An exploratory use of audiovisual displays on oceanographic data

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Abstract

The present study is an interdisciplinary endeavour that transmutes science, technology, and aesthetics into an audiovisual experience. The objective is to highlight the potential of combining sonification with visualisation in order to enhance the comprehension of extensive and complex sets of data. Moreover, this paper describes contemporary tools and methods for the implementation of the practice and suggests effective ways to monitor environmental changes. It can be regarded as an exploratory study for familiarisation with the potential of sonification and visualisation in the exploration of environmental data.

Keywords

Sonification, Visualisation, Audiovisual display, Oceanographic data

1. Introduction

The demand to explore and expand the capabilities of audiovisual displays raises expectations for using the practice in many real-world data applications. In particular, the utilisation of sonification and visualisation in combination and the ability to facilitate multi-modal bonds between the auditory and vision channels [1] can be a strong advantage of the practice. Furthermore, a thorough exploration on the modes of perception could lead to meaningful estimations or conclusions of multiple aspects arising from the audiovisual data representations.

Information visualisation is a common way to present large sets of complex data [2]. In recent years, there has become an increased interest in sonification and its wide range of applications and uses among various fields [3]. While there is a number of studies that applied data sonification [4, 5], there is only little work on combining sonification and visualisation. This combination may be a practical method which can make a good use of the positive features of perception offered by each modality [1]. Particularly, the better memory offered by sight [6, 7] and the ability to display extensive sets of data in a comprehensive and accessible form are major benefits of visualisation [2]. Sonification has perceptual advantages in comparison to visualisation over temporal constrains. Studies have indicated that the perceptual capacity of audition exhibits greater temporal precision in comparison to the visual channel [6, 8]. Moreover, auditory perception can effectively detect small changes that can be imperceptible in the visual domain, and the easy access in audio technology is a significant advantage in sonification [9]. Consequently, the combination of sonification and visualisation may be a powerful tool that can reveal characteristics, trends and patterns in complex and big data by utilising multi-modal bonds [1, 10].

There is only limited research with experiments on oceanographic data and sonification so far. Sturm [4] applied sonification to study patterns in spectral oceanography data collected by directional buoys. Additionally, Ben-Tal et al. [11] also implemented sonification on oceanographic data using the SonART software. These studies focused on sonification. By contrast, the present study combines sonification with visualisation as a means to explore oceanographic data.

The primary aim of this study was to explore the use of audiovisual displays through oceanographic data. Furthermore, it experiments with the effect of introducing aesthetics to audiovisual displays and musical approaches to sonification, while its pragmatical use in oceanographic studies remains unexplored.

The secondary aim was to indicate contemporary methods for implementation and design of audiovisual displays. The exposure to both auditory and visual representations may effectively increase cognition and in-depth comprehension towards data.

This paper is based on a Bachelor's dissertation, which described the approach, aims and design procedure carried out during the spring 2021.

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2. Methods

To explore the practice of audiovisual display multiple methodological approaches were used.

2.1. Multi-modal assessments

At first, focus was on designing an approach of effectively utilising different modalities to represent and communicate information in a enlightening and meaningful manner. Certain test environments and paradigms were implemented to explore how different modalities deal with the information, and interact so that features of the represented information can be detected and assessed.

The overall process was divided in three stages. Firstly, the raw datasets were reviewed and each wave parameter was identified to the according column. Thus, the assessments derived from the sonification in the second stage could be interconnected with the visual representation.

Secondly, the extent to which data features and trends could be outlined through sonification was explored. Due to perplexity of sonification, confusion can sometimes occur. Especially when multiple data parameters in the sonification are mapped to a larger number of sound characteristics, i.e., frequency, amplitude. Auditory perception might find difficulties to process and interrelate each stimuli to the according information source. However, this may be helped with reliable visual elements to support the auditory perception.

Finally, visualisation was introduced. The potential of combining the two modalities to create an environment for on-site re-evaluations of the incoming information was an valuable aspect. This perceptual interplay of the auditory and vision channel notably contributed in the overall cognition process. In addition, the “mutual” support between the displays was instrumental in both identifying concrete points within the data solidly and objectively but also efficiently describing trends and features. Moreover, another important aspect was related to the real-time confirmation of the events. In particular, the ability of “confirming” to a certain degree the occurrence and influence of a data event as well as its significance in the overall analysis process could be beneficial.

The ability to interpret information as multi-modal representations might also show important advantages with regards to the estimations and assessments derived by a third perspective of analysis. In particular, the use of two modalities to communicate information might create a start line for further hypotheses and associations between two different representations of the same data. The combination of auditory and visual stimuli may support cognitive processes as a way for triggering cross-modal perception derived from evaluating auditory and visual elements as well as their associations with the actual events.

