OBSERVATIONS ON AN INTERDISCIPLINARY DESIGN PROCESS USING A SONIFICATION FRAMEWORK

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ABSTRACT

In sonification of scientific data, designers know very little about the domain science and domain scientists are not familiar with the sonification methodology. The knowledge about the domain science is not given, but evolved during the problem-solving process. We discuss design challenges in auditory display design regarding user-centerdness and introduce an approach to involve domain scientists throughout a sonification design. We explore this within a workshop in which sonification experts, domain experts, and programmers worked together to better understand and solve problems collaboratively. The sonification framework that is used during the workshops is briefly described and the workshop process and how each group worked together during the workshop sessions is examined. Participants worked on pre-defined and exploratory tasks to sonify climate data. Resulting sonification prototypes and workshop sessions are documented on a wiki and could be used as a starting point for future sonification procedures. Furthermore, the participants grasped each others' domains; climate scientists especially became more open to use auditory display and sonification as a tool in their data mining tasks.

1. INTRODUCTION

Analysis of requirements and constraints, and understanding the users in the context of the systems functionality and the tasks that she is involved with are the key constituents for a successful design process. The concept of Task and Data analysis (Tada!) was first introduced by Barrass [1] as the first step for auditory information design. Tada! includes some crucial aspects of how to design an auditory display for a specific task, based on descriptions of the task and data, but it has limited applications. In Tada! what is going to be perceptualized using auditory display is known in advance, whereas in many domain sciences an exploratory approach is required without knowing exactly which features or patterns in data to look for. Additionally, Barrass [2] and Frauenberger [3] explored design patterns in the sonification field. Frauenberger showed that the design process for auditory display is mostly unstructured and it provides limited support to reuse the design knowledge created. Another issue is that methodologies and existing guidance in the auditory domain are often affiliated with a specific context and reusing them is only possible within the specific context [4]. A sonification tool as a general software package to develop quick sonification designs for a wide range of scientific domains has been explored by deCampo et. al [5]. Other tools, such as Sonification Sandbox [6] or SONART [7] have investigated a smaller range of applications. In our approach, we wanted to focus on a specific domain (climate science) and context (as Flowers et al. suggested) but giving a broad range of sonification design possibilities to the users and the power of designing sonifications. Sonification of scientific data requires understanding and expertise in the domain science, sonification design, and computer science. In order to create useful sonifications, experts design and develop sonification systems iteratively working with the domain scientists. In project SysSon, we proposed an approach to allow our users (domain scientists) to take control throughout the design process. The main concept of the project was to create an interdisciplinary sonification platform which enables climate scientists and sonification researchers to generate sonifications systematically. Climate scientists from Wegener Center for Climate and Global Change provided a huge variety of measured and simulated climate data for this research project. The starting point for our approach were previous interdisciplinary sonification workshops which had a broader user group than our project. The Science by Ear [8] workshops had domain scientists from different scientific domains with a variety of data (e.g. medical data, sociological data, physics data.) Our focal point was one specific domain with the variety and complexity of data sets and problems within this domain. Contextual inquiry and focus groups were conducted in the climate scientists workplace to gather information on climate scientists' workflow and data analysis tasks. Considering the results, a sonification platform was designed and developed. The development has been an iterative process and involved the users greatly at all stages of the design and implementation. In order to produce a wide range of sonification examples within the sonification tool using different data from climate scientists, we conducted a multi-disciplinary workshop. This paper describes the objectives, methodologies, and outcomes of the workshop in detail. It entailed collaborative work between climate scientists, sonification experts, and programmers.

