Assistive Multimodal Interfaces for Improving Web Accessibility

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ABSTRACT
Multimodal interfaces have been used in helping blind and partially sighted people to access visualization tools such as graphs and numerical tables. However, few studies have been undertaken to improve Web access and navigation using a multimodal approach. This paper describes a novel approach that addresses this Web accessibility issue by using an assistive tool which consists of a multimodal interface and a content-aware Web browser plug-in. A force feedback mouse and a real-time audio rendering tool form the basis of the multimodal interface. The Web plug-in constantly monitors the mouse position on-screen as well as detecting the objects in the vicinity. As a result, haptic and audio feedback are provided to inform users when they are close to an image or hyperlink. The multimodal interface and the Web plug-in are described in the paper. Results from a pilot study on the usability of this system are also presented.

Author Keywords
Haptic & audio interfaces, assistive technology, Web plug-in, accessibility, navigation.

ACM Classification Keywords
H.5.2 User Interfaces: auditory feedback & haptic I/O; H.5.4 Hypertext/Hypermedia: navigation

INTRODUCTION

For the blind and partially-sighted community, the Internet holds promise. The concept of accessing information and performing tasks such as online shopping and banking, with ease are appealing thoughts. However, barriers to accessing the Web are commonly experienced by visually-impaired users. A recent survey conducted by the Disability Rights Commission highlighted the disappointing levels of accessibility by the majority of UK web sites tested [13]. Problems can be attributed to the predominantly visual nature of information that is presented to users, via computer interfaces and the limitations that assistive devices pose. Tools such as screen-readers and Braille output devices place restrictions on the way that visually-impaired users browse the Web, by outputting information in a linear fashion. By omitting key structural information such as text formatting, and the inadequate handling of graphics or animations by assistive devices, it is difficult to gain a full comprehension of the material presented. Developing an awareness of the spatial layout of objects on a Web page can also present a challenge. Thus, a need has been identified for a tool addressing these issues.

The haptic modality has been used to improving access to interfaces. Force-feedback devices have been developed in response to the lack of non-visual feedback on a Graphical User Interface (GUI) allowing icons, controls and menus on the screen, to be tactually perceived [1, 10]. Research has shown that advantage can be gained when the haptic modality is used in conjunction with the visual and auditory channels [2, 15]. The IFeelPixel multimodal application [4] enables the user to mediate structures such as edges, lines and textures, depending on features of the pixels detected by the device. Both tactile and auditory feedback are experienced, as a result. Multimodal solutions have the capacity to extend visual displays making objects more realistic, useful and engaging [2].

Multimodal interfaces also provide assistance in the mental mapping process, allowing the user to develop a greater awareness of objects contained within the environment. A clearer spatial representation created by multimodal feedback, enhances the user's ability to orientate and navigate within their environment [3, 5]. It seems apparent that a multimodal assistive interface may provide a solution to reducing barriers that are currently faced by the visually-impaired community.

Findings from our pilot study with blind and partially-sighted participants have revealed that the positions of images are particularly difficult to detect on a page, due to the lack of feedback given. Images provide useful context to the corresponding text contained within a page. Alternative text descriptions are helpful, but the intention that the original image is trying to convey may not be immediately obvious to the user, thus rendering some pages difficult to interpret. The position of hyperlinks on a Web page is also a challenge to locate. Links themselves may not provide meaningful cues to the user. The URL that the link would follow may not offer a description of the intended target. By removing structural and contextual information concerning objects on a Web page, additional time and attention must be spent on a page, as the user tries to derive the meaning lost through the use of assistive technologies.

Our research aims to extend previous work by focusing specifically on improving accessibility for visually impaired users when interacting with Web pages, examining the presentation of information content, access to graphics, and navigation. It is hoped that by using the multimodal interface, additional structure can be brought to a page to give it more meaning, thus adding value to the perceptual experience described by Sharmin [12].

In the first stage of development (described in this paper), we hope to provide an increased level of spatial awareness using multimodal technologies compared to existing solutions, thereby improving orientation. In the second stage of development, additional feedback will be developed to assist in navigation through a web page. Both steps aim to reduce levels of task complexity and augment the subjective user experience with the Web.

CONTENT-AWARE PLUG-IN

An assistive tool, which consists of a multimodal interface with haptic and audio feedback and a content-aware Web browser plug-in which allows users to actively navigate on a Web page, has been developed (Figure 1).

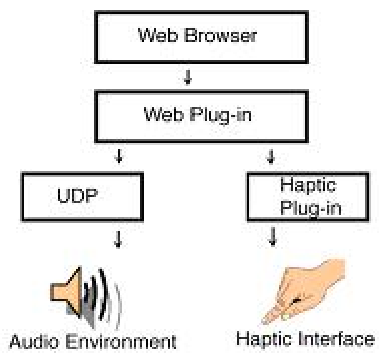

Figure 1. System Architecture.

