Vibro-Tactile External Memory Aids in Non-Visual Browsing of Tabular Data

Johan Kildal and Stephen A. Brewster
Glasgow Interactive Systems Group
Department of Computing Science
University of Glasgow
Glasgow, G12 8QQ, UK
{johank, stephen}@dcs.gla.ac.uk
www.multivis.org

Abstract
Tackling the problem of browsing complex tabular numerical data sets non-visually, TableVis is an interface that provides techniques to obtain quick overviews through data sonification, as well as to obtain details on demand in speech. For certain overview tasks and some data configurations, the need for external memory aids was identified. This paper proposes exploiting the tactile channel to access external memory aid, incorporating Tactons as information-rich vibro-tactile markers into the interface.

Keywords
External memory aids, Tactons, data browsing, visual impairment

Introduction and Background
Browsing data sets to extract information from them requires following a number of stages. If the data set is approached for the first time, browsing always starts with obtaining overview information that lets the user judge on general aspects of the data set and on whether it is of interest or not to take the browsing process any further. If the answer is affirmative, subsequent browsing stages are taken, which lead to filtering information, zooming into target areas and finally extracting detailed information, if required. This general process of approaching any data set starting with obtaining an overview, has been proposed by several authors, including Shneiderman's [1] stages to information seeking: overview first, zoom and filter, then details-on-demand.

For decades, many visual techniques have been developed to assist computer users in completing these stages of data browsing. Users suffering visual impairments cannot benefit from these visual techniques and have to base their browsing strategies on functionality offered by accessibility tools for the visually impaired, most notably speech-based screen readers. While these tools are very effective to access detailed information sequentially, they offer very limited support for extracting overview information. This problem is particularly acute when numerical data sets are explored, where visual data representations that convey overview information (graphs) cannot be accessed non-visually. To tackle this problem, we proposed TableVis, an interface to explore numerical data tables non-visually, using properties of auditory and haptic perception. This interface is described very briefly in the next section.

TableVis: a Very Brief Introduction

TableVis is a multimodal, audio-haptic interface that was designed following a strongly user-centred methodology, with the purpose to offer ways of browsing tabular numerical data non-visually. Much of the focus in the design was placed on providing techniques to obtain overview information quickly and easily, while also supporting ways to obtain details on demand.

A data table, whatever its size, is presented of the working area of a graphics tablet, scaled to fill up the tablet's working area completely (Figure 1, a). Since each cell of the table will stay stationary on the same position, using both hands (Figure 1, b) users are able to take advantage of proprioception and kinesthesis to maintain contextual information during the exploration (relative position of the cell being pointed at within the whole data table), which contributes to constructing a mental map of the complete data set, and being able to access different areas on the table by direct pointing. Data sonification is interactively generated by pointing with the tablet's pen at any position on the tablet (any cell on the table). As well as sonifying the cell being pointed at only, the complete row or the complete column that the cell being pointed at belongs to can also be sonified. A cell is sonified using MIDI piano sound, mapping values to pitch (where higher pitches correspond to larger numerical values). In rows or columns browsing modes, all the cells in a row or column are sonified quasi-simultaneously, which is perceived as played in a chord. Browsing is rows and columns, two complementary "views" of the same data set are obtained. This is an effective technique to hide local detail in the data and reveal the most salient features with which to describe the complete data set, thus being this an appropriate technique to obtain overview information. For a detailed description of this interface, the reader can refer to [2]. Previously conducted quantitative and qualitative studies with TableVis or the techniques used in it were reported in [2-4].