1.1. Beyond User-Centered Design

Creating a sonification platform to analyse scientific data that is user-friendly, efficient, and effective requires a broad knowledge of the domain science. The knowledge to understand, frame, and solve problems in the domain science is not given, but is established and evolved during the design process. In such an iterative process, users become co-designers not only at design time, but throughout the whole existence of the sonification system. Rather than presenting users with closed systems or predefined sonifications, we planned an iterative system design that evolves by user's engagement to explore and design a variety of sonification possibilities for their problem domain. This allows the users to extend the system to fit to their specific tasks and needs while being assisted by sonification experts in this process. We partially used user-centred [9] and participatory design, but we extended our approach in parts to meta-design [10] to shift some control from designers to the domain scientists by empowering them to create and contribute their own objectives in the sonification design method. A sonification system for analysing data is a living entity which evolves during and after the design process continuously. Thus, the participation of the users in the design decisions go beyond the processes at the design time. We also included participatory design [11] to involve users in the co-design process with the sonification designers. Despite the advantages of participatory design during the design time, sonification systems need to be evolvable to fit new needs and tasks created by users after the completion of the system. Therefore, we needed the domain scientists to be fully involved to contribute and modify the system themselves when new needs arise. Nevertheless, the sonification design space [**?**] is huge and impossible to be explored by novice sonification designers. Thus, during the workshops we focused on specific use cases that represent a variety of domain scientists workflows to explore the design space. The SysSon approach is an open framework for sonification researchers and climate scientists to develop a variety of sonifications but also having the option of using default mappings of climate parameters to sound parameters, suggested by experts. Fig. 1 shows the scheme of collaborative and individual spheres for climate scientists and sound experts (sonification experts and audio programmers) within SysSon platform.

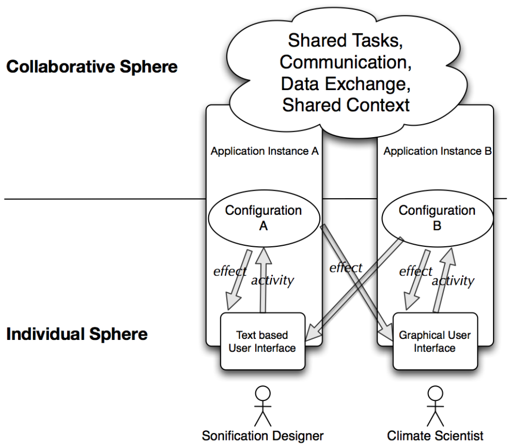

Figure 1: Collaboration between Domain Scientists (Climate Scientists) and Sound Experts in a Shared Context Scenario

1.2. PROBLEM DOMAIN

Climate data is an ideal domain to apply sonification for a number of reasons including the typically large multivariate data sets, the dynamically changing time-based nature of the data, and the complex nature and process of creating models. Climate data is usually temporal, spatial, or spatio-temporal. Measured and modelled climate data used for this project is provided by Wegener Center for Climate and Global Change (https://wegcenter.uni-graz.at) in the Network Common Data Form, an open standard for multidimensional data. (NetCDF, http://www.unidata.ucar.edu).

2. SONIFICATION PLATFORM

The software resulting from the analysis of the preliminary Contextual Inquiry is a platform that links data processing, visualisation, and auditory display. The framework has two front-ends for different users' purposes and skills; first as an analytical tool for the climate scientists and second as a development environment for expert users (sonification experts and sound designers). The second group has the option of editing and compiling new sonification scripts in an interactive shell. This option is also open for the first group in case the domain scientists are interested in exploring the sound domain further and taking over the role of co-designers. The graphical user interface (GUI) allows users to parameterise and explore pre-defined sonification designs with their own data sets. The main component of the interactive GUI consists of a plotting interface and a sonification interface. Users can interact with this interface by uploading a data set, zooming in and out of a plot, and exploring different dimensions of the data by using sliders. The SysSon platform is as an open source project, running on all major operating systems. It is released under the GNU General Public License. For more information see https://github.com/iem-projects/sysson. A screenshot of the sonification interface is shown in Fig. 2. This sonification platform is used as a collaborative design space in the workshop described in the next section.

