SIX SEASONS: COMPOSITION INSPIRED BY OCEAN SOUNDS FROM THE ARCTIC

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ABSTRACT

Six Seasons is a composition that features hydrophone recordings captured in the Chukchi Sea off the north coast of Alaska, one of the most inaccessible places to humans on earth due to the thick layers of ice that block access for most of the year. Hydrophones created at our University (anonymous) were deployed in this region and left alone for a full calendar cycle, while these recorded millions of data points at supersonic frequencies. The recordings were then studied and a microscopic subset of the entire data was shared with the music department to manipulate and amplify for live audiences. The final presentation of this work included a collaboration with the acclaimed *Mivos Quartet* [1] , who at times provided antiphonal gestures and at others augmented the soundscape via mimetic techniques.

1. INTRODUCTION

Six Seasons is a musical composition whose name refers to the six seasons used by the Inuit population of Alaska, who demarcate these seasons by the changes in the environment, not by the strictly quantified passage of time. The six seasons are denoted and characterized as follows:

- **Ukiuq** - very cold, sun returns (Jan-March).
- **Upingaksaaq** - bright, frozen days (March-May).
- **Upingaaq** - snow-free land (May-July).
- **Aujuq** - warmest time (July-Sept).
- **Ukiaqsaaq** - land is snow-covered (Sept-Nov).
- **Ukiaq** - dark days (Nov-Jan).

In *Six Seasons* we begin our journey in October, during the Ukiaqsaaq season which we entitle “New Ice”. To facilitate navigation with musicians, each season is assigned a specifier. Each season corresponds to roughly three months from the Gregorian calendar and is denoted and characterized as follows:

- **“New Ice” (Ukiaqsaaq)** - new ice starts to form in the Arctic.
- **“Darkness” (Ukiaq)** - no daylight, total darkness.
- **“Sunrise” (Ukiuq)** - deep winter, snow, raging storms.
- **“Migration” (Upingaksaaq)** - enormous pieces of ice collide and break, and migration begins.
- **“Cacophony” (Upingaaq)** - migration of marine life in full force.
- **“Bloom” (Aujuq)** - bowhead whales are moving from east to west.

At the end of the piece, there is an added *coda* for dramatic purposes, in which we can hear the sound of a lonely beluga whale crying out for help. The beluga, trapped under the heavy ice, and separated from its pod, can be heard making a distress call. This final sound signifies the end of the piece. Each of these six seasons has its own distinct set of sound files which comprise both the listening material and the composition itself - that is, there is no written score for this piece. Instead, the sound material produced by the: ice, sea, and, wildlife within it, is meant to be used as creative material to which musicians respond. This extends one of the first metaphors of the work, that of *echolocation*. The animals who inhabit the arctic ocean rely on this technique for their survival. Here, we examine the notion of the musicians’ senses behaving as the wall, from which these signals bounce, resulting in the musical gestures they create [2] .

In section Section 2 we will also describe the interactive nature of this score, which in a direct sense defines what the score is in real-time. While some “cues” are established between the musicians, composer, and the rest of the personnel, the techniques and moments, and the sequence in which these occur, are not strict. In the world premiere of this piece on October 15th, 2022, the musicians were encouraged to use specific techniques at various points of the piece or to refrain from playing during other sections. There were a few choreographed entrances but none of these are considered formal requirements for the work to be performed. These techniques and choreographies will nonetheless be outlined in Section 5 and more details about the instruments used to record these sounds will be presented in Section 6.

[1] https://www.mivosquartet.com/

[2] This metaphor can also be understood as the reaction of the audience to the interpretation of the musicians.

1.1 Nature in Music

Nature has been a driving force and inspiration to composers, and other types of artists, for hundreds of years. Taylor and Hurley [1] delineate in their article the long history of music inspired by the natural world. As early as the 17th century philosophers and astronomers, such as Johannes Kepler, have drawn relationships between the laws of the universe and their connection to consonant sounds. George Frederic Handel, the German-British baroque composer, and Beethoven both developed numerous works inspired by nature. Franz Liszt, the Hungarian composer from the romantic period, invented the expression, programme music, to describe instrumental music suggesting a pictorial scene. In this category exist composers such as Haydn, Wagner, Debussy, and countless others. The French composer, Messiaen is said to have been deeply inspired and guided by birdsong in his compositional process.

