DESIGNING HAPTIC COMPUTER INTERFACES FOR BLIND PEOPLE

Calle Sjöström
Certec, Lund University
Box 118
S-221 00 Lund, Sweden
+46-46-222 40 38
www.certec.lth.se/haptics
calle.sjostrom@certec.lth.se

ABSTRACT

Certec has been working on touch interfaces – haptic interfaces – since 1995, exploring the possibilities they can offer people with different kinds of disabilities. With a haptic computer interface a blind person can learn mathematics by tracing touchable mathematical curves, playing haptic computer games, and gaining better access to graphical user interfaces like Windows.

This paper presents a brief overview of a set of tests that have been made and some of the results from these tests. This is followed by a set of design recommendations that we have been able to extract as an extended result of this research and development work. These guidelines are grouped under the headings Navigation, Finding objects, Understanding objects, Haptic widgets and Physical interaction.

1 INTRODUCTION

Computer access and the wide adoption of the Internet as an information channel have given blind persons access to information that used to be almost inaccessible. The fact that text in digital form can be easily accessed has actually given blind persons a new way of communicating with the rest of the world.

Most blind computer users have a screen reader combined with synthetic speech and/or a Braille display. This gives them access to text on the screen, but not to the graphics. Haptic interfaces use the sense of touch in user interaction. With a haptic interface it is thus possible to feel shapes that are based on digital information. There are now computer programs available that present some of the graphical information in a GUI via a haptic device.

Certec is the Division of Rehabilitation Engineering Research, Department of Design Sciences, Lund Institute of Technology at Lund University in Sweden. We have been working with haptic computer interfaces and haptic games for blind people since 1995.

2 THE EXPERIMENTS

This paper presents a set of principles for haptic user interface design. The user tests and experiments that lay the foundation for this article have not been designed specifically to achieve or test the principles. Instead, these tests have been conducted to test different user interface ideas, games etc. and to get an idea of how useful it can be to include haptics in a computer interface for blind people. The principles have emerged and been refined with “ref-lection-in-action” and “reflection-on-action” [4] during our tests and software development. We have found these recommendations useful, and we believe that they can work as general guidelines for all developers of haptic interfaces for blind people.

2.1 User tests of a haptic memory game - The Memory House

These tests were conducted to find out if it is possible to understand and control a system like Windows with only haptic and auditive information.

The game consists of 25 buttons that produce a sound when pressed. There are 12 sound pairs and one non-paired sound (the “Old Maid”). The buttons disappear when the player presses two buttons with the same sound in sequence.

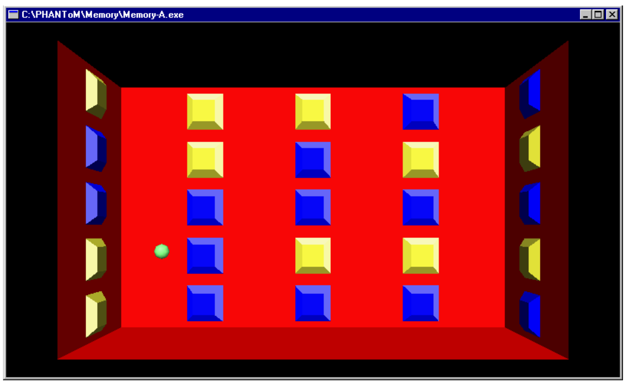

Figure 1. The Memory House

In the Memory House, the buttons are placed on five different floors. Between each row of buttons the user can feel a thin barrier that helps him to stay within one set of buttons. To make navigation among the floors easier, there is a voice that reads the number of the floor each time the user moves from one floor to another.

The program has been tested in a study comparing sighted and blind people (nine blind persons of different ages and 23 sighted children). The sighted testers used a regular mouse and pictures or sounds, while the blind testers used the PHANToM and sounds.

The main results from these tests indicate that it is possible for almost any blind user to navigate among the sounds and buttons in the game. Of the nine blind persons in our initial test only two were unable to finish the game (although they managed to find a few pairs). The other seven users managed to find all the pairs and many of them finished the game using about as many button pushes as the sighted testers. However, most of the blind testers needed more time than their seeing counterparts [6][7].

2.2 Pilot studies with Immersion's FEELit Mouse

In these tests, we conducted three different experiments using a prototype of the FEELit Mouse from Immersion Corporation. The experiments where:

1. Combining FEELit Desktop with synthetic speech for general Windows access
2. Testing "radial haptic menus"
3. Testing a set of virtual haptic search tools that can be used as aids in finding scattered virtual objects such as icons on the desktop.

The first is an example of direct translation from graphics to haptics. FEELit Desktop from Immersion is a program that directly translates many graphical interface objects to corresponding haptic objects. Our work has been to try to determine how well FEELit Desktop can compensate for things that are not made accessible by the speech synthesizer.

Radial menus are menus where the choices are indicated as rays pointing out from a center instead of being arranged in a column as in ordinary linear menus. A radial menu can be likened to a pie or a clock. In this case a radial menu with 12 choices was used and that made it very easy to use a clock analogy (e.g. "Copy is at three o'clock").

