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Transforming space and time, a compositional method by Pablo Rubio-Vargas using digital tools to remodel acoustic and spatial features into a musical interpretation.

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Transforming space and time, a compositional method by Pablo Rubio-Vargas using digital tools to remodel acoustic and spatial features into a musical interpretation.

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DOCTOR OF MUSICAL ARTS

in

MUSIC COMPOSITION

by

Pablo Rubio-Vargas

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Transforming space and time, a compositional method by Pablo Rubio-Vargas using digital tools to remodel acoustic and spatial features into a musical interpretation.

By Pablo Rubio-Vargas
Doctor of Musical Arts

Abstract.

The methodology explored in this cycle of compositions conceptualizes physical space and sound as hybrid compositional elements. This work builds on previous experiments with spatial awareness through sound localization. For example, orchestral piece *Terretektorh* by composer Iannis Xenakis displays acoustic immersive acoustic design, or multimedia piece *Great Animal Orchestra* by sound artist Bernie Krause that shows a collection of recorded soundscapes in different locations. Three compositions — *Hombre-Pájaro, ži'ilœ and Nat.er.ura* — comprise the focus of the present study. Each piece engages physical space as a compositional tool, combining ecology and spontaneous improvisation. *Hombre-Pájaro* combines a collage of granulated soundscapes as a sound-installation with a trio improvising on the top of the soundscapes. The piece *ži'ilœ* uses an open score to be interpreted in multiple ways by the musicians. The melodic material in *ži'ilœ* is the result of an algorithmic process of pitch contour recognition applied to a soundscape. And finally *Nat.er.ura,* a composition that conglomerates musical improvisation with modulated soundscapes.

Introduction, Spatialization a Compositional Tool. A Personal Method to Compose Using Space.

> "*We don't see much difference between time and space. We don't know where one begins and the other stops. So that most of the arts we think of as being in time, and most of the arts we think of being in space. Marcel Duchamp, for instance, began thinking of music as being not a time art, but a space art*." (Cage 1992).

This essay will introduce three compositions, *Hombre-Pajáro, Nat.er.ura,* and *ži'ilœ* that each shares an aesthetically-focused compositional process using field recordings to compose new sound material. My goal in this process is to expose the transformation of space-sound while composing. Similar to John Cage's idea, my compositional interest relies on creating music that combines space as musical element. "Space-sound" can be recognized as a field recording from a particular area in a given time, or a place where a musical performance occurs, as well as the interpolation between both examples. The initial step in this process is a method based on filtering various soundscape field recordings from different rural locations. After being filtered by using the software Spear, an algorithm based on pitch contour recognition is applied to the field recordings by different software such as PureData, or Melodyne. The algorithm produces as MIDI messages, and therefore this algorithm can be mapped as pitch-rhythm to obtain a musical score, or as panning-dynamic range to create vector sound trajectories displayed on a multichannel loudspeaker system.

In this project, the sound material used to obtain pitch contour is the house sparrow birdsong. Next, the filtered field recording along with the pitch contour applied to a granulator following the detected pitch motion from the birdsong. The result is a granular texture that resembles the original soundscape. The last step in this compositional process is to expose the musicians to the algorithmically processed multichannel tape, as they attempted to recreate the already transformed space. The musicians react to the processed tape recording to facilitate an improvised recreation of the sound-space.

The field recordings used in this project's compositions are samples from rural locations in California in the U.S., and Queretaro and Nuevo Leon in Mexico, collected by blended team of researchers and artists such as the Forest Ecology Research Plot (FERP), a research team from UCSC; *et al,* an artistic collective that has collected soundscapes from Nuevo Leon, Mexico; and my personal field recordings from Mompani, a rural location nearby Queretaro City in Mexico. Those databases were collected at different times, in different places, each with a recognizable sound that will allow the audience to identify the different locations. The granular texture is designed by filtering a particular range of frequencies, which initially is processed to obtain pitch contour. The filtering range is set between 1 KHz to 8 KHz, which according to different authors such as Christopher McClure (2011), Willem Verboom-Heij Cornelis (2018), Robert Dooling (1982), among others —is where the birdsong range from the house sparrow occurs.

The house sparrow's birdsong is the input to obtain a pitch contour algorithmically by a computer. Software such as Melodyne, and PureData, among others, is used to break the information into a digital grid to detect pitch contour. The collected data from this algorithmic process creates MIDI messages. Thus, the data can be mapped to melodic lines with a given pitch and rhythm to create a score, or projected sound-motion by the multichannel system when mapped to panning and dynamic range. The original material is transformed from its initial sound features into a granular texture, which later is spread on a given space by a multichannel loudspeaker system. The new granular textures still preserve original components from the initial field recording, such as crickets, owl's singing, human voices, air, traffic nearby, and so on.

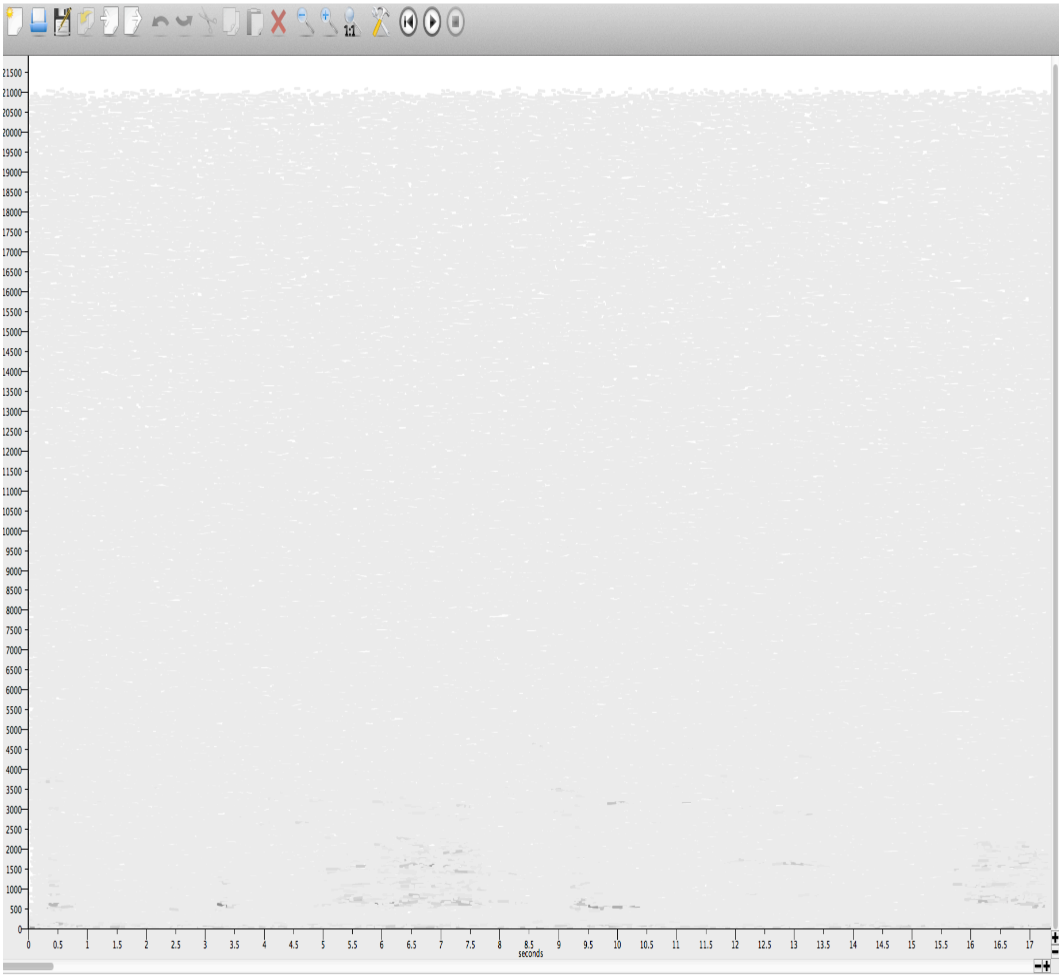

Figure 1. Full spectrum of frequency range of a field recording. On the left is shown the frequency fixed scale from 0Hz to 21500Hz. At the bottom the time in seconds.

In performance, techniques such as digital granulation, pitch contour recognition, and improvisatory scores are used to shift the perception of sound-space. Using the transformed field recording tapes, musicians are prompted to react in various ways. For example, in the piece *ži'ilœ,* a score is created with three melodic lines detected algorithmically from a granulated soundscape. The musician has the task of reading the score in a non-linear path (left to right). They can read it from right to left, jump into different sections of the melody, or the other two remaining melodic lines. Each instrument is placed in a specific location on the stage, according to an aural map that comes from the transformed soundscape into a granular texture.

The location of each individual instrument corresponds to a correlation of the granular texture and the individual capacity of the instruments to produce small attacks representing digital grains. The instrumentation of *ži'ilœ* uses traditional instruments from China such as *Pipa, Yangquin, Erhu, Zheng, Ruan, Dadi, and Sheng.* The distribution of each instrument on the stage corresponds to their capacity to produce short attacks. The Pipa*,* with the shortest attack capability, is placed at the center of the stage. The rest of the instruments create a half circle with Dadi a wood flute, and *Sheng* a mouth organ on the edges, due to their ability to produce sustained attacks. The sound material read by the ensemble is the result of the pitch recognition process from the house sparrow birdsong. Thus, *ži'ilœ* resembles the complete compositional method in which the space has been transformed four times: digital recording, granulation, pitch contour recognition process, and the interpretation of the resulting material by the musicians. The original field recording is filtered using Spear (see figure 1 and 2) to apply the pitch contour recognition. The final outcome is an artistic metaphor of natural complex sonorous environments altered by humans.

This compositional method transforms sound-space by building a complex acoustic experience. It attempts to conceive an artistic metaphor of natural complex sonorous environments altered by humans. In my own compositions, I attempt to create a path that prompts humans to react at spatial shift carried by sound technology. The artistic metaphors rely on the awareness of humans, transforming and interacting in a digital world that incorporates unexpected results in a sonorous world of steady changes.

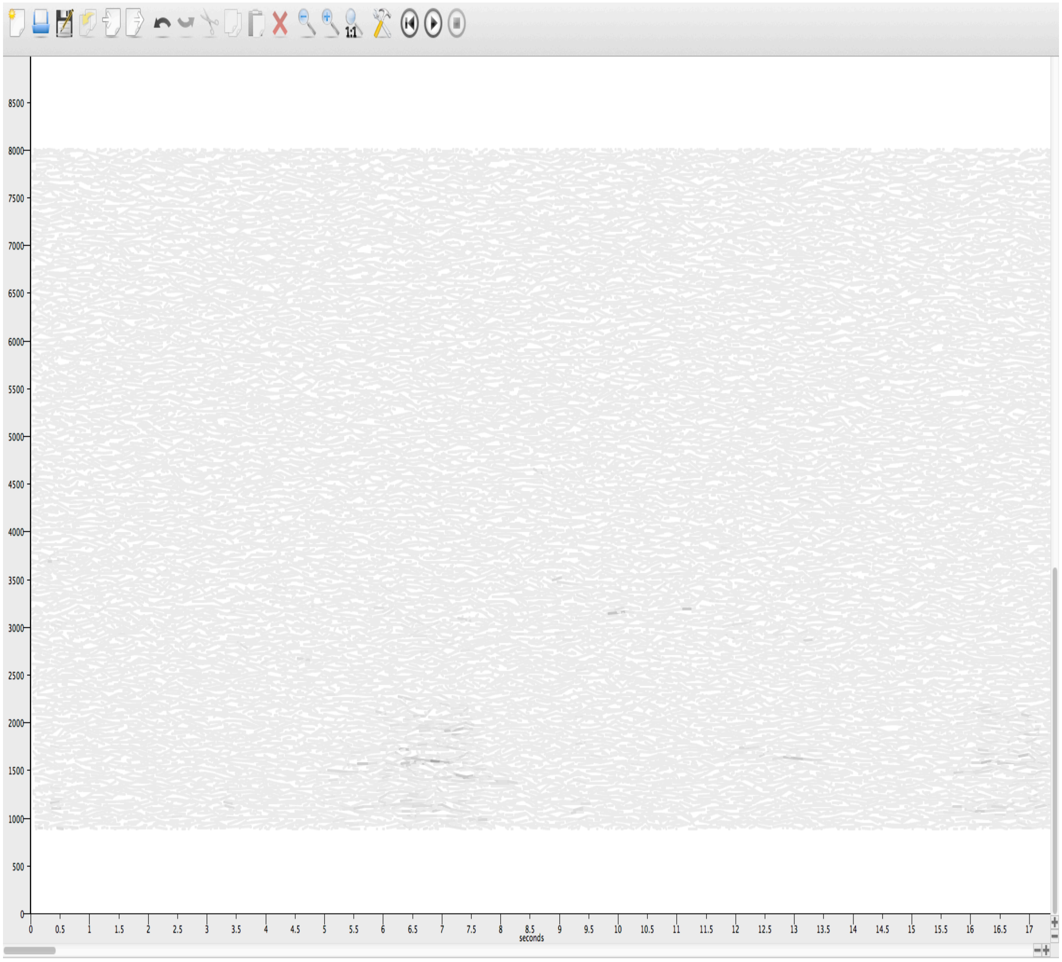

Figure 2. Selected frequency range from 1 KHz to 8 KHz from the same soundscape shown in image 1. By using the software Spear it was trimmed the frequencies not desired. The frequency range from 1 KHz to 8 KHz belongs to the house sparrow's birdsong.

