MICOLE – Inclusive Interaction for Data Creation, Visualisation and Collaboration

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Abstract
Creating, manipulating, accessing, and sharing information such as pictures, maps, charts and other visualisations as well as mathematical data and tables are fundamental skills needed for life. The development of new haptic technologies allows visually impaired users to access, manipulate and share information in a manner not previously possible. This paper will discuss the problems of creation and comparison of data, and collaboration and competition in multimodal environments for visually impaired and sighted users and discuss some potential solutions to some of the problems that we will examine.

Keywords
Haptic visualisation, two handed interaction, force feedback, tactile feedback.

INTRODUCTION
Visualisation is commonly used within almost every scientific discipline. To allow blind children and students to gain the skills needed for some everyday tasks that sighted people take for granted, new technologies are necessary to make information usable. The aim of the multimodal collaboration environment for inclusion of visually impaired children project (MICOLE) is to use multimodality to allow blind people to create, manipulate and share information using hearing and touch, and to work with other blind and sighted people. This is key in the building of an information society for visually impaired people, to empower them to take a full role in society and work at an equal level with sighted people.

A blind person typically uses a screen-reader and a voice synthesiser to access information on a computer. The screen reader extracts textual information from the computer's video memory and sends it to the speech synthesiser to speak it. This works well for simple textual information but fails with images and other graphics. The images often contain much information and without access to them the blind person is restricted. Other solutions such as dynamic Braille displays do not deal with images well due to the potentially high resolutions and colour depths of the images that do not translate well onto the small number of contact points.

Over the last few years there has been interest in systems to present graphical information such as visualisations and graphs non-visually. The main approach taken by researchers such as Wies, Van Scoy or Brewster has been to use haptic devices to present graphs that users could feel [1-3]. None of these tools allow the interactive creation and manipulation of visualisations. We are looking to build on work done by researchers such as Petrie [4], and Challis [5] who have developed guidelines which allow images and objects to be presented that are understandable through touch by blind users, and apply them to our visualisations.

There have not yet been any examples of systems designed to allow blind users to collaborate on creating and sharing information in this way. It is common for two (or more) sighted people to work together with some data to extract and discuss key points (and it is now common for people to be working together remotely across the Internet), but there are no tools to allow blind people to do this. Brewster created a successful prototype using 3D audio (but no haptics) to allow blind users to collaborate in finding key features of simultaneous non-speech audio data streams [6]. This allowed two users to explore data sonically and hear where the other person was in relation to them, allowing the task of finding intersections in three data streams to be shared. Initial results were promising but the lack of the haptic modality severely limited the system. Some work has been done on sighted people collaborating haptically: Oakley *et al.* [7] looked at shared editors to see how they could be supported. They showed that haptics could help users locate each other in complex scenes, indicate complex shapes with gestures and aid workspace awareness. Sallnäs [8] has looked at how two users work together to manipulate objects haptically. This is a small but growing area of research in the haptics community but it has not yet focused on blind people, for whom there are many potential benefits.

The project will specifically design systems with visually impaired children and young people between the ages of 5 and 18 as our user group. They have limited possibilities to utilise modern technology in collaboration and the learning of new skills. For them, appropriately designed technologies can have a major impact on quality of life and learning. Children of five years of age require very different systems from those that are suitable for children of 18 years of age. Thus, the systems that are built must support several levels of complexity and sophistication.

Our solution to the problem of user interfaces for blind and visually impaired people is to use auditory and haptic modalities to replace vision. Previous work has shown that using multiple sensory modalities is the most effective way of presenting complex information non-visually [9-11], far better than using any one sense on its own. MICOLE also aims at supporting collaboration between blind and sighted people. Very little research has investigated how this might be done, focusing on the problems of basic information presentation. We believe that collaboration is a key aspect of learning and providing access to information is not enough; people must be able to share it with others and to participate in discussion and argument about it. This is where the MICOLE project will focus its efforts.

COMPARISON AND CREATION OF INFORMATION

With any system involving visualisation, comparisons between objects on some object property or position will be important. There has been considerable work both in the real world and virtual worlds in haptic exploration of objects. Lederman and Klatzky identified Exploratory Procedures [12] that are typical movements made by a person during haptic exploration to identify different properties of the object. These EPs are instrumental for any comparison or ordering task. A number of different tactile properties for the objects could be used such as hardness, texture, shape, size, volume, weight, or stickiness. Alternatively, we may be interested in the object's relative positions within the environment. Wall *et al.* [13] discuss the issue of external memory problems when interacting and making comparisons in an environment with one point of contact. Comparisons become more difficult when the user must explore one object then navigate through the environment towards the second before exploring one or more other objects. This can place considerable demands on the user's short term memory.

