An Initial Investigation into Non-Visual Computer Supported Collaboration

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Abstract
In this paper we present an initial study of computer supported collaboration between visually impaired users based around the interactive browsing and manipulation of simple graphs. We specifically looked at supporting awareness of others activities and interaction between participants. We found that shared audio and haptic locating tools, to allow users to find each other, were useful. However further work is required to determine the general applicability of our findings.

Keywords
CSCW, Haptic Interaction, Non-Speech Sound, Visual Impairment

ACM Classification Keywords
H.5.2. Haptic I/O, Auditory (non-speech) feedback.

Introduction
Computer supported collaborative work (CSCW) has been applied to many different computer and traditionally non-computer based processes. CSCW systems, although bringing their own challenges, have allowed collaboration between individuals that would have otherwise been impractical or impossible. It is therefore unfortunate that more work has not been

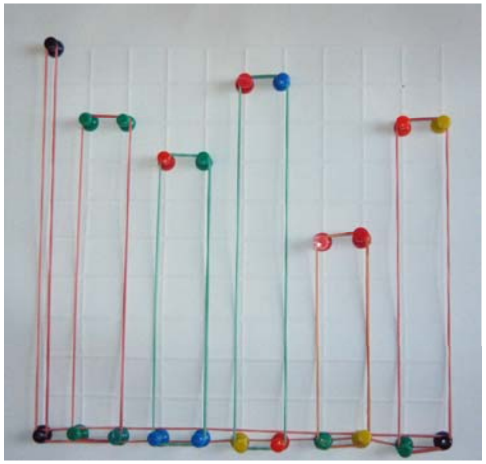

figure 1. An example constructed bar graph using a cork board, a raised paper grid, pins and rubber bands.

applied to the challenges of collaboration between visually impaired people. There is currently no clear guidance for building applications to support such collaboration. There are, however, many scenarios, both in education and later life, where collaborative work is important but frustrated due to technological and disability issues.

Non-Visual Information Access

There are several (mostly paper based) ways in which information is currently made accessible to visually impaired people. Textual data can be presented using Braille but diagrammatic information must be presented using raised paper diagrams which are browsed using the sense of touch. These diagrams must be specially prepared, can rarely be independently generated by a visually impaired person and cannot be altered after creation to present dynamically changing information. To create modifiable representations other technologies must be used. For example, using a cork board overlaid by raised paper grid lines, into which map pins are pushed and rubber bands wrapped to represent objects (see figure 1). These technologies have their own issues, with representations difficult to store permanently as pins can be knocked out over time [3].

Non-Visual Collaboration

Whilst there are no studies discussing how collaboration between visually impaired people is accomplished in industry, there are several studies which have investigated issues surrounding collaboration in educational settings. The teaching and learning of subjects in small groups, largely without direct teacher involvement, has been argued to improve the social, academic and cognitive abilities of students [6]. For visually impaired students, however, there are significant problems in accomplishing these aims. In interviews with visually impaired students, Sallnäs [5] describes how students enjoyed group work, noting that for one it allowed her to *"get to know the other pupils better that she had not talked to so much before".* Sallnäs also noted however that it was difficult for students to keep track of other's activities. For example, if two students were browsing a raised paper diagram they would each need a copy, making it difficult for one to point out something to his/her partner in the same way a sighted user might. This makes it difficult for each person to know what his/her partner is looking at, or to be sure both are referring to the same part of the diagram, therefore impairing collaboration.

Collaborative Graph Work

Whilst there are problems inherent in the use of paper based diagrams in both collaborative and non-collaborative scenarios, there is work which shows that audio and haptic virtual environments can be effective in overcoming many of the problems in single user information access [7]. However very little research has been undertaken on collaborative environments for visually impaired people. Work that has been done either used blindfolded sighted people, due to a lack of available visually impaired people, or has considered that the collaboration consists of a visually impaired person being assisted by a sighted user [8]. There is currently no research which investigates CSCW between pairs of visually impaired people. We therefore know little about how awareness can be provided or the best ways to support interaction between collaborative users. To address these issues we carried out a preliminary study on awareness and interaction between visually impaired users performing a graph

figure 2. The PHANTOM Omni haptic device used by participants to interact with the virtual graph. The user moves the "pen" like a 3D mouse. The device monitors this and uses motors to resist the user's movement.