Differences in classifying space as an element to compose.

This section discusses an approach in defining and using space as a musical element. Two main distinctions can be drawn in this compositional process. On one hand, there is the place chosen to obtain a field recording. Generally, it would be agreed that a soundscape recording from a city would be different than a natural environment. Therefore, to select a particular ecosystem will incorporate sounds that contrast from the others. On the other, the final digital interpolation from the original field recording into a musical performance carried by a multichannel loudspeaker system in a concert setting. The displayed technology and its musical interpretation carry the final arrangement that space and sound conglomerate as a musical experience. Since field recordings can be projected on different capacities of multichannel arrays such as quadraphonic, hexaphonic, or octophonic, the aural perception of space can be better enhanced as a surrounding sound experience.

Finally, instrumental position in a concert hall creates a path in which the space is explored by the sound emission of the instrument. Similar to a multichannel audio system, instruments have the capacity to surround the audience, and create relationships between different sound materials presented on a concert. As scholar Lelio Camilleri notes: “Mono and stereo spaces can be represented as two kinds of imaginary stage. In mono space, the difference between near and far can be articulated. This means that one can place sounds (instruments) into layers which, partly by means of their loudness, can be perceived as overlapped but at different distances.” (Camilleri 2010). In my compositional process two ideas of space are used to achieve sound-space as an element that can be transformed: first, original field recordings provide initial content; later, digital transformation carried either by a multichannel system, or placement of instruments on a given space.

A Brief history of Sound-Space as a Compositional Element.

It is commonly understood that “music” can be split into different elements such as pitch, rhythm, harmony, etc. In addition to distinguishing those musical elements, sound artists have used space as a controllable, interactive feature that can be manipulated as musical elements. One approach to surrounded acoustic compositions is to place instruments in a particular location to evoke the aural perception of space, or “sound” trajectories. Different composers have developed a body of compositions that address space as an artistic element for example: Iannis Xenakis’ *Terretektorh* (1965-66), Pauline Oliveros’ *Zina's Circle from Sonic Meditations* (1972), Roger Reynolds’ *Eclipse[Voicespace III] VIDEO VERSION* (1979), Kenneth Gaburo’s *Antiphony IV* (1968), Karlheinz Stockhausen’s *Mixtur* (1966) — to mention some. These pieces demonstrate that instruments have an active role in perceiving sound-space while playing. This practice can be traced to different historical eras, as composer Roger Reynolds points out: “...the physical disposition of instrumental or choral groups, …was a dramatic and structural factor in early church music, as a result of divided performance groups, and in the massed experiments through the late nineteenth century, particularly those of Berlioz.” (Reynolds 2005). Space and its relationship with sound can be seen as an historical interest among artists. After the second half of the twentieth century, such exploration has taken more relevance among composers.

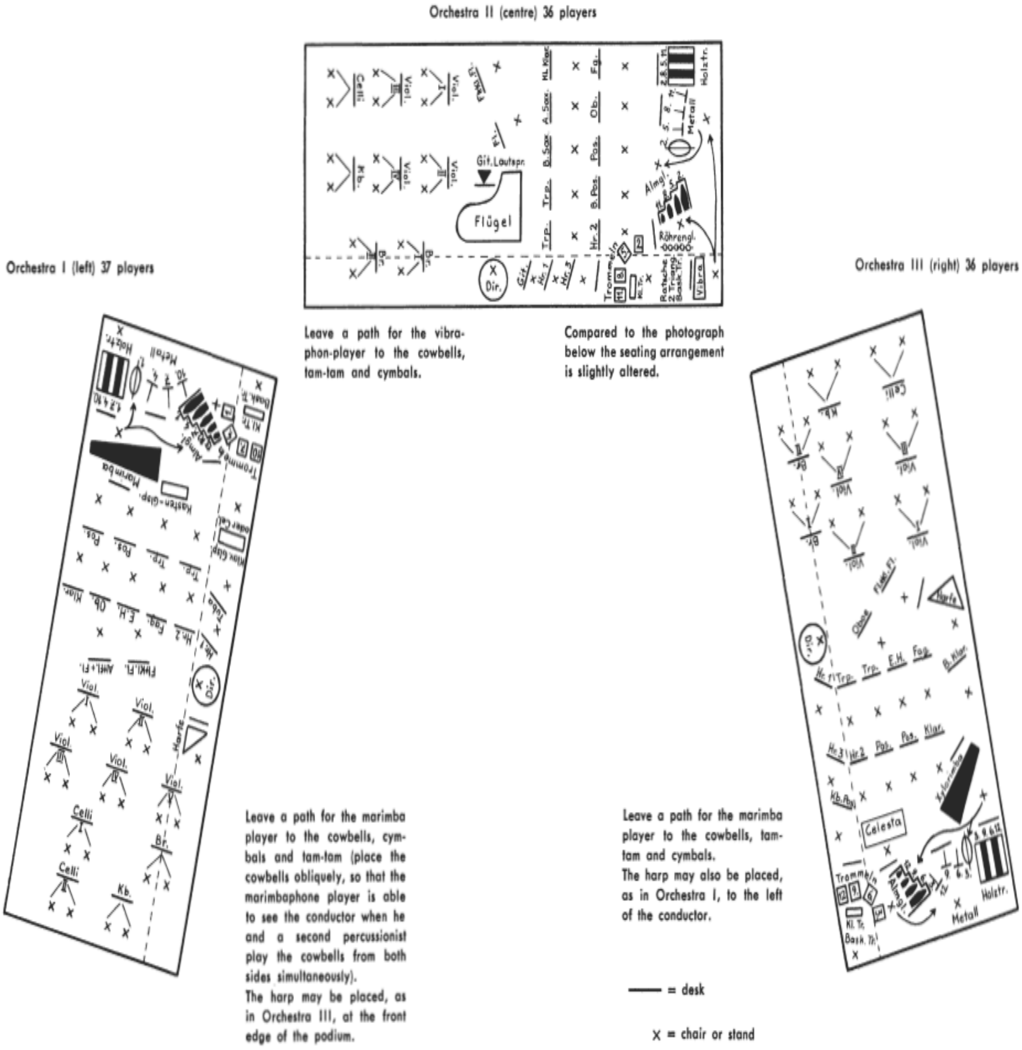

Figure 3. Stockhausen’s orchestra piece *Grüppen.* Chart indicating the distribution of the three orchestra’s sections divided on space.

Composer Karlheinz Stockhausen created two orchestral compositions *Mixtur* (1967) and *Grüppen* (1957)*,* which divide the orchestra to surround the audience in the middle while performing (See Figure 3). The audience would hear different sound events performed by the orchestra that was physically partitioned. The result is a surround-sound composition, an immersive musical experience for the audience (see figure 3). For example, when the orchestra is creating a crossover by fading-in and fading-out from one section to the other, the audience will hear that the sound is “moving” between orchestral sections. In recent times, this exploration has extended into the digital soundscapes, which can recreate acoustic features of a particular space/place/environment either by means of microphone techniques, digital reverberation acoustical design, or multichannel loudspeaker array (Barrett 2002).

Examples of using space as a musical and artistic element is found in many 20th and 21st century instrumental pieces. Composers like Iannis Xenakis, Roger Reynolds, Karlheinz Stockhausen, among others have created instrumental works that incorporate a particular localization of the instruments on a given space. The composition *Terretektorh* (1965-1966) by Xenakis, for example, prescribes that the audience is not in the middle of the performance space, but rather next to the performers. This creates a different relationship between sound-space and its perception. The orchestra produces an immersive experience, rather than a surrounding one. “The importance of *Terretektorh* lies therefore in its relative rhythmic simplicity —it is entirely notated and proceeds regularly in common time — and in the way this is applied to a spatial structure” (Dennis 1967). By reading the description from author Brian Dennis, we can see that in his personal judgment there is a link between temporal shift from introduced material by the orchestra and the location of individual instruments.

Developing an approach to surround-sound composition requires a wide spectrum of disciplines that explore sound-space in different ways, such as architectural acoustics, digital reverberation technology, multi-channel sound systems, and microphone code-decode systems. One

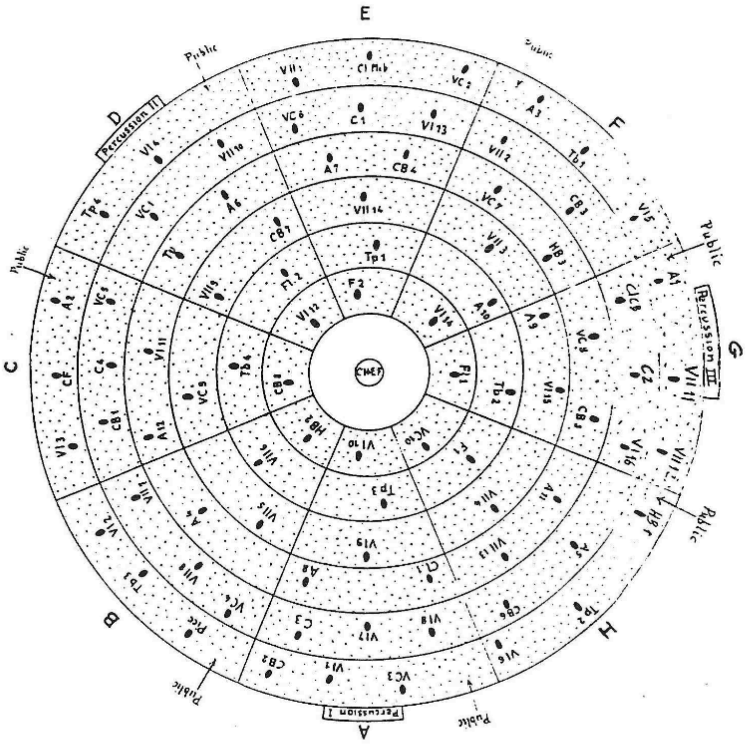

Figure 4. *Terretektorh* chart indicating the distribution of the three orchestra's sections divided on space creating a circle. The sections are split from section A to H. Bigger dots are the instruments, and the small ones are the audience members.

example of this interaction between sound and space can be seen on AUDIUM, which is a theater built for spatial musical composition. AUDIUM is a space "conceived exactly for this art form. Listeners sit in concentric circles, enveloped by 169 speakers in sloping walls, a floating floor and a suspended celling." (Shaff 2002). A given outcome will vary according to the combination of these disciplines, some would have a more closer relationship with architecture, music, and others to environmental issues taking the recorded space and the transformation while playback in a different time and place, as previously introduced. In music, those outcomes create sonic relations between projected sound and space either by acoustic instruments distributed throughout a given space, or loudspeakers creating geometrical perimeters. With rapidly developing technologies, multiple artists have cultivated artistic practices that include the exploration of space and sound as one artistic element.