One novel aspect of the MICOLE project work is both in the creation of visualisations and the sharing of environments. The creation and manipulation of a data set such as a line graph presents interesting research problems. Again, maintaining an awareness of the environment around the current interaction point is key.

In traditional graphical user interface systems, it is possible to use vision to maintain an overview of the current states of the system, and the user. The visual channel is ideally suited to providing this overview as it provides a high degree of spatial resolution. However, haptic exploration of the data involves the temporal integration of haptic cues from an object or environment. This is, particularly the case in computer haptics with the limited contact points available to the user due to the immaturity of the technology. Devices tend to provide the user with force feedback through a severely limited number of contact points. Current tactile feedback technologies can present the user with more contact points and therefore more information about the immediate environment. However, these interactions typically take place through a pin array display or tactile mouse allowing interaction in a two dimensional world only.

The MICOLE project intends to explore the use of multiple devices to allow more natural interactions between objects. The PHANToM from SensAble Technologies [14] allows one high resolution but infinitely small point of contact with the virtual world. Adding a second device to the environment allows an extra point of contact with the environment. The two points of contact add to the bandwidth of information that the user can receive through the haptic devices, but also allows actions that are not possible using one device only such as object grasping and manipulation. Two PHANToM devices – used in different hands – could also provide the opportunity to make simultaneous comparisons between two objects. It allows the user to mark a position within the environment while he or she navigates to another position. This allows the user to make instantaneous spatial comparisons as opposed to the temporal explorations available using one device. Calibration of the devices becomes an important issue in such circumstances. The relative positions of the devices in the virtual world and the physical world must match to provide a convincing sensation. Careful physical positioning of the devices is also necessary to reduce the number of occurrences of 'false' haptic feedback caused when the arms of the devices collide.

Alternatively, the introduction of a second, different device allows the possibility of providing complementary information to both hands. The Virtouch mouse can display information to the user through the two finger tip sized 4x4 pin array cells (as shown in Figure 1). There is now the potential to display different but related information to a user about his or her current state in the environment. This method naturally lends itself to focus and context presentation where the user will interact with a three dimensional world with a high resolution force feedback device with few points of contact. The user may receive high fidelity information from the device, but this will be information about a focussed area of the space. The tactile array can present a general overview but less high resolution information about the area surrounding the user's cursor.

Figure 1. The VT Player Mouse (left) and a close up of its two pin array cells (right).

NAVIGATING A MAZE

Consider an application where a user is navigating through a maze using different combinations of the PHANToM, the Virtouch mouse and the keyboard. Initially we consider the user navigating through the maze using the PHANToM. The motors will constrain the user to the path and allow the user to feel the walls. However, he/she will not discover a branching path unless the cursor is pressing against the wall due to the lack of local context information. Alternatively, the user may navigate through the maze using the mouse. Information about the surrounding environment can be displayed to the user through a 'pin up' representing a wall and a 'pin down' representing no wall (shown in Figure 2). The user can be restricted to the path by not allowing the cursor to move when his/her movements would move it through a wall. However, the user cannot feel the restriction of a wall other than through interpreting the lack of change of information from the tactile array. A combination of PHANToM and tactile interaction would allow the user both to feel and be physically restricted by the walls while receiving information about the local context through the pin array cells.

We will examine the effect that the presentation has on the user's understanding of the environment. Will the presentation of information to the users through two different channels allow them to build a better spatial representation of the environment that they are navigating?

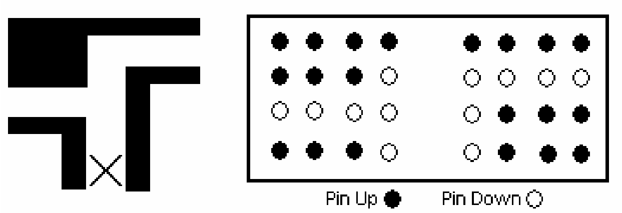

Figure 2. A section of a maze (left) and it's tactile representation on the two pin array cells of the VT Player tactile mouse.

One other question that might affect the user's understanding is the perspective of user's interactions. In the above scenarios, the user is interacting with the cursor from a third person perspective. He or she is navigating an object through a maze. We might also consider a first person view where the user is placed in the maze. The user could rotate his or her avatar left and right and step back and forwards using the keyboard with one hand and receive feedback through a tactile array on the other hand. This presents similar problems of interpreting feedback for collisions with walls. However, the user can now actively rotate the view of the environment to provide a method of actively searching for paths in the environment while maintaining the current position.