The virtual search tools are intended to help the user when exploring an unknown environment, for example, the Windows desktop on somebody else's computer. With these tools it is possible to feel objects without touching them directly. Three different search tools were proposed but only the first one was tested in this experiment.

- A "cross" that makes it possible to feel when you line up with an object horizontally or vertically.
- A "magnet" that pulls the user towards the nearest object.
- A "ball" that makes it possible to feel objects at a distance but with less detail.

We have carried out a case study of the usability and usefulness of these concepts involving two blind computer users [8]. Both users had minor problems with the small workspace of the FEELit Mouse. Their spontaneous reaction was: "This device requires tiny, tiny movements. Can't it be made a little bit bigger?"

The radial menus worked very well for both of the testers. They were successful in handling the menus and they were also able to make good use of the clock metaphor. Even though both testers thought that these menus worked well they where skeptical about introducing them in a Windows access system. They both wanted the access system to be as transparent as possible and they wanted it to give them the same picture as a sighted person gets when looking at the monitor.

The cross search tool was especially well accepted by one of the testers. He found the cross very helpful when searching. The other user was more uncertain about the cross. He talked more about magnetic objects as a way to guide the user. Since all search tools apart from helping the user to find and explore virtual objects, also alter the sensation in different ways, it seems important to be able to easily switch between different search tools and no tool at all.

2.3 Informal demos and tests of a haptic games and programs

Certec has developed a number of haptic games and programs that have not been tested formally. However the programs have been demonstrated at exhibitions and conferences to both sighted and blind visitors, and there also have been many trial sessions at Certec with blind children and adults, as well as with a group of deaf-blind persons.

The programs used at these sessions were scenes with simple static or dynamic geometrical objects, a game called "Submarines", and a simple clay-modeling program (provided by SensAble Technologies).

"Submarines" is a haptic variant of the well-known battle-ship game. The ordinary pen-and-paper-based battleship game has been used to give school children an initial idea of what coordinate systems can be used for. With "submarines" it is possible for a blind child to get the same kind of playful introduction to coordinate systems.

The player feels 10x10 squares in a coordinate system. In the game, your finger in the PHANToM is a helicopter that is hunting submarines with depth charge bombs. If you put your finger on the "surface of the water" you can feel smooth waves moving up and down. There are four different states for a square with associated haptic feedback:

- Not yet bombed - calm waves
- Bombed, but missed - no waves (flat)
- Bombed, hit part of a submarine - vibrations
- Bombed, hit entire submarine - bubbles

“Submarines” has also been tried by a group of deaf-blind persons. Since the different conditions of the squares are provided as haptic feedback, our hypothesis was that it should work well for deaf-blind users too. As it turned out, it seemed like the haptic feedback of the game was sufficient, in all but one case. In the game, the space key is used to drop the bomb in the water, and while the bomb falls, a hearing person hears the sound of the falling bomb in the speakers. However the deaf-blind users became confused since they did not get any haptic feedback before the bomb reached the water and there was no direct haptic feedback indicating whether it was a hit or not.

The first PHANToM program at Certec was a painting program for blind children, “Paint with Your Fingers”. With the PHANToM, the user chooses a color from a palette. Each color on the palette has an associated texture that the user feels when painting with it. By changing program mode the user can feel the whole painting and also feel what other people have painted.

All of these programs have been tested by more than 20 blind children [5][7]. Perhaps the most interesting result from these sessions was that it is actually possible for a blind person to use virtual touch to create an inner picture of rather complex environments. And they are also able to connect sounds to objects in this inner picture.

Another finding is that some of the subjects were able to compare what they felt with the PHANToM to earlier experiences. For example, one tester likened a virtual model of a house to “The money box I got from the bank when I was a child”. The money box he mentioned had the form of a small house and he remembered it from the time when he could still see.

2.4 A haptic mathemathics program

Early in our work we also developed a simple mathematics program. People who try to explain mathematics to blind persons often notice that to some extent it is a visual subject. Our program makes it possible to feel a mathematical curve or surface with the PHANToM. A program like this can help blind persons to understand equations in terms of curves and surfaces. A similar program, but with more functionality, has been developed at ASEL, University of Delaware [1].

It is interesting to compare the two programs because they demonstrate two different ways of showing 2D graphs in a 3D environment. The program from ASEL displays the graph as a thin line with a “virtual fixture”, which gives the line an attractive force that helps the user find and follow the function. The program from Certec shows the function as a ridge or a groove in a flat surface. In this case the user can sweep the surface until she finds the ridge or groove and then follow it easily. Both ways are feasible.

3 APPARATUS

Most of our work has been carried out with the PHANToM, a high performance, 3D haptic interface from SensAble Technologies. We have also used other devices such as force feedback joysticks and the FEELit Mouse from Immersion Corp.

Figure 2. The PHANToM (photo by SensAble Technologies Inc.)

