Integrating Sonification and Visualization – But Why?

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Abstract

The research communities studying visualization and sonification share exceptionally similar goals, essentially aiming to make data interpretable to humans. One community uses visual representations, while the other employs auditory (nonspeech) representations of data. Although the two communities have much in common, they developed mostly in parallel, with only comparatively few examples of integrated audiovisual data analysis idioms presented so far. This panel brings together researchers from both the fields of visualization and sonification to collectively discuss the question: 'Integrating Sonification and Visualization – but why?'

In the panel discussion, we will tackle this question along two main hypotheses: Combining the modalities to (1) increase the "bandwidth from data to brain," or (2) to increase a user's personal engagement during the data analysis process. On the one hand, designers might aim to communicate more data in less time or gain more and more complex insights from the data by using a multi-modal display. This argument follows an understanding that two senses should be capable of processing more information than "just" one. On the other hand, sometimes, a more engaged analysis of the represented data is desirable. Engagement with data visualization stands as a crucial topic in numerous contexts within our field, encouraging "deeper" thinking by expert analysts, readers of data journalism articles, and students in educational settings. We hypothesize that integrating visualization with sonification holds the potential to enhance user engagement during analysis. Through the panel discussion, we want to delve into the spectrum between aiming for bandwidth and engagement, seeking to understand the opportunities and challenges of integrating sonification and visualization.

1. Introduction

Visualization and sonification are two approaches for conveying data to humans based on complementary high-bandwidth information processing systems [CMS99, HHN11]. Kramer et al. [KWB*99] defined sonification as "the use of nonspeech audio to convey information." Both visualization and sonification address the purpose of involving human analysts in data analysis. There are several similarities between the methods and design theories of both approaches, such as the use of perceptual variables to encode data attributes, and the role of interaction in manipulating the data representations. Over the recent decades, both fields have established research communities, theoretical frameworks, and toolkit support. Although extensive research has been carried out both on the auditory and visual representation of data, comparatively little is known about their systematic and complementary combination for data analysis.

Actual multimodal approaches for audio-visual analytics should be based on complementary and mutually supportive interplays between data representations on the visual and the auditory domain (Figure 1). Hildebrandt et al. [HARM16] showed how the additional use of sound could facilitate anomaly detection or root cause analysis of irregularities and errors. Jovanov et al. [JSR*99] added sonification of global asymmetry to a 3D visualization of brain electrical activity. Groppe et al. [GKW21] studied the combina-

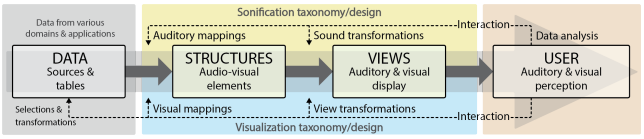

Figure 1: *A suggestion of an audio-visual data exploration: from a data source via representations of data to user perception, including user interaction.*

tion of sonification and visualization of networks and Malikova et al. [MAFP19] discussed sonification helping users identify small symmetry differences in the visualization of scalar fields. While publications suggest that sonification can complement visualization to support conventional analysis tasks such as outlier detection or correlation estimation, we can also take a different perspective: the potential of sonification to increase user engagement during analysis processes. What if a tool's design nudges researchers to invest *more* time, rather than less, in analysis, which leads to "deeper" thinking and better results [HAS11, RR20]? What if viewers enter a flow state, becoming immersed in a visualization [EMJ*11]? Engagement is an often-cited topic for future research in the visualization field [HP17a, HP17b, Hun19, SES16]. At the same time, several publications from the field of sonification investigate the potential of sound to support engagement [MHT*18, MHT*23, VHW17, ZHL*22]. A few works [DCM*18, Rön19a, EEBR21] are already discussing integrated audiovisual designs with a perspective of user engagement.

Figure 2: *What should we aim for when combining Sonification and Visualization? Should we aim to increase the bandwidth between the data and a user's brain, or should we aim to support user engagement during the analysis process?*

We think that a panel discussion dedicated to this topic (Figure 2) will be a stimulating event, hopefully inspiring the attendees to delve deeper into the field in their future research. No prior knowledge on sonification is required to attend the panel, though a deeper review of the intersection of sonification and visualization will be provided as a STAR presentation at the same event [EEC*24].

2. Panel

The four-person panel is composed of two participants from each of the sonification and visualization communities. They have heterogeneous research foci in their own fields and diverging experience in collaborating with the other community.

2.1. Panelist (Sonification): Sandra Pauletto

Bio Sandra Pauletto is associate professor in media technology at KTH Royal Institute of Technology, Sweden. Her research spans across sound and music computing, sonification, media production and sound design. Currently, she leads three research projects: Sound for Energy (Swedish Energy Agency), Personalizing Sonic Interactions (Swedish Research Council), and she is the Swedish lead for the Lullabyte EU Project. For more information, see https://www.kth.se/profile/pauletto.

Statement In media such as film, sound and image work together to produce new meanings that go beyond what the image and the sound convey individually. Chion's concept of "synchresis" "the spontaneous and irresistible weld produced between a particular auditory phenomenon and visual phenomenon when they occur at the same time" [Chi19] relates well to this idea. Additionally, in film, sound is often used to guide the audience's visual attention and to shape expectations. Furthermore, sound and images are most engaging when they are juxtaposed rather than when they are "saying the same thing". I suggest that these mechanisms could be useful also when displaying data audiovisually. This might be dependent on the purpose and task at hand, but in my opinion we should learn from successful audiovisual media and leverage the differences between audio and visual materials rather than similarities and redundancies.

