Sonifying the Arctic: A Generative Sound Installation Employing Ecoacoustic Data Sonification

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Abstract. *Combining field recording and sonification techniques offers great potential for aesthetic exploration and data perceptualization. Various artists have explored this combination through their artworks, developing methodologies for artistic creation with different intents—ranging from scientific inquiry and knowledge dissemination to purely aesthetic affectation. In this project, we explore a combination of methodologies, including the sonification of spectrograms, and using weather data to modify granular synthesis parameters affecting samples created from our denoised field recordings. A key feature of this project is the development of a harmonization system that integrates sensor data collected from a field station with event detection, species classifications, and spectrograms derived from field recordings of the areas surrounding the field station. We also implemented an autoencoder architecture for data imputation to address the disparity in data volume and time resolution between both sources. In Sonifying the Arctic, we developed a method to create an auditory identity for each data point, an approach we termed digital soundprint. Through this method, we are able to perceive complex environmental changes in the Arctic through data manipulation, enhancement, and affect, with the goal of opening new doors for knowledge dissemination through audience engagement with Sonifying the Arctic.*

1. Introduction

Our environment is undergoing rapid and significant changes driven by human activity [Eyring et al. 2021]. To comprehend the full scope of these environmental changes in the Arctic, where our project is based, we rely on data collection from various sources, with a particular emphasis on passive acoustic monitoring (PAM) stations. As outlined by Ross et al. (2023), PAM offers valuable insights into the presence and behavior of wildlife species and the dynamics of environmental changes over time, especially when combined with other data sources [Ross et al. 2023]. In our project, we analyzed our PAM data to determine species present, noise pollution levels, and environmental fluctuations in combination with sensor data from field stations monitoring Breiðamerkurjökull and the surrounding area using the Arbimon platform [Aide et al. 2013].

PAM surveys are commonly used in ecoacoustics to examine the acoustic dimension of ecosystems [Bradfer-Lawrence et al. 2019]. Here, the original data format is sound, which is then transformed into numerical data for analysis [Merchant et al. 2015]. Conversely, numerical data and the relations within the data set can be transformed into sound with the intent of communication or interpretation through different sonification techniques [Kramer et al. 1999]. Both approaches aim to enhance our understanding of phenomena through different display modalities.

In our project, we were particularly interested in using numerical data derived from field recordings together with numerical data collected from various sensors in a field station to create a harmonized system that consolidates all data into a single data frame. This allowed us to explore auditory representations of the complex relationships underlying environmental changes, resulting in a cohesive sound narrative with the intention of data communication and information dissemination for a general audience through data affectivization [Buening et al. 2022].

Due to the technological capacities of the instruments, techniques surrounding data collection, and varying deployment schedules, we faced differences in data volume and time resolution from our sources in the harmonization system. To address this issue, we implemented an AI technique, particularly autoencoders, to generate and impute missing data, creating a complete and continuous data set based on Macias' approach for clinical data imputation [Macias et al. 2020].

Using our data harmonization and imputation/generation system, we developed a method to explore each data point through a unique sound identity. This process involved sonifying spectrograms and processing samples from PAM surveys using granular synthesis. The resulting auditory display, which we call a digital soundprint, serves as an identity sound that conveys environmental changes by comparing data points in our dataset.

2. Contextualization

Our work explores a creative integration of field recording, sonification, and AI-driven data imputation. The project extends over eco-oriented artistic research and Ubimus practices based on environmental sound and weather data. The sound design in *Sonifying the Arctic* uses both synthesized sounds such as filtered noise as well as recorded sounds that are then processed in a variety of ways such as by granular synthesis, building on research on ecologically-based granular synthesis [Keller and Truax 1998]. In their research, Keller and Truax (1998) use environmental sound samples as grains and apply meso-time control functions to create a sounding output that mirrors natural processes. Similarly, we use sound samples from Arctic field recordings as grains, with weather data dynamically modifying synthesizer parameters to enhance the ecological relationship between the data and the resulting sound display.

Furthermore, our work connects with Basanta's exploration in 2010 of syntax in electroacoustic composition, where syntax refers to the structured arrangement and evolution of sound events that create meaning within a composition [Basanta 2010]. In our project, the use of data imputation influences the syntactical output of our algorithm in Basanta's conceptualization, as it introduces new perceivable relationships between the data points which create meaning in the auditory contextualization of the data. Basanta (2010) argues that ecological models in composition should not simply mimic nature but instead create new meanings and relationships within the composition. Similarly, our sound design creates an aesthetic abstraction of our sound dataset, reflecting a poetic interpretation of what both human and non-human objects sound like in our recorded environment. By extending the sound data through sonification techniques into the unheard world of weather data, we adhere to Basanta's notion that ecological models in composition can transcend mere imitation to generate complex, abstract forms of signification.

Sonifying the Arctic also resonates with the artistic practices of Andrea Polli and Jacob Kirkegaard, both of whom utilize sound to explore ecological transformations. Polli's *Sonic Antarctica* connects science and art by employing field recordings and sonification with fragments of radio interviews, creating an artwork that engages the public with climate change in Antarctica [Polli 2009]. Similarly, Sonifying the Arctic employs field recordings and sonification to craft a sonic identity of Iceland's Vatnajökull National Park. Our work also aligns with Kirkegaard's *ISFALD*, which uses field recordings and data audification from glaciers in Greenland to create a space for attentive listening and perceiving the processes of glacial retreat [Kirkegaard 2013]. Both ISFALD and Sonifying the Arctic engage with the ecological phenomena of rapidly changing environments, aiming to create a space for perception of the state of nature and its drastic transformations.

