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Tactile Web Browsing for Blind Users

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Abstract. Recent developments in tactile technologies have made them an attractive choice to improve access to non-visual interfaces. This paper describes the design and evaluation of an extension to an existing browser, which enables blind individuals to explore web pages using tactile feedback. Pins are presented via a tactile mouse to communicate the presence of graphical interface objects. Findings from an evaluation have revealed that fifteen participants were able to learn the tactile HTML mappings developed, and were able to perform a range of web-based tasks in a less constrained manner than using a screen reader alone. The mappings presented in this paper, can be used by web developers with limited experience of tactile design, to widen access to their sites.

Keywords: Blind, human factors, tactile, web browsing

1 Introduction

Tactile technologies play a vital role in supporting exploration of an interface by blind individuals. In contrast with speech-based output, which mainly provides an overview of the textual content present on a graphical user interface (GUI), tactile cues can be used to communicate the layout of objects (e.g. icons, textboxes and buttons) through cutaneous stimulation of the skin. Examples include the non-visual system described by Petrie et al. [1], where a touch-sensitive pad is used to provide a spatial overview of a GUI, while a Braille display enables direct manipulation of objects at a finer level. Wall and Brewster [2] have represented graph-based data using a tactile mouse. Pins are presented underneath the fingertips to indicate the presence and height of bars, providing the user with an alternative to raised paper graphs. BrailleSurf [3] has been developed to browse the Web. The tool synthesizes the contents of a page directly through to a Braille or a speech output device. The HTML source code is analyzed by the application, graphical objects are filtered and the page is restructured in a textual way to aid effective comprehension of page content. Rotard et al. [4] have presented text, graphics and other interface objects (e.g. tables, lists and frames) from web sites on a tactile graphics display. The content is presented in Braille format, while images are displayed in tactile pin format. The solution has addressed the issue of limited graphical information presented via screen readers. However, it still remains to be seen whether users can access the tactile information coherently, or whether the user will be overloaded with the amount of stimuli present.

The limited number of tactile web browsing interfaces is rather surprising owing to the fact that touch is used by a number of blind individuals for both communication (e.g. Braille) and understanding graphical concepts (e.g. raised paper diagrams). Exploring a web page using an device such as a tactile mouse, would enable blind users to explore the page freely, rather than dealing with the constraints of navigation using a screen reader where the user is required to move sequentially through objects. It would also enable the structure of the web page to be retained, aiding a range of tasks which can pose challenges when using existing assistive technologies. Examples of these tasks include moving through unfamiliar pages where content is tightly-packed, filling out web-based forms, and collaborative tasks with sighted users (Murphy et al., [5]). In this paper, we describe the development and evaluation of tactile cues for a non-visual browsing interface, to provide blind users with an overview of the layout of content and to provide assistance with the process of navigation.

2 Existing Non-Visual Browsing System

A content-aware plug-in was developed for the Firefox browser, to overcome the challenges faced when using a screen reader. The solution enables blind individuals to explore web pages using a force-feedback mouse (Figure 1) [5]. Cues such as spatial textures, magnetic effects and vibrations were mapped to various graphical objects on the GUI [6]. Text-based content from the interface was also presented using the Microsoft Speech SDK. As the user moves around the interface, cues are presented via the mouse, enabling users to develop a mental representation of the layout of content.

Fig. 1. Logitech Wingman force-feedback mouse (www.logitech.com)

Fig. 2. VT Player tactile mouse (www.virtouch2.com)

To extend the research, we wanted to identify the ways in which tactile pin-based cues could be developed to offer the structural and navigational benefits achieved through the use of a force-feedback mouse. The aim was to develop a library of tactile sensations which web developers could reference, and integrate with their sites to make them more accessible to blind users. This would allow the users to utilize the type of feedback (e.g. tactile or force-feedback) that best suits their preferences.