R. Murray Schafer (1933-2021) is best known for this World Soundscape Project (WSP), his influence on the field of acoustic ecology, and his book *The Tuning of the World*. The focus of the WSP was to educate people about noise pollution, and recording and cataloging soundscapes of dying sounds and sound environments. There are countless other pieces that were influenced by nature such as Luc Ferrari's *Presque Rien No. 1, Lever du Jour au Bord de la Mer* (1967–1970) which was created from a day-long recording at the shores of a beach. Douglas Kahn's *Earth Sound Earth Signal* sonifies natural phenomena such as electromagnetic fields and brainwaves. Paul Wade's *Requiem for a Glacier* memorializes British Columbia's Jumbo Glacier area. Barry Truax, prominently known for compositions such *Riverrun* (1986), also contributed enormously to the field of acoustic ecology.

In the introduction to volume 18 of the European Journal of Musicology, Sweers writes [2]:

> In nearly all cultures, nature and music are closely intertwined. Not only does nature provide the materials for musical instruments, natural resources also provide the foundation for musical/sound-based ideas and subjects for compositions and performances. Many cultures, artists, and composers have thus reflected on the relationship between humankind and nature in their performances and works, while revealing the consequences of "humans as part of nature," working out ideas surrounding nature, and exploring new ideas, such as "nature as part of humankind." Either way, they remind us that the relationship between humankind and nature has to be redefined in times of climate change and global warming.

One final related reference comes from George et al. [3]. In this article, the authors discuss the development of a system that creates musical compositions from over a century of weather observations. In contrast to other sonification approaches here, the authors generate scores that are then performed by humans, rather than synthesizing instruments digitally. "Since its 2013 release, the video for *A Song of Our Warming Planet* (a composition by George et al.) has been watched on Vimeo more than 150,000 times, with another 16,000 views from YouTube." This demonstrates that projects such as these can have a small, yet meaningful impact if they reach the right audience.

2. THE PATCH

2.1 The MAX/MSP Version

The patch for *Six Seasons* comes both in Pd [3] and in MAX/MSP [4]. We will describe the development of the software in the chronological order in which it was developed. The first *Six Seasons* patch was written by composer Theocharis Papatrechas in MAX/MSP using the IRCAM Spat5 package [4]. Shortly thereafter, a new version of the patch was started using the same tools entirely from scratch and it was decided that a simple MIDI controller would be used to control the program. The selected controller was chosen based on its low cost, popularity, and simplicity.

The new MAX/MSP patch was developed over the course of several weeks in collaboration between the composer and engineer. Initial versions of the patch were tested in our spatial audio labs using a 22.2 surround sound system which we connected to via Dante Virtual Soundcard [5]. The patch would encode the 5.1 surround sound files which had already been created into ambisonics, allowing us to playback the spatial audio mixes in any configuration we desired: from quadraphonic to 128-channel systems. The added benefit of ambisonics was that we could also encode the various 5.1 files at various elevations, which gave us the possibility of encasing the audience under the ice.

Many additional features were incorporated into the patch in order to create a tight loop between the hardware and software. One button was designed to move between "seasons" which effectively correspond to folders containing multiple surround sound mixes. Another button allowed us to record the entire sound field as well as the raw microphone signals, which we could use to later produce a suitable CD-quality mix. Another was designed to add live processing to the microphone signals; this would pan the microphone inputs around the room while applying a delay with feedback, an aesthetic we designed to fit the theme of echolocation.

Five additional controls were assigned to each of the eight sound file players (SFPs), which allow us to: solo, mute, restart, and control the gain, and reverb, of each layer of sound. It should be noted that each SFP plays only one particular type of sound at a time, such as ice, belugas, or wind, these are never mixed a priori but rather it is the job of the composer, acting as a conductor, to mix these signals in real-time. In other words, at any one time, it is possible to mix eight 5.1 surround sound files in real-time using this system and decode the resulting signals in arbitrary configurations, such as quadraphonic, octophonic, or the

[3] `https://puredata.info/`
[4] `https://cycling74.com/`
[5] A proprietary product by Audinate.

16-channel system we used in our premiere [6]. See Figure 1 for a diagram of this configuration.