COLLABORATION AND COMPETITION

Collaboration introduces complications into building a multimodal environment, particularly when the environment involves the creation or manipulation data. The visual system is good at giving an overview of any changes of context of the interaction, but how would these changes made by one user be reflected to a visually impaired user through touch or sound? Again a two handed presentation of information can be used to address this. A PHANToM and pin array display combination can be used in a focus and context manner where the user interacts and manipulates the environment using the PHANToM, feeling the results of his or her interactions through the PHANToM motors. Information can be relayed through the pin array to provide users with information about any interactions in the vicinity of the user's cursor.

For environments that require some element of competition (such as games), two or more users that may or may not have a visual impairment are interacting in the same environment. We are specifically interested here in the concept of sensory equivalence. Due to the different properties of the haptic auditory and visual channels, it is difficult to present exactly the same information in two or more different modalities. However, here we consider the definition that two representations of a given dataset are equivalent if they can be understood, browsed and used as fluently as one another. Fluency can be defined empirically in terms of the time required to perform some task on the dataset, the error rate in this process and the subjective effort exerted in order to achieve it.

The MICOLE project is specifically interested in allowing visually impaired children to interact with their peers. Computer based games are becoming an increasingly important medium for children to interact, learn and play.

The games considered rely on several different component factors that make up the challenge to the user. The factors considered here are comparison and ordering, memory, navigation, and motor skills.

WORKSHOP DEMOS

At the workshop, some early prototype systems developed for the MICOLE project will be introduced. Attendees will be able to explore a multimodal version of the maze demo described above using the different combinations of input and feedback mechanisms described in the paper to navigate and visualise the maze. Attendees will also be able to explore the maze from both first and third perspective in order to better appreciate the strengths and weaknesses of both methods.

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REFERENCES

1. Brewster, S.A. Visualization tools for blind people using multiple modalities. in Disability and Rehabilitation Technology. 2002. p.613-621.

2. Van Scoy, F., et al., Haptic display of mathematical functions for teaching mathematics to students with vision disabilities: design and proof of concept. Haptic Human-Computer Interaction. Springer LNCS, 2000. 2058: p. 31-40.

3. Wies, E., et al., Web-based Touch Display for Accessible Science Education. Haptic Human-Computer Interaction, Springer LNCS, 2000. 2058: p. 52-60.

4. Colwell, C., et al. Haptic virtual reality for blind computer users. in Annual ACM Conference on Assistive Technologies. 1998. p. 92-99.

5. Challis, B.P. and A.D.N. Edwards, Design Principle for Tactile Interaction. Haptic Human-Computer Interaction. Springer LNCS, 2001. 2058: p. 17-24.

6. Ramloll, R. and S.A. Brewster. A Generic Approach for Augmenting Tactile Diagrams with Spatial Non-Speech Sounds. in Extended Abstracts of ACM CHI2002. 2002. p.770-771. ACM Press.

7. Oakley, I., S.A. Brewster, and P.D. Gray. Can You Feel the Force? An Investigation of Haptic Collaboration in Shared Editors. in Eurohaptics. 2001. p.54-59. Birmingham, UK.

8. Sallnäs, E.L. and J. Kjoberg. Handing Over Objects in a Haptic Collaborative Environment. in Eurohaptics. 2002. p.77-81. Edinburgh, UK.

9. Grabowski, N.A. and K.E. Barner. Data visualisation methods for the blind using force feedback and sonification. in SPIE-Int. Soc Opt. Eng. Proceedings of Spie - the International Society for Optical Engineering. 1998. p.131-139.

10. Roth, P., et al. An Audio-Haptic Tool for Non-Visual Image Representation. in Proceedings of The Sixth International Symposium on Signal Processing and Its Applications. 2001. p.64-67.

11. Yu, W. and S.A. Brewster. Multimodal Virtual Reality Versus Printed Medium in Visualization for Blind People. in Proceedings of ACM ASSETS. 2002. p.57-64. Edinburgh, Scotland: ACM Press.

12. Lederman, S.J. and R. Klatzky, Hand Movements: A Window into Haptic Object Recognition. Cognitive Psychology, 1987. 19: p. 342-368.

13. Wall, S. and S.A. Brewster. Providing External Memory Aids in Haptic Visualisations for Blind Users. in Proceedings of International Conference on Disability Virtual Reality and Associated Technologies (ICDVRAT). 2004. p.157-164. New College, Oxford, UK.

14. Massie, T.H. and K. Salisbury. The Phantom Haptic Interface: A Device for Probing Virtual Objects. in Proceedings of the ASME International Mechanical Engineering Congress and Exhibition. 1994. p.295-302. Chicago, IL.