IRMINGER CHANNELS: EXPERIMENTAL SONIFICATION DESIGN UTILIZING SPATIALIZED MEASUREMENT DATA

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ABSTRACT

Irminger Channels is a short (5’39”) audio work for which undersea measurements, taken by a pair of subsurface Atlantic Ocean sensor collections 20km apart and between 30 and 2,700m deep, are sonified. Since the measurements were collected over a period of six years (2014-2020), the sonification perceptualizes long-term environmental cycles and environmental fluctuations in temperature, conductivity, and organic material within seawater. Sonifications from the two identical sensor sets are discretely mapped onto two channels of the stereo field, each performing independently of the other as a mono channel. Differences in simultaneous measurements by the moorings within their shared environment are thus rendered as separate channels of sound, synthesized according to identical processes, and played back within the listener’s environment via headphones or loudspeakers: a simple design approach that allows investigation of qualitative relationships by ear. Further compositional choices reflect concern to frame a field for listener-led investigation of the sonified datasets and their relationships.

1. INTRODUCTION

Irminger Channels is an outcome of ongoing research in sonification of data from locally spatialized simultaneous measurement arrays within a shared environment. This piece utilizes complex data, generated from measurement of interrelated phenomena in the marine ecosystem. The datasets were analyzed and a sound production system designed respecting the physical relationships within the measured systems, by applying them co-productively to process of synthesizing sound. The large-scale collapse of the period of measurement (2014-2020) to a listening duration of 5’39” also serves to render latent periodicities within the data as audible periodicities. Compositional process, related research, details of measurement array and data utilized, and a technical discussion of the sonification approach adopted in this piece follow.

2. GOALS, DESIGN, COMPOSITIONAL CHOICES

The aesthetic aim of this work is (at least) twofold. The primary concern is to highlight the effect of distance between the two flanking subsurface sensor moorings and to frame this as an aesthetic experience for listeners to investigate. The second concern is for the phenomenological apprehension of implicit relationships, so-called knock-on effects, and correlations between the sonified datasets, whether within a single mooring or between the two. These research interests, in combination with reflection as to the construction and operation of the instruments used for measurement, led to the design and compositional decisions taken in the work. A later section of this paper discusses the measurement array and the datasets utilized.

The position of the listener, as discussed in Vickers, Hogg, and Worrall (2018) is central to the conception of this work [1]. The presence and attention of embodied listeners is of central compositional importance in addressing the primary concerns of this piece. Particularly where headphones are employed, a listener to this piece not only hears the sound field, but connects it together in the manner of closing a circuit, granting it cohesion through listening. Physically speaking, this provides an apt metaphor for the system being modeled: for instance, if difference or change is to be registered in two synchronized sensor systems operating at distance from one another in a shared environment, it is a third perceptual system that is needed to make the comparison and give it meaning, whether the information be apprehended in numeric or sonic form. It is the listener, regardless of their intentions or training, who provides this connectivity, giving meaning to the piece. As Bob Strum writes in describing an aspect of his sonification work with ocean buoys, “without knowing the science, the sounds are still influential” [2].

Of great concern in any sonification design is what has been referred to by composer Larry Polansky and others as the “mapping problem” [3]. Whether it be for interests primarily scientific or aesthetic, for monitoring, demonstration, or oriented towards investigation, mapping phenomena or information between domains leads to losses and gains, revelation and distortion. As Polansky highlights in discussing this issue, “The only thing that is not an embellishment is the thing itself”. Yet the “thing” in this case is a complex set of processes that make up the underwater dynamics of the northern seas. At best only partially understood, these processes are being measured for further study. Due to the complexity of both the measurement process and the phenomena measured, the resulting data is difficult to grasp. Attempts to perceptualize such measurements aid in understanding what they contain and how they relate to one another. How this is done depends on the scale and features under consideration for the designer, and the context they design for.

Each step in a sequence of measurement and interpretation is a move away from the actuality of the phenomena in question. In this case, the issue is further complicated in that the phenomena studied exhibit structure on multiple spatial and temporal scales. My approach is to sonically frame the situation such that listeners phenomenologically reconnect some of the pieces of information that have been quantified from the phenomena measured. While some quantitative aspects of the measurements may be rendered less clear by aspects of my design decisions (events existing on relatively short temporal scales, for example) other aspects (the periodic waves of temperature change or the relationship between temperature and organic matter in the seawater) are rendered more easily perceptible.