3 Developing Tactile Cues for the Browsing System

The VT Player (Figure 2) has been chosen as a means of presenting tactile information to blind users. Two cells are positioned on top of the mouse, each containing a matrix of sixteen pins. These pins can be raised to form patterns, which are discretely presented underneath the fingertips. A series of tactile cues were integrated into a web page, to be presented via the tactile mouse. Patterns were developed by drawing inferences from the earlier workshops performed in the study by Kuber et al. [6], where blind screen reader users and haptic interface designers had worked together to advise on ways to convey the presence of icons using force-feedback. Examples are shown in Table 1, with a more definitive listing of other objects in Kuber [7].

Table 1. Inferences made to design tactile cues

Objects	Force-Feedback Representation	Inferences Drawn	Tactile Representation
Images	A slightly lowered or raised enclosure effect to encase the visual border. A spatial texture applied to the image's interior.	Border needed to convey outline, with interior texture to communicate body.	All pins raised on the left-hand contactor in the shape of a block.
Hyperlinks	A spring effect to direct the user towards the relative centre of a hyperlink. Optional use of distinctive spatial texture or weak periodic wave effect to communicate body.	Provide awareness of the length of the text string to be selected.	Middle two horizontal rows are raised on one contactor pad.
Textbox	A lowered enclosure effect applied to a text box, to enable the user to explore its contents.	Present the outline of a text box.	Pins raised in outline of a square with no interior.

A participatory-based approach was adopted to design tactile feedback tailored to the needs of blind web users. One blind screen reader user, one tactile interface designer, and one blind tactile interface designer who had participated in the workshop to determine the design of force-feedback cues (termed 'force feedback workshop'), were asked to participate in a new workshop (termed 'tactile workshop'), with the aim of suggesting and prototyping ideas for communicating graphical objects on a web page using tactile feedback. Participants were presented with a scenario of a blind employee using a tactile mouse to access a search engine. They were asked to comment on the different types of feedback that would benefit him in his particular situation. The researcher read aloud the scenario (*below*) to the group, with gaps where the character in the scenario encountered an object. Within each gap, the researcher asked each of the participants to evaluate the tactile mappings designed which were presented on the web pages developed.

John encounters a textbox underneath his fingertips. This is indicated by a pin pattern <<play tactile sensation>>. He then clicks the device when positioned over the box <<play tactile sensation>>. He feels a small stimulus from the pad of the device <<play tactile sensation>>, so knows that the cursor is positioned in the box and he is able to enter his search term.

The group was encouraged to suggest design ideas for communicating graphical icons, and had the option of mocking these up using a series of props. These included headed pins which could be quickly arranged to represent the patterns by placing into a sponge (Figure 3). Two sponges could be adjacently positioned to convey the stimuli presented by the two contactor pads of the mouse.

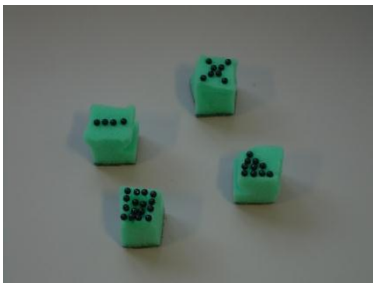


Fig. 3. Headed pins are arranged into patterns, and inserted into sponges (props).

Fig. 4. Support aid for mouse enabling user to move vertically and horizontally in straight line

Participants from the tactile workshop stated the majority of design ideas presented to them were appropriate for use on a web page. For example, to convey the notion of a hyperlink, pins were arranged into the shape of a long bar on one contactor pad by raising the appropriate pins on the mouse. Further discussion by the group resulted in the strengthening of the idea. Participants suggested that additional feedback should be offered to indicate the status of the link when selected. Using an identical representation of a bar on the second contactor pad, would provide the user with the awareness needed of selection (Table 2).

The blind participants suggested that by providing a distinctive stimulus to indicate the presence that a textbox had been selected, valuable contextual information would be provided to a blind user when filling out a form. He/she would then know that text could be entered within the box, as the object was active. A sequence of pins raised and lowered in a time sequence, was thought by the group to grab the user's attention. This effect was mocked-up and presented for a period of two seconds. The group suggested that this 'animated stimulus' should be on-going as long as the user remains positioned inside the box, to heighten awareness of position on the interface. The user would have otherwise missed the cue due to its short duration.

