A Cross-Modal Collaborative Tool for Workplace Inclusion

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ABSTRACT
We present the design of a cross-modal tool for collaborative diagram editing. The tool was designed to address the challenge of supporting collaborators who access a shared interactive space through different sets of modalities. This was achieved by augmenting a visual diagram editor with auditory and haptic views to allow simultaneous visual and non-visual interaction.

Author Keywords
Collaboration; cross-modal interaction; accessibility; inclusion; haptics; auditory interfaces; diagrams; workplace.

ACM Classification Keywords
H.1.2. User/Machine Systems: Human factors; K.4.2. Social Issues: Assistive technologies for persons with disabilities; H.5.3. Group and Organisation Interfaces: Collaborative computing, Computer-supported cooperative work.

General Terms
Design; Human Factors.

INTRODUCTION
Diagrams are a key form of representation used in all manner of collaborations, yet there is currently no practical way for visually impaired co-workers to access, let alone edit, diagrams. This is a major barrier to workplace collaboration that contributes to the exclusion of visually impaired individuals. Indeed, the RNIB estimate that 66% of blind and partially sighted people in the UK are currently unemployed [3]. Addressing the challenge of designing support for cross-modal collaboration in the workplace has thus the potential to significantly improve the working lives and inclusion of perceptually impaired workers.

BACKGROUND
Approaches to supporting non-visual interaction with visual displays employ one or a combination of two models of representation; *Spatial* or *Hierarchical*. The two models differ in the degree to which they maintain the original representation when translating its visual content [2], and hence produce dramatically different non-visual interactive displays. A spatial model captures the spatial properties of visual displays, such as layout, form and content arrangements. These are then projected over a virtual or a physical space so that they could be accessed through alternative modalities. Spatial models typically combine the haptic and audio modalities to support interaction. A hierarchical model, on the other hand, preserves the semantic properties of visual displays and presents them by ordering their contents in terms of groupings and parent-child relationships. Many auditory interfaces, such as phone-based systems, are based on such a model as they inherently lend themselves to hierarchical organisation. Audio therefore is the typical candidate modality for non-visual interaction with visual displays when using hierarchies.

DESIGNING A COLLABORATIVE CROSS-MODAL TOOL
We ran a workshop to engage with representatives from end user groups in order to encourage discussion and sharing of experiences with using diagrams in the workplace. Eight participants attended the workshop including participants from BT and the Royal Bank of Scotland and representatives from the British Computer Association of the Blind and the Royal National Institute for the Blind. The discussions highlighted the diversity of diagrams encountered by the participants in their workplaces and the shortcomings of current accessibility solutions. Solutions included using the help of a human reader, swell paper, transcriptions and stationary-based diagrams, all of which share two main limitations; the inability to create and edit diagrams autonomously, and inefficiency of use when collaborating with sighted colleagues. We chose to focus on nodes-and-links diagrams because they are frequently encountered in the workplace and we already have evaluated a single user version for audio-only interaction with such diagrams [1]. Our cross-modal tool[1] combines hierarchical and spatial representations to support autonomous non-visual editing of diagrams as well as real-time collaboration by augmenting a graphical diagram editor with auditory and haptic views.

Graphical View
Figure 1 shows the graphical view of the tool. This view presents the user with an interface similar to typical diagram

[1] An open source release of the tool can be downloaded from: `http://ccmi.eecs.qmul.ac.uk/downloads`

editors where a toolbar is provided containing various functions to create and edit diagram content. The user construct diagrams by using the mouse to select the desired editing function and has the ability to access and edit various parameters such as labels, position, etc.

Hierarchical Auditory View

The design of the auditory view is based on the multiple perspective hierarchical approach described in [1]. According to this approach, a diagram can be translated from a graphical to an auditory form by extracting and structuring its content in a tree-like form such that items of a similar type are grouped together under a dedicated branch on a hierarchy. This is aimed to ease inspection, search and orientation.

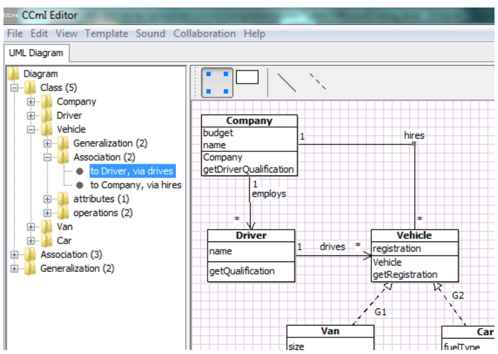

Figure 1. Auditory hierarchical view (left) embedded in the editor.

We use a combination of speech and non-speech sounds to display encountered content and to support editing. The auditory hierarchical view is thoroughly described and evaluated in [1].

Spatial Haptic View

We use a PHANTOM Omni haptic device (Figure 2) to display the content of a diagram on a virtual haptic plane. Diagram nodes are rendered as magnetic points on the virtual plane such that a user manipulating the stylus of the device in proximity of a node is attracted to it through a simulated magnetic force. A similar magnetic effect is used for the links with the addition of a friction effect that simulates a different texture for solid, dotted and dashed lines. Contact with nodes and links is accompanied by earcons with distinct timbres while their labels of are displayed in synthesised speech. We implemented two modes of interaction in the spatial haptic view. In a *sticky* mode, the attraction forces are increased to make it harder for the user to snap away from contact with a given item on the diagram. This simulates an impression of being "stuck" to the diagram content and thus one can trace its content by following the connections from point to point. In a *loose* mode, the attraction forces are decreased such that a user can freely move around the virtual space without necessarily having to be in contact with any diagram content.

Additionally, the user has the ability to move nodes and bend links by locating an item – or a point on a link – on the virtual plane, clicking on the stylus button to pick it up, dragging

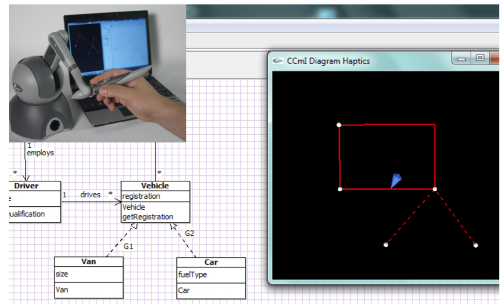

Figure 2. Spatial haptic view (right). PHANTOM Omni device (top left).

the stylus to another point on the plane, then dropping it in a new desired location with a second button click. We designed two extra features to support this drag-and-drop action. First, three distinct auditory icons are used to highlight that an item has been successfully picked up (a short sucking sound), that it is being successfully dragged in space (a continuous chain-like sound) and that it has been successfully dropped in the new location (a dart hitting a dartboard sound). Second, a haptic spring effect is applied, linking the current position of the stylus to the original position of where the item was picked up from. This allows the user to easily relocate the item to its original position without loosing orientation.

Collaborative Interaction

Simultaneous shared access to a diagram is currently achieved by connecting collaborators' computers through a local network with one of the computers acting as a server. We have incorporated locking mechanisms which prevent collaborators from concurrently editing the same item on the diagram. Besides these locking mechanisms, the tool does not include any built-in mechanisms to regulate collaboration, such as process controls that enforce a specific order or structure of interaction. This was done to allow users to develop their own collaborative process when constructing diagrams.

CONCLUSION

We presented the design of a collaborative cross-modal tool for editing diagrams which we used to explore the nature of cross-modal collaboration between visually-impaired and sighted users in the workplace.

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