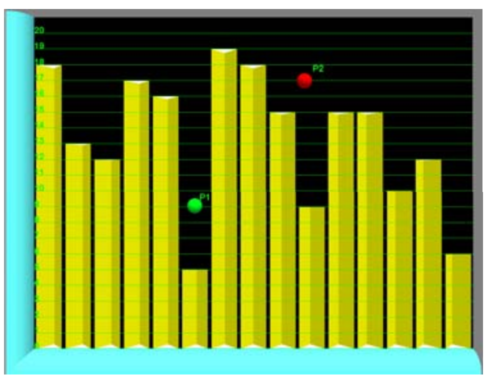

figure 3. A screenshot of the collaborative GraphBuilder tool. The bars are grooved. Each sphere represents the proxy of one user's PHANTOM.

validation task. We use graphs as better access to these is a motivation for our work and we already have an evaluated single user application to work from.

System Overview

Our existing single user application, GraphBuilder, is fully described and evaluated in McGookin and Brewster [3]. It allows browsing and modification of bar graphs using haptic force feedback via a PHANTOM Omni (www.sensable.com) (see figure 2), which is like a 3D mouse with a "pen" the user holds, the position of which is tracked. Motors are used to resist motion creating the illusion of a touching a physical object. Speech and non-speech feedback is also used. Bars are represented as recessed grooves (see figure 3) and can be modified by holding down a button near to the PHANTOM (see figure 4) and touching the top of one of the bars with the PHANTOM proxy. When a bar is selected, moving the PHANTOM up or down causes the bar's height to be changed, with a different musical note being played to indicate each unit increase or decrease in the position of the bar as it is moved. Releasing the button sets the bar at the current PHANTOM position. The name of a bar can be retrieved by touching the bar and pressing one of the buttons on the PHANTOM pen. The value of a bar can be retrieved similarly by pressing the other button on the pen. Synthetic speech is used for the bar name and a sequence of musical notes, one for each unit of the bar, is used to represent its value.

In adapting GraphBuilder for multiple users we have attempted to avoid constraining collaboration by limiting the types of strategies that can be used. We have therefore integrated two PHANTOM Omni devices into the collaborative version. This allows two users to interact and manipulate the same graph concurrently and as such each other. Participants cannot concurrently modify the same bar.

As discussed by Dourish and Bellotti [1] it is important that users have awareness of each other's location and activities. As described by Sallnäs [5] such awareness is currently a problem. Whilst in visual collaborative systems awareness is achieved by using an avatar or cursor to indicate the position of the other user, this is difficult to do without a visual display. We provided basic awareness by sharing the audio output from the application with both users. Each participant could hear the audio generated by the other user's interaction with the application, as well as freely talk to the other user as both participants were collocated. Gaver *et al.* [2] note that shared audio is an effective way of improving collaboration when users cannot see the entire display, however the impact of no visual display is unknown. Modifications to the audio output were made to avoid confusion between participants. Different text-to-speech voices were used to differentiate which user had requested information from the graph. When requesting a bar value, a different timbre was used for each user. Sound was delivered over a pair of stereo speakers, with the audio generated by each user panned to the speaker closest to that user.

In order to help users locate each other we implemented two features based on the work of Oakley [4] who investigated haptic collaboration in a shared visual drawing environment. The first feature, "come to me", is activated by holding down a button on the desk (see figure 4) causing the other user (*not* holding down the button) to be haptically dragged towards the proxy of their partner. Effectively this allows one user to control and guide their partner. The second feature, called “go to you”, is again activated by a button. Here the user who holds down the button is dragged to the position of the other user. Effectively the user cedes control of their PHANTOM to his/her partner.

Study Outline

Eight registered blind students at the Royal National College for the Blind (RNCB) in Hereford, UK took part in the study. All were aged 18-40 and comprised 6 men and 2 women, each was paid £15.

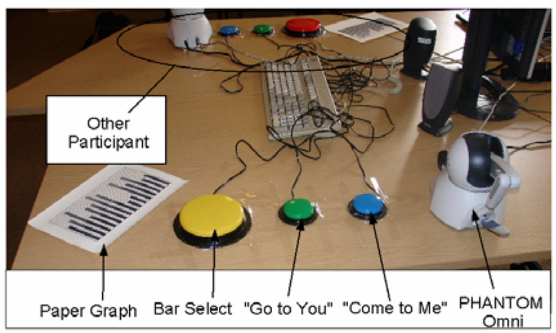

figure 4. The experimental setup for each participant.

Pairs of participants carried out a graph validation task. Participants were presented with a raised paper bar graph each (see figure 4) and a “virtual graph” presented via our application. Participants had to ensure that the bars in the virtual graph were the same as those on the raised paper graph. If participants determined that a particular bar was not the same they were instructed to change the virtual graph so that the bars were the same. Participants were videotaped carrying out the task for later analysis. Participants completed 6 different graphs after which they were debriefed and interviewed on their experiences.