Discussion continued until all members of the group achieved consensus on design ideas. Table 2 displays the tactile stimuli designed as part of the system, which originated from the tactile workshop. These tactile cues were developed and integrated into the non-visual browsing tool, enabling the user to perceive a tactile mapping when alighting over a graphical object.

The blind participants from the group found it difficult to move in a straight line both vertically and horizontally using the VT Player device, due to the lack of reference points available. Participants suggested that it was difficult to detect twisting or rotations of the mouse, also identified by Jansson and Pederson [8]. This prompted participants to suggest the design of a support structure for the mouse (Figure 4), which would allow the device to move along a slider both vertically and horizontally, enabling the user to maintain a straight path. This would enable the researchers to determine the usability of the tactile feedback, without having to consider problems with the device itself.

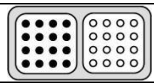
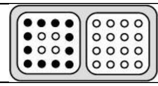
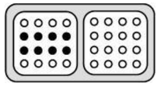
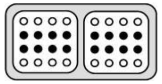
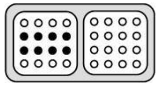
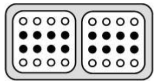
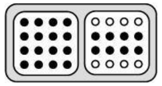
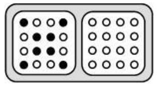
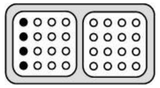
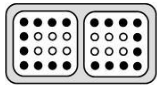
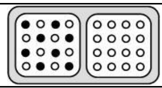
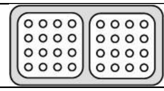
4 Evaluation

The aim of the evaluation process was to validate the benefit provided by cues which had been developed through the course of the tactile workshop. The main hypothesis examined was that the tactile cues designed, would be able to provide the structural and navigational support missing from presentation via a screen reader. The tasks selected were also used in an evaluation six months earlier, to validate the force-feedback plug-in (Kuber et al., [7]). However, web pages presented were manipulated (i.e. objects were arranged in different positions) to ensure that even if participants would have remembered the layout of content, it would have not assisted them in their tasks.

4.1 Participants and Training

Ten sighted and five fully-blind screen reader users, all aged between 20 and 68, were recruited for the study. None had previously made use of the tactile mouse for purposes of browsing. The sighted participants were blindfolded for the study. Participants were introduced to a web page containing all the tactile representations shown in Table 2. Speech icons were presented when hovering over blocks of text, hyperlinks, and alternative text associated with images. Participants were asked to explore the interface using the tactile mouse with support aid (Figure 4), and describe each pin-based cue presented by the mouse, followed by the object’s respective location on the interface.

Table 2. Library of sensations to communicate the identity of web-based objects using tactile feedback

Interface Objects	**Description of tactile representations**	**Tactile representations (Raised pins shaded)**	**Interface Objects**	**Description of tactile representations**	**Tactile representations (Raised pins shaded)**
Images	All pins raised on the left-hand contactor in the shape of a block.		Text box	Pins raised in outline of a square. Animated stimulus to communicate that the box is active, when selected.	
Hyperlinks	Middle two horizontal rows of pins are raised on one contactor pad. May need additional directional support if moving horizontally through a series of links.	When located:  When selected: 	Buttons	Middle two horizontal rows of pins are raised on one contactor pad to represent button. Additional auditory icon required to differentiate from the hyperlink mapping. If selected, further feedback should be presented via flashing pin pattern on second contactor.	When located:  When selected: 
Image-hyperlinks	All pins raised on the left-hand contactor in the shape of a block. Middle two horizontal rows are raised on right-hand contactor pad.		Adverts	The shape of a cross or X can be visualized when presented in tactile format under the fingertips. Ensure that it can be differentiated from outer border sensations.	
Page border	One line of pins raised on the contactor pad(s), reflecting the side of the page where cursor is located.		Headings	Pins raised in the outline of a rectangle over two contactor pads. Can be reduced in size to represent a smaller heading (e.g. a sub-heading).	
Area outside page border	Chessboard style texture (e.g. presentation of alternate pins forming a pattern).		Page Background	No feedback for background or text.	