Sound artist and ecologist Bernie Krause, creates databases helping in perceiving the transformation of a natural place caused by human activity. The relationship between Krause's work and space relies on running field recordings at natural locations. These recordings capture different acoustic events displayed by animal life, wind, and different sounds that occur while recording. Krause takes his field recordings as model of soundscape compositions. As he recalls, "when I began recording in the late '60s, the typical methods of recording were limited to the fragmented capture of individual species like birds mostly… to me, this was a little like trying to understand the magnificence of Beethoven's Fifth Symphony by abstracting the sound of a single violin player out of the context of the orchestra and hearing just that one part." (Krause 2014). The approach of sound and space from Krause is intimately related to preservation of natural habitats. Through his experience, Krause introduced terms to describe sound sources: geophony refers to non-biological sounds like wind, rain and thunder; biophony sounds are created by organisms like birds, mammals, insects, etc; and anthropophony are the sounds from humans. By hearing differences recorded in audio from contrasting ecosystems, we can presume that each field recording might result in a musical composition, if that is the artist's intention. Krause give us a clear sound image of a particular ecosystem, creating an awareness of the sonic alteration across time due human activity (Krause 2014).

Similar to Krause, David Dunn has developed a unique approach to ecological-sound art making, and sound environmental work. In Dunn's work, the relationship between space and sound is more imaginative and sophisticated in terms of transforming the original recorded sounds to be perceived by humans. For example, Dunn has performed field recordings aiming particular sounds produced by bats' and bark beetles, species that produce sounds outside the range of human sound perception. The task for Dunn is not only to record, but also to produce a method and provide tools that allow him to capture and arrange the original sounds perceptively for humans (Ingram 2006). He shifts the original frequency range to a region that can be perceived by a human hearing. By doing so, we are able to hear the surroundings of those species, and how they interact by sonic means (Hofstetter, Dunn & et al 2014).

In Dunn's work on bark beetles, he expands the idea of recreating physical acoustic spaces with another dimension outside of human perceptual experience: this particular parasitic insect lives inside of trees, gradually killing them. Dunn attempts to create an aural portrait of the acoustic world inside a pinyon pine. This portrait is created by projecting the resulting sounds of a chaotic system of oscillators through transducers into the tree. The result of such experimentation is an alteration in the behavior of the insects when exposed to the aural portrait created by Dunn. The relevance in Dunn's approach lies in creating a physical environment that cannot be occupied by humans, but transposed to become aurally perceptible by them.

Technology used to incorporate sound-space as an element.

Tape compositions are frequently the best medium used to recreate spatial cues or sound trajectories. Different strategies can be used while composing on tape, such as recordings that capture sound trajectories. Or sound synthesis molding the panned amplitude moving from one speaker to the other. Tape music introduced novel possibilities of materials such as timbral, rhythm, and spatial shift, among others. Different composers have used tape as a medium to incorporate new strategies and create unknown sonic relationships. Composer Kenneth Garburo is one example of historical development in using tape compositions due novel sonic possibilities. “Tape was a medium which Kenneth had a lot of respect for… since there are no scores, anecdotes, or tradition to fall back on, one has to deal with the sound, the music, on its own terms.” (Burt 1995). In recent time tape compositions also include spatial relationships carried by sound as part of the entire concept of the composition.

By using tape, the desired sound motion can be designed either by synthesizing the projected sound and its amplitude by fading in and out from one speaker to the other, or by capturing sound on a recording with proper microphones set to code sound trajectories. Contemporary compositions that use space and sound as an artistic element take into account human perception to recreate, or emulate mechanisms of human hearing.

This process can be seen in the works of American composer and artist Maryanne Amacher. In her pieces M*usic for Sound Joined-Rooms* (1980), and M*ini-Sound Series* (1985), she explores architectural features of a building to customize sound, visual, and spatial elements, creating multi-dimensional environment-oriented experiences (Amacher 1998).

Portuguese composer, João Pedro Oliveira brings a different approach to surround sound. His interest is on the live-performance of spatialization using software Spatium*,* which can control the parameters of sound motion (Oliveira and Pehna 2012, Oliveira and Pehna 2013). Regardless of the specifics of the software, Oliveira exemplifies a community of artists, such as Natasha Barrett, Trevor Wishart, and Adriana Madden, among others, who work with audio files that later are manipulated during performances to create different sound motion patterns. This particular method of interaction can be related to improvisation, due the facility of live-spatialization. By using virtual tools such as HarpeX, Spatium, among others composers and sound artist can create motion patterns, or add reverberation reflections in order to create live-performances on spatialization.

Three important categories can be drawn according to the elements that integrate these types of compositions:

- Instruments located at different places within the performance hall/venue
- Ambisonics recording and reproduction emulating important aspects of human hearing through reverb and convolution techniques
- Auditory motion through multichannel speakers placement.

Before the widespread use of digital tools for sound spatialization, composers and sound engineers used mixers or soundboards in diffusion. The most straightforward diffusion strategy of this type uses a single mono sound source that can be panned around a speaker array by a performer. In pieces like …*Between* (1968) by Roger Reynolds and *Mixtur* (1967) by Karlheinz Stockhausen, acoustic ensembles are combined with electronics that surround the audience in performance.

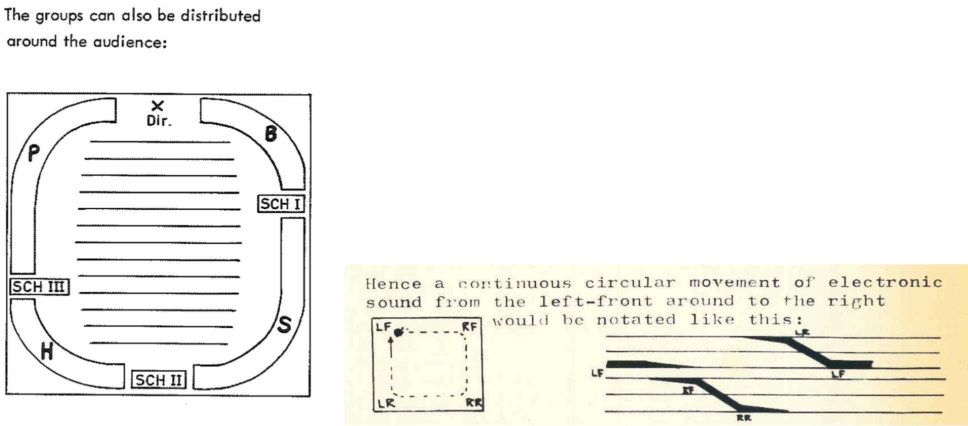

Figure 5. On the left, *Mixtur's* ensemble arrangement surrounding the audience. On the right, musical notation and distribution of the quadraphonic sound system interpreted by a performer in the composition *….Between* from Roger Reynolds.

…Between uses an acoustic ensemble as sound material to be spatialized, while *Mixtur* uses four oscillators, each one of which are placed within a section of the divided orchestra. The mechanism by which the sound is spatialized in this composition is by capturing the ensemble's output using contact microphones and processed by electronic like ring modulation, or amplitude modulation. The resulting sound is diffused through a quadraphonic sound system by a performer following instructions in the score via the manipulation of gain sliders on a mixer. Similar to Reynolds, Stockhausen in compositions like *Mixtur* and *Mikrophonie* also notates diffusion instructions in the score. The result of

such explorations can be heard as sound surrounding the audience, if not precisely sound motion.

A possible method to infuse sound with motion and localization is the use of microphone-recording techniques. When set up in particular configurations, arrays of microphones can create phantom images, that is, recordings that contain spatial cues such as reverberation, sound motion, echoes, etc. The phantom images can be heard in a particular area known as the sweet spot. In order to produce a recording and play it back in a way that carries realistic sonic location cues at the sweet spot, the microphone and loudspeaker configuration need to be set with precise angle. Different recording techniques such as *stereo* like A/B stereo recording, X/Y stereo recording, ORTF, Blumline pair, *ambisonic* and *binaural* require precise angular position. In a stereo configuration, speakers should be equidistant at a 60º angle from the perspective of the listener. (Kendall 2010). In some multi-channel speaker configurations, speakers are equally spaced along a circle surrounding the sweet spot. In the context of ambisonic playback, when the speakers are not evenly distributed, it is known as irregular periphonic 2D. Other surround multichannel sound systems which not spread speakers evenly around a circle can be 5.1 and 7.1

The sweet spot is a particular area where the sound material appears to the listener to contain realistic audible spatial cues. These factors can be problematic, since the physical limitation of the playback's sweet spot has spatial information carried in a limited area, if compared to

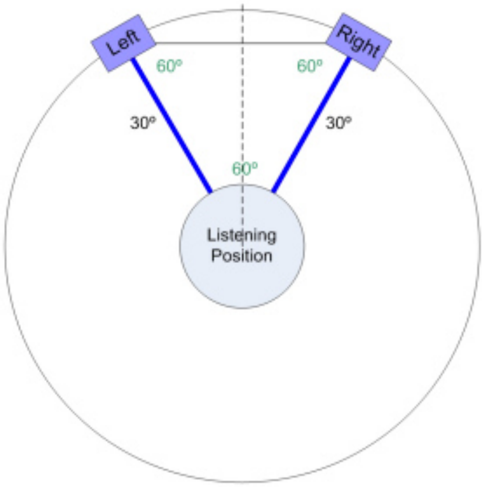

Figure 6. Stereo arrangement. Each speaker is located at 30º from the listener's perspective. The area where indicates listening position is where the "sweet spot" is located.

experiencing sound-motion of an actual space where it occurs the sonic event in motion (Kendall 1995). The success of the different stereo recordings often relies on the simplicity of the relationship between the microphone configuration and the speaker array. In other words, stereo recording techniques capture the differences of amplitude or arrival-time difference (ATD) (Kendall 2010), which are reproduced in a pair of speakers creating constructive aural interference for perceiving the space's characteristics.

Commonly, surround-recording technology has been developed and used to immerse audiences into sound. Different recording techniques, such as stereo microphone angle placement, binaural recordings, and ambisonics 3-D sound, are used to record spatial characteristics, which are playedback through a sound system. In general, those recording methods capture audio signal with decoded (recorded) location that later will be decoded into a sound system.

The debate about the ability of sound systems to enhance aural perception of sound spatialization is ongoing. Diverse research literature compares which is the best recording techniques for enhancing the aural perception of sound localization in stereo and multi-channel playback systems (Kendall 1995, Braasch & et al 2008, Barrett 2002). Stereo recordings are classified as coincident, near-coincident, binaural, spread microphones, and Blumlein. These techniques can provide spatial cues about where the recording was done by capturing room reflections known as reverberation. Using different stereo recording techniques implemented in stereo playback systems can represent spatial recorded cues through sound. Stereo system immerses the audience, either by projecting the recorded acoustic reflections from rooms, or by artificial reverberation with temporal trajectories. Binaural recording techniques make use of two omnidirectional microphones, placed inside the earlobes, or into prosthetics that resemble the human head and ears. Binaural recordings emulate the human perception of sound by providing important aural information about the distance and the direction of the sound as it refracts around and reflects off of the human head and earlobes. The principles guiding binaural techniques rely upon capturing or synthesizing the spectral information necessary to represent precise spatial location cues, which is meant to be played back via headphones.

The last recording technique I will discuss is ambisonics, a method developed by Michael Gerzon in the 1970s in which an abstract multi-channel recording represents a 3-D sound field, and can be processed to

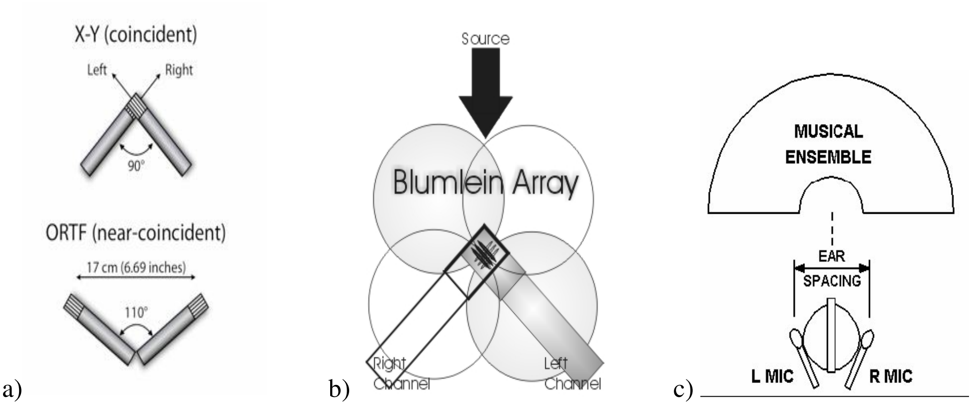

Figure 7. Different stereo recording techniques. On the left is the X-Y, the microphone capsules are up one of the other. Below the ORTF technique that has a separation of 6.69 inches. Blumlein uses two bidirectional (figure-8) microphones placed at the same point with an angle of 90º. This technique works better at shorter distance, since it can grab lower frequencies. On the extreme right is described the binaural microphone technique.

recreate that 3-D sound field in a variety of different playback situations. (See figure 8). "One advantage in ambisonics technology is that the spatial cues are carried out accurately regardless of the listener's position." (Barrett 2002). Ambisonic techniques involve the capture of multi-channel recordings which must first be encoded into a special format before being processed for playback. This encoding is known as B-format. Generally, the decoding playback is performed on quadraphonic systems. The ambisonic decoding methods are based on physical positional information. This encoding and decoding method allows, for example, the ability to encode a moving sound object in space. Therefore, when the same sound object is decoded later, it will behave acoustically the same despite the sound system's output characteristics. The encoding method uses at least four audio channels encoding the spatial cues according to the requirements of the sound system.