The main purpose of this approach is to give users an opportunity to explore a Web page's layout through active haptic interaction. A force feedback mouse is used and its cursor position is constantly monitored by the plug-in which detects the surrounding objects. If the plug-in finds an object nearby then it will inform the user by enabling the haptic and audio features. Depending on the user's intention and the context of the task, appropriate prompts can be given, such as giving users guidance to the desired destination or informing users about nearby objects, such as images and hyperlinks.

The open-source Firefox browser has been selected to work with. The browser is based on Mozilla, which fully implements the W3C standards in the Web Content Accessibility Guidelines 1.0. Visually-impaired users can apply their knowledge from using other browsing technologies to Firefox. This would reduce the workload associated with learning how to use a completely unfamiliar application.

STAGE ONE: HAPTIC DEVELOPMENT

By providing additional awareness of objects such as images and hyperlinks, it is hypothesized that the user will develop a clearer mental representation of the spatial layout of a web page, improving the ability to orientate and navigate within the page. It is hoped that the multimodal experience provided will replace some of the structure that has been removed through the loss of the visual channel, thus enabling the quick and effective targeting of objects contained on a page.

Mynatt & Weber [8] have discussed the need to develop intuitive and efficient non-visual feedback to promote exploration and learnability of interfaces. Maclean [6] has recommended the use of metaphor, suggestibility and simplicity as one potential method, thus augmenting the interaction. On many Web sites, javascript is used to produce a visual effect when the cursor rolls-over an image, and a different effect upon leaving the image. If a similar effect could be modelled haptically, allowing the user to intuitively perceive when they have reached the edge of the image and when they have moved on top of it, additional spatial feedback will be gained. Alternative text can complement the interaction, providing a richer experience, similar to that of a fully-sighted user accessing a visual roll-over effect. Awareness could be gained using a similiar method when moving on or off a hyperlink.

The Logitech Wingman force-feedback mouse has been chosen to access haptic cues. Reasons for selection include the device's compatibility with the Firefox browser, and its portability for testing with users. Accompanying software allows a small set of haptic effects (primitives) to be modelled and accessed via the mouse.

Studies have shown the force-feedback mouse to be of benefit to achieve a multimodal representation through the cutaneous (relating to the skin) and kinesthesic (relating to the feeling of motion) haptic interactions with the user [3, 14, 15]. Caffrey & McCrindle [3] have discussed the benefits of using the force-feedback mouse to improve object targeting and navigation. Wies et al. [14] found that the use of force-feedback mouse aided the comprehension and learning process. Interacting with a force feedback mouse to access Web pages is a new experience to blind people in particular. Initial findings from interviews with visually-impaired users have revealed that using the device will be welcomed providing that the 'perceptual experience' is improved.

The three-step approach employed by Yu et al. [15] in order to render haptic cues on a Web page, has been adopted as a method for development. The steps are as follows: (1) the type of haptic cues needs to be decided upon, (2) the haptic effect must match the modelling object, and finally (3) events surrounding the start and end of the effect must be implemented. Haptic cues in the multimodal interface were developed, adhering to recommendations from [6, 11, 15]. General principles of developing distinctive sensations to aid object identification and providing constraints to facilitate navigation were taken into account for the 2D nature of a Web page. Appropriate design and mapping of haptic cues to suitable objects on a Web page would lead users to develop a clearer mental representation of spatial layout.

The following haptic primitives have been employed to develop the 'roll-over' metaphor; the *enclosure effect* has been coupled with clipping effects bordering an image. This has given the illusion of a ridge, which needs to be mounted. *Cursor clipping motion* increases a user's psychological perception of the wall's stiffness. Upon rolling over the image, a *buzz effect* has been produced along with force-feedback. The dual effect of audio coupled with force-feedback, will heighten the sense of positional awareness.

The *periodic effect* has been used to provide location awareness of the cursor when directly hovering over a hyperlink. This effect produces a wave that varies over time, promoting a locked sensation when directly hovering over the link. It is intended that this will promote a sense of orientation within a page for the visually-impaired user.

REAL-TIME AUDIO

Auditory icons are played as the user rolls over an image or a link with the force-feedback mouse, to reinforce the haptic effects. For this system, the image sound icon is a short descriptive auditory clip of a camera shutter clicking, suggesting a photograph or image. The auditory icon used to depict a link is a short "metallic clinking" sound suggesting the sound of one link in a chain hitting off another. Outside the image or link space, the cursor location is mapped to panning and pitch-shift parameters of a continuous background sound (*earcon*), allowing the user to gain assistive feedback when moving towards the HTML element.