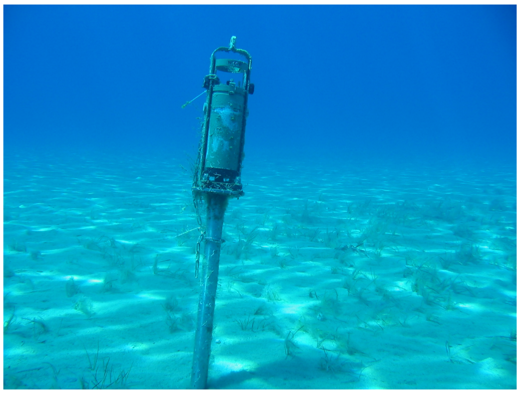

Figure 1: Underwater picture of the instrument. Photograph by Panos Drakopoulos [17]

2.2. Data acquisition and apparatus

The oceanographic data were recorded in the northeastern part of Gavdos island and more specifically in the “Karave” port area [12]. The creation of a terrestrial calibration station for the altimetry radar satellites TOPEX-POSEIDON, Jason-1 and ENVISAT was financed and implemented by the European Union operational program and corresponding programs of NASA [13, 14, 15].

The WTR9 is an instrument for wave, tide and water temperature measuring (see Figure 1). Briefly, the instrument is activated every hour and takes hydrostatic pressure measurements of water with a frequency of 2 Hz. Then, a Discrete Fourier transform is applied to calculate the wave parameters (significant wave height, mean zero crossing wave period and maximum wave height) [16].

2.3. Sonification

SuperCollider (SC) was used for the sonification [18]. SC is a programming environment for real-time sound synthesis and algorithmic composition [19], widely used for sonification (see [20, 5]) as it enables rich synthesis possibilities, Open Sound Control (OSC) protocol [21], extensive peripheral connectivity, and more. OSC was used for data transmission among the different platforms (see 2), i.e., Python, SC, and openFrameworks [22] (oF).

Data processing was implemented in Python. Each type of data (temperature, significant wave height, zero crossing period and max height) was processed in the sonification algorithm by an ”OSC definition”. In Python, the temperature values determined the delay time among iteration cycles. Each value was scaled by 16 to facilitate perception of the periodicity, resulting in a delay range of 1.185 to 1.66 seconds. The frequency mapping was based on the the temperature and max height val-

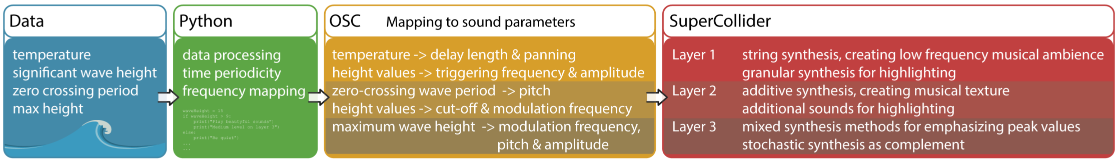

Figure 2: The oceanographic data were processed in Python and transmitted via OSC to SuperCollider where various sound parameters were mapped to the data values.

ues, with increased pitch for higher values according to the Phrygian musical scale. Afterwards, the frequencies of the musical scale were conditionally selected. This scale was chosen to render the "divine" dimension of the natural world, as the "ethos" of the Phrygian way is described by Aristides Quintilianus as "ἔνθεον" (inspired by god) [23]. The dataset was divided into three layers with different sound synthesis techniques and mappings as a means for experimentation. This design enabled time dependent comparisons to explore different sonification and synthesising methods. The musical approach was based on stacking consequent sound layers, one layer for each section of the data. All sound parameters in the sonification design were linearly mapped to the data.

The *first layer* consisted of low frequency sounds, to create a musical ambience. The temperature values were mapped to the filtered delay length of a Karplus–Strong string synthesiser (i.e., the Pluck UGen), divided by a factor of 10:1, as well as to the modulation of the stereo panning of the sound. Additional granular synthesisers were used to highlight significant height values. The grain triggering frequency and amplitude parameters were mapped to the height values. For the *second layer*, additive and modulation synthesis were used, by mixing multiple layers of sine, pulse, and saw-tooth wave oscillators. This was done to create a "continuous" and somewhat "dull" musical texture. The pitch of the additive synthesiser was mapped to the zero-crossing wave period values. Additional synthesisers based on phase and ring modulation, and subtractive synthesis were mapped to significant height values, with increased modulation frequency of the phase and ring modulation and increased cut-off frequency for increased height values. In the *third layer*, the maximum wave height was represented by a combination of four synthesisers, utilising phase and ring modulation, as well as subtractive synthesis and dynamic stochastic synthesis generators (i.e., the Gendy1 UGen) to create the impression of "presence". The modulation frequency of the panning, pitch and amplitude were mapped to the value. This layer aimed to gradually convey the sense of a peak that occurs in the final stage of the sonification and visualisation "experience".

The overall musical ambience was characterised by a peaceful balance of sounds that are disturbed by expressive "discharges". These occur at specific times to express through their distinctive sound the element of accumulated energy and that of the "unexpected" in nature.

2.4. Visualisation

While oceanographic studies illustrate wave parameter data with static visualisations, dynamic mapping was used in this study to represent the fluctuations.