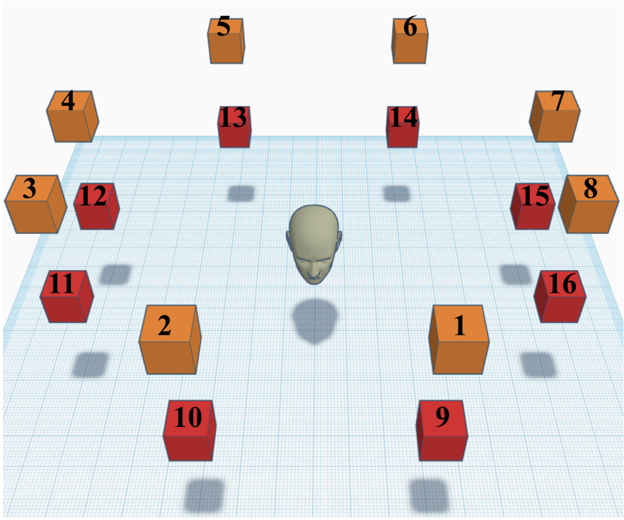

Figure 1. 16 Channel Speaker Array Diagram

One final noteworthy aspect of the project involves the packaging of the software. Additional work was done in order to turn the MAX/MSP code into a standalone application that can run on OSx machines without an MSP license. The other benefit of this system is that one does not need to install Spat5 or configure the path to the sound files, this is all done automatically. In order to reduce the total size of the application the command line tool FFmpeg was employed allowing us to batch compress the original AIFF files into a lossless format requiring far less memory.

2.2 The Pd Version

While packaging the MAX/MSP patch into a standalone application increases the accessibility to the system, the program takes considerable computing power to run and cannot be modified without a MAX license. While the MAX software, by Cycling 74, is relatively accessible, we were also interested in creating a version of the patch that was completely free and open-source, such that it could not only be used to perform the work worldwide but also so composers could enhance, adapt or alter the behavior of the system to satisfy future compositions. For composers who prefer writing patches in the Cycling 74 system, the unpackaged patch is also available [7].

Unfortunately, the Puredata (Pd) version of the patch cannot be packaged as neatly as the MAX version, but we have made efforts to include all the libraries in the distribution, so installation can remain as simple as possible. One of the downsides of the Pd version of the patch is that it does not allow for playback of compressed audio formats, such as FLAC, which we used in MAX, therefore one needs to download and use the uncompressed sound files for this version which are six times larger in memory.

In Pd, it was not possible to perform all the necessary operations using a single instance of the program as it is designed to run off a single core and one core alone cannot handle the computational load. MAX/MSP uses multiple cores by default, without the user having to program this behavior. We were able to ultimately get the patch to work by using multiple instances of Pd via the [pd_tilde] object, which allows sub-processes to run on various computer cores. All in all, there a total of 14 instances are required: eight for the SFPs, four for the spatialization of live inputs, one for the recording of the higher order ambisonic (HOA) signal plus the raw live inputs, and finally the super-process (e.g., the main patch which holds the master clock).

One additional difference between the MAX and Pd versions is the number of channels that each version computes. In the MAX version of the patch, regardless of the preset selected by the user, 16 channels of sound are always calculated and produced. This is because the state of the objects which handle the spatial audio is defined during initialization and cannot be dynamically changed, to the best of our knowledge. This means that some older computers or slower processors might not be able to handle the demands of this patch. For this reason, it was deemed appropriate to create additional versions in Pd. The three versions of the patch are: 16-channel, octophonic, and quadraphonic. We hope that these lower-resolution versions can be suitable for performance at smaller universities or artistic settings with fewer resources.

3. THE CONTROLLER

In order to provide the composer with a greater sense of control over the playback of the sound files, a hardware system was selected and integrated into the compositional process. The selected device, Korg NK2, was chosen due to its low cost, popularity, and simplicity. In contrast to other hardware devices on the market which sometimes have hundreds of possible controls, the NK2 has only a few dozen buttons, which makes it possible for anyone to learn how to operate the system in less than half an hour. It was important for us to consider the replicability of the work, and to provide a simple framework that could be easily understood and deployed. Figure 2 shows an image of the controller which at the time of this writing can be purchased for under $100.

The track controls in the NK2 are assigned the task of switching between seasons, which updates the files which each of the SFPs references. The cycle button is used to reset the entire system, only the rotary knobs and faders are left unchanged. Since the device is not motorized resetting those values to zero could result in abrupt jumps, therefore it is up to the operator to reset these controls manually. Backtrack and fast-forward work as anticipated, changing the playback speed by integer factors.

