HELPING THE BLIND TO COMMUNICATE

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Haptic Interfaces in Today's Technological World

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INTRODUCTION

Humans receive visual and auditory sensations from specific organs, namely their eyes and ears. Typical personal computers provide visual and auditory interaction and feedback as their interface. Sensations of force, however, can theoretically come from any part of body. A computer's interaction with sensations such as these is handled by haptic interfaces. Because of their many uses and many different means of implementation, haptic interfaces can take on a wide variety of shapes and forms, several of which are discussed in this paper.

Haptic user interfaces are specifically gaining popularity among the blind and visually impaired, as they enable them to interface with computer through more intuitive means than were traditionally available. Blind people can now learn mathematics by tracing touchable curves, play haptic computer games, and gain better access to graphics user interfaces like Windows and its numerous supporting applications. Because many current screen readers (tools that convert digital text to auditory words) cannot handle graphics, the benefits of the World Wide Web have been largely unavailable to blind and visually impaired people. Those computer tools that are capable of handling graphics are often too expensive for the common user. New advances in haptic interfaces, however, are lowering the price of such hardware and software and are allowing users to actually *feel* features on a webpage such as links and images while gathering a clearer mental picture of the page's layout.

As will be presented in this paper, haptic interfaces are often combined with auditory interfaces to provide blind and visually impaired people with the most complete computer experience possible. Defining the role of each of these two modalities presents a challenge to the human-computer interface designer [1]. Indeed, making internet content accessible to the blind and visually impaired relies heavily on individual website developers to provide products that are universally accessible. Captology may play a role here as some website developers push to make their site as accessible as possible, persuading others in the open market to do the same.

HAPTIC DISPLAYS

Two general categories of displays will be focused on in this paper: force displays and tactile displays. A third category of full body haptic devices will not be discussed in detail here, but comprises the devices and methods that allow users to virtually “walk through” simulations via treadmills and other machines that capture walking movement. These devices are somewhat obviously used for virtual exploration of homes, terrains, or other models.

Force displays feed back reaction forces from virtual objects to the user. These displays often take advantage of electrical sensors and mechanical machinery to provide the proper model reactions at the proper time. Tactile displays, on the other hand, work to create sensations on the skin that mimic the feelings one has when in contact with an object. Textures, vibrations, and other more miniscule feelings can be simulated with these more specialized displays.

Force Displays

Perhaps the most commercially popular force displays are the many variations of simple tool-handlers. These force displays often employ pantographs [2], which are mechanical linkages connected in parallelogram fashion so that they move in a fixed relationship to each other. Any given pantograph in this case is capable of 3 degrees of freedom (DOF). Most tool-handling force displays use two serially linked pantographs in order to achieve a total of 6 DOF. These tools are often shaped like a pen or joystick so that the user can easily hold the device and manipulate it so as to apply force in the intended direction about the pivot point.

The Omni PHANToM is generally accepted as one of the most popular haptic interface devices available on the open market [2]. This device is specifically being used by Dr. Frederick McKenzie and colleagues at Old Dominion University in Norfolk, Virginia as part of a surgical wound debridement simulation-based training system to provide force feedback to the user trainee while virtually cleaning a virtual wounded leg. (Wound debridement refers to the process of removing necrotic, devitalized, or contaminated tissue and/or foreign material to promote healing [3].)

Other common force displays include exoskeleton force displays, object-oriented force displays, and passive props. Exoskeleton force displays consist of a set of controlled actuators physically attached to hand or body via straps or a glove or some other means. They often require lots of hardware and are typically quite expensive but are able to generate forces on and between specific fingers, something most other force displays are not capable of. Object-oriented force displays move or deform their physical boundaries to mimic virtual shapes. The main advantage to these devices is that the user can touch a physical object with their bare hand. Passive props also allow the user to use their bare hand, but do not cause a three-dimensional physical object to deform, only to virtually mimic their alterations to that object on a computer output screen [2].

Tactile Displays

As mentioned above, tactile displays are capable of providing a user with a sense of vibration and/or texture among other sensations. Tactile displays work to selectively target the four types of mechanoreceptors found in the human skin (Merkel disks, Ruffini capsules, Meissner corpuscles, and Pacinian corpuscles) in order to create the illusion of these various feeling sensations [2].