4.2 Procedure

Participants were asked to perform two main tasks to determine whether the hypothesis would be supported. The tasks selected were found by Murphy et al. [5] to pose a challenge to some screen reader users when performing them.

Task 1 - Determining the Layout of Objects

The pages used in the current study contained a larger number of interface objects (two images, eight hyperlinks and one image-hyperlink) (Figure 5 - left). Participants were provided with a maximum of three minutes to 'think-aloud', identifying any interface objects that were encountered. If participants were unable to explore the whole page, prompts were presented by the researcher to explore the remainder of content. For example, 'move the mouse to the left-hand side of the page and explore'. They were then asked to either draw or arrange tactile objects (Lego) to indicate the layout of content perceived.

Task 2 – Targeting Objects of Interest

A different web page was presented to participants. It contained thirteen hyperlinks, two images and text, all positioned in relatively close proximity to one another (Figure 6). Participants were asked to locate and retrieve information from three separate locations on the page:

- Counting the number of links presented horizontally at the top of the page (Q1).
- Naming the third hyperlink listed vertically under 'Further Information' (Q2).
- Targeting and selecting the email address of the named contact (Q3).

A questionnaire was then presented, to solicit views on the experience using tactile feedback to explore the Web. Issues such as confidence in use of the tactile mouse and the ability to distinguish between stimuli were examined.

4.3 Results and Discussion

Task 1 - Determining the Layout of Objects

Participants were generally able to perceive and identify the majority of tactile feedback presented, as they had been exposed to these cues in the training process. They were then asked to explain the layout of objects on the page (Figure 5 - left). Participants were able to accurately identify the position of the image-link at the top left of the page, with two images aligned vertically underneath it. Other hyperlinks and text present on the page were also identified. It was clear from the descriptions provided, that participants were able to form a mental picture of page layout through the use of tactile feedback, and able to externalize this representation in diagrammatic form. Diagrammatic representations were generally thought to represent the visual nature of the web page, supporting the hypothesis.

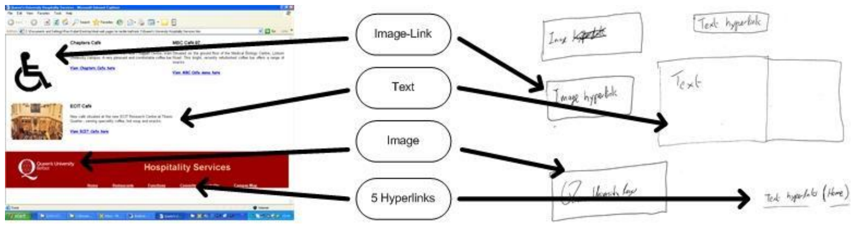


Fig. 5. Example of a blindfolded participant's spatial representation of web page

Inconsistencies were observed in some participants' diagrams. For example, in Figure 5 (right), the image and image-hyperlink are positioned incorrectly. This was not necessarily due to the quality of the tactile cues provided. It could have been attributed to the difficulties remembering the page layout to represent it diagrammatically. These same errors were not present when the participant provided a verbal description of the page layout.

Task 2 - Search and Targeting Tasks

In order to more comprehensively address the hypothesis, participants were asked to search and target objects. Results indicated that participants performed some sub-tasks faster than others, taking on average 94.9 seconds (SD: 58.5 seconds). The sub-task which caused the most issues was counting the small hyperlinks present on the interface (Q1). Only nine out of fifteen participants were able to accurately identify the presence of five links, with others suggesting between three and four. Participants generally spent longer performing this sub-task compared to Q2 and Q3, with two spending over 180 seconds counting hyperlinks. Difficulties could have been due in part to the small size of the hyperlinks and their spatial proximity to each other. When moving the mouse quickly, it was difficult to identify gaps in between the hyperlinks. All fifteen participants were able to accurately complete Q2 and Q3.