3. RELEVANT WORK BY OTHER ARTISTS

In addition to Strum and Polansky's works briefly referenced above, along with Vickers and Hogg's theoretical work [4], I am indebted to composer Maryanne Amacher for her active engagement of listeners in her in 'third ear music' [5]. These works activate listeners with considerable confidence, centering listeners' bodies as instruments within Amacher's composition. Physiological as well as a cognitive resonance in response to sound is of particular interest for my research and for the textural approach adopted for this piece.

David Gauthiier's work, and specifically his ocean-related pieces such as *Measure for Measure for Measure* and *53°32'.01N, 003°21'.29W* serve as important points of reference for *Irminger Channels* [6]. In these and other works, Gauthiier adopts a playful approach to information and its technologically-mediated presentation, while also treating data collection on equal terms with sonic and visual presentation. Consideration of the perspective of viewers in Gauthiier's work results in a case of perceptual 'sea legs'. Gauthiier undermines viewers' frames of reference while offering them a critical awareness of the presence of the technologies that make this position possible. Conceptual content is treated with both gravity and levity and calls upon reflections on human imperfection and fragmentation of environmental data to render visitors as participants rather than as passive observers.

4. TECHNICAL DISCUSSION

4.1. Data Workflow

The workflow for *Irminger Channels* required a researched understanding of the construction and instrumentation of the two subsurface moorings whose data were utilized. The data had to be analyzed and the datasets modified to a format consistent with control and audio rate signals for real-time synthesis and digital sound processing (DSP) in Pure Data (Pd) [7]. This required modification of the file format and a non-lossy rescaling of the values contained. My sound design ecosystem for this project consisted of three layers of synthesis and one layer of processing per channel, with identical deployment between left and right. A broader discussion follows.

Irminger Channels presents sonifications of datasets from two of the subsurface moorings of the Global Irminger Sea Array [8]. These moorings, 20 km apart, form two flanks of the triangular shaped array, which in total consists of four subsurface moorings containing sensors along their mooring cables, and several mobile undersea gliders. The center of the triangular array is located off the coast of Greenland at 60.4582, -38.4407, a part of the North Atlantic known for high wind and extreme wave conditions [8]. The datasets utilized represent roughly six years of data, with measurements ranging in interval between fifteen minutes to two hours depending on the sensor considered. All datasets used in this piece are made available to the general public by the United States of America National Science Foundation via the Ocean Observatories Initiative Data Portal [9].

In *Irminger Channels*, the sonifications are discretely mapped onto the two channels of the stereo field, each performing independently of the other as a mono channel. Data from the mooring referred to as *Flanking Subsurface Mooring A* has been mapped to the sonifications produced in the left channel and *Flanking Subsurface Mooring B*'s data has been mapped to the right channel. The mappings produced and synthesis methods used are otherwise identical.

Explanation of the mapping from data to synthesis can be simplified since although I used a total of twelve datasets, they represent time frames and average depths that were considered functionally identical for both moorings. Distortion of time frames in the sonification process is kept to a minimum through my implementation of a single master clock on the DSP side, against which all running processes where calibrated. As the twelve datasets are split evenly at six per channel, it is expedient to simply refer to the mapping of six datasets, as the mapping is identical between the channels. Furthermore, within each channel's group of six datasets, three sensor-collections were used to collect measurements. Therefore, in **Figure 1** below, data is grouped by instrument-sensor type. It bears mention that these sensor instrument groupings, where meaningful in terms of data correlation, have been retained in the sound production instrument groupings. These correspondences can be seen in Figure 1, which summarizes the datasets and their implementations.