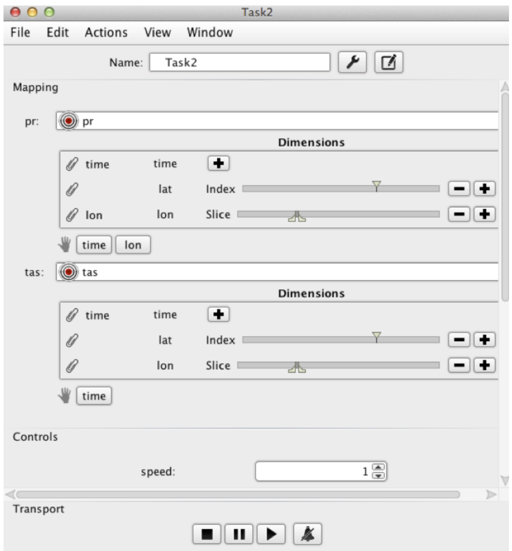

Figure 2: A Screenshot of the Sonification Interface.

3. PROCEDURE

As described in the previous section, a combination of user-centered and meta design is used to collaboratively create sonification solutions to the climate scientists' problems. This collaborative research process was compacted into an experimental Climate by Ear workshop process. The multidisciplinary workshop was two and a half days long and it brought together sonification experts, climate scientists, and audio programmers. There were 4 climate scientists, 6 sound experts (3 out of 6 Professors), 7 males and 3 females in the workshop. The participants were from different levels of expertise in their field. 4 PhD. candidates, 2 PostDocs, and 4 Professors were present at the workshop at a time.

At the beginning of the workshop, the project team introduced the project and the sonification platform. A climate scientist from the project team also gave an introductory lecture on climate data and the data sets that were going to be used during the workshop.

Afterwards, participants were divided into two groups. The groups changed by each task. In each group, there was at least one project member, one or two audio programmers, two climate scientists, and one or two sonification experts. The workshop was divided into hack sessions within groups and discussions between all groups at the end of each hack session. Hack sessions lasted between 2 to 4 hours. The hack sessions entailed the development of three tasks that included sonification strategies and experimentation with the SysSon platform via iterative coding. Some scripts for data input and basic sound synthesis routines were prepared in advance to allow participants to focus on the sonification design process.

During the first session, both groups worked on the same task. By the second and third sessions, each group was structured to work on a separate problem to allow a variety of tasks to be explored. Each group started tackling the task by brainstorming and identifying potentially more interesting research questions for the climate scientists within the data sets used in the task. Then sonification experts introduced some ideas and the sonification design process turned into a more collaborative and experimental approach. The dynamic and experimental nature of the collaboration made it more difficult to stick to the pre-defined tasks and finally each group either focused on the data and research questions that were more interesting for the climate scientists in that specific team, or were more manageable to sonify within a short amount of time for the audio programmers.

3.1. First Session

For the first task, we used near surface temperature and precipitation data in monthly means (one value/month) over 156 years in the past (1850 - 2005) and 295 years in the future (2006 - 2300). The goal for this task was to scan temperature and precipitation data and listen to both simultaneously to find different patterns in various geographical regions. We wanted that teams make decisions on how to read through data dimensions, chose specific regions or global data, find metaphoric sonification designs to distinguish between temperature and precipitation changes, and compare the zonal data sets to the full range of data sets.

3.1.1. Group A Strategy

The sonification approach for this task was parameter-mapping using granular synthesis. The group restricted themselves to a specific region. Some ideas that were implemented in this group entail:

- Using pitch and amplitude to perceptualize precipitation level.
- Keeping the density of the grains fixed.
- Using upward glissandi for north, downward glissandi for south mapping.
- Using panorama for east - west mapping.
- Using noise gate to display only data above a certain threshold.

The climate scientists suggested to combine multiple parameters because one parameter alone does not represent extreme scenarios in climate. Precipitation is not linearly distributed and shows only a few outliers and it sounds pretty uniform in one area. Thus, it needs to be displayed over broader regions. Examples of sonifications created during the workshop could be found on the workshop's wiki: https://github.com/iem-projects/sysson/wiki/ClimateByEar.