Many tactile displays employ micropin arrays, which are very useful for conveying texture, but not a virtual object's actual shape as the pins are limited in the amount of deflection they can withstand. Such tactile displays are sometime used in conjunction with larger object-oriented force displays to provide a localized texture on a larger surface.

RECENT USE OF HAPTIC COMPUTER INTERFACES

Blind and visually impaired computer users today primarily use audio screen readers and/or Braille displays, both of which can provide sufficient access to digital text but provide almost no access to digital graphics [4]. Haptic interfaces, however, have the potential to allow such users to feel shapes based on digital information. Tactile mice or tactile display boards can be used in conjunction with other hardware and software to convey pertinent computer information. Implementation of these devices is discussed in the paragraphs that follow.

Windows Navigation

Researchers at Lund University in Sweden ran experiments to see if a blind person could control a graphical system like Windows with only haptic and audio information. They used both blind and sighted testers in their study, the blind testers using a PHANToM device and the sighted persons using a regular mouse. While the sighted testers could obviously use visual cues seen on the computer output screen for feedback, the blind testers relied on feeling thin bumps or barriers and/or hearing sounds when crossing dividers to know and comprehend their location. Most blind testers accomplished this task in close to the same number of keystrokes or clicks as the sighted testers but did require more time on average to complete [4].

These researchers also experimented with radial menus, where choices are presented as rays out from a center point rather than as traditional dropdown columns. Blind users were found to successfully and quickly navigate the menus but commented that they were skeptical such a widget would become popular for future use. "They 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" [4]. This, of course, raises another instance of whether or not captology is appropriate. Should the researchers push this new interface technology out onto the market to aid blind people in more quickly and accurately finding the information they need or should they honor the blind users' opinions that they do not want to feel any different when using a computer from their sighted counterparts?

Web Navigation

Similar research was performed at the Queen's University of Belfast in Northern Ireland, where developers sought to understand how blind people might better navigate the World Wide Web. They proposed that audio play a leading role in the navigation process, with haptics providing assistive feedback. Melodic motives could help to build an audio map in the user's mind and haptic interfaces would allow the user to select links and feel the layout of the page [1].

The researchers also suggested in regard to web page information representation that blind and visually impaired users could benefit from being able to examine a page from different viewpoints. Sighted users browse web pages looking for color keys, font sizes, links, images, etc. so it seems feasible that "equivalent alternatives based on haptics and audio" should be investigated for blind users [1].

Virtual Graph Creation

Some of the same staff members at Queen's University had done prior work with this topic, creating a web-based haptic application for blind people to create virtual graphs [5]. Their Java-coded tool interfaces with an inexpensive (but now discontinued) Logitech Wingman Force Feedback mouse and is capable of creating line graphs, bar charts, and pie charts that users can feel and respond to [5]. Tactile diagrams and audio tablets were the traditional approaches to non-visual graph rendering, and these inefficient and error-prone processes detracted many visually impaired people away from technical education and work. In fact, this system allowing users to draw and explore graphs manually is much easier and safer than the current "pins and rubber bands" method used by many blind children in primary and secondary classrooms. This specialized tool also has the added bonus of being about to print out graphs that can then be raised onto special swell paper, the traditional means of graph data communication between blind and sighted people [5].

Two kinds of haptic feedback effects were primarily used to indicate to the user the location and movement of their mouse cursor. Grid effects are ridges that the user feels anytime the mouse rolls over a gridline [5]. The user can easily count these "bumps" to determine where they are at in the virtual environment. Enclosure effects, on the other hand, are virtual areas bound by force walls. The mouse cursor can be trapped inside these areas unless the user applies enough increased force to overcome the restraining or magnetic force holding the cursor in [5]. Despite the beneficial constraints of these effects, four kinds of errors were recorded during the testing of the system: (1) extra points in the lines, (2) points at the wrong place, (3) missing points, and (4) unrecognized double clicks [5]. Most of these errors could be classified as skill-based errors since it would appear that they were either slips or mistakes, errors of omission and commission.

A Think Aloud approach was used in these researchers' design process to capture user comments and feedback. The users were tested operating the system separately from both a keyboard and the force feedback mouse. The keyboard mode was found to take less time than the mouse mode and was rated by the users as having a lighter cognitive burden, mostly because it was more accurate and therefore required less rework. One particular subject said that the keyboard mode was simply “a faster and more logical way to input information”. It was also found through this Think Aloud feedback that the force on the interface’s external boundary was not always strong enough and the user could exit the drawing area without realizing they had done so, causing confusion in their location. Users also commented afterwards that stereo planning of the audio would be useful to provide a general indication of their cursor location.