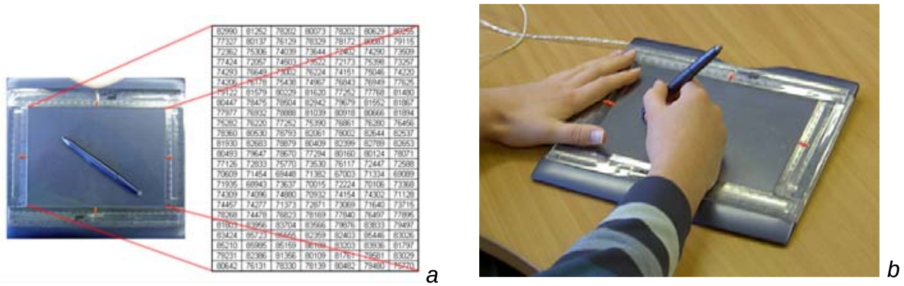

Figure 1. *The data table to be explored is presented on the active area of the tablet, scaled to fill it completely (a).A user explores a data table generating data sonifications interactively with the pen, while the left hand feels the boundaries of the data set to provide contextual information (b).*

Need for External Memory Aid (EMA)

During some of the quantitative and qualitative studies conducted with TableVis, it was observed that, under certain circumstances, users had difficulties to complete some of the tasks that required filtering information in the data set [4]. The data sets that presented difficulties for their exploration were those in which data did not evolve smoothly along the axes, but presented large variations without following any particular pattern. In those cases, when participants had to identify locations were data exhibited extreme values in certain attributes (e.g. finding the area containing cells with the highest values), participants tried to follow the strategy of pre-selecting the locations that were identified as candidates for the final answer, and then performing comparisons between those candidates to find the final answer. The difficulty to complete this task appeared when trying to keep track of the candidate locations and the information that they contained. With only a few candidate locations, the users' working memory got saturated, preventing them from progressing confidently. Some users tried to overcome this limitation by marking candidate locations with the fingers in their non-dominant hand, used as external memory aids (EMA), but this approach had several limitations: the number of locations that could be marked was limited; the marking method was inaccurate and often awkward to use; the marks were often removed accidentally; the non-dominant hand could not be used in the exploration, and maintaining contextual information became more difficult.

From these observations and the experiences reported by participants in the evaluation of this interface, it was concluded that an appropriate mechanism had to be provided to be systematically used as EMA, at the users' choice.

EMA-Tactons

Since the auditory channel is intensively used in TableVis to analyse data, it is more appropriate to use the haptic channel to communicate EMA information. In applications to analyse simpler data sets non-visually, Brown *et al*. [5] already had identified the need for EMA for certain exploratory tasks, suggesting that the sense of touch should be used for this purpose. Wall and Brewster [6] used force-feedback to provide EMA in similar situations as those described here. One of the dominant criteria for the design of TableVis was to make use of inexpensive and of-the-shelf technology that resulted in affordable systems, which were easily scaleable and where components could be replaced flexibly (e.g., any consumer computer with basic sounds card and a graphics tablet from any manufacturer should suffice). Following the same criteria, the possibility of using force-feedback devices was left aside for the first prototype of TableVis incorporating EMA functionality, as was also initially discarded to use pin-array-based tactile displays. Vibro-tactile actuators are much more common devices, which are already used in multiple applications (the most popular of them being vibration in mobile phones). Thus, using vibro-tactile information was the approach taken to incorporate EMA functionality into TableVis. Far from only using a binary indication of whether certain piece of data had been marked or not, the intention from a design point of view was that the information conveyed could be richer, potentially informing about which element of the data table (a single cell or a complete row or column) had been mark, and importance ranking information that had been assigned to that particular piece of data when it had been marked. This richness of the information would match that of the notes and marks a sighted user would make while exploring a data set. The concept of Tactons was seen to be appropriate for this purpose, as defined by Brewster and Brown [7], who said that Tactons are structured, abstract tactile messages that can be used to communicate complex concepts to users non-visually.

In TableVis, a TACTAID VBW32 transducer (www.tactaid.com) was installed on the rear end of the electronic pen of the tablet. When this actuator vibrated, the vibration was transmitted along the pen, and it was felt on the user's hand that was holding the pen. If the location being explored was marked by pressing a button, the pen would vibrate until it was moved away from that location. When the pen passed again over that location, it would vibrate again for a minimum period of 50ms or as long as the pen remained on the marked data. Depending on the navigation mode, a cell, row or column could be marked. Additionally, cells could be marked as the intersection of a marked row and a marked column. Marked areas of the data could be unmarked at any time. A frequency of 270Hz was used in the vibrations. Although the nominal resonance frequency of the TACTAID is 250Hz, if was observed through a test-bench programmed in PureData (www.puredata.info) that the resonance of the pen plus the TACTAID (joined using adhesive tape) was strongest at around 270Hz.