4.2. Design of Sound Textures

Sound design for *Irminger Channels* centers around a few relatively simple modules. In general, compositional consideration of data and sound sources highlight perceptual correspondences between the channels and frame a neutral field for aural discovery of implicit correspondences. Explicit convergences (measurements quantifying related qualities) are mapped to the same sound source or modulate one another. My approach is inquisitive, experimental, and a work-in-progress. The results heard here were selected for their interesting sonic qualities and for the interplay between measured time scales and qualitative thresholds of subjective perceptual attention. Thus, the work is proposition, an experimental step in a developing design strategy. **Figure 2** summarizes sound design and data integration.

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5. Tables

Instrument Type	**Measurement Type (NSF specification)**	**Interpretation**	**Implementation in DSP**
Fluorometer (WET Labs, ECO Triplet-w)	Fluorometric CDOM Concentration (CDOMFLO)	Colored Dissolved Organic Matter: tannins and lignins from decaying plants and animals re-emit light resulting in some of seawater's color	*Fluctuations in CDOM data alter the frequency of the root note within the modal-triadic synthesizer. Note that a separate synthesizer operates for each channel.*
Fluorometer (as above)	Fluorometric Chlorophyll-a Concentration (CHLAFLO)	Chlorophyll: sensor measures difference between a light it emits and light re-emitted by phytoplankton as a way of measuring their biomass in a given region.	*Fluctuations in Chlorophyll data alters the distance between a tone and the root note within the modal-triadic synthesizer by moving further or closer with respect to the root.*
Fluorometer (as above)	Optical Backscatter (Red Wavelengths) (FLUBSCT)	Optical Backscatter: red light measured as a proxy for suspended material in seawater	*Optical Backscatter triggers a complex of post-synthesis processes that operate discretely for each channel.*
pH (Sunburst, SAMI-pH)	Seawater pH (PHWATER)	Measured quantity of hydrogen ions in solution	*Fluctuations in pH data alter the distance between a note and the 1st interval within the modal-triadic synthesizer by moving further or closer with respect to the 1st.*
Conductivity-Density-Temperature (CDT), (Sea-Bird, BE 371M)	Temperature (TEMPWAT)	"Surface" temperature, as in this case shallowest ~ 40m sensor data was utilized	*Temperature values are rendered audible by the filtered noise-band that rises and falls in density throughout the piece. Temperature values also attenuate the modal-triadic synthesizer.*
CDT (as above)	Seawater Pressure (PRESWAT)	Pressure from seawater column above sensor	*Pressure data provides index modulation to the frequency modulation synthesizers.*
CDT (as above)	Conductivity (CONDWAT)	Ability of seawater to conduct electricity, by proxy a measure of salinity; This property was measured at both the shallowest ~40m and deepest ~2600m sensor locations available.	*Values from the conductivity readings are mapped onto carrier, modulation, and index values for frequency modulation synthesizers operating discretely, one per channel.*

Figure 1 *(above)* : Measurements Utilized, Interpretation, Implementation within DSP [9].
Figure 2 *(below)* : DSP ecosystem for *Irminger Channels*

Instrument Type	**Design Notes**	**Description of Sound Produced**	**Data Utilized**
Noise-driven Oscillator	White noise is filtered by temperature data, low passed and used to drive a fast sine wave oscillator.	*Wind-like fluttering noise with pitch indications. Long- and short-time scales are rendered audible.*	Temperature
Modal-triadic Synthesizer	From a tuning established prior, two intervals above a root note are calculated using input data. Tuning is a modified Lydian-minor mode.	*Sustain square-saw waves and scalar variations, dynamic swells. Interplay of measured qualities is present.*	Fluorometer (CDOM, Chlorophyll) Ph, Temperature
Frequency Modulation (FM) Synthesizer	Shallower water conductivity mapped to carrier wave, deep water conductivity to modulation, pressure to index.	*Quickly changing bursts of pitched sine-based modulations Effects of amplitude in measurement reflected in modulation and 'steadied' by pressure (depth) index.*	Conductivity (2 contrasting depths) Pressure
Spectral Processing	Combined Fast Fourier Transform (FFT) filter, comb filter, and reverberator process output of all other sources, summing the results of this.	*Mostly short interruptions "over the top" of the rest of the sounds, color and momentary or prolonged qualities of reverberation. Reflecting the 'reflective' nature of the measured quality.*	Optical Backscatter

7. REFERENCES

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