Ambisonics is a theoretical application of encoding-decoding sound motion patterns. Since, it cannot be done due to physical restrictions of microphone features to grab all sound's directionality, however, "if incident sound can be measured across the surface of a sphere, it is a mathematical exercise to calculate what would be detected at an infinitely small point at the center of that sphere." (Robjohns 2001) By using four microphones pointing in different directions, it can create a matrix of six different axis. By rendering the different axis is obtained a signal that can measure the ATD, and therefore to amplify those differences to be heard.

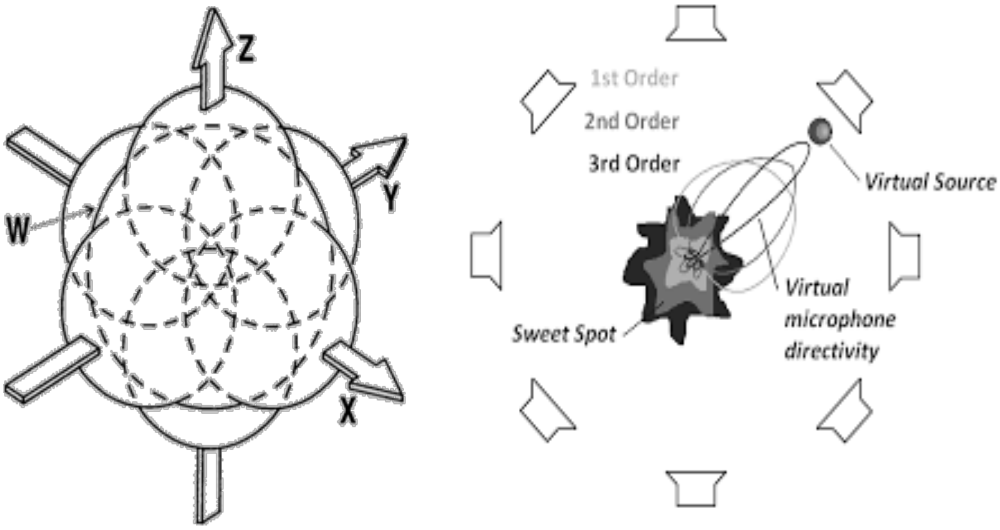

Figure 8. On the left ambisonics microphone. Six axis. By comparing the different possible pairs of microphones is that the axis are obtained. On the right ambisonics different orders. The idea of the first order is in the horizontal plane, the second order would be in vertical, and the third one would be creating an angle of 75º compared with the other two orders.

Earlier attempts for using ambisonic techniques were rare and expensive, but as commercial multichannel home systems were introduced, the exploration of 3-D sound has become more popular increasing the quantity and quality of artistic explorations. Ambisonics has been incorporated into the field of surround in order to create 3-D sound. The increase of such exploration and research in human spatial awareness has led to sophisticated acoustical techniques, such as Head Related Transfer Function (HRTF) (Kendall 1995), which measures the

ADT to create sound-motion patterns. The process of decoding the B-format signal to the appropriate loudspeaker placement allows for the creation of immersive sound fields. This results in spatial focalization on the sweet spot where the phantom images occur, which have the spatial features designed to be heard.

Fixed media or tape music that incorporates recording techniques are under constant research and development. As a result, better and better techniques for the encoding and decoding of ambisonic signals are increasingly available to artists. This can involve a particular sound trajectory to be played back in a multichannel sound system. The possibilities of interacting without modifying the spatial cues are very limited, since it is a sound picture that is moving with a given trajectory in given time that has already been recorded. While modulating and processing sound sources to be spread around the audience creates an immersive experience, as seen in the examples from Reynolds, Stockhausen and Xenakis, the combination of these surround technologies and the natural sound emission of acoustic instruments create an impossible interpolation of sound fading in and out from all directions.

Soundscape ecology

> *"Broadly interdisciplinary, acoustic ecology studies the relationships and interactions among humans and sounds in an environment, including musical orchestrations, aural awareness, and acoustic design"* (Pijanowski & et al 2011).

The term *soundscape* is used in a number of different disciplines to describe a landscape and the sounds that compose it (Pijanowski & et al

2011). In order to create art pieces that investigate ecological concerns, many artists have participated in cross-disciplinary collaborations with ecologists, biologists, and other scientists. One approach to ecologically aware art-making can be seen on soundscape or sound-installations. Pieces such as *Great Animal Orchestra* (2012) by Bernie Krause, or *Insects, Trees, and Climator: The Bioacoustic Ecology of Deforestation and Entomogenic Climate Change* (2006) by David Dunn, or *El sutil sonido de las plumas* (2012) by Daniel Schachter are examples of pieces created in a collaboration between music, sound art, and environmental studies.

Before the 1950s to the end of the 1980s, composers exploring electronic technologies needed to be associated with electroacoustic laboratories or studios to produce art pieces. This necessity was mainly due to the high expense of the recording and synthesis technologies of the day. Usually, work in these studios resulted in tape music in its final form that would be presented at a concert. Since the early 2000's, the cost of new musical technology has decreased, making these technologies available to the broader public, renewing the concerts' format. (Schachter 2012). Likewise, the development of faster global communication has allowed for the performance of "concerts" in multiple locations at once. Now, composers have the ability to perform music and participate in collaborations at home and abroad. Broadly, this has facilitated the interaction between music, sound art and ecology by making easier to have access to technology that help such interaction.

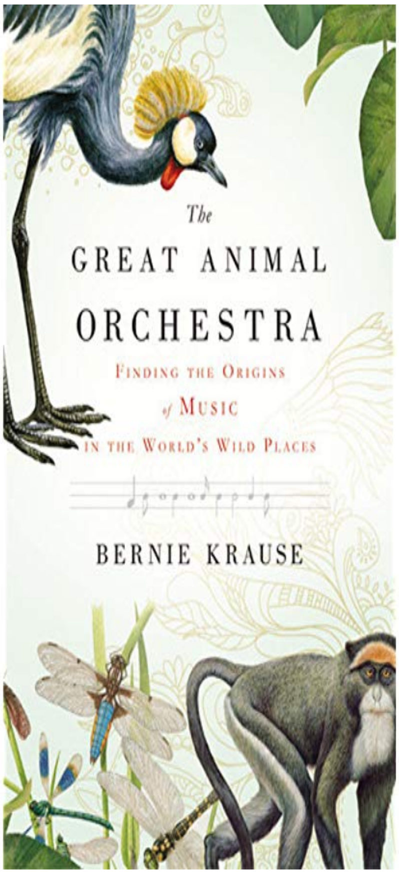

Figure 9. *The Great Animal Orchestra's c*over, a multimedia work by Krause. It displays a big collection of sound recordings data from diverse locations around the globe. *The Great Animal Orchestra* brings Krause's personal narrative of the planet's natural sounds and rhythm.

In his article *Wilderness as Reentrant Form: Thoughts on the Future of Electronic Art and Nature,* David Dunn explains that the influence that artists get from naturally occurring patterns allow them to find new paths in developing technologies and technological methods. "It is therefore appropriate", Dunn writes, "to examine those patterns of artistic activity that might support a life-enhancing potential for technological innovation by expanding our interaction with the non-human world." (1988). One example of technological innovation related to soundscape ecology can be seen on digital audio recording devices. In general, recording devices are now smaller and have bigger storage capacity, if compared to previous decades. The perpetually improving portable recording technologies allow for the creation of higher quality field recording techniques for capturing nature and its behavior. As a consequence, now we are able to obtain better sound samples and collected data, resulting in higher audio fidelity and a better opportunity to hear and study the sonic diversity of animal communicative patterning. In the context of this collaboration between artist and scientist, the artist can be seen as a creator that challenges ideologies and traditional concepts (Dunn 1988). Now, many artists working in this field are neither strictly ecologists or artist, but fall somewhere in between, creating artworks that explore ecological awareness as well as capturing important data for scientific research.

An interview between René van Peer and composer and sound artist David Dunn (Dunn & Van Peer 1999) reveals why composers and sound artists might find existing outdoor sonic environment as source of a rich and surprising sound complexity, which expands beyond the understanding of humans interacting with nature through sound. For example, as Dunn demonstrates in his piece *Mimus Polyglottos* (1976), the synergy between bird species and humans through sound occurs all the time in unexpected ways, and often unnoticed. *Mimus Polyglottos* observes the extraordinary mimicking ability of the mockingbird when exposed to electronically generated birdlike sounds. Another example from Dunn can bee seen in an experiment with trumpet players at the Grand Canyon. “We hadn’t seen any ravens during the previous days. They appeared as soon as the trumpets started playing... cawing in and out of the trumpets, and matching pitches with the trumpets.” (Dunn & Van Peer 1999).

Interdisciplinary collaboration and shared interest between musical studies and animal communication opens the possibility to distinguish human consciousness from other animals (Dunn 1983). For example, we can hear birds, frogs, insects, etc., that each have developed a system of communication that operates in a particular frequency range. As journalist Brandon Keim writes: “Each animal occupies a unique frequency bandwidth, fitting into available auditory space like pieces in an exquisitely precise puzzle.” (2017). According to Keim’s observations, if we listeners zoom out our scope, and pay attention to different ecosystems, we would see and hear the differences among them. If we compare a desert from a forest, for example, we would hear that biophony and geophony are different in their content.

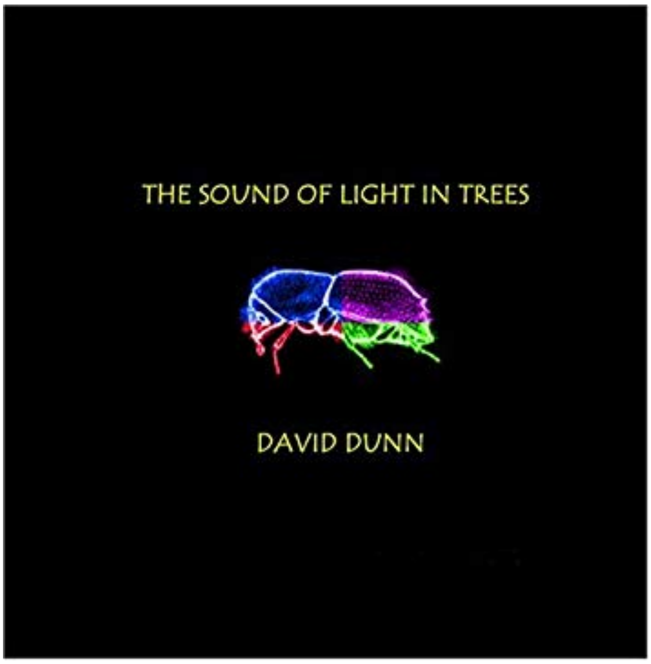

Figure 10. David Dunn’s album *The Sound of Light in Trees* (2006). The album was created by using innovative microphones of Dunn’s design. This album presents a composite audio portrait of what we might hear in the myriad branches of a single pinyon pine in the foothills of the southern Rockies. David Dunn takes us into the unknown acoustical world inside pine trees, home to an extraordinary array of living sound makers. Dunn’s intimate sonic environment includes the sounds of the trees' circulatory system, branches moving in the wind, and the communication of insects, most strikingly a concentration of bark beetles. 100% of the revenues from sales of this CD will support the work of the Acoustic Ecology Institute.