Qualitative Pilot Study

As a proof of concept, a very simple version of the functionality described above was implemented and presented to a group of five participants who were blind or visually impaired. During the evaluation the participants explored data tables with seven rows and 24 columns, in columns mode only, i.e. they accessed 24 chords made of seven notes each, by moving the pen horizontally on the graphics tablet. Each one of the 24 chords had a different perceived average pitch. The information conveyed by the EMA was binary in this case, since only column were marked, and no other information was initially encoded. A sine wave at constant amplitude (which could be adjusted by the participants at wish) was used to generate the vibrations. The first two participants were initially asked to find the one chord in the whole set with the highest perceived average pitch. This task happened to be simple enough to allow participants to complete it without the need for EMA. While both participants agreed that EMA-Tactons offered help to complete the task, they preferred to try first to complete the task making little or no use of them. Later, a second task was set, in which five chords with the highest perceived average pitch in the whole set had to be identified. This task was observed to overload the participants' working memory very quickly, due to performing multiple comparisons between all five chords, remembering where the potentially highest chords where, as well as remembering how many chords had already been founds as candidates. This task turned to be much simpler once the EMA-Tactons were made available to them. The three remaining participants in this pilot study were only asked to complete the more difficult of those two tasks, with similar results. EMA-Tactons had very good acceptance among all the participants. All participants except one found that the vibration was not an intrusive element, and that it did not feel uncomfortable of tiring. One participant said that s/he found the vibration to be "a bit strange", and took longer to get used to it. However, s/he did not find it uncomfortable or tiring either. During the evaluation, the marking/unmarking of chords was done using a large push-button placed on the desk. An alternative way of doing this could be pressing one of the two buttons on the pen, which would reduce any possible spatial dislocation between the action (pressing the button) and the reaction (feeling the vibration). Using the buttons on the pen was avoided because blind and visually impaired users tend to have less dexterity using pens (because they rarely use them), and it has been observed in earlier stages of this project that pressing the buttons on the pen is often very awkward a error prone (the pen is displaced while the button is pressed). No problems with spatial dislocation were observed or reported, however.

Conclusions and Future Evaluations

Using vibro-tactile cues as external memory aids (EMA) is proposed in non-visual interfaces that already make heavy use of the auditory channel. Tactons can permit encoding complex information into the EMA, potentially opening possibilities beyond mere binary marking of data. A full set of evaluations, both quantitative and qualitative, is going to be conducted, and design proposed here will be further developed and tested.

References

[1] Shneiderman, B. *The eyes have it: a task by data type taxonomy for information visualizations*. in *IEEE Symposium on Visual Languages*. 1996. Boulder, CO, USA: IEEE Comput. Soc. Press.

[2] Kildal, J. and S.A. Brewster. *Providing a Size-Independent Overview of Non-Visual Tables*. 2006.

[3] Kildal, J. and S.A. Brewster. *Non-visual Overviews of Complex Data Sets*. in *Extended Abstracts of CHI 2006*. 2006. Montreal, Quèbec, Canada: ACM Press.

[4] Kildal, J. and S.A. Brewster. *Exploratory Strategies and Procedures to Obtain Non-Visual Overviews Using TableVis*. in *6th Intl Conf. Disability, Virtual Reality & Assoc. Tech.* 2006. Esbjerg, Denmark.

[5] Brown, L., et al. *Browsing Modes for Exploring Sonified Line Graphs*. in *16th British HCI Conference*. 2002. London.

[6] Wall, S. and S. Brewster. *Providing External Memory Aids in Haptic Visualisations for Blind Computer Users*. in *Proceedings of International Conference Series on Disability, Virtual Reality and Associated Technologies (ICDVRAT)*. 2004. New College, Oxford, UK.

[7] Brewster, S.A. and L. Brown. *Tactons: Structured Tactile Messages for Non-Visual Information Display*. in *AUIC 2004*. 2004. Dunedin, New Zealand: Australian Computer Society.