available users is quite limited

(making the group both small and diverse) but also since these users are children which, among other things, makes it hard to do more extensive or “dull” tests.

To deal with these problems we have used an adapted user centered approach. User involvement has been achieved through a reference group where we have had discussions and performed qualitative and explorative tests. This process has been complemented by more formal tests of basic functionality by a larger group of sighted users. This way we avoid subjecting the limited group of end users to too many tests and also avoid putting them in front of uncomfortably dysfunctional applications, by performing tests to evaluate basic functionalities with blindfolded sighted users. The above described approach was based on the assumption that for more basic functionalities we expect reasonably similar results for blind and blindfolded sighted participants. It should be noted that for more complex tasks and realistic situations this is not generally true, and in these cases we will always need to involve the real end users.

### **Initial user requirements**

At the start of the project we performed an initial round of interviews with 10 blind persons (ages ranging from 10 to 66). The answers suggested several application areas that could be of interest: images, arts & drawing, maps and geographical data, mathematics (including tables, graphs, geometry, and statistics), physics (rigid bodies, electricity, magnetism, waves, quantum mechanics etc), chemistry, games & gymnastics and following what happens on the blackboard.

Since we were targeting an application that could be made useful over a range of years and that was available through a stationary computer we decided to start working on a simple drawing program which could cover some basic aspects of most of the application areas above (except games and gymnastics). This choice was also discussed with and approved by our reference group.

### Current status of application

The Reachin 4.1 API software has been used to develop the haptic part of the application, along with FMod Ex 4.04.30 for non-speech sound and Microsoft SAPI 5.1 for speech synthesis. A PHANToM device is used for haptic feedback and control, and a mouse can be used for non-haptic control of the program.



Figure 1 Two pupils collaborating in using the drawing application.

The virtual environment consists of a virtual sheet of paper. The PHANToM user draws by pressing the switch

when in contact with the paper. The mouse user draws while pressing the left mouse button. The haptic image is produced as positive or negative relief. The drawing is presented on the screen as a grayscale image – a positive relief is seen as black, and a negative relief is seen as white. The paper color is grey. The PHANToM user can feel the lines while drawing. Each line is attached with a number and text tag which is spoken by the application each time a user selects an object by touching it with the PHANToM pen or hovering over it with the mouse cursor. Objects can be manipulated in the different ways; moving, resizing, copying, pasting and deleting. Additionally, text tags for the shapes can be changed, and shapes can be transformed into straight lines, rectangles or circles. The manipulation tools are fitted with feedback sounds designed to resemble a real world manipulation of similar nature. E.g. the copy function sound effect is a camera click.

The mouse user can guide the PHANToM user by a pulling force that drags the PHANToM pen tip to the mouse cursor position. It is also possible to place beacons at specific points in the environment. The user can later return to these beacons by activating a pulling force.

There is the possibility to turn on a sound field to aid localization. When in contact with the virtual drawing paper the volume is louder, and when the user is drawing the tone is changed to a saw-tooth wave. Vertical position is mapped to the pitch of the tone, while horizontal position is mapped to the pan of the sound source.

A png import and export function is available. The files imported must be grayscale and 256\*256 pixels.

### User evaluations

The application has been tested at five different occasions by a reference group of five school children, aged 10 to 16. Two of the participants are blind from birth, and three participants have various forms of low vision. All of them read Braille and are integrated in normal schools in southern Sweden.

2 separate studies with sighted participants have also been conducted. The first investigated the usability of the sound field feedback and the relief preference. 11 adults (aged 25 – 72) participated. The second was to test force beacons and force design. 14 participants aged 10-73 performed this test.

#### *Qualitative evaluations with reference group*

The reference group has visited the lab and used the drawing program at informal meetings, followed by discussion. During the first three occasions, drawing was tested with and without audio feedback, with positive and negative relief and with program interaction by virtual haptic buttons and keyboard commands.

At the fourth meeting, the shape drawing tools were used. All three users were first introduced to the tools and how to use them and then guided to complete a specific task – drawing a house.