2.2. Panelist (Sonification): Niklas Rönnberg

Bio Niklas Rönnberg is a researcher in sonification, the study about sound as a complementary modality in different application areas. His main research interest is in how deliberately designed and composed musical sounds can be used as complement to visual information in different application areas such as information visualization, process control, and decision support. He is teaching sound technology, procedural audio for user interfaces, research methodology, electronic publishing, visual storytelling, and video production for students at the Media Technology and Engineering and at the Graphic Design and Communication study programs. For more information, see https://liu.se/en/employee/nikro27.

Statement Visualization is the commonly most frequently used approach to represent collected data. However, in visualization there are some challenges for the visual perception. Some of these might be addressed by the sonification, but sonification by itself might not be sufficient for analysis of data. There are strengths and shortcomings in using visualization as well as in using sonification, and I believe that combined audiovisual data analysis might support a user in interpreting data [Rön19b], making data analysis a more fruitful and engaging experience [Rön19a, Rön21].

2.3. Panelist (Visualization): Renata Raidou

Bio Renata Raidou is assistant professor in medical visualization and visual analytics at the Research Unit of Computer Graphics of the Institute of Visual Computing & Human-Centered Technology at TU Wien, Austria. She is a holder of the Dirk Bartz Prize for Visual Computing in Medicine (1st Place) at Eurographics 2017 and the Best PhD Award 2018 of the EuroVis Awards Programme. In 2022, she was awarded the EuroVis Young Researcher Award. She is currently

on the steering committee of EG VCBM, GI-VCBM, and GI-Vis, and a Eurographics Junior Fellow. She is also associate editor for Computer & Graphics. Her research focus is on the interface between visual analytics, image processing, and machine learning, with a strong focus on medical applications. Recently, she also got enthusiastic about data physicalization and its application to anatomical edutainment. For more information, see https://renataraidou.com/.

Statement Imagine if you could see, touch, and hear your heart! Integrating visualization, data physicalization, and sonification offers a multi-sensory approach that can uncover new insights across various domains. Visualization translates complex data into clear insights while data physicalization provides a tangible, interactive experience. Adding sonification can further engage auditory perception. In domains such as scientific research, education, and healthcare, this integrated approach can lead to deeper insights and more effective communication of complex processes.

2.4. Panelist (Visualization): Niklas Elmqvist

Bio Niklas Elmqvist (he/him/his) is a Villum Investigator, an IEEE Fellow, and a full professor in the Department of Computer Science at Aarhus University in Aarhus, Denmark. He received his Ph.D. in computer science in 2006 from Chalmers University in Gothenburg, Sweden. Prior to joining Aarhus, he was faculty at University of Maryland in College Park, MD, USA from 2014 to 2023, and at Purdue University in West Lafayette, IN, USA from 2008 to 2014. His research area is data visualization, human-computer interaction, and visual analytics. He was elevated to the rank of IEEE Fellow in 2024 and ACM Distinguished Scientist in 2018. For more information, see https://cs.au.dk/~elm/.

Statement Integrating sonification and visualization—but why? I would rather say, why stop there? The movement toward multimodal data presentation is not just a trend but an inevitable part of the future of data analytics. This broader, multimodal approach leverages multiple sensory channels, expanding beyond traditional visual methods to include tactile, auditory, and other sensory data interactions. Such integration not only supports diverse cognitive and perceptual abilities but specifically enhances accessibility for people with disabilities (PWD), such as blind and low-vision (BLV) individuals. By facilitating equal participation in data exploration, we enable a truly inclusive environment, ensuring that insights are accessible to everyone, regardless of sensory ability. My students and I have worked on supporting BLV individuals since 2018, including for reverse-engineering charts [CJP*19], cross-modal touch-enabled scatterplots [CRJ*23], and supporting general accessibility for data visualization [Elm23]. In the future, I think that data visualization needs to expand this multimodal vision even further.

3. Organizers and Moderation

The panel is organized by the co-authors of the EuroVis 2024 STAR "Open Your Ears and Take a Look" [EEC*24]. The session will be moderated by two of the organizers.

Kajetan Enge is a junior researcher at the St. Pölten University of Applied Sciences and a doctoral student at the University of Music and Performing Arts Graz, where he conducts research on the combination of sonification and visualization for exploratory data analysis [ERI*22, ERI*23, EER*24]. For more information, see https://icmt.fhstp.ac.at/en/team/kajetan-enge.

Wolfgang Aigner is a professor for visualization at St. Pölten University of Applied Sciences where he is the PI of an ongoing research project on the combination of sonification and visualization and an author of the book "Visualization of Time-Oriented Data" [AMST23]. For more information, see https://icmt.fhstp.ac.at/en/team/wolfgang-aigner.

4. Schedule and Audience Interaction

We aim for a lively discussion between the panelists and the audience. The 90-minutes session will be organized as follows:

15m	Welcome and introduction by organizers
60m	Moderated discussion
15m	Concluding statements by panelists & organizers

Community Interaction: Inspired by Hendrik Strobelt, we will prepare a short qualitative survey to collect statements from individuals of both communities regarding the integration of sonification and visualization. We will distribute it via mailing lists and social media before the EuroVis conference takes place. At the panel, we will summarize the responses and quote selected statements (with permission) to enrich the live discussion.

Audience Interaction: Furthermore, discussing the spectrum between bandwidth and user engagement offers the potential to involve the audience via Mentimeter. Using Mentimenter, the audience will be able ask questions and vote for the next topic we should discuss on stage.

5. Previous Events

This panel follows up to a series of workshops and panels organized under the the theme of audio-visual analytics:

- Workshop @ ACM Audio Mostly 2021, September 3, 2021
- Workshop @ IEEE VIS 2021, October 25, 2021
- Workshop @ ACM Advanced Visual Interfaces, June 7, 2022 [AEI*22]
- Application Spotlight @ IEEE VIS, October 20, 2022
- Panel @ ICAD 2023, June 29, 2023

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