The visualisation was implemented with the oF C++ toolkit [22]. Two major advantages of oF is that it can sufficiently provide OSC protocol support and a has a great number of classes and add-ons to support different kinds of visual representations.

The particle system technique in computer graphics is a practical way to simulate natural phenomena such as fluid motion, smoke and other [24]. An algorithm based on this technique was considered suitable for simulating the sea ripple effect (see Figure 3) although demanding in terms of computing resources [24].

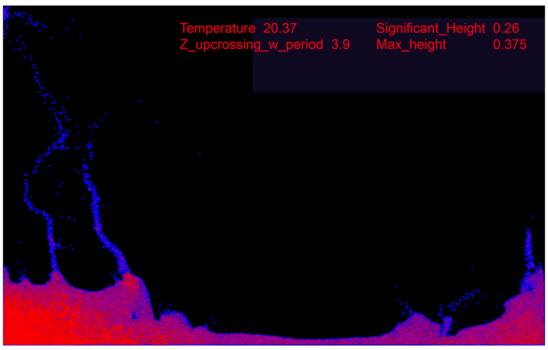

Figure 3: Visualisation result. Upper right: Sea wave parameters. Temperature, significant wave height, mean zero crossing wave period, maximum wave height.

First, the OSC communication setup between SC and oF was established. Then, for the fluid-like simulation of the sea wave ripple the ofxBox2D [25] add-on was used. The particle interaction algorithm was based on an example included in the add-on. For the parameter mapping, each temperature value depending on whether it is even or odd affects the gravity towards the edges of the system. In this way, a motion similar to that of sea waves was simulated. The significant wave height and zero-crossing period values configured the red and green colour value respectively in the particles. The maximum height values represented a gravity multiplier and mapped linearly to a scale from 1 to 1.5. Greater values had excessive effects in the particle system.

3. The audiovisual display

In this work, the combination of sonification and visualisation was explored through the prism of oceanographic data. By implementing both techniques synchronously it is suggested that the perception and comprehension of the fluctuations is more effective than using the techniques separately. The representation of the same data in an audiovisual form may lead to a interactive interplay between the perception channels. Furthermore, the observer might be also benefited in terms of comprehension time. The data could be represented swiftly and accurately regardless of the extensive collection time period.

Experimentation with synthesis techniques revealed a wide variety of manifestations in data representations. The different synthesis parameter mappings allowed many expressive capabilities when designing for the auditory perception. While working on the sonification design, the bond between the particle system and granular synthesis was explored. Both were based on the central idea of grain/particle re-synthesis. Binding grains and particles to create audio and visual totalities may be associated in an abstract manner. Introducing these in audiovisual displays is a rather unexplored approach. However, the prototypical way of their interaction may create a springboard for further analysis and re-evaluation.

Sonification can be a valuable tool to interpret data trends in exploratory data analysis [3]. Many times sonifications lack objective reference points due to our way of perception with regards to the sound properties. For example, it is easy to objectively assess information from a visualisation where visual points represent specific values. While, it is much harder to identify and perceptually correlate frequency or loudness to accurate estimations. This was also the case in this work, as associations between wave parameters being presented as a continuous stream might become unambiguous and hard to perceive. This should be addressed in future explorations.

The tools used provided a sufficient environment for such an application. There were no major latency issues in data transmission. SC and oF provided sufficient materials, classes and a wide range of different representation modes for sonification and visualisation.

The potential of introducing the aesthetic aspect (see further discussions in [26, 27, 28, 29, 30]) to audiovisual displays may create a springboard for further research on this relatively unexplored practice. Art is a highly approachable way for people to communicate. Thus, the potential of utilising art as a medium for information provision (i.e., environmental awareness) based on real phenomena through the data might be beneficial.

A demo video can be found at: https://bit.ly/3KloIF9

4. Discussion

During the design process, sonification and visualisation were applied to the data individually. However, in the audiovisual display, sound conveyed information while it was combined with visual elements to facilitate perception of data. This endeavour not only is encouraging to further the research on the practice, but also for finding effective ways to develop useful scientific tools.

This work may inspire the use of multi-modality in the cognitive process of exploratory data analysis. A valuable aspect regarding this is the emergence of information source crossing and its continuous re-evaluation as a product of an interactive interplay between the channels.

The present study is an exploration into the aspects of utilising audiovisual displays by means of oceanographic data. However, certain elements and aspects should be revisited. The main weakness of this work was the paucity of a proper subject study. The process should be repeated with exposing participants to the practice while reporting the results concerning the cognitive outcome.

5. Conclusion

This study aimed to explore the capabilities of combining sonification and visualisation using oceanographic data.

This audiovisual display aimed towards facilitating perception of incoming visual information by the introduction of auditory elements. Future work should address if the perceptual process can be supported by the the on-site re-evaluations as well as associations between the auditory and visual stimuli. Furthermore, the interrelations between the two modalities in combination with audiovisual displays are other aspects to be revisited.

This study is unable to evaluate the use of auditory displays pragmatically in oceanographic studies. While the primary focus is on implementing the practice using oceanographic data as the means for exploration.

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