Due to technical differences between versions, in the MAX design, it is not possible to move backward, whereas in the Pd version one can scrub through files in reverse. Stop and play buttons work as one would imagine, while the recording buttons, as aforementioned, allow one to record

[6] The 16-channel system consists of two octophonic systems stacked one on top of the other.
[7] See https://www.schott-music.com/en/.

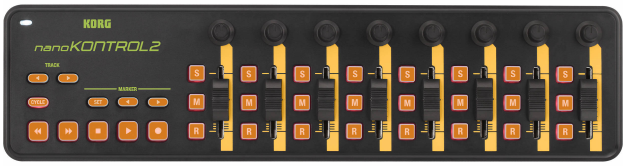

Figure 2. Korg NK2 Controller

the sound field together with the raw inputs. This method assumes that there are always four musicians performing. In the Pd version, the ambisonic order changes based on the number of speakers needed. For the 16-channel version, we record third-order ambisonics, for the octophonic version we use second order, and for the quadraphonic version, we record first order [8]. While the recording function assumes four musicians are always performing the piece, this is not a requirement of the work (e.g., one can perform this work with 1-4 musicians) [9].

The marker buttons on the controller are used to turn on and off the sound effects (SFX) for the live inputs. The left marker and right marker buttons are used to select the input, while set is used to enable, or shut off, the SFX for the selected input. One may choose using this logic to turn on the SFX for one, all, or none of the musicians at any time. The SFX module relies on the Vector-Based Amplitude Panning (VBAP) [10] [6] algorithm to pan the musicians' signals and four independent delay lines to create the echoing effect. When on, random low-frequency oscillator (LFO) values are selected, generating Lissajous curves which modulate the azimuth and elevation of each source. Random feedback coefficients and delay times are also generated such that each time the SFX module is engaged, the decay time of the delay and timing between each echo is different. When the module is shut off, the feedback coefficient is slowly returned to zero, and the position of the source is returned to its original location. By default *Six Seasons* anticipates the quartet to be positioned in four corners of the room following the order: North West (1), North East (2), South East (3), and South West (4).

The rotary knobs in the NK2 are configured to control the dry/wet balance of the reverb units inside the patch. This provides a psycho-acoustic mechanism for controlling the perceived distance of sources. The faders are used to control the volume of the SFPs, as one would expect, and the S and M buttons are used for soloing and muting. The R buttons are used to "restart" sound files. These also act as independent "start" buttons if the global start button is not adequate, or one wishes to create different textures or sonic environments. In other words, with these "restart" buttons, the number of possible permutations which can be created jumps exponentially, as it provides the conductor with a means to re-trigger SFPs at any time.

4. THE GRAPHICAL USER INTERFACE

The Graphical User Interface (GUI), seen in Figure 3, provides the controller operator with visual feedback to indicate the status of various elements of the patch. On the right-hand side of the panel, we list all the available sound files based on the current season, making it simple to know what each SFP is currently responsible for reproducing. Below these symbols, with the filenames, we included a visual representation of which SFX modules are on and a simple timer. We also added a kill-switch in case the SFX begins to cause unwanted feedback between the microphone and speakers, which can be triggered with the letter k on the keyboard, this shuts off all the SFX modules.

The gain of each musician must be manually set using the green panel and a preset from the radio list should be selected. In the pink panel, we have the option to set the position of the musicians in space. By default, the musicians originate from the four corners of the room but in cases where solo, duo, or trio arrangements are wanted, this allows us to position the players in arbitrary configurations. Finally, we included a "yaw" control in the front panel which allows us to rotate the sound field by a given angle amount. This was included in the event that an octophonic system, for example, was offset relative to our configuration by a given amount [11].

Each of the seasons has a distinct set of audio files which correspond to the timeline described in Section 1. Generally speaking, here are the types of sound files present in each season:

- **"New Ice" (Season 1)** - ice popping, ice slipping, and internal ice pressure.
- **"Darkness" (Season 2)** - ice undergoing thermal cracking.
- **"Sunrise" (Season 3)** - thermal cracking and wind sounds.
- **"Migration" (Season 4)** - ice collapsing, bearded seals, belugas, and bowhead whales.