4 GUIDELINES FOR POINT INTERACTION HAPTICS - DESIGN REQUIREMENTS

In the course of the work with the above-mentioned experiments we have also gained general knowledge and experience of using haptics in computer interfaces for blind people. This knowledge was first summarized in my licentiate thesis “The IT Potentials of Haptics – Touch Access for People with Disabilities” [8]. The list presented here is a revised version of those principles.

4.1 Navigation

- Provide well defined and easy-to-find reference points in the environment. This is necessary to facilitate navigation. Natural reference points are for example the corners of a room. Good reference points are easy to find and come back to, and they should also be easy to identify [6].
- Do not change the reference system unnecessarily. A disabled haptic button should not be removed, but rather “grayed out” for example by giving it a different texture and making it impossible to click. This way the button can still be used as a reference point even though it is nonfunctional. [6].

4.2 Finding objects and getting an "overview"

- With pure one-point haptics it is easy to miss an object even if one is really close to it. One can often compensate for this when designing haptic software by using objects with large connected surfaces rather than scattered, thin and/or small objects [6][8].
- It can be just as difficult to determine that an object does not exist as it is to find an object. It is always easier to move along some kind of path (a ridge, a groove, a magnetic line, etc.) to the place where the object is located or where there is no object [6][8].
- In both of the cases just mentioned one can also choose to give the user a "virtual search tool" [8] instead of changing the virtual objects. A virtual search tool could be a bar, a ball, or a magnet, for example.

4.3 Understanding objects

- If it is not absolutely necessary for the haptics to feel like something real, it may be beneficial (and sometimes essential) to help the user follow the outline of the object. It is easy to make a thin touchable hose easier to find by giving it the appropriate attractive force. Without such a force it is almost impossible to feel the hose in 3D [1].
- Sharp edges and corners are much more difficult to feel and understand than rounded shapes when they are felt from the "outside". The user almost always loses contact with the object when moving past a sharp corner, thereby disturbing the cognitive process that translates the impressions received into an inner picture. Moreover, it is difficult to determine the size of the angle; many users believe that the angle is more acute than it really is [6].

4.4 Haptic widgets

- When going through a thin wall or past an edge, the finger often accelerates a great deal. Consequently, the next wall or edge should not be very close since there is a risk that the finger will go through that wall as well (sometimes without the user noticing). In this case it can sometimes help to replace the thin walls (between the areas) with a magnetic line that pulls the user to the center of the area instead. The problem becomes apparent when one wishes to represent menus and coordinate systems [3][8].

4.5 The physical interaction

- Be careful with the manipulandum design. The manipulandum is the tool that the user grasps in his hand. In the PHANToM the manipulandum is a stylus or a thimble. In other cases it might be a mouse body, a joystick handle or some specialized tool. The choice of manipulandum can affect the haptic sensation a great deal. This is because the form and surface of the manipulandum have an effect on how the resistive force is applied to the user, the kind of movements used, and the feeling of being in contact with the virtual object. For example, a thimble with sandpaper on the inside causes many people to use less force when grabbing a virtual object because they get the sensation that the objects are less slippery [2][8].

5 CONCLUSION

Haptic interfaces can be used in many different kinds of computer programs for blind people. We have found that our haptic programs in general work better when considering these guidelines, even though we do not claim to have complete knowledge of how digital objects should be accessed haptically in all cases.

Some of the tests presented here make effective use of sounds along with the haptic information; we have found that sound and haptics often complement each other very well.

We will continue our work with haptic interfaces and expect to refine and add to this list of guidelines continuously.

6 REFERENCES

[1] Fritz, J. P., Barner, K. E. Design of a Haptic Visualization System for People with Visual Impairments, IEEE Transactions on Rehabilitation Engineering, vol. 7, No 3, 1999, pp 372-384.

[2] von der Heyde, M. Psychophysical experiments in a complex virtual environment, Proc. of the Third PHANToM User Group Workshop, Dedham, MA, USA, 1998.

[3] Miller, T., Zeleznik, R. An insidious haptic invasion: Adding Force Feedback to the X desktop, Proc. of the Third PHANToM User Group Workshop, Dedham, MA, 1998.

[4] Schön, D. The Reflective Practitioner, Basic Books, 1983.

[5] Sjöström, C. Jönsson, B. To Use the Sense of Touch to Control a Computer and the World Around You. Proc. of the AAATE conference, Thessalonica, Greece, 1997.

[6] Sjöström, C. The Phantasticon - Haptic Interfaces Give New Possibilities for Blind People. Master's Thesis, Certec, Lund University, Sweden, 1997.

[7] Sjöström, C., Rassmus-Gröhn, K. The sense of touch provides new interaction techniques for disabled people, Technology & Disability Volume 10, Number 1, IOS Press, 1999.

[8] Sjöström, C. The IT Potential of Haptics – Touch Access for People with Disabilities, Licentiate Thesis Certec, Lund University, Sweden, 1999.