Historically, different musicians have found inspiration in nature to create musical pieces. The desert, for instance, provides an example for how different artist such as Ferde Grofé, Edgard Varèse, Olivier Messiaen, Steve Reich, among others take ecosystems as source of inspiration (Feisst 2016). These composers interact and relate to the ecosystem as a source of inspiration to create musical pieces. However, a deeper connection exists between certain artists that have a closer relation with deserts, such as Richard Lerman, Maggi Payne, and David Dunn. Musicologist Sabine Feisst explains the musical relevance related to deserts: “They have lived near these deserts, pondered their ecological fragility and paid tribute to them in many works. Their sonic *desertscapes* stand as sensitive engagements with these places and as compelling examples of gentle environmental activism.” (Feisst 2016). While it is debatable that the creation of a piece of art inspired by nature is necessarily a political act, it is worth noting that artists who speak about the current ecological issues create awareness in addition to aesthetic experiences.

Among others, Bernie Krause and David Dunn fill the role of artist as ecological activist. Both have pointed out that human activity has radically modified nature, and that it is dangerous to ignore these changes. Composer David Dunn has pointed out the danger of climate change. “Given the avalanche of messages that we are receiving from the Earth in the form of disrupted natural cycles, increasing natural disasters, unprecedented loss of biological diversity, global warming, etc., it seems apparent that we are truly beginning to pass through the eye of the environmental needle." (Dunn 2012). By creating sound art that addresses the current ecological circumstances, these artists permit the possibility of resolving these issues in a collaborative, cross-disciplinary way. The production of art with an ecological conscience that may lead to modification of human behavior is needed, and required. The role of the artist, it seems, must be reimagined to bring about an increased ecological awareness.

General description of Pablo Rubio-Vargas' works related to space-sound as a creative tool. Three compositions dealing with soundscape shifting space acoustic attributes.

> *"The essential difference between an electroacoustic composition that uses prerecorded environmental sound as its source material, and a work that can be called a soundscape composition, is that in the former, the sound loses most of its environmental context…. In the soundscape composition, on the other hand, it is precisely the environmental context that is preserved, enhanced, and exploited by the composer."* (Truax 2001).

This section introduces compositions *Hombre-Pajáro, Nat.er.ura,* and *ži'ilœ,* as well as the personal process that led me to compose them. This compositional process involves digital transformation of field recordings, pitch contour recognition from house sparrow birdsong, granular processing, and collaborative systems of improvisation. My compositional process uses miscellaneous computer-based techniques like real-time granular synthesis, or granulation of sampled sound, pitch contour recognition, among others. This is a reflection of artistic usage of technology, which has become more popular and available to researchers and musicians widely (Truax 2015). In general, *Hombre-Pajáro, Nat.er.ura,* and *ži'ilœ* propose different strategies and outcomes while using space-sound as a musical element that can be controlled, modified and interpreted.

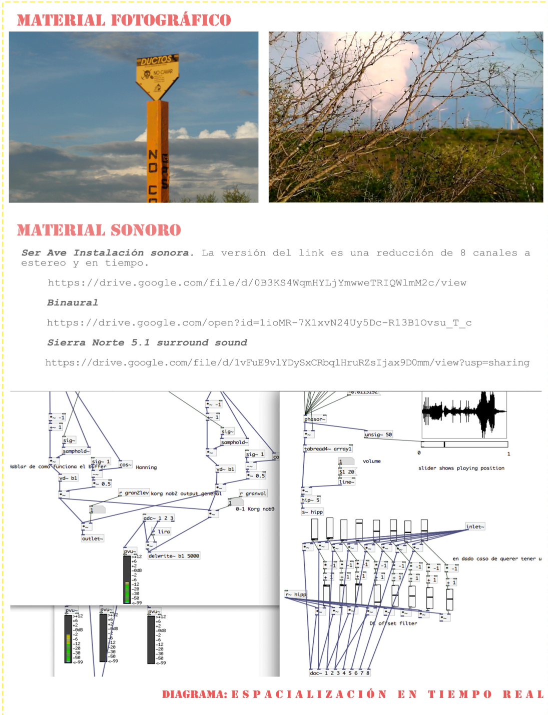

Figure 11. Pictures from different locations of field recordings were performed. The bottom section of the picture displays the patch built on PureData.

Essentially, the first step in this compositional process was to collect different field recordings or soundscapes from rural locations to function as the sound source material. The field recordings used are samples obtained from rural locations from Wilder Ranch, Mompanin, and Nuevo Leon. Later, different processes were used to create the before mentioned compositions while attempting to shift the spatial attributes. *Hombre-Pajáro* is a collaborative composition that involves a sound installation in an eight speaker multichannel array as well as a musical improvisation of two electric guitars and electric bass. The instruments are digitally transformed by granular processing and projected in an octophonic sound system. In addition, two videos are displayed on the sidewalls of the venue; in addition multiple architectonic plates are hung on the wall in front of the stage. In contrast, the second described composition is *ži'ilœ* is a composition that presents the material collected by the pitch contour algorithm recognition from a soundscape. The result is a score that an ensemble of Chinese instruments interprets transformed by applying granulation in real time, and distributed in a multichannel array. The last composition, *Nat.er.ura* is a piece for electric bass, electric guitar and trombone. This composition incorporates not only similar process as the previous ones (pitch contour recognition, spatialization of sound in a multichannel system), but it also specific performance instructions that interact with space—either by projecting sound in a specific speaker from the multichannel system or instructing at the trombonist to walk a particular direction in the hall.

The main idea in this compositional process is to transform spatial sonic attributes from the original soundscapes into a granular texture distributed in a multichannel sound system augmented by musical interpretation. This sonic transformation relies on four different actions that define space: record at diverse ecosystems; apply pitch contour recognition to obtain melodic materials from the house sparrow's birdsong; use granular processing to the soundscapes; and compose strategies to follow in a collaborative approach.

Record at diverse ecosystems.

When recording in a particular location, hearing different sound content distinguishes one place from others. Later, the field recording is playedback in a different place from the original one like a venue, or concert hall, indirectly: playing a soundscape in a concert setting creates

Figure 12. Picture from the field recording at Mopanin 2018. Pablo Rubio-Vargas is in the middle of the picture.

an awareness of the sound content and the circumstances that create it. Recording acoustic spaces, establishes a virtual background as part of the final composition (Murphy 2006). This particular way of introducing the musical repertoire soundscape that can be stored, transformed, and reconfigured was first introduced by composer Pierre Shaffer, as *musique concrète* during 1940s (Akiyama 2010). Similarly, my compositional process uses multiple digital processes like granulation or pitch contour recognition aiming to obtain a new sound material that resembles the original place where the soundscape was collected.

Pitch contour recognition and the house sparrow's birdsong.

Applying algorithmic pitch recognition on different software—like PureData, Melodyne and Spear—breaks soundscapes' content into melodic material while aiming to recognize birdsong. This process results in melodic material to integrate into a musical score to be interpreted by musicians. The first step in this process is to cut frequencies out of the selected range by using Spear software (see figure 1 and 2). Spear analyses the spectrum content of sound files to trim the desired frequency range. Spear then predicts linear partial amplitudes and frequencies to conclude the best continuations for sinusoidal tracks (Klingbeil 2006). After this process, the content is handled using the PureData software feature Sigmund, a digital object that operates to obtain a pitch contour on a given recording (a similar process is achieved by Melodyne software as well). The outcome is data as MIDI messages that integrate a musical score, among other possible applications in the final form piece like speaker amplitude distribution.

Granular processing applied to the soundscapes.

The idea in applying granular processing is to modify the original timbre by creating particles of the same sound source. The outcome is a granular birdsong, wind, instrumental sound, and humans' noises transformed, while maintaining some of the initial characteristics. The new granular timbre is spatially distributed into patterns called trajectories (Truax 1990). The tape then has a new granular texture with a given multichannel distribution. By using live-processing granulation the instruments are transformed in a granular texture mirroring the tape content. Different digital tools were developed on PureData to perform and adjust to diverse spatial features, such as reverberation, multichannel loudspeaker array projection of sound's amplitude, and granular processing. The composition *ži'ilœ* is the only piece that uses a precise localization of the acoustic instruments to accomplish granular processing. Various digital tools were created to interact and modify different parameters from both field recordings and musicians' performance. *Hombre-Pajáro* and *Nat.er.ura* combine electric guitar and electric bass to avoid spatial cues of the instruments' position.

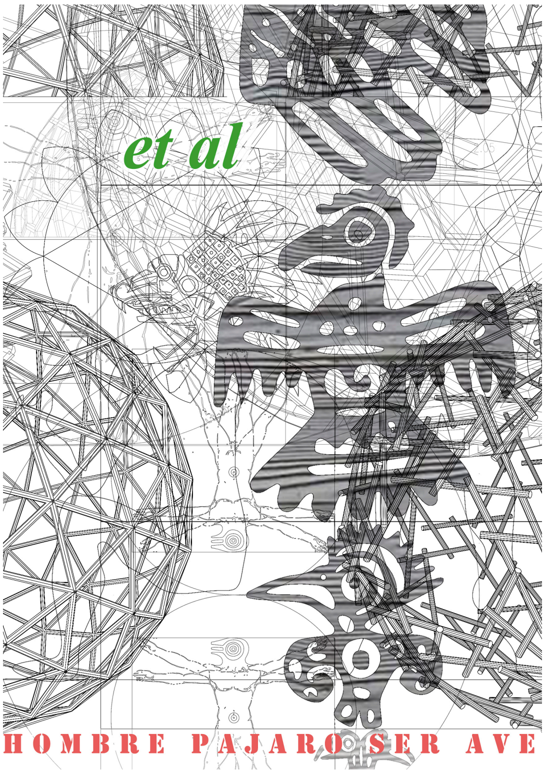

Figure 13. Cover from *Hombre-Pájaro*. It is used as part of the images within the sound-installation. It symbolizes a hybrid shape emulating half human half bird.

Compose strategies to follow in a collaborative approach.

Different tasks are prompted to the musicians in order to interact with perceptual transformation of the original field recordings. This particular action refers to a musical score, or verbal instructions to follow while performing. In electronics performance, the diffusion of sounds refers to project sound-trajectories distributed into a multichannel sound system by using a sound mixer (Truax 1998). Combining either material that can interact with sound-space like short-long durations, high-low pitch, projecting sound in a given set of loudspeakers, or a path to follow inside of the hall, is the method employed to enhance the spatial transformation during the musical interpretation. The last example of strategies employed to create a collaborative piece can be seen on *Hombre-Pájaro.* The method used to create this collaborative piece was in sharing electronically different soundscapes to compose a collection of multichannel tape tracks.

Hombre-Pájaro a multimedia work by artistic collective _et al_.

Hombre-Pájaro is a work created by *et al*, an artistic collective integrated by architect Alberto Navarro-Garza, bass player Hector Pérez-Villanueva and composer Pablo-Rubio Vargas. *Hombre-Pájaro* combines an electric trio (two electric guitars and an electric bass) modulated through an octophonic sound system. In addition, two video projections are shown on the two sidewalls of the venue, with multiple architectural plates hanging in front of the musicians. The work captures and interpolates natural environments into a concert setting in a multi sensorial awareness carried by sound, images, and musical improvisation using space-sound as a malleable element.

Hombre-Pájaro modulates and alters perception of space-sound and identity-nature by creating a musical experience based on a collage of architectural-sonic projection, and musical performance that transforms the symbolism of birds and humans. The piece is an artistic metaphor of both species (humans and birds) as migratory beings travelling and singing through the world. This is a multimedia work that demonstrates a multidisciplinary collaboration focused on sound-space and its perception. Space is expressed as a multilayered area occupied by sound, images, and audience.

This work attempts to expand the linear concept of time by combining prerecorded sound, granular textures, and musical improvisation. The sound source comes from a collection of modified soundscapes in multichannel tape tracks. (See figure 14). The tape part intents to work as an installation by itself. The length of the tape part is a minimum of 3 hours. The trio's live performance occurs within the given frame of time of the exhibition, which mimics the sounds from the tape. Finally, the trio is processed digitally to interpolate grains of sound shifting of the sound material from the tape recording.