USER EVALUATION

Three blindfolded users were asked to perform information-seeking tasks on different Web pages. Two computer test environments were employed; one having a browser and JAWS screen-reader, and the second with screen-reader, browser and the assistive tool developed in this research. Qualitative data was elicited using the 'think-aloud' protocol. Each user was asked to describe their location in terms of the spatial layout of links and images. They were then asked to subjectively rate the quality of audio and haptic cues.

Results showed that the users were able to locate images quickly due to the force-feedback effects encasing the graphic. The 'buzz effect' employed on the main body of the image was sufficiently noticeable, providing feedback that the user was positioned on top of the image. The 'roll-over' metaphor helped to promote levels of spatial awareness and orientation on a page. Similar results were obtained when hovering over a hyperlink. Haptic cues were generally thought to be of an appropriate intensity. However, it was noted that haptic feedback on top of a hyperlink may not have catered for groups who experience a reduced level of cutaneous sensitivity, such as the elderly.

Further testing would need to be completed to establish whether masking effects would occur if two hyperlinks or images are in close proximity to one another. Spatial, temporal and perceptual constraints would need to be examined to uncover the exact limits that are faced by the user so a totally inclusive solution could be developed. Additional testing would also reveal whether object targetting time would be reduced when using a force-feedback mouse, compared to conventional keystrokes, and whether fewer errors would be made in selection.

In terms of audio, shorter icons were found to be more effective in conveying object information. Auditory feedback was generally found to complement the haptic cues developed. However, the excessive use of sound in conjunction with the screen-reader led to the overloading in the auditory channel.

STAGE TWO : FUTURE HAPTIC DEVELOPMENT

Analysis of our current user interviews has revealed that visually-impaired users would benefit from assistive guidance when moving through a Web page. People new to the Internet, requested additional feedback and help navigating towards items such as headings, paragraphs, images and links. The feedback would enable novice users to move to a section of interest with ease, allowing them to visualise the structure of a page. Expert users were found able to remember the structural information on a Web page to effectively navigate through a page. In order to reduce the memory burden, they requested assistive guidance for moving through a Web page in a customised manner, and filtering out extraneous information that is not useful to them.

To improve awareness and navigation for Internet novices, haptic icons could be embedded in the landscape at strategic points, such as headings, paragraphs, images or emboldened text. These points would be obvious to the fully sighted, but not necessarily perceivable by the visually-impaired. As the user moves towards the point of interest, the force-feedback would increase in intensity until the user meets the haptic icon. A sense of guidance would be promoted as a result.

For more advanced users, a haptic feature will be developed to automatically direct users to certain section of the content on a web page, reducing feelings of frustration when encountering advertisements or repetitive hyperlinks located on each page throughout a site. The path taken through a page could be customised by the user, allowing time to be saved by skipping over information that is not useful to the individual. Similar approaches could be applied to web-forms which have been found difficult to navigate, due to poor labelling of form boxes.

The role of texture may form one method of providing assistance when distinguishing between parts of a page. Haptic textures can be used to convey clues to object identity and function. When designing cutaneous feedback, it may be advantageous to complement effects with other modalities such as audio, due to the device limitations discussed by [2, 7].

FUTURE WORK

The audio and haptic interface designed for this plug-in is an example of the ways that multimodality can be used to enhance a visually impaired user's awareness of navigational position and location of objects on a Web page. Following an extensive survey and analysis of the current problems that visually impaired people experience when interacting with the Internet, a more comprehensive system will be developed based on a user-centric approach.

In response to the auditory overload issue, we aim to investigate whether haptic icons could provide similar navigational cues to auditory icons, and whether these haptic icons could then be used as a replacement in the event of auditory channel overload.. Research would need to focus on the development of intuitive and meaningful haptic cues. The careful selection and use of metaphor [6] has proved to be one useful method of designing intuitive feedback, however Norman [9] has warned that if the metaphor does not completely fit the purpose, the haptic sensations created could lead to the user to confusion.

If pages are difficult to access using a screen-reader due to poor layout of information, the user may want to return to the page at a later point in time, when more attention can be spent on the page. By embedding a haptic sensation in the title bar of the browser, the user could be alerted to a page with complex information. He/she could then make an informed decision whether to stay on the page or to return at a more convenient stage in the future..

CONCLUSION

This paper has described a novel technique which can determine when a user's cursor is in close proximity to a region of interest on a Web page. The described approach presents a new way of human-computer interaction which benefits visually-impaired people by increasing their level of spatial awareness as well as making the Internet more accessible.

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