AUDITORY GRAPHS: A SUMMARY OF CURRENT EXPERIENCE AND TOWARDS A RESEARCH AGENDA

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ABSTRACT

In this paper we shall briefly review previous work we have found directly relevant to our own research on the use of auditory graphs. We will then summarise previous unpublished experiences of using auditory graphs in the domain of medical signal analysis, and further recent work on the use of auditory graphs for analysing spreadsheet data. We conclude by outlining issues we believe to be relevant in the formation of a research agenda for the design and evaluation of the technology.

1. PREVIOUS WORK

Mansur devised a method for line graph sonification called Sound Graphs where the y-axis of the graph is mapped to pitch and the x-axis to time. Movement along the x-axis in time causes notes of different pitches to be played, where the frequency of each note is determined by the y value of the graph at that time. Mansur found that after a small amount of training, test subjects were able to identify the overall qualities of the data, such as linearity, monotonicity, and symmetry, on 79 to 95% of the trials [1].

Brewster and Browne [2, 3, 4] conducted a number of experiments sonifying graphs containing one and two data series, showing that sonification allowed users to visualize graphs containing two data series while listening to them and assigning different instruments to each range. Brewster and others [5] conducted experiments exploring 2D tables with speech and non-speech sound and discovered that users found the use of pitch to be valuable in determining the shape of the data within the table. Further extending the number of different data ranges, Bly's [6] direct mapping approach maps four different variables to pitch, volume, duration and the fundamental wave shape of a note. The resulting notes enabled users to place each sample in one of three related sets. This kind of approach has its limitations however, as inevitably the user's attention is drawn more to certain variables than others, making the design of a balanced display all but impossible [7]. It is worth noting from this however, that pitch is particularly strong as a means of displaying changing variable values. 'There is something fundamental about frequency in the response of the brain to sound, right up to the highest level, the auditory cortex' [8].

2. UNPUBLISHED APPLICATIONS AND CURRENT WORK

As a part of the process of carrying out work investigating the interaction between respiration, blood pressure and heart rate variability (HRV), one of the authors used auditory graphs extensively to enable him as a visually impaired person to carry out various tasks. During data capture, by mapping signal amplitude to frequency, variations in the signals of interest were monitored over time, in particular to identify discontinuities which would have rendered them unsuitable for Fourier analysis. During the analysis phase, auditory graphs were constructed of a range of time and frequency domain signal measures, including auto and cross correlation, Power and cross power spectra, simple coherency and auto regression spectra. In the frequency domain the frequency of the transformed signal/s was mapped to time, and the amplitude of each spectral component mapped to frequency. The graphs were useful for the following tasks:

- Monitoring the level of correlation within parts of the same signal and between signals.
- Overviewing the frequency distribution of power in a signal.
- Helping to verify the correct implementation of digital filters.
- Overviewing the frequency distribution of power common to two signals.
- Identifying the approximate position of peaks in the signal and the approximate distribution of power in sidebands of those peaks, due to variability in the underlying physiological signal such as respiration or heart rate.

Recent work at Queen Mary has involved sonification of database and spreadsheet applications, where auditory graphs have been used in combination with a speech-based screen reader to improve accessibility of large data sets to visually impaired users. Again frequency has provided the most effective parameter into which to map data characteristics of interest, so far always using an up-up polarity mapping. Users are able to control a number of parameters of the auditory graph, such as the frequency range used to map variables, the length of tones and gap between tones. Where two or more variables are being displayed, users can select whether these are displayed serially or interleaved. The results of recent evaluations are described in more detail in [9], but overall we have seen the successful use of these displays across half a dozen applications. In particular we have found auditory graphs provide overviews of the values in sets of data in a way that is simply not supported in current screen reader technology. Their advantages are substantially the same as those of visual graphs for sighted users, in providing a relatively quick overview of the changes in the underlying data, and helping to identify the approximate number and position of outliers.

A boundary can be defined specifying limits to the area of interest (AOI) in the spreadsheet. When this is done, the auditory display is recalibrated in order to make maximum use of the frequency range currently in use to map the data values in the AOI. A typical example of the use of this boundary mechanism is to change between the graphing of percentage scores obtained by students in an examination and the marks achieved on individual questions marked out of 25.

3. POSITION STATEMENT AND TOWARDS A RESEARCH AGENDA

We believe auditory graphs have considerable potential in the following areas:

- In sensory substitution, to improve accessibility to large data sets as exemplified in the applications described here and others such as [2] and [10].
- As a means of enabling the presentation of data when line of sight access is not possible.
- As a means of preserving screen space in mobile applications.

At the same time, lack of basic research into the most effective ways of creating auditory graphs [10] and integrating them with other technologies remains a substantial limiting factor in their use. Furthermore, there is a general lack of knowledge about them, even among visually impaired people that may benefit substantially from their use.

We believe the following to be issues worth considering in the formation of a research agenda for basic and applied research into auditory graphs:

Mapping Matching data characteristics with suitable auditory parameters, polarity and scaling identified and described in more detail in [10].

Presenting overviews Issues relating to how to design good auditory overviews (described as Gists in [12]) as discussed in [12] and [13]. Such issues include the desirable length of the graph, the length and gap between auditory points, how multiple dimensions may be organised in time.

Identification of absolute values Including the use of annotations as described in [11], visual or spoken presentation of points of interest, use of alarms.

Use of meta information Guidelines on how and when to provide meta information to assist in graph comprehension

Use of 2- or 3-D space Methods of presentation as discussed in [13], achievable resolution, organising the spatial display of multiple dimensions, the effective use of time and space in combination.

Multiple views How to design intuitive means of representing the same information using different levels of detail, and natural ways of switching between these views.

Interactivity Identification of the interactive controls that are useful and designing effective ways of making these available. Examples of such controls include pause, reverse, slow, speed up, compress/expand resolution, jump to crossing points, max/min, zero crossing.

Collaborative working Facilitating communications between users of auditory graphs or situations where the same graphs are being analysed by different people in different modes. Issues include pointing to specific points or areas, making and disseminating changes, collaboratively exploring different scenarios.

Integration with haptic and/or visual displays.

Standardisation Are there things we can learn from current audio standards such as the DAISY standard for presenting spoken word books. Should the results of research into auditory graphs become, in turn, a part of the DAISY or other standard?

4. USABILITY STUDIES

The following usability studies for auditory graphs would be valuable in informing many of the design questions described above.

- Differences between blind, partially and fully sighted users of auditory displays.
- Differences between congenitally blind and people who lost their sight at various stages of their development.
- Influence of learning within populations.
- Comparisons of understanding and recall for sonified charts compared with spoken word approaches automatically or manually produced using a screen reader.
- Ergonomics: what are the most useful means of deploying auditory graph technology? Blind managers may wish to use a small piece of hardware that can be placed on a graph which enables immediate auditory display and interaction to facilitate co-working. Mobile users may wish to use applications integrated into phones or PDAs.

5. REFERENCES

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