Overall, our work falls within the field of data art [Hannigan et al. 2023], with the intention of creating a new channel for climate perceptualization—a growing tendency especially in climate data art [Lindborg et al. 2023]. The aesthetics of our sound design resemble ambient music, but our approach also incorporates drastic contrasting elements driven by data mappings to make the changes in the data more perceptible. The resulting auditory display is crafted from synthesized numerical data, which not only captures the audible sounds of the Arctic ecosystem but also translates the silent, underlying weather data into an auditory experience.

3. Data and Methods

Our methodology combined field recording, data analysis, and sound design to create an immersive sonic experience representing environmental changes in the Arctic. We used two types of data: weather data and sound data. The weather data, fetched from the Solander's Eye field station in Jökulsárlón National Park website [The IK Workshop Society at The IK Foundation 2024], included metrics such as temperature, wind speed, humidity, and precipitation. The sound data, collected over six months using AudioMoth devices strategically placed around the park, consisted of audio recordings capturing the natural environment.

Harmonizing these datasets—numerical weather data and sound recordings—was a key challenge. To integrate them into a unified data frame, we transformed the sound data into numerical values using FFT analysis, and event classification and clustering. Additionally, we addressed differences in time resolution: weather data spanned two and a half years with 15-minute intervals, while sound data covered six months, with one-minute recordings every five minutes. To address this disparity, we created time windows anchored around sunrise and sunset daily times, with statistical analyses conducted within these windows. For all of these data types, we calculated mean, minimum and maximum value, and standard deviation for all the values inside each window returning a single row for each window. Moreover, by dynamically changing the anchor hours based on the sunrise and sunset time, we created a moving time window system that reflected the drastic changes in Icelandic seasons due to day-night length.

Furthermore, given that sensor and sound data represent the same environment, by harmonizing them, we aimed to create a comprehensive representation of the environmental context. Our goal was to explore the relationship between weather conditions and environmental sounds—how seasonal changes influence environmental sound and how these auditory changes correlate with weather data. Thus, we sought to display the complexity of a dynamic ecology and the disturbance of humans in the environment.

Faced with a large data imbalance, we chose a simple autoencoder technique based on Macias' successful application in clinical data imputation [Macias et al. 2020]. Our primary motivation was to experiment with this method and explore how it could affect the sonification process in our project. The simplicity of the autoencoder made it an attractive option for our initial exploration, allowing us to easily generate the missing values in our harmonized data set through a masking technique, and focus on the conceptualization of our harmonization system. While we acknowledge that Variational Autoencoders (VAEs) could offer smoother interpolations and capture more complex relationships within the data, we opted for the simpler approach to start with and focus on the sound design of our digital soundprint concept. Additionally, while linear interpolation could provide a straightforward method for data imputation, it might not fully capture the nuances and complexity of our environmental data. In future iterations, we are considering exploring VAE to compare its effect on the auditory display and the perception of data.

4. Artistic Description

Sonifying the Arctic is an immersive and explorative sound installation that reconceptualizes the sound environment of Jökulsárlón National Park in Iceland via sonification techniques. The project captures drastic seasonal weather changes, extreme shifts in day and night lengths, and the unique ecological relation of a land in constant expansion, a land of flowing magma and receding eternal ice.

Through the artistic use of our digital soundprint concept, we enhance the perception of a complex ecological relationship between the sounds of wind, rain, animals, people, ice, and data from changing seasons. The system uses data stretching over two and a half years and moves linearly through the dataset at a set rate. Each day lasts roughly ten seconds—as the data unfurls, you can hear the sunlight hours stretching longer during the summer and compressing in the winter. Bird and animal activity changes drastically throughout the data, represented by the changing presence of bird sounds.

The complexity and dynamism of the Arctic ecological relations captured in Sonifying the Arctic are enhanced by treating both datasets as a single entity. By harmonizing the data, we aimed to create a deeper auditory representation of the heard and the unheard—tangible environmental sounds and intangible elements like temperature or humidity. This strategy led us to create a layered sound design, with broader, slow-moving planes of sound representing the gradual changes in the environment and more punctuating, granular synthesized sounds capturing the rapid shifts in biodiversity.

Sonifying the Arctic offers an auditory map of environmental and anthropogenic influences on the Arctic region. The resulting auditory display not only enriched the auditory experience but also provided a more nuanced understanding of the environment.

The way the project helps in new understandings of the data will be described in a future paper focusing on sonification techniques implemented in the project. All in all, the system paints the picture of fragile ecosystems whose sounds are changing as fast as their climates.

5. Conclusion

We have developed a process for an artistic creation that blends environmental sounds and weather data through a numerically harmonized data set approach and our *digital soundprint* concept. This tool holds significant potential for further exploration, with the possibility of evolving into a tool for data analysis. However, to fully realize this potential, comparative studies on AI architectures and other methods for data imputation are essential, along with the incorporation of a larger sound data set.

In the future, we aim to expand this project by integrating satellite imagery into our harmonization system, adding a new dimension of data and enhancing the nuances in our auditory display. Additionally, conducting user studies will be crucial to refining the design of our digital soundprint.

Finally, we believe that more projects that bring together passive acoustic monitoring (PAM) and remote sensing are needed to unify these diverse data sets into a single data environment. This approach is vital for exploring the complexities of the environment, offering new insights, and enhancing our understanding of ecological systems in a state of crisis.

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