***et al* collective: an artistic system of collaborative production.**

The artistic collective *et al* was created by architect Alberto Navarro-Garza in 2013. This artistic collective seeks to blur artistic disciplines as a method for creating art pieces; this comes as collaboration between multiple artist with diverse backgrounds. In 2015, composer Pablo Rubio-Vargas joined the collective to explore space and sound through the usage of multichannel speaker technology. Later, in 2017 bassist and *norteño* musician Hector Pérez-Villanueva joined the collective. Alberto Navarro-Garza, Hector Pérez-Villanueva and Pablo

Rubio-Vargas contributed in composing *Hombre-Pájaro.* Many issues related to authorship were raised while creating this piece. The three members have agreed the authorship is a collaborative piece. Although to introduce such issues of authorship in the present work is an extensive task, and led me to a completely new thesis. Therefore, I concentrated on focal points of this essay as to point out the creative and collaborative practices.

While creating *Hombre-Pájaro* three main tasks were collaboratively accomplished by different members. The first task was to record and share soundscapes. Multiple databases came from different sources such as FERP, *et al*'s collection, and my personal field recordings, among others. Later, these soundscapes were digitally modified. Diverse manipulations in digital processing of audio like equalization, amplification, shifting pitch, changing the order of events were mainly used to get new sound materials. The second task was, to build a collection of multichannel tape tracks. Finally, the last task was to create a sound map of the musical interpretation within the collected multichannel tape tracks, because no musical score was used in order to increase musical spontaneity.

Diverse collected soundscape databases were recorded at different places such as Wilder Ranch in Santa Cruz, CA; Mompani, a rural community near by Queretaro City; and different rural areas in the state of Nuevo Leon in Mexico. Such soundscapes came from contrasting ecosystems like forests, deserts, and a mountain chain in the inner land of Mexico. The equipment used to record was mainly by portable recording devices like the Handy Recorder H4n developed by the Zoom company. The reason to use this kind of device is practicality and ease for creating stereo recordings with calibrated microphone capsules.

The members of *et al* collective were located at different places at the time of creating *Hombre-Pájaro.* Therefore, the mechanism for creating the multichannel tapes was by sharing the modified material electronically. The usage of internet was a regular way of interacting by modifying the original sound files. In the particular case of *Hombre-Pájaro*, this was possible due to the constant development of technology applied to informatics and communication systems (TIC), which influenced the approach to work with sound particularly by the transition from analog to digital (Schachter 2012). Each member was free to digitally modify the soundscapes as they wished. The result was a collection of different transformations from the original soundscape. This process drifted multiple times until a set of multichannel tape track files were established as the final tape composition.

Different digital processes applied to the original soundscapes comprised the sound materials displayed in each multichannel tape track. The soundscape with the least digital processes from the original soundscape is the quadraphonic soundscape, which has a length of 40 minutes and 20 seconds. It features mainly original sounds from the field recordings. Amplification and equalization were the two main processes employed in order to get a better quality of the sound material recorded. The next track, hexaphonic, presents more digital processes, which has a length of 20 minutes and 27 seconds. The stereo track also presents multiple digital processes, but the granular processing is more noticeable. The binaural track presents almost unaltered material; although a binaural motion decoding mechanism was used to hear patterns of artificial motion, it is only perceptible on headphones. Finally, the octophonic track is a musical improvisation recorded by the three members and later distributed on eight speakers. All the multichannel tracks are meant to be played at the same time from beginning to end (see figure 14).

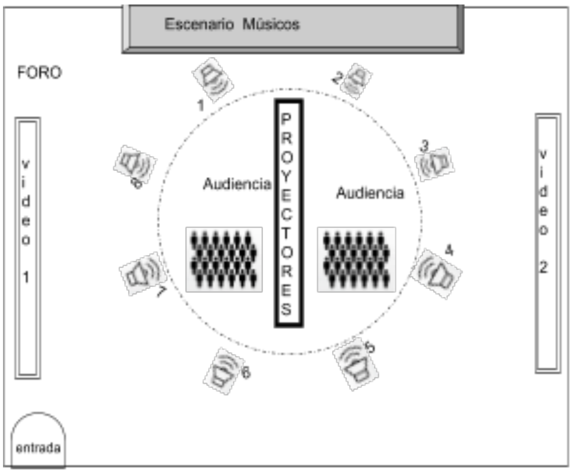

Figure 14. Upper view of the physical dispotion of octophonic system, video projections, audicence, and stage. On the upper section in the gray are is the stage where the trio performs.

Similarly to the sound material, the videos in the piece presented came from the different collections of the members. As previously mentioned, two video projections are displayed on the sides of the venue. One comes from the field recording session performed at Mompanin by Rubio-Vargas while the other video (on the other side of the venue) is a collage of different recording session by Navarro-Garza. The architectonic plates were created by Navarro-Garza as an analysis of urban settlements and its impact on ecosystems. It focuses on migratory and stationary routes of birds on the North American continent, from Nearctic to

Neotropical regions. It shows the shift in patterns on birds' migratory behavior, which indicates Mexico is a region of mega-diversity.

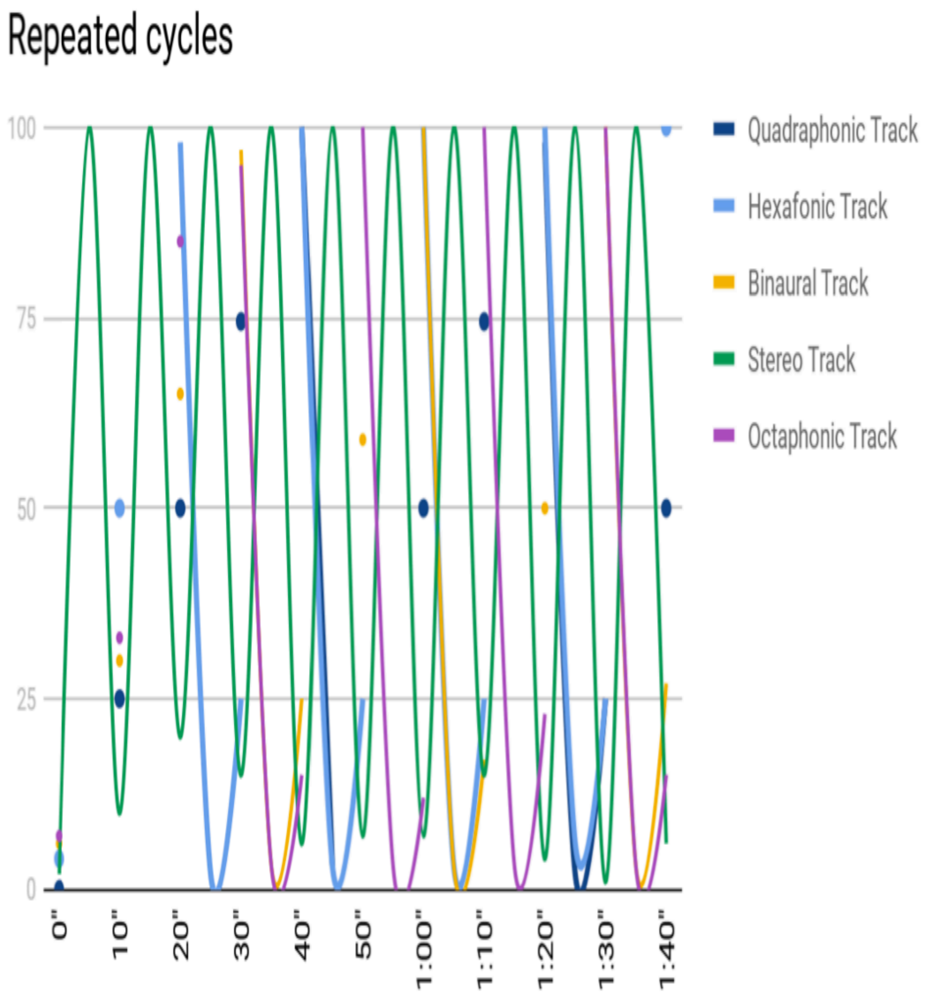

Figure 15. Cycles created by playing at the same time the different multichannel tracks. On the Horizontal axis is shown the time length of 1 hour and 40 minutes. The graphic shows the different complete cycles and where the begging of individual track coincides.

The interest from *et al* as an artistic group laid mainly in elaborating customized methods of multi-sensorial sound exploration transmitted as a cluster through space-matter. As artists, we depart from each identity towards collaborative artistic creation as in we are "the others". We attempt to provoke an insight at the spectator reflecting on ecology, and art. *Hompre-Pájaro* works as a human perception of natural environments transformed by digital means that integrates human perception.

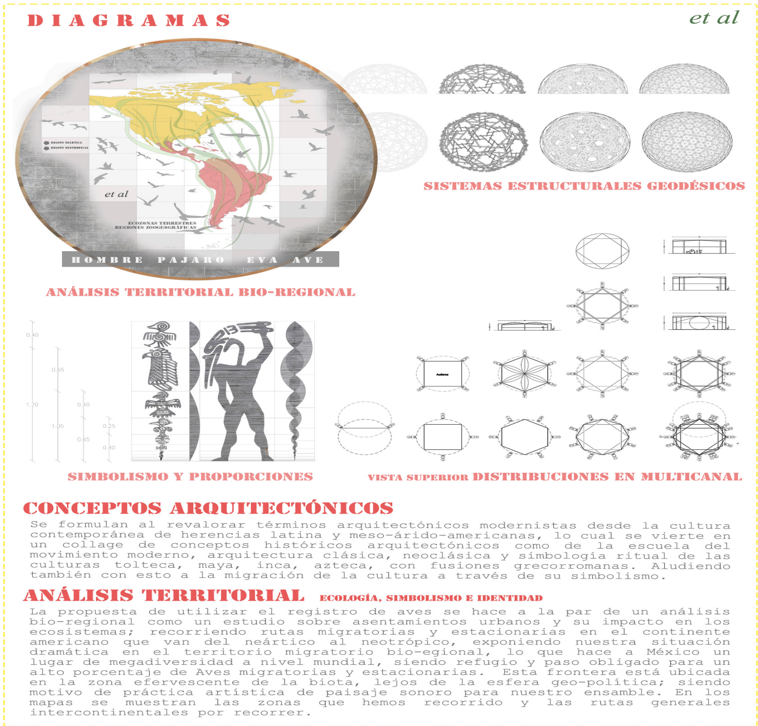

Figure 16. Architectonic plate. The upper right corner shows diverse sketches alluding to pre-Colombian human-bird shape. The left displays the multichannel array and the sound vector trajectories of sound.

ži'ilœ, a musical score that deals with notational systems describing sound and space with musical instructions of performance and interpretation.

The title, *ži'ilœ* is a term from *Zapoteco* language that means "East". The title relates to the idea of using Chinese acoustic instruments (Pipa, Yangquin, Erhu, Zheng, Ruan, Dadi, and Sheng), while interpreting a musical score obtained from the previously introduced process of algorithmically detect pitch contour from birdsong, with the resultant material formed as MIDI messages. The piece is dedicated to Little Giant Chinese Chamber Orchestra, a Taiwanese ensemble formed to perform new, and traditional repertoires. The work premiered at UC Santa Cruz during March 2017; later took place on September 2018 in *Visiones Sonoras* Festival in Morelia, Mexico. The last interpretation was in Taipei, Taiwan in March 2019. The composition *ži'ilœ* was the first piece integrating the compositional process discussed here related on space-sound as a musical element. The melodic material was obtained by applying algorithmic pitch contour recognition. Different software programs were used to perform the pitch contour recognition.

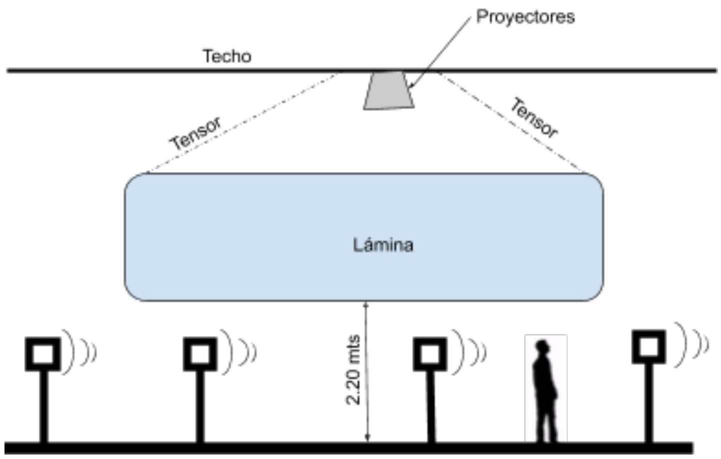

Figure 17. Sketch of *Hombre-Pájaro.* Lateral look of the octophonic arrangement, video projection, and a possible solution to combine the audio and video at the same time.