[8] The ambisonic recording in Pd follows the SID channel format implemented in the `iem_ambi` package from IEM Graz. The MAX version records in the more standard Ambix format [5]. The Ambix toolkit is recommended to convert between formats.

[9] In the Pd version there is no way yet to change the direction from which the musicians' sounds are projecting, this is the subject of future work.

[10] Professional closed-source software typically uses a combination of ambisonics for environmental sounds and VBAP for point sources, we decided to implement a similar approach.

[11] Some octophonic systems start at -45 degrees, while others start at -22.5 degrees.

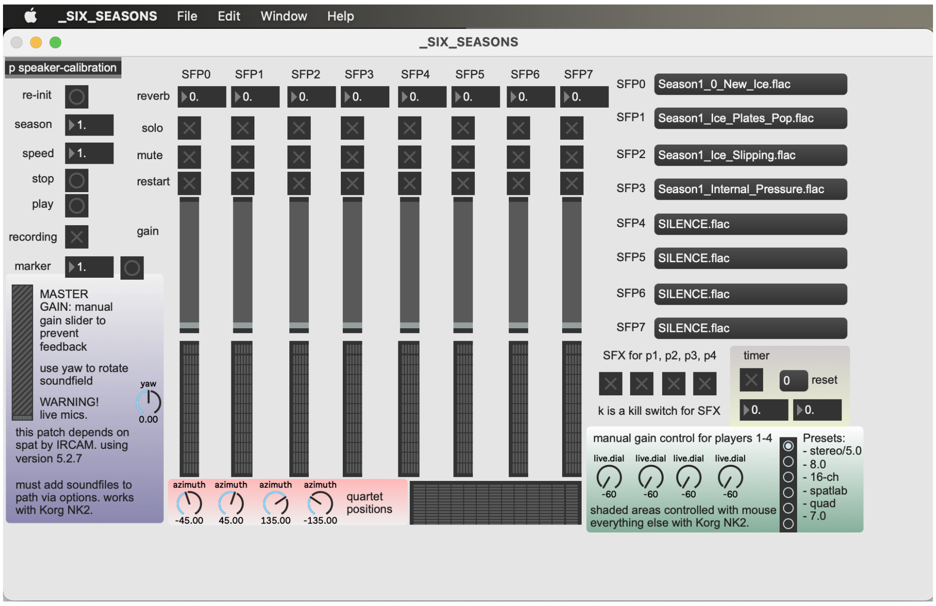

Figure 3. GUI for Six Seasons MAX/MSP Packaged App

- **"Cacophony" (Season 5)** - ice sounds, and much more marine life activity from the three aforementioned species.
- **"Bloom" (Season 6)** - ice sounds, more animal life, and open water.

One noteworthy element here is the "open water" sound. In the process of modifying the hydrophone recordings for musical presentation, a series of treatments were performed to attempt to improve their quality. The sounds had to be re-sampled from 200kHz to 44.1kHz, but, additionally, hours of manual labor were involved in removing the sounds of the recording hardware, glitches/artifacts in the recording process, and de-noising the sound files. The de-noising process unfortunately also removed the sound of the ocean currents, which form part of the environment, as these are stochastic in nature. The "open water" sounds are exactly this, the noise-like acoustical signals created by the ocean currents, which are re-introduced, and highlighted, in this season.

5. SCORE

As was already mentioned, there is no formal score for this composition - in the traditional sense of the word - instead, we make use of what we call a *living score*. While the audio projected from the speakers, which is a direct result of the live manipulations the system operator performs, should be considered the real score, there were nonetheless some requests the composer made for the premiere of the work. That is, there were specific instructions for each season of the piece, and even for different sections of the seasons, which were agreed upon in advance. These instructions, however, were conceived in collaboration with the musicians themselves, who would propose a particular technique during rehearsals. Additionally, from all the possible combinations of sound files that could be played back in any given season, a specific sequence of sound files was chosen and their relative duration was set to create a cohesive narrative. In other words, *Six Seasons* invites the performers to listen to the sounds of the ocean and create for themselves a dictionary of techniques that can be invoked in response to various stimuli. No major alterations are performed upon the recorded sound besides spatialization or adding reverb, the principle was to maintain the pure essence of the original sound as unadulterated as possible.