Discussion

Two strategies were employed by the participants. The first was a “divide and conquer” strategy where participants split the graph in two, one participant working from the left of the graph to the right, with the other participant working from right to left. As such there was little discussion between participants until one had a problem and the other had to assist. This strategy was employed by three of the pairs. The other pair used a more “turn taking” strategy where they worked from left to right in the graph together, with one participant using the raised paper diagram and the other manipulating the graph using the PHANTOM. Here participants swapped roles on alternate bars.

Shared Audio Awareness

As discussed earlier one of the problems with visually impaired collaboration is the lack of awareness. Without explicit notification it is not possible for users to know what their partners are doing. In our study audio was shared. Participants in the study found this both to be an advantage and disadvantage. In situations where the audio was providing speech based status information about the other user, such as which bar he/she was on, participants found the use of shared audio to be useful in providing awareness of his/her partner’s progress allowing he/she to *“know which bar they are on, so when you have overlapped them or know that they are doing a bar you have already done”*. Participants who had followed a “divide and conquer” strategy, whilst finding the status information useful, did find some of the audio to be distracting. Here participants were independently checking and modifying separate bars. When playing back the sounds that presented the value of the bars, or provided feedback when a bar was being manipulated, it could be confusing if his/her partner was simultaneously working on another bar. One participant noting that *"If you were trying to change the value of the bar, sometimes it's confusing hearing the other person counting the bar they're on."* The pair who used the turn taking strategy did not mention such problems. It seems that the amount and type of shared audio should be altered dependent on the strategy that participants adopt. Some participants said they would like headsets to allow them to control the audio that was shared.

Haptic Guidance

Participants' use of the "come to me" and "go to you" features was also dependent on the strategy that was used to check the graph. Participants who used the "divide and conquer" strategy used the haptic guidance tools when one participant got lost, or simply to find the location of their partner. Some participants seemed to get used to using the PHANTOM sooner, and by using the collaborative features could assist their partner. Whilst these participants liked the "go to you" feature with one saying *"The thing I liked about it is that as blind people, people tend to not ask and just grab your hand and put it on something. Whereas with this you can be more independent and people don't need to keep grabbing your hand."*, the "come to me" feature was less popular. In discussions with teachers we found that they tend to explicitly move visually impaired peoples' hands as this is the only way to indicate features using existing paper based technology. However participants noted that they did not like the ability of the other person to simply drag them from wherever they may be working. The pair who used the turn taking strategy did not use the collaborative tools, possibly because they were always collocated with each other in the graph.

Audio as a Communication Mediator

In addition to the discussion as to whether audio should or should not be shared between the participants, there is evidence from the video transcriptions that the use of shared audio helped to mediate communication. In several cases at the start of a trial participants simply started to browse the graph and modify the bars without communication with their partner. Only with the speech feedback from the system did the participants start to discuss and formulate a strategy as shown in the following transcript. P1 and P2 represent the two participants, N describes significant non-verbal events such as the application of the haptic effects, and words in italics represent utterances by the application.

N: P1 moves PHANTOM

N: P2 moves the first bar to the bottom position

N: P1 applies go to you effect

N: P2 moves the position of the second bar.

N: P1 is at P2's position "*you are touching the other person*" is repeatedly read out by the computer using each of the voices for each participant.

P2: So will we start at different sides of the graph Will you start at the left hand end and I'll start at the other end, otherwise we are going to....

In addition to encouraging collaboration, there were several instances where the shared audio was used as a reference point for participants. This was notable with the pair who used a turn taking strategy. Here the participant who was not actively manipulating the virtual graph could still assist and contribute as shown in the following transcript:

N: P2 tries to find the correct bar by moving between the bars and playing the names of each of them. *"Brazil, Greece"*

P2: No that's not it.

N: *"Norway"*

P1: That's it. If you change Norway.

N: P2 plays the value of Norway.

P2: 14?

P1: 14 yeah.

N: P2 changes the bar value.

P2: Is that correct?

N: P1 rechecks the paper diagram.

P1: It's 15. You need to go up one more.

This use of shared audio is similar to that identified in Gaver *et al*'s ARKola bottling plant simulator [2]. In comparing performance between an audio and non-audio version, they noted that *"Sounds served as shared reference points for partners, allowing them to refer to events they couldn't see."* It seems this also applies where no visual information is available.

Conclusion

The work presented here is at an early stage but shows promise. The use of shared audio did allow participants awareness and promoted collaboration, however the amount and type of shared audio that supports awareness seems to be dependent on the strategy adopted. The haptic guidance tools were also of use with participants preferring those which allowed them control over their own guidance rather than their partner assuming that control. We have however only considered one collaborative task and it is difficult to know how generally applicable our findings are. Future work will investigate visually impaired collaboration on different tasks to further refine and validate the findings presented here. In doing so we can further improve our knowledge of supporting collaboration between visually impaired people.

Acknowledgements

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