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## Interaction with sound for participatory systems and data sonification

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## Summary

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This thesis deals with the use of sound in interactions in the context of participatory systems and data sonification. We investigate an interactive environment where participants perceive information of the data through sound elements. To define the interactive process, we employ the dialogue model, breaking it down into three components: subject, verbal, and adjective. This supports the purpose of having a better understanding of the topics addressed in this thesis: i.e., interaction models, data sonification, interaction & design, and evaluation of data sonification. Moreover, it contributes new findings and perspectives to these topics.

We started by exploring behavior with respect to sound. To that end, we use the audience in a sound interaction as an example to investigate the behavior of the subjects (persons) in a dialogue. We reviewed a series of real-time participatory musical performances and analyzed the dialogues between the audience and the systems. In the majority of the related work, sound is controlled by or mapped to other forms of data. Our analysis reveals that an immersive and ongoing interactive environment can be developed within an ideal framework (see Chapter 2). Using our framework will assist us in making the interactive sound design intuitive for the audience to grasp and understand. We have applied our initial findings to two case studies:

In the first case study, we apply the ideal framework to an interactive sound installation - presented as Băi (see Chapter 3), to further understand how to use sound as a tool for interaction and navigation. In this installation, sound changes according to the intensity and duration of the control input from the participants, i.e., the measurement of the motion data of a pendulum speaker. In this way, sound is used to construct a dynamic and responsive relationship between the participants and the installation, which achieves an ongoing interactive system. Additionally, noticeable sound changes serve as feedback, allowing participants to make inferences about future states or next steps. Therefore, the design of the feedback, i.e. the adjective part

of the dialogue, plays a crucial role in enabling the participants to understand and navigate the sonification design in an intuitive way. We elaborate on the observations of participants of the installation and relate this to our approach to sound design.

In a second case study, we study the sonification design of molecular structures through various approaches to interactive auditory navigation (see Chapter 4). We establish a metaphor for the connection between atomic mass and pitch, which could assist the participants to understand the meaning of sounds and learn the mappings. An evolutionary design process of the sound synthesis and composition provided a good insight into how a sound is developed from data step by step based on the expert reviews.

Finally, we design and conduct two different validations to evaluate the sonification approach to molecular structures, depending on the hypotheses we aim to examine. Tests are accomplished with reasonably sized test populations in a lab setting. A pretest-posttest experimental setup is chosen to assess the learnability of the sonification approach. A within-subject design is used to compare the performance between two conditions, allowing us to investigate specific features. After the first round of experiments, adjustments have been made based on the findings from the previous experiment. This formative research is essential for design and testing, facilitating the continuous improvement of a sonification design. It is important to note that this is exploratory research aimed at evaluating an unconventional representation of data (i.e., sonification approach). As a result, evaluation methods, based on usability testing, have to be specifically designed to align with the goals of the approach.

These exploratory studies have shown that dialogue and interactivity can be employed to bridge the gap between complex data and human understanding mediated by sound. They have provided the foundation for more extensive investigations with larger populations. The lessons learned here will encourage fellow researchers to continue to push the boundaries of knowledge and innovation in this field.