Listening to Graphs & Hearing Diagrams

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ABSTRACT

Developments in Human-Computer Interaction have always exploited screen space, basing solutions around and emphasising visual output. In situations where the user's eyes are occupied, lack of screen space, or visual impairment, vision cannot always be relied on for optimum performance, in which cases information must be communicated through other means of presentation. Hearing is now a popular alternative and research into Auditory Display has provided evidences of its significant potential for successfully delivering information. We present an overview of the newly emerged discipline of Sonification and Auditory Display, briefly describing previous successes, current research in the field, and outline our approach for sonifying graphs and auditorally representing diagrams.

Keywords: sonification, auditory display, graphs, diagrams

INTRODUCTION

What is Sonification?

Sonification is a term employed to describe the rendering of data relations using acoustically perceived means of presentation. Emphasising its function, *Auditory Display* can be defined as the presentation of sounds in a way determined by the nature of the data to be transformed, i.e. data-controlled sound [1] this includes the use of speech and non-speech sounds to represent information that is otherwise visualised. Just as data variables can be used to create visual displays allowing conclusions about a data set to be drawn from the employment of visualisation techniques, auditory presentation of information can also be computed to provide further and new perspectives on the data through listening. In some instances this can not be provided through other means of presentation.

Why use sound at all?

Our ability to extract meaning from sound is certainly a sophisticated one, the tying together of our perceptual and cognitive skills successfully manage to bridge a wide gap between the raw waveform of information that we receive at each ear and the rich semantic levels of meaning that we extract from it. The natural integrative properties of sound are increasingly being proved suitable for presenting high dimensional data without creating information overload especially in environments where changing variables and/or temporally complex information must be monitored simultaneously. Good common example of such can be seen in both spoken language and music. Think of a doctor's ability to understand the state of a patient using a stethoscope, or the ability of a trained mechanic to deduce the cause of a faulty engine from listening to how it sounds. Indeed, such sophisticated mechanisms allow us to make sense of current environmental settings and our complex interactions with it.

SUCCESS IN SONIFICATION & AUDITORY DISPLAY

Exploratory Data Analysis (EDA)

Possibly some of the thriving examples where sonification has been successfully implemented lie in EDA. These are techniques that assist in detecting patterns, uncovering structures and extracting important variables anomalies in a given dataset. Due to the intricate nature of the data, in addition to the complex relationships that reside between data sets, much work on data exploration and analysis has tried to implement auditory displays to aid with these complex tasks proving that sonification and auditory display sometimes exceed the results that can be obtained when using visualisation alone. A fitting example of such situations would be in the medical domain where doctors routinely use sound for inspecting and analysing medical data, such as Electroencephalogram (EEG) records [2], or to monitor and analyse a patient's state while their visual focus is on the patient or elsewhere. More recently the sonification of the human genome project [3] has captured research interest where attempts to incorporate ideologies from music perception has been used to create a sonification which shows trends in data. Equally as successful is the use of sonification in seismology. Here the motivation for using sound is the shear volume of data which challenges traditional visualisation techniques for data analysis. Seismologists are able to review 24 hours of data in about five minutes; significantly and positively affecting their performance [4].

Assistive Technology

Auditory display has found considerable success is in assistive technology in which audition is used as a substitute sensory input to access information that is otherwise visual. Most of these technologies employ synthetic speech in the form of talking interfaces and screen-readers, by far the most widely used technology for accessing textual representations. Other technologies employ complex sonifications to enhance the non-visual interaction in a variety of contexts; a good example is the integration of non speech sound in the popular applications of spreadsheets [5]. These solutions provide evidence that the benefits of using sound can go beyond the obvious use of speech, especially in situations where the verbalisation of information will be inadequate, such as graphs and diagrams.

LISTENING TO GRAPHS

Graphs such as line and bar charts are frequently used to present data in an easy to analyse way; an application where this is useful is in the analysis of trends and distribution of data which can be depicted more efficiently on a graph than on a table. Therefore, graphs are frequently used in finances, mathematics and numerous scientific fields. However, this kind of data visualisation technique is not so useful in situations where the user's eyes are occupied, lack of screen

space, or visual impairment. Non-speech sounds can provide alternative ways to expose this information [6] [7] [8].
Research on auditory graphs presently use the knowledge gained from general sonification as a way of constructing soundgraphs [9]. An example of this would be the systematic selection of sound parameters which would result in the most accurate mapping of the data. Some of the variables that researchers experiment with are different frequency, location, timbre, panning, tempo and duration.

HEARING DIAGRAMS

While graphs typically convey numerical data, a diagram can depict concepts carrying semantics that are based on other types of data. Some forms of diagrams represent entities that, even though graphically situated, successfully convey meaning regardless of their spatial and graphical properties. The graphical layout in such instances is simply an artefact of the presentation medium rather than an inherent part of the information [10]; i.e. it is only 'conveniently' visual. This raises the potential of using another modality to translate the concepts illustrated through a diagram, especially in situations where vision is no longer convenient.
As the information is non-numerical, no direct mapping of data parameters into acoustic parameters can be used to represent such information auditorally. The challenge therefore is producing intuitive mappings using either or both speech and non-speech sounds to deliver perceptually comprehensible semantics of a given diagrammatic representation
Strategies combining different modalities have been explored in various research projects, such as [11] in which it was possible to translate technical diagrams and successfully communicate the information encoded in them. Sound has been proven particularly efficient in conveying hierarchical information [12].

RESEARCH GOALS

Although research into sonification has seen considerable success, as a discipline and in comparison to its much more established counterpart field of visualisation, sonification and auditory display is still considered to be in its infancy.
Our work aims to tackle some of the current challenges facing the design of efficient and usable auditory representations that are specific to graphs and diagrams. We are currently focusing on empirically evaluating the efficacy of employing different mapping strategies for sonically representing visual attributes with the aim of producing a methodical and evidence-based approach to mapping graphical characteristics into sound.
We are also particularly interested in exploring the impact of learning effects on the ability to interpret and use auditory graphs and diagrams, both in individual and collaborative contexts, focusing on the use of sound as the main means of presentation and thus empirically assessing it's potential as a medium of communicating the semantics and structure of diagrammatic representations.

CONCLUSION

Research into Sonification and Auditory Display investigates aspects of information presentation and accessibility when using sound as the main communication medium. One of the major questions in this field is to establish appropriate and reliable methodologies for allowing alternative access to information that is graphically represented. Our work focuses on systematically studying the effectiveness of employing different strategies for representing graphs and diagrams sonically to support non-visual interaction with diagrammatic representations.

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