***Six Seasons*: Composition Inspired by Ocean Sounds from the Arctic**

By Gabriel Zalles Ballivian

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 University of California, San Diego UCSD 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 to determine migratory patterns, 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. The composition was written by Lei Liang, while the computer system which capacitates the work was designed by the author. The hydrophone recordings are the work of the Whale Acoustics Laboratory at UCSD. The aim of this article is to raise awareness for climate change and demonstrate a landmark case of computer music facilitating new music which broaches this theme. The title of the musical composition 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, the 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 – a metaphor that can also be understood as the reaction of the audience to the interpretation of the musicians.

The score is of interactive nature, 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 as well as more

details about the instruments used to record these sounds are presented in the last part of the text.

The Patch

The MAX/MSP Version

The patch for *Six Seasons* comes both in Pure Data Pd and in MAX. I 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 (Carpentier, 2018). Shortly thereafter, a new version of the patch was started from scratch using the very same tools. It was also decided that a simple MIDI controller would be used to control the program. The controller was chosen based on its low cost, popularity, and simplicity.

The new MAX patch was developed over the course of several weeks in collaboration between composer and engineer. Initial versions of the patch were tested in the spatial audio labs of UCSD using a 22.2 surround sound system which were connected via Dante Virtual Soundcard, a proprietary product by Audinate. The patch would encode the 5.1 surround sound files that had already been created into Ambisonics, allowing to playback the spatial audio mixes in any configuration desired: from quadraphonic to 128-channel systems. The additional benefit of Ambisonics was that it also allows to encode the various 5.1 files at various elevations, which provided 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 to record the entire sound field as well as the raw microphone signals, which could be used to later produce a suitable CD-quality mix. Another feature 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 which was designed to fit the theme of echolocation.

Five additional controls were assigned to each of the eight sound file players (SFPs), which allow 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 16-channel system which was used at the premiere of *Six Seasons*, consisting of two octophonic systems stacked one on top of the other.

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.

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 to consider the replicability of the work, and to provide a simple framework that could be easily understood and deployed.

The track controls in the NK2 are assigned the task of switching between seasons, which updates the files with 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 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, third-order ambisonics was recorded, for the octophonic version second order, and for the quadraphonic version, first order.[2] 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 one to four musicians).[3]

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)[4] (Pulkki, 1997) 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 that 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 psychoacoustic 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 that can be created jumps exponentially, as it provides the conductor with a means to re-trigger SFPs at any time.

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*. 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: he gave 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 include a sequence in which each musician plays a solo, and as the recording gets louder, their dynamics, too, create a crescendo. Then, the recordings were abruptly stopped to hear only the musicians playing at full force. The lights shut off immediately and the musicians stopped as well. The sound of ice collapsing plays and migration begins, the musicians then continue to play along with the sea mammals. During season five, the musicians were asked to stop playing altogether, and only the sounds of animals should be enjoyed together with the ice sounds. Season six 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 the interpreters. In addition to these sonic elements, for the premiere, also satellite images from the recording site were employed to provide technical information about each season using the QLab software. This is also an optional part of the experience.

Some additional techniques, composed by Olivia De Prato, Maya Bennardo, Victor Lowrie Tafoya, and Tyler J. Borden at the time of this writing, were employed over the course of the piece by the Mivos quartet, including:

- 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 it should provide an impression of the type of musical material in use. One more detail about the patch that is compositionally relevant: there is no way to cross-fade between seasons. In order to maintain momentum, the musicians were asked to perform between certain seasons.

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 one year. Careful attention was required to preserve the timestamps associated with each sound file, which allows to pinpoint exactly the hour at which these different passages were recorded. The first recordings began on October 29, 2015, just three days after new ice had started to form.

The High-frequency Acoustic Recording Packages (HARPs) were developed at UCSD over many decades by the Whale Acoustics Laboratory (WAL) with the purpose of studying marine life and determining how 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 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 (Jones et al, 2022).

The HARPs were designed to remain underwater over the course of an entire calendar year recording the sounds of the ocean at a rate of 200kHz, well above the audible frequency range of humans.[5] Massive memory units were installed allowing the team at UCDS 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.

Processing the Raw Data

Prior to encoding the sound files using Zachary Seldess's (2014) MIAP software into a surround sound mix, the hydrophone recordings underwent a series of additional steps carried out 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. However, 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.

Summary

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 UCSD. Supersonic hydrophones deployed off the north coast of Alaska captured the ecological acoustic signature of one of the most remote places on earth, allowing 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 an artist operating in an interdisciplinary project with marine scientists, I believe that we have a responsibility to faithfully present these sounds in an effort to sway public opinion and affect human behavior. My hope is that this work can serve as an emotional catalyst, resulting in some net gain for the environment. This is where I 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 that 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.

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Music

Lei Liang and the Mivos Quartet: *Six Seasons*
http://mediathek.slub-dresden.de/vid90003602.html

Notes

[1] https://www.mivosquartet.com/.
[2] 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 (Nachbar, 2011). The Ambix toolkit is recommended to convert between formats.
[3] 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.
[4] Professional closed-source software typically uses a combination of ambisonics for environmental sounds and VBAP for point sources, so we decided to implement a simi-

lar approach.
[5] A future work is to isolate spectra outside the human hearing range and transpose it for human listening.

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