Sonification Support for Information Visualization Dense Data Displays

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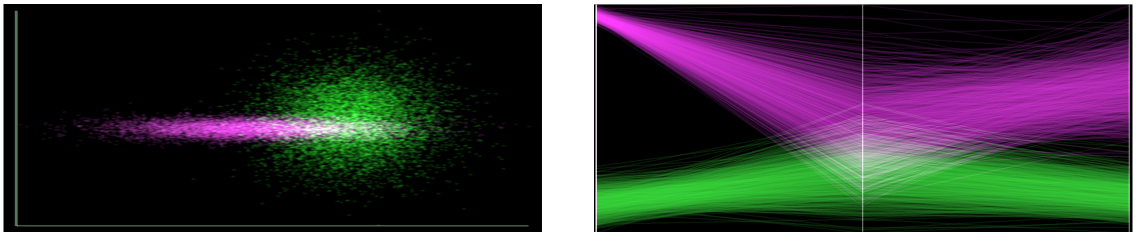

(a) A Density based scatter plot. (b) A density based parallel coordinates plot.

Figure 1: The two visual representations used in the sonification evaluation. Each representation includes two data clusters consisting of different number of objects and densities.

Abstract

This poster presents an experiment designed to evaluate the possible benefits of sonification in information visualization. It is hypothesized, that by using musical sounds for sonification when visualizing complex data, interpretation and comprehension of the visual representation could be increased. In this evaluation of sonification in parallel coordinates and scatter plots, participants had to identify and mark different density areas in the representations. Both quantitative and qualitative results suggest a benefit of sonification. These results indicate that sonification might be useful for data exploration, and give rise to new research questions and challenges.

Index Terms: Evaluation, information visualization, sonification, density representation.

1 Introduction

In order to reduce visual clutter and facilitate analysis of large data sets, it is common to employ renderings based on the data density. This is typically achieved by render semitransparent objects and additively blending them together. This can reveal structures in data that otherwise would have been missed. Using density information has, however, a drawback that it is difficult to perceive the actual number of blended objects for different areas in the density representation, making it hard to find areas of similar densities or find areas of highest densities.

This poster evaluates the use of sonification as a second modality with the aim to facilitate the analysis of large data sets, that is data sets that result in visual clutter. Two common visualization techniques are used in the evaluation: scatter plots and parallel coordinates, see Fig. 1. The evaluation compares the visual representations with only density renderings, using additive blending, and density renderings with added sound. Since the clusters have different colours, which could result in that the same densities mapped to different colours could be perceived as having different intensities, a colour model that counteract this is therefore used.

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2 Related Work

Multimodal visualization and sonification have been sparsely evaluated in various fields of application, for example in connection to depth of market stock data [9], to augment 3D visualization [6], and to enhance visualization of molecular simulations [10]. All these studies suggest that there is a benefit of sonification in visualization. By combining the visual and the aural modalities it should be possible to design more effective and efficient visualization.

When it comes to scatter plots there are not many research articles addressing density representations, however [8] and [2] present interesting work. For parallel coordinates, on the other hand, there is a significant number of research articles addressing this issue. For the interested reader, the authors refer to, for example, [11, 4, 1, 5]. None of this research do, however, exploit the use of sonification.

The aim of the study presented in this poster is to evaluate sonification in relation to information visualization of abstract data to generate research questions and challenges for future work. As far as the authors are aware, this is the first evaluation of this kind.

3 Sonification

The two composed sounds used in the evaluation differed in pitch as well as in meter, but were tuned and in the same tempo. The pitches used were C4 and G4, creating a rather pleasant but still separable interval of a fifth [3]. The tempo used was rather slow, 70 bpm, and the different meters of the sounds created a rhythm that further enhanced the perception of, as well as the distinction between the two sounds. A series of experiments were performed ($n = 20$) to verify discrimination between the sounds, and to discern the just noticeable difference in amplitude for each sound, as well as to normalize the audibility of the two sounds. Each sound was mapped to one of the two data clusters (Fig. 1), and the amplitude of each sound was mapped to the density of the respective data cluster. It was assumed that these sounds could create responses by means of harmony, rhythm and amplitude; illustrating the density of, as well as the blend between, data variables.

4 Colour Correction

In both representations, scatter plots and parallel coordinates, cluster one was coloured using a shade of purple and cluster two had a shade of green. This results in that the two clusters had uniform perceptual contrast, as presented in [7]. These isoluminant colours are

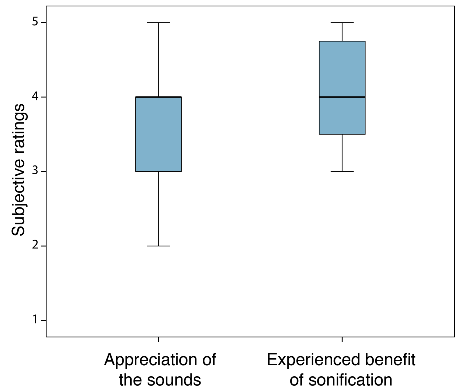

Figure 2: The users' experience as stated via the Likert scale. The participants were tending towards appreciating listening to the sounds, and agreed that there was a benefit of sonification.

of equal perceptual lightness, which is necessary if the task of the evaluation is to determine different densities of two data clusters.