PureData and Melodyne were used to break soundscapes' information to detect pitch contour from the house sparrow's birdsong. The material obtained by the algorithmic process of recognizing pitch contour from the soundscapes resulted as three melodic lines. Selected events or prominent materials were combined to integrate the score of *ži'ilœ*. In the actual performance, live-processing granulate the acoustic sound of the ensemble. A musician familiar with a developed digital tool in PureData performed the electronics.

A particular spatial distribution on stage is required for the ensemble, which correlates to the capacity of creating short-long attacks. Pipa is the instrument with the shortest attacks; thus, it is placed at the center. Instruments that can produce sustained attacks like Dadi and

Sheng are placed at the corners. The ensemble creates a half circle with two microphones in the center in order to capture spatial cues from the instruments while performing. The instruments' timbre is transformed by granular live-processing on PureData. The combination of a particular instrumental placement on the stage, along with digital granulation controlling attack response at a given venue was used to create a musical performance that resembles the birdsong, now algorithmically transformed. Furthermore, the piece attempts to reference digital birds later "put it back" into nature by the musical interpretation of the ensemble.

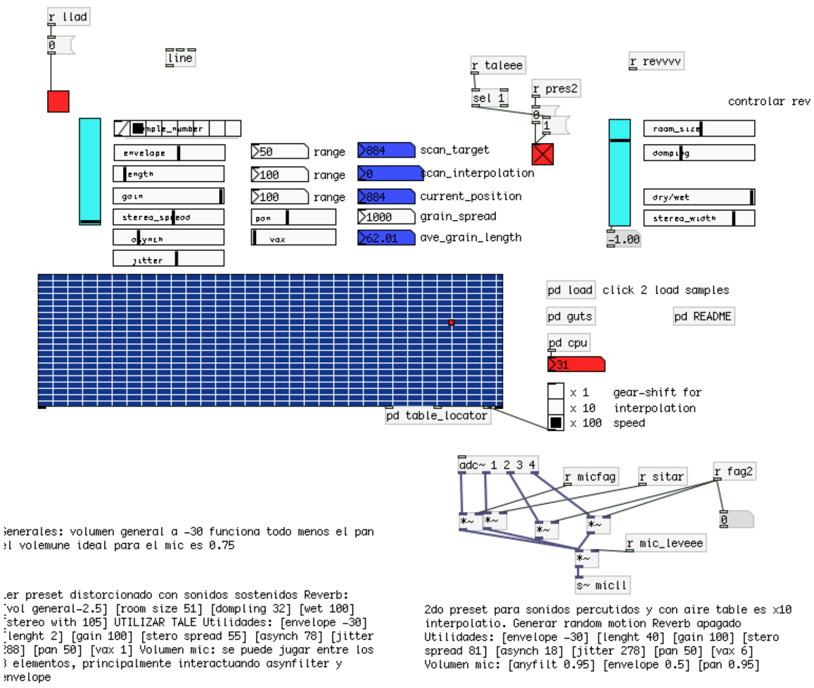

Figure 18. Digital granular tool built on PureData Software. The vertical bars in light turquoise color, the one one the left represents the original input level from the microphone signal. The one on the right represents the output level of the granulated sound. The blue grid is a pointer that controls the granular level from the original sound. On the grid, the vertical position indicates the pitch alteration, while the horizontal position modifies the size of the grain oscillating from the extreme left to the extreme right about 500 milliseconds.

ži'ilœ is an experiment of digitalized nature that would take its new form while preserving some of its essence. The result is not an evocation of the birds' singing, but a timbral re-construction of a digitalized, and granulated birdsong. Lastly, the digitalized transformed birdsong is put back into nature by acoustic sound of the instruments. Consequently, the nature of the sonic bird interpreted by the ensemble now incorporates digital and granulated sounds.

Pitch contour recognition resulting in a musical score.

The score consists of two pages; the first one indicates the particular placement of each individual instrument on the stage, as well as melodic materials to be chosen by the musician. The second page suggests possible instrumental techniques of each instrument and a possible layout of instrumentation. The musical techniques are written in traditional Chinese musical notation. In contrast, the three different melodies are displayed on standard stave musical notation. The part of the electronics' performance in manipulating the digital granulation is not written because the electronics' performer reacts differently in each new performance. The acoustic performers may read the musical score in a non-linear way. The melodic lines can be read freely by the musician; thus, the musician can read one gesture from one line and jump into the second one, or repeat any gesture as wanted. The goal is to create a collaborative work between all the members involved, while exploring materials that came from a soundscape that mirrors nature. What is heard is not the original field recording, but the musical interpretation of the ensemble.

Music that combines acoustic instruments with new technology embraces novel approaches for notating the prescriptive performing tasks or describing the sonic elements within the electronics. In the case of *ži'ilœ,* I intended to illustrate

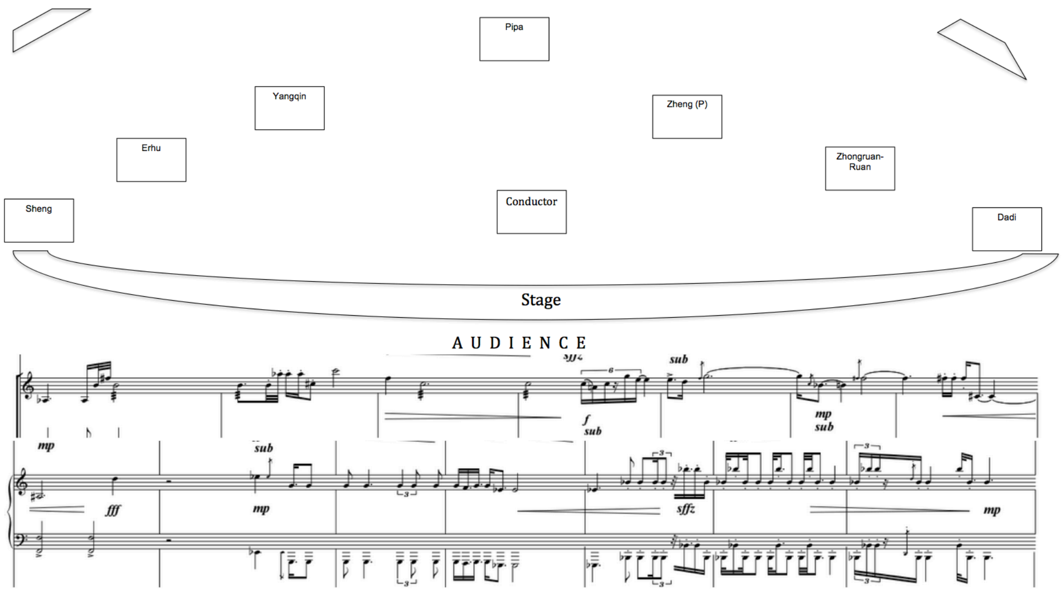

Figure 19. First page of *ži'ilœ.* On the tope is the physical disposition of the ensemble on the stage. At the bottom, it is shown the three melodic lines as result of the pitch contour recognition process.

not only the melodic material, but also the particular location required for each instrument. Author Marc Battier addresses the current and complex situation for notating electronics: "With the advent of digital techniques, now universally used, through the development of musicological studies in the field, and with the surge of interactive devices between computers and performers, the need for various forms of representing sounds and data has never been so strong" (Battier 2015). This particular problem of notating the electronics, whether it is descriptive or prescriptive, results in multiple explorations in musical notation. Now, with new media and technological resources, the problem has become more a matter of facilitating performance practice. My solution is not to indicate musical practice on the score, rather to provide a plate of options. Meanwhile, other digital processes are automatized in time. The performer thus knows the possibilities in amplifying, granulating, and distributing multichannel loudspeaker array.

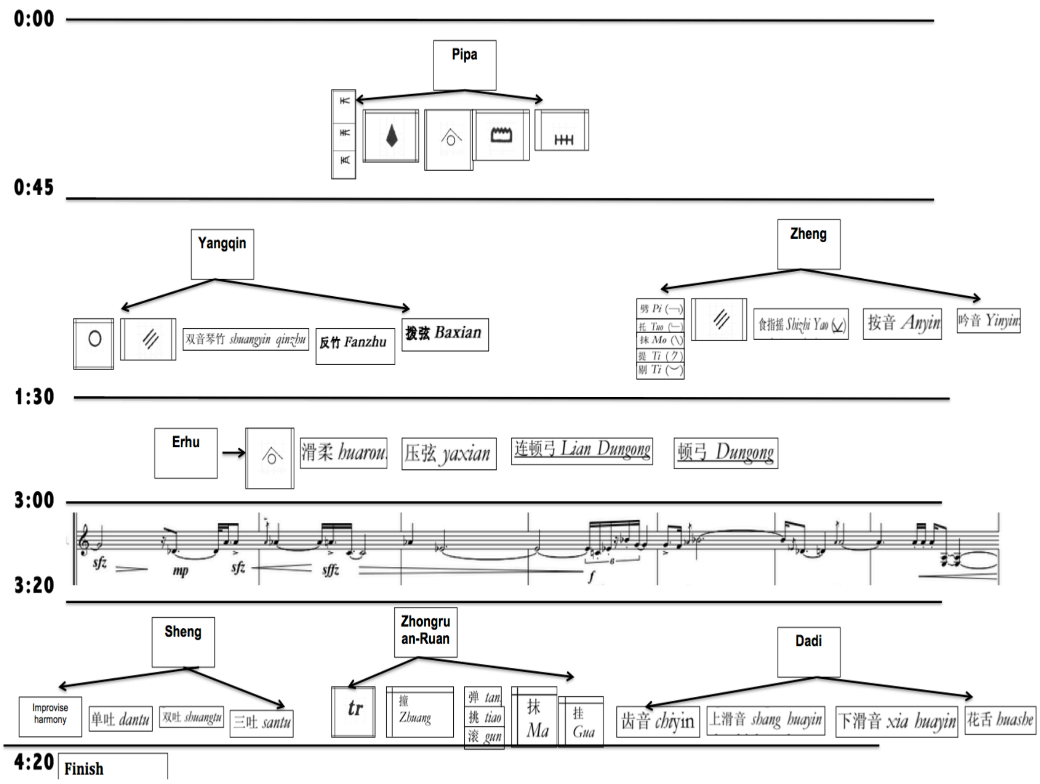

Figure 20. Second page of *ži'ilœ*. The score is read from top to bottom. The left indicates an approximation of lengh; however, the ensemble is free to expand it as desired. At the begging the Pipa introduces different materials with multiple options of techniques that can be added to the melodic lines. Later Yangquin and Zhen are added. A similar process is carried out during the entire duration of the piece.

ži'ilœ's score was composed by three melodic lines detected algorithmically from a soundscape. Later, the score is freely interpreted by the ensemble following an instrumental layout. The musical score has multiple options of interpretation by choosing different paths to read same material. The goal is to create a double transformation of nature. The first transformation consists on creating a musical score from natural birdsongs and its pitch contour recognition. The second transformation is to "put back" the birdsong into nature as a musical performance of the digitalized materials. The artistic outcome is to create an awareness of the natural world now modified digitally.

Nat.er.ura **an improvisatory piece using space-sound as musical element. Interaction between space and sound.**

> *"Some compositions demand a specific diffusion performance for the musical structure to be clear. Other music gives the performer a greater degree of interpretation. But whatever the intentions from the compositional side, you cannot project the simultaneous spatialization of different sound streams, do things that are impossible to do with one pair of hands, work with the idea of spatialization as a structuring method reliant on details a performer may miss, and so forth."* (Otondo & Barrett 2007).

Nat.er.ura is the last composition created for this cycle. It is for electric bass, electric guitar, trombone, and hexaphonic sound system. *Nat.er.ura* incorporates the usage of digital technology to granulate prerecorded sounds as well as live performance of instruments but particularly modifying spatial attributes of sound. A musical score was created by incorporating sound materials collected by the pitch contour operation, as well as particular sound projection of a modified soundscape on the sound system. The outcome is a score of two pages, which is somewhat similar to *ži'ilœ.* The first page incorporates harmonic materials that integrate a rhythmic pattern. Three harmonic areas with a given rhythmic structure are displayed on this page. On the second page graphical notation guides the musicians to fade in or out of a given harmonic content. Thus, the musicians need to perform a harmonic content with a disposed rhythmic structure when prompted. On the same page, the trombonist is provided with instructions to walk on a path inside of the room while performing. The audio projection of the hexaphonic system accompanies the trombonist's path.