In the first season, there is only the sound of ice present, and the overall volume is still low. At this stage, the musicians were asked to play pianissimo and use a mimetic approach to their playing. In the second season, there are more melodic techniques employed, but the dynamics are still subdued and the lights in the room are dimmed to match the theme of the season. The third season has another sequence in which musicians each have a solo, and as the recording gets louder, their dynamics do too in a crescendo. We then abruptly stop the recordings and hear only the musicians playing at full force. The lights then shut off immediately and the musicians stop. The ice collapsing plays and migration begins, the musicians then play along with the sea mammals. During season 5 we ask the musicians to stop playing altogether, and only the sounds of animals are enjoyed, together with the ice. Season 6 gives the performers one more opportunity to play along with the fauna until they slowly fade out. The coda is reserved for only the single sound of the stranded beluga, which calls out a couple of times before the piece concludes.

It should be noted, that all these notes are not a formal requirement for the performance of the piece. Rather, each composer interpreting the work is invited to craft their own narrative around the sounds. The duration of each season, the number of musicians, the instrumentation, and the number of seasons played are also up to the discretion of

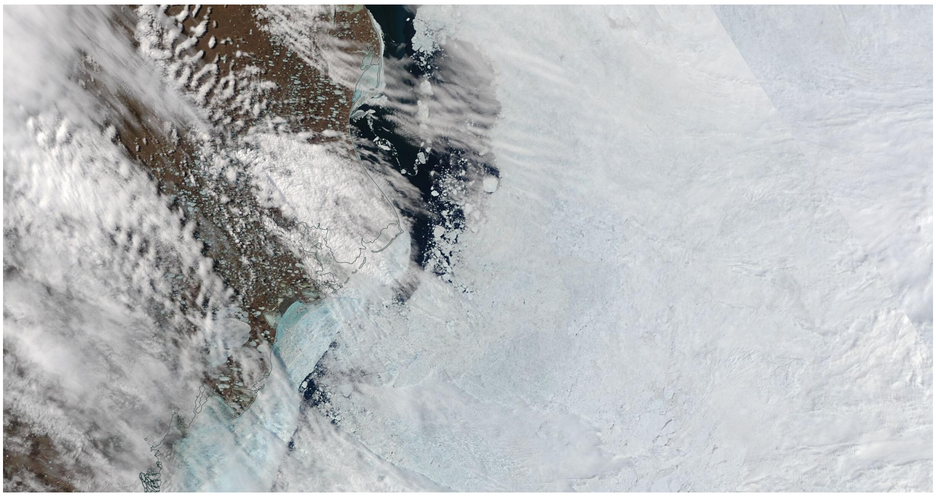

Figure 4. Satellite Image from Season 5: "Cacophony"

the interpreters. In addition to these sonic elements, for the premiere, we also used satellite images from the recording site and provided technical information about each season using the QLab software, this is also an optional part of the experience. Figure 4 shows one of these satellite images from season 5.

Some of the other techniques employed over the course of the piece by the Mivos quartet [12] included:

- **Crunching** - applying pressure to strings with the bow, to imitate ice sounds.
- **Bowing on wood** - to imitate the sound of the wind.
- **Sul Pont bowing** - bowing close to bridge; a responsive gesture.
- **Rubbing wood** - either with hands or super ball to imitate bowheads.
- **Multiphonics** - multiple notes from a single string, extended technique.
- **Muted pizzicato** - plucking strings to imitate loud ice pops and clicks.
- **Rattling with clothespins** - attaching clothespins to the instrument and intentionally hitting them.

This is by no means an exhaustive list of all the techniques used, but we included it here to give the reader a sense of the type of musical material that was used. One detail about the patch that is compositionally relevant is that there is no way to cross-fade between seasons; in order to maintain momentum, the musicians were asked to perform between certain seasons.

6. THE HYDROPHONES

Hydrophones were placed about 300 meters below the sea surface at a seafloor recording location 160km north of Utqiagvik, Alaska. These captured the sounds of sea ice, marine mammals, and the underwater environment over the course of the year. Careful attention was required to preserve the timestamps associated with each sound file, which allow us to pinpoint exactly the hour at which these different passages were recorded. The first recordings begin on October 29, 2015, just three days after new ice had started to form.