The fifth meeting introduced the collaborative version of the application. The accompanying persons used the mouse and the visually impaired pupils used the PHANToM. Aside from some general experimentation with the application, the users were asked to solve 2 tasks of school work nature. Both tasks were focused on exploring, marking and text-tagging in prepared

drawings (one on finding right angles in a figure, and the other on marking points of interest in a map).

#### *Formal pilot studies with sighted persons*

The first formal pilot study included image recognition tasks, and to find out how different images, sound/no sound and positive/negative relief influenced the recognition performance. A pair of headphones was used when sound field feedback was available.

The second test concerned the design of the dragging forces used to return to specific points in a drawing (so called beacons). Although beacons have been tested before [14] the actual design of the force has not been systematically investigated. We tested six different types of radial dependencies: two roughly constant forces (constant,  $\tanh(r)$ ), two forces that increased towards the target ( $1/r$ ,  $1/\sqrt{r}$ ) and two forces that decreased towards the target ( $r$ ,  $\sqrt{r}$ ). Forces that did not tend to zero at small distances had a short linear part for very small distances. This linear part was attached so that the force function was continuous throughout the whole space.

The PHANToM Premium was used for both tests.

### Results

In [15], detailed results on the first three qualitative evaluations and the first formal test are described. Here we present the results for the drawing tool test and the collaborative test involving the reference group, and the beacon test with sighted participants.

#### *Drawing tool test*

All users completed the test with no apparent problems other than remembering commands. The tools worked

as expected, and the users managed to draw houses (figure 2) but it was commented on the problem to find the corner of the house and connect the roof to it. All participants also appreciated the audio feedback for the manipulation tools. They found the application noticeably more interesting than in previous meetings. At the particular test session, no tools for the creating of straight lines was implemented, but it was asked for and therefore realized shortly afterwards. More tools were also asked for, e.g. tools for making triangles or stars.

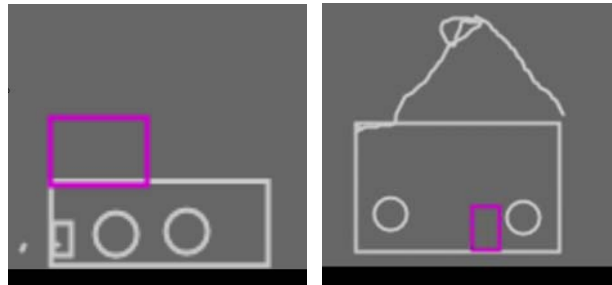


Figure 2 House drawings from the two participants in the user trials. The houses on the right looks as intended from the instructions given. The colored rectangles in the drawings indicate the object currently selected.

#### *Collaborative test*

The results of the fifth test with the collaborative environment were very diverse, although all pairs of users can be said to have succeeded in solving the tasks at hand. In most pairs, the visually impaired user was the one that marked out the points on the map and the angles in the figure. However, there is the issue of speed – it is simply much faster to obtain an overview of the scene visually compared to using the PHANTOM. Thus, the sighted participant guided the other user in

all pairs – sometimes verbally, and sometimes with the dragging force. Especially one user, who, despite continuous test sessions with the PHANTOM had not learned to use it efficiently, was guided with the force by a parent. This actually made the child understand better how to move with the PHANTOM in order to get good feedback. In the pairs with children and parents together (3 of the pairs), the sighted parent was the one who lead the work and prompted the child to do things. One pair was a child (12 yrs) and a friend of the same age, and in this case the lead was not so clearly taken by the sighted pupil.

#### *Results from formal beacon experiment*

For the type of tasks studied, users preferred forces that did not interfere too much with exploration. Also, depending on the task, some short distance snap-to-point behavior was seen to be useful. The favorite force dependencies were constant,  $\tanh(r)$  and  $1/\sqrt{r}$ . The  $1/r$  was thought to be too weak far away and too strong at close distance while the opposite was true for the linear force (too strong far away and too weak at short distances). An interesting observation is that the beacon force can be quite strong towards the end of a movement compared to what is tolerated initially.

#### **Conclusion**

The design process used has provided us with an increased understanding of how to design a working haptic-audio drawing application to be used by blind and sighted school children in collaboration. This application will be tested in schools with tasks of school-work nature during the spring of 2007.

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