5 Evaluation

For the study, 20 participants with a median age of 30 (range 20 to 60) with normal, or corrected to normal, vision were recruited. In the evaluation the participant had to identify and mark different density areas in parallel coordinates and scatter plots using a computer mouse. The tasks were performed in two setups: (1) with visual modality alone, and (2) multimodal with both visual and aural modalities. Both test setups had the same visual information, but in the multimodal modality the densities of the two data clusters were sonified by corresponding amplitude levels of the two sounds as the computer mouse hovered over any position in the representation. The tasks were to find the highest density areas in the data clusters, and finding a matching density level in one data cluster from a given density level in the other. The experiment yielded objective measures of sonification benefit, accuracy and response time, as well as subjective measures by a questionnaire about the users experience via a 5-point Likert scale with ratings that ranged from 1 (strongly disagree) to 5 (strongly agree).

When accuracy was analysed using a repeated measures ANOVA with one within-subject factor, sonification (no sonification, sonification) a main effect of sonification was found ($F(1,39) = 12.34, p = 0.001$), where accuracy was significantly higher with sonification compared to without. The mean performance for accuracy was 81.6% without sonification and 85.5% with sonification.

The mean response time was 9.6 seconds without sonification, and 20.5 seconds with sonification. When response time was analysed using a repeated measures ANOVA with one within-subject factor, sonification (no sonification, sonification) a main effect of sonification was found ($F(1,39) = 49.16, p < 0.001$), where response times were significantly longer with sonification.

Regarding the subjective measures from the Likert scale, the participants agreed that there was a benefit of sonification (mean value 4.1, range 3 to 5), see Fig. 2. Also, the participants were neutral about listening to the sounds towards appreciating listening to the sounds (mean value 3.7, range 2 to 5).

6 Discussions and Future Work

The results presented in this poster suggest that sonification can improve perception of density in visualization of complex data in parallel coordinates as well as in scatter plots. This was shown by improved accuracy when sonification was used when determining the highest density level in a specific cluster. However, response time did not improve by sonification. This indicates that the participants used the benefit of sonification to improve accuracy of the response, rather than responding faster but with the same accuracy as without sonification. The subjective measures supported the objective accuracy measurement, which suggests that sonification simplified finding the highest density level in each of the data clusters. However, the experience of the sounds were slightly more divergent, but regardless if the participant liked the sounds used for sonification or not, there was an experienced benefit of sonification. Overall, these results suggest that sonification might be a useful tool for data exploration. The results found in this study are therefore encouraging and give rise to new research challenges.

For future work, the first step is to investigate sonification for a wider range of information visualization representations. This should show where the benefit of sonification is as its greatest, as well as when the visual modality is less loaded or when it is highly loaded. The second step is to investigate whether the benefit of sonification translates from accuracy to response time as well. By creating an evaluation setup that demands fast response times, it should be possible to investigate the benefit of sonification on response time rather than on accuracy. When these studies have given a basic understanding of how sonification relates to visualization, the third research challenge is to further explore different kinds of sounds for sonification, such as different timbres, different tempo and rhythm, as well as different harmonies and intervals. This in turn leads to a fourth research challenge in personification of sounds used for sonification. Most probably, users have different abilities to comprehend and distinguish between musical sounds, as well as respond differently to them and have different taste for the sounds. This leads to a more user experience evaluation setup.

Acknowledgements

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References

[1] A. O. Artero, M. C. F. de Oliveira, and H. Levkowitz. Uncovering clusters in crowded parallel coordinates visualizations. In *Proceedings of the IEEE Symposium on Information Visualization*, INFOVIS '04, pages 81–88, 2004.

[2] S. Bachthaler and D. Weiskopf. Continuous scatterplots. *IEEE Transactions on Visualization and Computer Graphics*, 14(6):1428–1435, 2008.

[3] I. Deliège and J. Sloboda. *Perception and Cognition of Music*, volume 32. 1997.

[4] G. Ellis and A. Dix. A taxonomy of clutter reduction for information visualisation. *IEEE Transactions on Visualization and Computer Graphics*, 13(6):1216–1223, 2007.

[5] J. Johansson, C. Forsell, M. Lind, and M. Cooper. Perceiving patterns in parallel coordinates: Determining thresholds for identification of relationships. *Information Visualization*, 7(2):152–162, 2008.

[6] M. Kasakevich, P. Boulanger, W. Bischof, and M. Garcia. Augmentation of visualisation using sonification: A case study in computational fluid dynamics. In *13th Eurographics Symposium on Virtual Environme (IPT - EGVE 2007)*.

[7] S. Maureen. In color perception, size matters. *Computer Graphics and Applications*, pages 8–13, 2012.

[8] A. Mayorga and M. Gleicher. Splatterplots: Overcoming overdraw in scatter plots. *IEEE Transactions on Visualization and Computer Graphics*, 19(9):1526–1538, 2013.

[9] K. Nesbitt and S. Barrass. Evaluation of a multimodal sonification and visualisation of depth of market stock data. In *Intertional Conference on Auditory Display (ICAD 2002)*, 2002.

[10] B. Rau, F. Frieß, M. Krone, C. Müller, and T. Ertl. Enhancing visualization of molecular simulations using sonification. In *Proc. 1st IEEE International Workshop on Virtual and Augmented Reality for Molecular Science (VARMS 2015)*, pages 25–30.

[11] E. J. Wegman. Hyperdimensional data analysis using parallel coordinates. *Journal of the American Staistical Association*, 85(411):664–675, 1990.