3.1.2. Group B Strategy

This group decided on convection areas, e.g., Monsoon areas, where temperature and precipitation are highly interacting. For their first attempt, they tried to sonify data from the Himalaya region with panned longitude, latitude as frequency, and density as rain. They also explored the sonification of different regions. For instance: temperature seemed to be very stable in Northern India in the sonification which is not true. Then they chose a new region, where there is more variation in both temperature and precipitation such as Boulder, Colorado.

The grid resolution of the data might have been too coarse for the task in order to calibrate the sonification properly. Thus, the sounds created during this task did not meet the expectations of the climate scientists.

3.2. Second Session

As mentioned before, for this session we did not use the pre-defined data sets and tasks. Instead, the climate scientists in each group discussed what are some of the more challenging and interesting phenomena they would like to analyse using sonification. The structure of the wokrshop was very dynamic and the participants were in different groups during each session.

3.2.1. Group C Strategy

This group consisted of more climate scientists who work with radio occultation (RO) data sets. The RO method is a remote sensing technique making use of GPS signals to retrieve atmospheric parameters (refractivity, pressure, geopotential height, temperature) in the upper troposphere-lower stratosphere (UTLS), which is defined as the region between around 5km and 35km height.

The group focused on the quasi-biennial oscillation (QBO); a quasi-periodic oscillation of the equatorial zonal wind between easterlies and westerlies in the tropical stratosphere with a mean period of 28 to 29 months. An extratropical QBO signal should be hearable at higher latitudes with a different phase. Reading and processing data for this task took most of the time of this session and the group managed to finish an Audification of the data.

3.2.2. Group D Strategy

This group adopted the sonification patch of the first task (including a monthly/yearly reference to display the time passed). They focused on finding interesting patterns in the El Nino region: -170 degrees South to +120 degrees North (Equator: +/-5) They tried different frequency mappings and examined a high density of sound grains with a randomly chosen dataset. Through experimenting by slowing down the playback time, playing grains with higher densities, and tuning the frequency, the resulting rhythmic patterns got more hearable.

Using granular synthesis for both temperature data and precipitation data made it difficult with quick playback to hear the synchronicities, because the precipitation grains are longer than the temperature grains and some patterns got masked. Then the group tried a different approach by changing the mapping polarity of precipitation sound because low precipitation as very high pitches was not very useful using this granular synthesis. (Examples could be found on the workshop's wiki page)

3.3. Third Session

3.3.1. Group E Strategy

This group explored using climate model data - future projections for temperature - to examine atmospheric variability patterns in climate model projections (e.g., Monsoon.) The data used was from three different sources for two different scenarios from the time frame 2006 to 2100. Some problems that the group ran into were that within such small datasets they were not sure if the difference between the two models is hearable at all. It was not clear if the problems are generated by the sound synthesis patch or from data reading complications. Another challenge was the limitation of the programming language (ScalaCollider) we were using throughout the workshop regarding sound synthesis capabilities. ScalaCollider is a SuperCollider client for the Scala programming language. Since the sonification platform we were using is built in Scala, ScalaCollider was used for the user side. ScalaCollider is still an experimanl system which reduces functionalities comparing to SuperCollider and provides higher level abstractions. The documentation is also very sparse which makes the learning curve, especially during a workshop, steeper.

3.3.2. Group F Strategy

This group tried to sonify wind data. The main question to answer in this task was how to display a vectorial value. The approach was to map timbre space to represent vector's angle (e.g. North-South direction as rising-falling sound; East-West as crescendo/decrescendo sound). Exploring wind data took so long that this session was finished without any completed sonifications. The discussion continued with the other group the next day and all participants together finished a patch for this task collaboratively which could be found on the workshop's wiki.

3.4. Pre and Post Questionnaires

The participants of the workshop filled out a questionnaire before and after the workshop. The format of the pre and post questionnaires were the same but the content was slightly different. The aim of these questionnaires was to get an overview on the participant's familiarity with the basic concepts of the other discipline before and after interacting and working with people from the other domain. In both questionnaires, each participant was supposed to describe six words related to climate science, six words related to sound, and five words that could belong to both domains. The words were ordered randomly and there was a different set of words given in pre and post questionnaires. The climate words were chosen from the results gathered by the preliminary Contextual Inquiries mentioned before. The list of words used in the pre-workshop questionnaire is illustrated on Fig. 3.