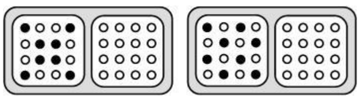


Fig. 6. Mapping for advert (left) and mapping for outer border (right).

4.4 Usability of the Interface

Fourteen out of fifteen participants expressed confidence in using tactile feedback to explore a web interface, as they thought that tactile information could be used to provide an effective overview of page layout. Participants described the tactile feedback to be more subtle compared to force-feedback which could on occasion be intrusive. The one participant who disagreed with the statement felt that further practice with the cues would have increased his levels of confidence in using the tactile device. While the majority of mappings could be distinguished from one another, some participants in the training stage encountered slight difficulties differentiating between adverts and the outer area around the border (Figure 6). This could have been attributed to limited human spatial resolution abilities, and the relatively short duration of the training period itself.

4.5 Blind Participants' Perceptions of Tactile Exploration

Results indicated that blind participants completed sub-tasks on average 33.2 seconds (SD: 23.2 seconds) faster than their blindfolded sighted counterparts. When questioned on their ability to manipulate the mouse, participants stated that controlled movements could be made using the device, simplifying the process of both focusing-in on an object, and enabling them to explore the relationship between items on a page. They suggested that the tactile browsing solution developed addressed the constrained method of navigation faced when using a screen reader. While the tactile mouse was larger than an ordinary mouse, it would not attract too much attention from others in the work environment. The main problem encountered was gauging object size. It was difficult for some participants to suggest whether images were large or small compared to the relative size of the page. This may have been due to the low resolution of the device, also discussed by Wall and Brewster [2].

4.6 Comparisons with Mappings from Other Studies

In terms of similarities, Rotard et al. [4] have used solid lines to represent the outline of borders of objects (e.g. tables). In the tactile workshop described in this paper, participants suggested that one line of raised pins would be able to indicate the edge of the page. The spatial position of this line when presented via the VT Player mouse, would provide further information about the location of the border (e.g. if the line is on the left edge of pin matrix, it would suggest that the user is positioned at the left-hand border of the page). Discussion prompted participants to extend the idea by suggesting using an animated directional effect to provide awareness of the edge of the page window. This would offer gentle persuasion for the user not to leave the confines of the page, unless he/she really wanted to do so.

Certain findings from our participatory-based approach differed from other work. For example, Rotard et al. [4] have represented headings through the use of Braille, providing information about the actual HTML tag used on the web page. Participants in our study believed that the user should not need to learn HTML code or Braille in order to explore a page. Instead participants felt that the heading should be conveyed using pins raised forming the outline of a bar. They suggested that the pin pattern should be varied in size depending on whether the object is a main heading or sub-heading. Braille has also been used to communicate contextual information on the GUIB interface. Mynatt and Weber [9] have suggested that text attributes such as font and color changes) can be presented in this way. Findings from our evaluation, revealed that while participants were able to learn the mappings presented, they suggested that too much tactile information on a page would lead to overload.

While some parallels can be drawn between findings from our study and other work, using a participatory-based design approach has led to the development of targeted feedback addressing the needs of blind users when performing web-based tasks which were difficult to perform solely using a screen reader [5].

5 Conclusion and Future Work

This paper has described the development of pin-based tactile cues for browsing the Web. Blind screen reader users and tactile interface designers were able to suggest and strengthen design ideas, using the novel design approach. Findings from the evaluation have helped to validate the tactile cues developed (Table 2), demonstrating that tactile information can be used to provide the structural and navigational support missing from speech-based screen reader presentation. These cues can be replicated by web developers, enabling them to provide an accessible representation of content for their blind users. In terms of future work, we aim to perform a more comprehensive comparative evaluation between the tactile and force-feedback cues, examining a number of browsing scenarios to determine whether one form of feedback is more appropriate for performing particular web-based tasks.

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