The High-frequency Acoustic Recording Packages (HARPs) were developed at our University (anonymous) over many decades with the purpose of studying marine life and determining how the anthropogenic activity is affecting wildlife in these remote regions. Climate change has directly affected these populations, and the primary purpose of these recording devices is to evaluate the effects of this man-made climate change. The cycles of ice, flora, and changes in sea currents, all affect the lives of these creatures. Noise pollution caused by large ships breaking through the ice can also affect species' migratory patterns and ability to echolocate food. These devices have to consider the: pressure created by water at the bottom of the ocean, battery requirements for such a system, and the quality of recordings, which is a function of the design of the electronics [7].

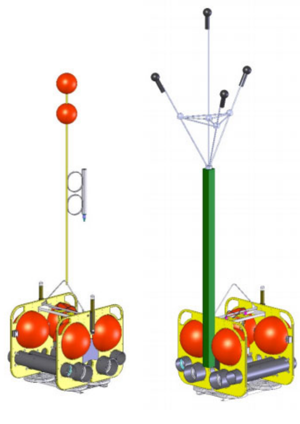

Figure 5. HARP

[12] Composed of Olivia De Prato, Maya Bennardo, Victor Lowrie Tafoya, and Tyler J. Borden at the time of this writing.

These HARPs were designed to remain underwater over the course of an entire calendar year recording the sounds of the ocean at a rate of 100kHz, well above the audible frequency range of humans [13] . Massive memory units were installed allowing the team at our institute to record terabytes of information. Using signal processing techniques it was possible to quickly analyze, detect, and isolate regions of high activity, which were used for bio-marine studies and later in our compositional interdisciplinary collaboration. Figure 5 shows a HARP in two configurations, on the left, a single-channel version, and on the right, a tetrahedral array for a time of arrival difference analysis (e.g., 3D tracking mammals' path using the acoustic data.). In *Six Seasons* we only use the single-channel version, implementing the multi-channel recordings is the subject of future work.

6.1 Processing the Raw Data

Prior to encoding the sound files using Zachary Seldess's MIAP software [8] into a surround sound mix, the hydrophone recordings underwent a series of additional steps by collaborators Nick Solem and Theocharis Papatrechas. Firstly, the audio files needed to be re-sampled into 44.1kHz but in addition to this, there were several noises that needed to be manually removed. Every few minutes the HARPs suffer from digital noises created by the mechanism of the recording device. Unfortunately, there was no way to automate the removal of these glitches so many hours of manual work were undertaken to clean the sounds. There were also subtle but noticeable discontinuities in the recordings which had to be fixed including thudding caused by hydrophone displacement. We believe it should be possible to create an automated system to automatically remove all these anomalies and generate the final sound files; this system is the subject of future work.

7. CONCLUSIONS

This paper has described the development of an artistic work entitled *Six Seasons*: a multi-year interdisciplinary collaboration between the departments of marine biology and music at University []. Supersonic hydrophones deployed off the north coast of Alaska captured the ecological acoustic signature of one of the most remote places on earth, allowing us to hear the calls of some of the rarest species on earth. These sounds, along with the sounds of polar ice and wind, were incorporated into a computer music program which allowed for multi-channel interactive playback in a concert setting. The piece featured performances by the Mivos quartet, who used this sonic material to advise their playing. No written score was created for this performance yet it is not entirely improvisatory: the musicians and composer co-created the rendition of the piece drawing inspiration from the sonic material provided, creating - and employing - a language of both imitative and contrapuntal musical gestures.

As artists operating in an interdisciplinary project with marine scientists, we believe we have a responsibility to faithfully present these sounds in an effort to sway public opinion and affect human behavior. Our hope is that this work can serve as an emotional catalyst, resulting in some net gain for the environment. This is where we believe the sciences may rely on the arts, to make the objective data into something moving, which can influence people who we know from research are not only driven by logic but also emotions. Furthermore, it is unclear from an evolutionary perspective if these species will be able to survive the changes to the environment which are currently ongoing - preserving and disseminating these sounds, therefore, is part of a global cultural heritage mission. The Inuit people themselves have been an integral part of this research, collaborating closely with the marine science lab and providing critical feedback which has been driving the work.

Acknowledgments

Blank for anonymity.

8. REFERENCES

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[8] Z. Seldess, "Miap: manifold-interface amplitude panning in max/msp and pure data," in *Audio Engineering Society Convention 137*. Audio Engineering Society, 2014.

[13] Part of our team's future work is to isolate spectra outside the human hearing range and transpose it for human listening.