

Workshop on Audio-Visual Analytics

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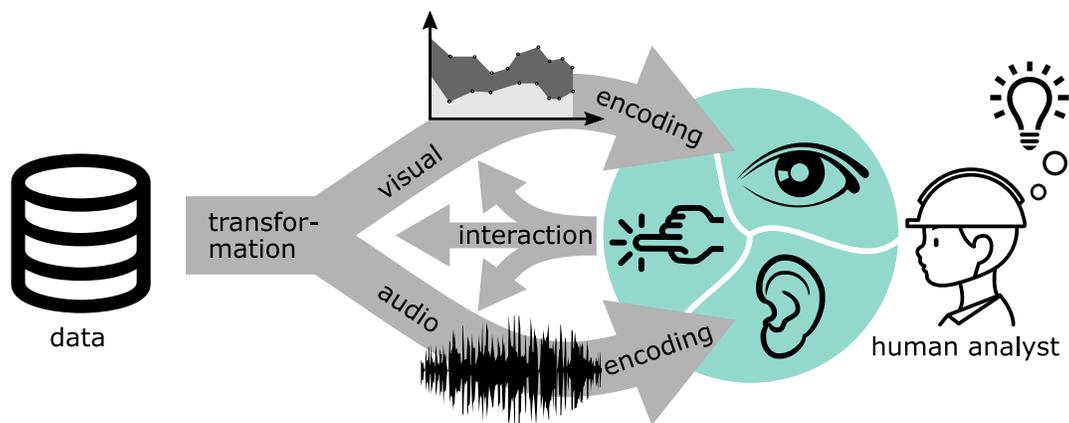


Figure 1: Conceptual process of audio-visual data analysis: data are transformed and encoded to form visual and auditory representations for the human analyst who interactively steers the idiom for their data analysis. (Figure by Alexander Rind is licensed under CC-BY using work by Pawnee E. from the Noun Project.)

ABSTRACT

In their daily lives, people use more than one sense to perceive and interpret their environment. Likewise, audio-visual interfaces can support human data analysts better than interfaces relying on just one sense. While the research communities of sonification and visualization have both carried out extensive research on the auditory and visual representation of data, comparatively little is known about their systematic and complementary combination for

data analysis. After two workshops at Audio Mostly 2021 and IEEE VIS, this 3rd workshop on audio-visual analytics continues building a community of researchers interested in combining visualization and sonification.

CCS CONCEPTS

• **Human-centered computing** → **Auditory feedback; Visualization theory, concepts and paradigms; Sound-based input / output**; • **Applied computing** → **Sound and music computing**.

KEYWORDS

Visualization, Sonification, Audio-Visual Data Analysis

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1 INTRODUCTION & RELATED WORK

Visualization and sonification are two approaches for conveying data to humans based on complementary high-bandwidth information processing systems [3, 12]. Kramer et al. [17] defined sonification as “the use of nonspeech audio to convey information.” Tamara Munzner [19] defines visualization as follows: “Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively.” 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. One example of multimodal research is Keith Nesbitt’s dissertation [20]. Also, Walker and Kramer pointed out that research on the design and the use of multimodal sonification is important to drive sonification research forward [35]. There are potential powerful synergies in combining both modalities to address the individual limitations of each other. Nevertheless, existing research on combinations has often focused only on one of the modalities.

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). Some of the previous works are the following: Zhao et al. [39] augmented maps and scatter plots with sonification and speech output to assist blind users in exploratory analysis. Hildebrandt et al. [13] showed how the additional use of sound could facilitate anomaly detection or root cause analysis of irregularities and errors. Rönnerberg et al. [27] successfully used musical sounds to support the interpretation and comprehension of visualized complex data. Férey et al. [11] developed a multisensory system to investigate protein-docking interactions including visual, auditory, and haptic feedback. Rabenhorst et al. [22] use sonification to augment a vector field visualization currently not having mouse focus. Jovanov et al. [16] added sonification of global asymmetry to a 3D visualization of brain electrical activity.

This workshop series aims to build a community of researchers from both fields, to work towards a common language, and to tackle research gaps of a combined visualization and sonification theory. Generally, a theoretical foundation for multimodal design can advance both research areas individually, as goals are often similar, but strategies differ. Specifically, visualization research faces some research questions regarding the adequate complexity of visual idioms versus the training needs or the benefits and limitations of the time-based encoding of data through animation. Sonification research will benefit from the adaptation and complementary extension of systematically structured data representations that have been established in information visualization. This third workshop

on audio-visual analytics, provides a venue for positions papers, work-in-progress presentations, and interactive discussions to develop the audio-visual analytics community further.

2 ORGANIZERS’ BACKGROUND

The organizer team brings together high-level expertise in both visualization and sonification. Its members are actively involved players in the international research communities on visualization and auditory displays.

Wolfgang Aigner is a professor for visualization at St. Pölten University of Applied Sciences and habilitated lecturer at TU Wien. He is an expert in information visualization and visual analytics and performs research on concepts, methods, and software prototypes that support humans in dealing with large and complex information structures, particularly in the context of time-oriented data. Aigner is the lead author of the book “Visualization of Time-Oriented Data” [1] and co-chaired the Doctoral Colloquium at IEEE VIS in 2019 and 2020. Furthermore, he is an associate editor of the *Computer Graphics Forum* journal.

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. He conducts basic research on the combination of sonification and visualization for exploratory data analysis [8, 9, 23]. In his Master studies, he focused on plausible acoustic modeling for virtual reality environments [7].

Michael Iber is a professor and responsible for the master class audio design at St. Pölten University of Applied Sciences. His main research interest lies in the presentation of acoustic information and data sonification [14, 15]. Iber studied piano at the Royal Academy of Music in London and pursued a classical concert career. As part of his PhD in International Logistics at Jacobs University in Bremen, he developed a method for the auditory analysis of production data.