Selected Usability Guidelines for Haptic Interfaces

- Provide well defined and easy-to-find reference points [4].
- Size and space haptic widgets appropriately so to avoid long delays finding objects as well as the skipping over of objects. Using enclosure effects or “magnetism” can help the user in this case.
- Disabled haptic widgets should not be removed but given a different texture and start no action on clicking, similar to the “graying out” of visual widgets [4].
- Do not have the haptic interface occupy the full screen. This way the mouse cursor will always be within the confines of the interface [5].
- Remember that screen resolution affects the size of force effects. Developers should check a user’s screen resolution before drawing the application window and establishing any force effects [5].
- Avoid sharp corners wherever possible as when users move past them they almost always lose contact with the objects they are tracing, “disturbing the cognitive process that translates the impressions received into an inner picture” [4].
- The perception of force varies from user to user. Establish an average expected force to use from user trials or customize the application to fit the current user’s force needs [5].

Using sandpaper or a rough surface at the point of physical contact also causes people to use less force because they imagine the virtual objects to be “less slippery” [4].

- Provide constant feedback via the haptic interface (vibration, force, etc.) anytime something is happening in the virtual environment. Otherwise the user may not know if the computer is working or not as they may not be able to see a light blinking or hear a processor humming.

RECENT USE OF TACTILE DISPLAYS

Tactile displays provide humans with information through their sense of touch just like a computer monitor provides them with optical information through their sense of vision. Below is a discussion of a specific tactile display being developed for the use of blind and visually impaired people to read Braille.

Skin Stimulation

Research and development in skin stimulation has traditionally based around indentation of the fingertip. Today, tangential deformation of the skin in a controlled manner is being explored. An apparatus developed at McGill University in Montreal, Canada contacts the skin at two separate locations about one millimeter apart and either stretches and compresses it using piezoelectric benders [6]. This lateral deformation of the skin triggers certain mechanoreceptors that give the user’s brain the illusion of various sensations. The peak displacement and peak force of these benders is limited, though, due to short length of the benders and their inherently small allowable deflection. Subjects were polled in a study to determine what magnitudes of force and positions of the benders they could sense and not sense in order to determine the optimal placement and spacing of the instruments [6].

Braille via Skin Stimulation

Even today, Braille remains the primary or secondary access medium for many blind and visually impaired computer users. Typical Braille displays cost significantly more than personal computers, however, meaning not everyone can afford one. Hence some researchers at McGill University set out to determine the feasibility of a lower cost Braille display using the newer skin stimulation methods described above.

Their system attempts to recreate the essential aspects of skin deformation caused by Braille without actually creating or forming physical dots. It laterally deforms the skin of the user's fingertip in the manner of a progressive wave to give the feeling of sliding along an object. Previous studies conducted elsewhere trying to use deformation by waves of normal indentation or localized vibration did not provide such a "scanning" feel to the user [7].

The study found that individual characters having one dot were harder to read than those containing two or none. Additionally, users reported that reading with this system required a large amount of concentration, or cognitive load, because the dots were subtle. This lack of clear definition may be due to the limited range of motion of the piezoelectric benders and/or because the dots did differ in shape from actual Braille dots. Users also complained of loss of tactile sensation over time, which supported the observed data showing decreased performance as time went on [7]. For these reasons, it was determined that the system was feasible but needed to better mimic the size and shape of a real Braille dot.

When the system's experiments were compared with a control set, it was found that users had a slower sliding speed over dots and more frequently returned to dots [7]. This would seem to indicate that different reading strategies were being applied when using this system than were used in normal Braille reading. Subjects did comment afterwards that they found system more difficult than normal reading but mentioned that the task was cognitively more strenuous because the test used meaningless strings of words and had no cues on the bottom rows as would normally be expected. Users also are forced to read with only a single finger in this system and could not stop and hover over or press on a single set of dots [7].

CONCLUSION

New haptic interface technology can help blind and visually impaired people to explore more of the functionalities found on a personal computer and to learn and communicate through a common medium with their sighted peers at work and school. As mentioned before, though, it is ultimately up to application and website developers to provide such accessibility options, which seems more feasible as the cost and development risk of this technology continues to drop.

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