

Exploratory data analysis using multimodal representations - Joint Sonification and Visualisation

Kajetan Enge

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1 The Project

This PhD is closely linked to the FWF-funded project *SoniVis* at the University of Applied Sciences in St. Pölten by Wolfgang Aigner, Michael Iber and Alexander Rind. This exposé is intended to outline the scope of the project and is strongly based on the FWF research proposal of *SoniVis*. This exposé will develop further and will become more detailed in the first months of the project starting in October 2020.

This PhD aims to develop a combined design theory for audiovisual analytics of multivariate time-oriented data which guides the design, development, and application of exploratory data analysis using the auditory and visual channels effectively in combination. Information visualisation and sonification both are techniques to make data perceptible but usually they are used independently from each other. This PhD intends to develop a new design theory for their combination. In order to do so I will investigate what works best in visualisation, what works best in sonification and what does for combined applications. As a first step it will be interesting to have a look at the visualisation theories and to think about their usability in sonification. Part of this will also be to find a proper terminology for the audiovisual therorie. A second important part will be the development of appropriate test methods for the combined field.

2 Current state of research

Data analysis, especially in an exploratory setting such as preparatory tasks in data mining applications or manufacturing data analysis, includes tasks that cannot be automated completely but require the active involvement of human analysts [5, 17]. To effectively and efficiently gain knowledge about a collection of data, analysts need appropriate and adjustable methods and tools that allow versatile insight into the object of research [2]. Information visualization is defined as “the use of computer supported, interactive, visual representations

of abstract data to amplify cognition” [3] and provides several of these methods and tools. The field is building a growing body of research and guidelines regarding visual encodings [1, 4, 12]. Recent work in information visualization and visual analytics has focused on intertwining visual representations with user interaction and automated analysis techniques to push these limits further [10, 16]. Meanwhile, only little research considered to include other senses such as hearing. When psychologist Bruce Walker describes the auditory channel as “the best pattern recognition system that we know of” [6], he refers to human capabilities to “extract a huge amount of information” while listening to music. Consequently, the auditory channel can be expected to bear an enormous potential for further innovation, also in the field of data analysis. Even if our auditory system is confronted with many parallel data streams which are too complex to be analyzed in detail, we can learn to notice deviations from the “normal state” [Roginska et al. 2006]. Sonification is defined as “the use of nonspeech audio to convey information” [11] and is studied by the research community of auditory display (ICAD). The methods of auditory exploratory data analysis [7] and model-based sonification [8] focus on interactive data analysis. While there has been a reasonable amount of research on data sonification for more than 20 years, most studies in the field are restricted to comparisons of the auditory and visual perception of data displays and the evaluation of users’ performance in order to demonstrate the legitimacy of auditory display by scientific means.

3 Objectives

Thus, comparatively little is known about systematic and complementary combinations of auditory and visual representations for data analysis and the interrelation of these two channels. Existing research on combinations has mostly focused on one modality while neglecting the other. To fill this knowledge gap, the proposed project aims to work towards a combined design theory for audio-visual analytics. To pursue this target, we will follow the paradigms of design science research [9?] and action design research [13, 15]. We conduct (1) design study research in a specific application domain (using manufacturing data for proof of concept) and (2) empirical studies that evaluate different combinations of visual and auditory encodings for time-oriented, multivariate data. The scientific outcomes will include not only a study design, and empirical results, but also the extension of an existing theoretical framework such as a visualization grammar [14, 18] including both channels. The SoniVis project aims to use the insights to develop guidelines for the design, development and application of data analysis interfaces that use the visual and the auditory channel effectively in combination.

4 Method

From a methodological perspective, we will follow the design science research methodology that is characterized by being concerned with relevance, i.e. practical applicability in a problem area, on the one hand, and rigor, i.e. scientific grounding in terms of used methods as well as extension of the knowledge base, on the other hand. Following Vaishnavi and Kuechler [2015], expected research outputs of the proposed project will primarily be design principles (core principles and concepts to guide design) and instantiations (digital artifacts, i.e. situated implementations in certain environments). Based on this, we will work towards a design theory for integrating interactive visualization and sonification for data analysis tasks.

After collecting in-vivo evaluation results in the design study, we formulate design hypotheses and investigate these with experimental tests of design hypotheses in a controlled study considering aspects of psychoacoustics and user experience. This approach ensures both, theoretical contributions that can be broadly applied and contribute to the knowledge base of the field, as well as concrete methods with proof-of-concept prototypes and empirical evidence of their evaluations.

5 Work Plan

In the course of this PhD the following goals are pursued:

1. Development of terminology and theory for the combined design space sonification and visualisation.
2. Realisation of a design study in cooperation with an industry partner of FH St. Pölten.
3. Adaptation of the theory and development of hypotheses according to the results of the design study.
4. Realisation of a controlled study to test some of the hypotheses.
5. Adaptation of the theory.

6 Personal Qualification

In the course of my studies, I have participated in many interdisciplinary projects within and outside the university. My bachelor thesis, my sound engineering project and also my master thesis dealt with human perception in an artistic/audiovisual context. As far as sonification is concerned, I realized a project in the Katharina Vogts seminar, in which we built a prototype of the "Trinkerinnerer", a bottle that used sonification to remind the user to drink more water. The SoniVis project will explicitly use virtual and mixed reality environments, which fits perfectly to my master thesis. There I investigated the perceived plausibility of different rendering methods of binaural audio in different VR scenarios. In order to do so I conducted a listening experiment that was programmed in Unity, hence a setup that is most likely going to be used in the SoniVis project too.

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