Alexander Rind is a visualization researcher at the St. Pölten University of Applied Sciences. He conducted research on electronic health records visualization, tasks on time-oriented data, and knowledge-assisted visual analytics. His current research focuses on the combination of sonification and visualization [8, 9, 23].

Niklas Elmqvist is a full professor and former director of the Human-Computer Interaction Laboratory (HCIL) at University of Maryland, College Park, USA. His research areas span data visualization, human-computer interaction, and visual analytics. He has recently begun working on data representations that are complementary to visual modalities, such as smell [2, 21], as well as on making data visualizations accessible to blind users [4, 5]. He was papers co-chair for IEEE InfoVis 2016 and 2017, and again in 2020. Furthermore, Elmqvist is a series editor for the Springer Nature *Synthesis Lectures on Visualization*.

Robert Höldrich is the professor of audio engineering and acoustics and the head of the Institute of Electronic Music and Acoustics (IEM) at the University of Music and Performing Arts Graz (KUG). His scientific research activities include studies of sonification [33], psychoacoustics, signal processing, sound analysis and synthesis, recording and playback technology, virtual acoustics, and media philosophy. His artistic works range from instrumental and vocal compositions to electronic music and live electronics through to sound installation.

Niklas Rönnerberg is an associate professor in sound technology at the division for Media and Information Technology, Department for Science and Technology, Linköping University. His research interests is in the connection between sonification and visualization [24, 25, 28], as well as in sonification as a mean for communication in public spaces [29], and sonification for conveying emotion [26]. Furthermore, he teaches media technology courses with focus on sound and sound technology.

Bruce Walker is a professor at Georgia Institute of Technology, with joint appointments in the School of Psychology and the School of Interactive Computing. In addition, he is a member of Georgia Tech’s HCI faculty and HCC faculty, as well as the Graphics, Visualization, and Usability (GVU) Center. He coordinates the Psychology Track in the GT Masters Program in HCI (MS-HCI). As founding director of the Georgia Tech Sonification Lab, Dr. Walker leads an interdisciplinary program of research into sonification, auditory displays, and multimodal data presentations. He has been a core member of the International Community for Auditory Display for nearly 3 decades and has served as the President of ICAD. His long history of publication in the field of auditory displays includes seminal papers on the theory of sonification [17, 34, 37] and applications of multimodal displays [18, 32, 36, 38].

3 PREVIOUS WORKSHOPS

Before the AVI 2022 workshop, two workshops on audio-visual analytics took place at:

- ACM Audio Mostly 2021, September 3, 2021
- IEEE VIS 2021, October 25, 2021

Both workshops were held in a virtual setting due to the COVID-19 pandemic and focused on interactive discussions in break-out groups and plenary. Discussion topics were theory, design process, tools, and evaluation.

4 GOALS

The goals of the workshop are:

- to continue building a network of members from the sonification and the data visualization communities.
- to get inspired by the members of the respective other communities, as our goals are often similar, but our strategies differ.
- to identify research gaps for a combined visualization and sonification theory.

5 WORKSHOP CONTENT

The half-day workshop alternates between presentations of the accepted contributions and interactive discussions of research gaps (Table 1).

A call for positions papers and work-in-progress paper was announced on the website and distributed over widely subscribed mailing lists for visualization and sonification researchers. Five short papers were submitted until the submission deadline on April 3, 2022. Each submission was reviewed by two members of the international program committee of the workshop. Based on the

Table 1: Preliminary Schedule

09:00 - 09:30	Agenda & Lightning talk by the organizers
09:30 - 11:00	Presentations of contributions
11:00 - 11:30	Coffee break
11:30 - 12:30	Interactive discussion
12:30 - 13:00	Summary & Follow-up planning

written reviews, final decisions were made by the workshop organizers and four short papers were accepted for presentation at the workshop (acceptance rate: 80%).

5.1 Accepted Contributions

Towards the Combination of Visualization and Sonification for Cylindrical Displays [6] – Elias Elmquist and Kajetan Enge present an immersive environment with cylindrical display and a circular sound system. They investigate visualization and sonification approaches that play together well in this environment. This combination has significant potential as a collaborative audio-visual data analysis space.

Exploring Sketch-based Sound Associations for Sonification [10] – Lars Engeln and Mandy Keck propose to use sketches of sounds as mental models. This should enable the derivation of further qualities that can be considered to make sonifications feasible for the mapping of abstract data.

Questionnaires Assessing Usability of Audio-Visual Representations [30] – Niklas Rönnerberg and Camilla Forsell posit that standardized questionnaires are needed for assessing the usability of audio-visual representations. Standardization should improve the comparability and validity of research studies in this field. After a survey of standardized questionnaires that can be used for visualization or sonification, they conclude there is a need of combining different measures as well as developing new.

An Exploratory Use of Audiovisual Displays on Oceanographic Data [31] – Iason Svoronos-Kanavas, Vasilis Agiomyrgianakis, and Niklas Rönnerberg combine sonification, visualization, and aesthetics in innovative ways into an audio-visual experience conveying both information and artistic intention. With this combination it improves the comprehension of complex data sets and suggest new directions to explore environmental data.

6 FOLLOW-UP STRATEGY

An international community of researchers and practitioners that are interested in the combination of information visualization and sonification, emerges from the workshop series. The audio-visual analytics community communicates over a Discord server and organizes virtual meet-ups on a bimonthly basis. At these meet-ups, guest speakers present their ongoing work in an informal setting. Additionally, a follow-up workshop with a call for contributions is planned for 2023. Updated information can be found at <https://audio-visual-analytics.github.io>.

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