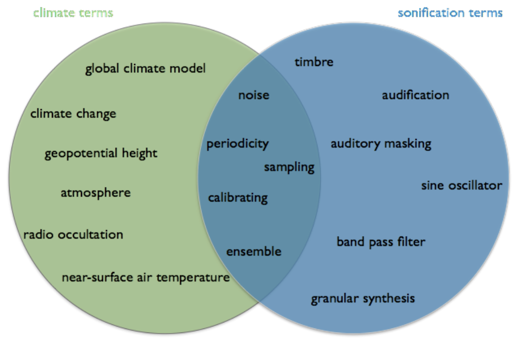

Figure 3: Domain Specific Terms used in Pre-Workshop Questionnaire

Results from pre and post questionnaires showed (Fig. 4) that the number of correct answers regarding the other domain improved only slightly for climate scientists after the workshop. However, there was no statistically significant outcome in our analysis due to the small number of participants. Additionally, there were setbacks in responses of sound experts regarding climate terms and neutral terms after the workshop which we estimate to be because of fatigue.

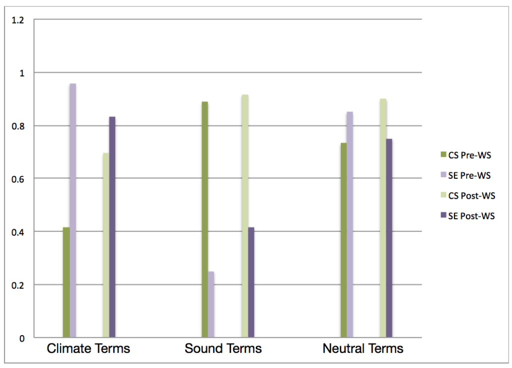

Figure 4: Correct Answers of Sound Experts (SE) and Climate Scientists (CS) to Domain Related Terms in Pre and Post Workshop (WS) Questionnaires.

4. REFLECTIONS

Based on feedback from the participants, the collaborative nature of the workshop was very refreshing and innovative. Empowering the users in making design decisions helped to engage them more in the process of sonification and designing sonifications together with sound and sonification experts gave the climate scientists more perspective on how sonification is really done, what are some of the possibilities, and how sound parameters could be used. Sound experts on the other hand gained deeper insights on climate data science and some of the interesting features of climate data that could be interesting to sonify and analyse.

The main issue faced by the participants throughout the workshop was the time pressure. The programmers and sound experts did not get a chance to develop all the ideas discussed in the groups thoroughly. Another challenge was that climate scientists were not very involved in the technical problem-solving related to the software platform which took a huge amount of time. Having more technical preparation together with the programmers beforehand could have saved some time. Reading and handling data in a language new to programmers was very challenging and time consuming in some sessions. Additionally, having a workshop at the early stages of the software development cycle worked as a usability test with expert users. In order to get experts to develop a larger variety of sonifications, regular interactions after the workshop would be necessary to keep them familiar with the system updates and new features and possibilities as the sonification platform evolves.

5. CONCLUSIONS

Overall, the approach to create a pool of sonifications using a framework with a multidisciplinary group is very challenging. The process worked in the sense that we gathered a diverse set of data analysis problems, solutions, and methods that work for climate scientists within our sonification framework.

One of the main challenges that we had throughout the project is the domain scientists skepticism towards sonification and auditory display as a useful tool. The user's cultural bias is discussed in previous papers of the authors. The multidisciplinary workshop helped to reduce this skepticism because of the hands-on nature of the hack sessions. However, there are still very few convincing examples of sonifications which demonstrate a great improvement over the existing data analysis methods that climate scientists use. As our future work, we continue to involve and update climate scientists and sonification experts through ongoing workshops, tutorials, and usability tests as the framework and our sonification prototypes improve.

6. ACKNOWLEDGMENT

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