By combining the trombonist's path with a particular audio projection from the hexaphonic system, different relationships are created such as a contrapuntist texture spread on space. For example, at the opening of the piece, the electric guitar is playing, at the same time, its granulated and projected on two speakers

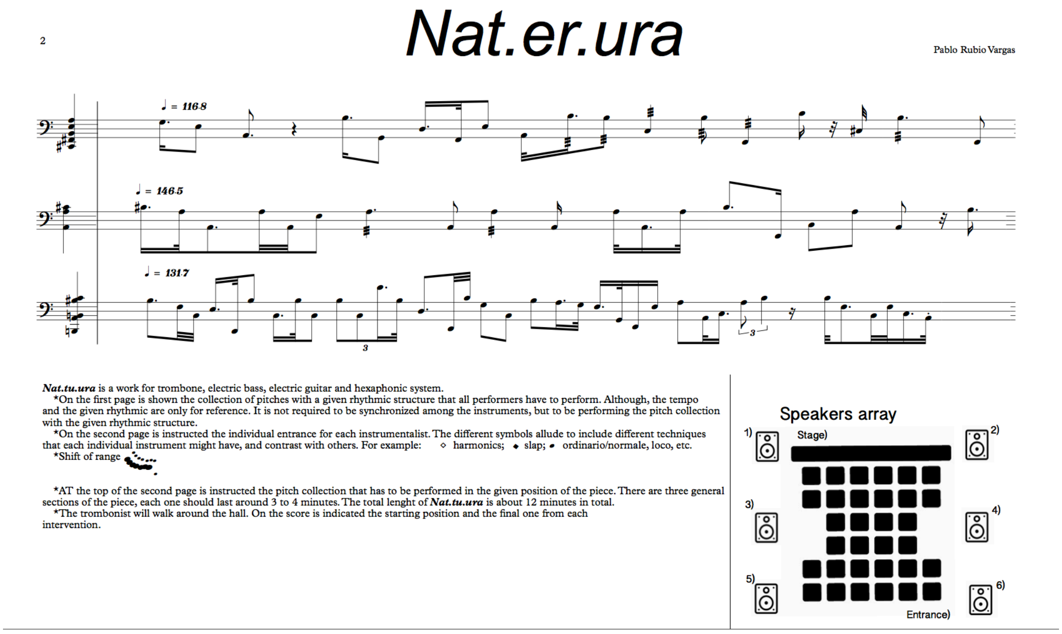

Figure 21. First page of *Nat.er.ura*' page of instructions. The creation of this piece was supported by *FONCA*, a Mexican institution that support art production.

located nearby the trombonist. Later, the trombonist starts to play where the two speakers are projecting the guitar's sound. As the piece moves along, the sound projection of the sound systems start to move with the trombonist; although, in some section the audio is projected in speakers that are far from the trombonist. In this sense, the relationship of proximity between the trombonist and the audio projected through the audio systems create a counterpoint of spatial reference.

The original soundscape that serves as sound material digitally modified comes from a field recording from a natural place that later is presented in a venue, which would ideally enhance the spatial shift. In other words, the soundscape is a recording from a natural ecosystem that is presented later in a venue like a theater, or hall. It is intended to intensify the sound-space shifts by a musical performance. In *Nat.er.ura,* different digital processes like digital granulation, pitch contour recognition, improvisatory score, among others were used to change perception of sound-space. The original soundscape is transformed by digital processes. Later, the musicians are prompted to react to the transformed materials that result as a musical score and a tape composition. The goal in this composition is to link sound localization as a musical experience.

Aesthetically, these pieces explore how to use space as a musical element that has multidimensional features. For example, soundscapes may function as a particular snapshot in sound from a particular place and time, or sound trajectories spread out in a given multichannel sound system, with vectorial sound projections. Finally, these works illustrate musical performances that augmenting the spatial perception of sound as a musical interpretation. In this way, this compositional process incorporates space as a source of sounds and as a musical experience.

Conclusion.

Sound artist and composers have developed compositions or art pieces that incorporate soundscapes from ecosystems as a source of inspiration. As result, a contrasting variety of art pieces have been created ranging from mainly artistic-aesthetical concerns to a more environmental and activist standpoints. My compositional process creates an awareness of spatial transformation interpreted by musicians and the role of technology as the carrier. The result is that the musician reacts to the sonic material impressed on the multichannel tape attempting to create a space-sound experience. The final compositions are complex sound-landscape of nature digitally transformed into a unique sound world. This personal compositional method focuses on space-sound as a link to environmental and artistic issues.

This compositional process uses soundscape recordings as a source of sonic material modified and interpreted both by musicians and digitally. Algorithmic tools used to get pitch contour from field recordings facilitated the creation of a musical score. In addition, digital granular tools

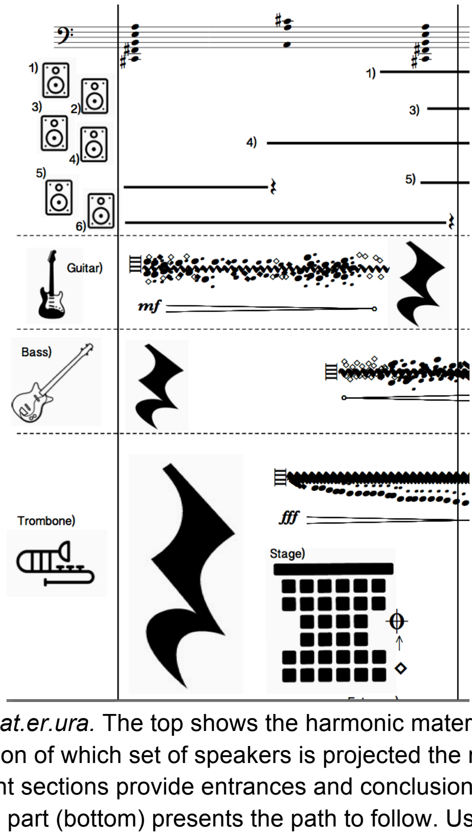

Figure 22. Introduction of *Nat.er.ura.* The top shows the harmonic material that the trio needs to relate. Below is the instruction of which set of speakers is projected the material from the electric bass and guitar. Subsequent sections provide entrances and conclusion of the instrumental participation. The trombone part (bottom) presents the path to follow. Using a diamond symbol represents the walking path when the trombonist is performing. A circle indicates the end of the walk. An arrow indicates the direction to follow.

were created on PureData to improvise by projecting and granulating the original sound source like multitask tape compositions or the musical interpretation of musicians. Digital granular technique was used so as to shift acoustic features while retaining the sound identity. The last step was to create a new composition that incorporates fixed elements with performative instructions such as a score, multichannel tape, and improvisatory tools. By using this compositional process, the compositions *Hombre-Pájaro, Nat.er.ura,* and *ži'ilœ* were composed.

The first composition created using the described compositional process was *ži'ilœ*. In contrast to the other two compositions, *ži'ilœ* does not present prerecorded sounds on the actual presentation of the concert but it uses the prerecorded field recordings as a source to get melodic lines from the algorithmic process of recognizing pitch contour. In addition, a granular processing system was created in order to interact with the instrumental performance. The intention is to recreate a virtual birdsong put it back into nature by musical interpretation.

Hombre-Pajáro combines a collection of multichannel tape track compositions along with video projections, architectonic plates, and a musical improvisation. This composition was created in collaboration as *et al* an artistic multidisciplinary collective. The goal of this piece is to create art that reflects on environmental issues by addressing the figure of birds. This composition works either as an art installation or as a concert, as an installation and as a musical improvisation.

Nat.er.ura deals with novel methods of interaction with acoustic and virtual sound while shaping spatial acoustic experience. The goal in this piece is to interpolate the physical location of the trombonist accompanied by the other two instruments granulated and projected in a hexaphonic sound system. This composition creates a new relationship between sound-space while retaining desired spatial sound features such as birdsong pitch contour, sound trajectories, among others. In this particular case, each event seems to be a spatial shift of placement that “may seen to belong outside of time, but their realization is always temporal. For instance, the perceptual experience of musical layers originating from different spatial locations involves the awareness of their succession and simultaneity” (Trochimczyk 2001). The material shown in the score is a bare guide of each instruments' participation of entrance.

In summary, this compositional process allowed me to create three works in a collaborative way using digital technology to modify soundscape’s spatial features. The artistic outcomes are pieces that focus on current environmental issues, relating them to a bigger artistic community interested on changing the ecological problems that we faced. My artistic production is a humble attempt to recreate natural phenomena interpreted by technological means. For later, putting it back in nature by humans that now use technology as a natural way of experiencing life.

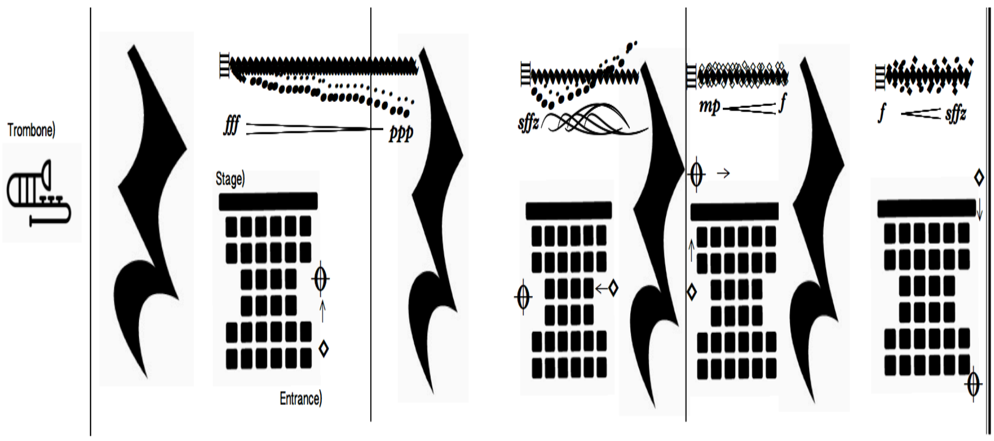

Figure 23. A closer look of the trombone part in *Nat.er.ura.*

Glossary

Ambisonics: "The ambisonic surround-soundsystem is essentially a two-part technological solution to the problems of encoding sound directions (and amplitudes) and reproducing them over practical loudspeaker systems so that listeners can perceive sounds located in three-dimensional space." (Malham & Myatt 1995).

Algorithm: It is a process to be followed by a set of rules to calculate or resolve a problem.

Amplitude modulation: Knows also as AM. It is a modulation in which the amplitude of a carrier wave is varied in accordance with some characteristic of the modulating signal.

Amplification: Expansion or augmentation. In sound, it refers to the electronic procedure that sounds can be made louder.

Anthropophony: Sounds generated by humans. (Krause 2014).

Binaural: Relating to or used with both ears. Sound recorded using two microphones and usually transmitted separately to the two ears of the listener "by attempting to capture human hearing's response to sound in terms of phase, directionality, and physical separation." (Hoose 2015).

Biophony: Refers to the sounds created by living organism like birds, mammals, insects, etc. (Krause 2014).

Birdsong: The song of one or more birds.

Collage: An art work technique that pastes on single surfaces various materials that normally are not associated with one and other.

Counterpoint: In music, counterpoint is the relationship between melodies or voices that are independent in rhythm and contour, yet harmonically interdependent. It is mainly used as a polyphony technique.

Databases: is an organized collection of data. More specifically, a database is an electronic system that allows data to be easily accessed, manipulated and updated.

Decode: Translate data or message from a code intro the original language or form.

Descriptive: It has the quality of describing. In musical notation Descriptive musical notation refers to a sound image where the final sonic result is not certain. (Seeger 1958).

Desertscapes: Term introduce by author Sabine Feisst in her article*The American Southwest as Muse: Maggi Payne's Sonic Desertscapes* (2016).

Ecosystems: In ecology refers to a biological community or region interacting organisms and the physical circumstances around it.

et al: Artistic multidisciplinary collective founded by architect Alberto Navarro-Garza. Originally created by Alberto Navarro and later joined by Pablo Rubio on 2015, *et al* collective has shifted multiple times on its members. *et al* is a collective of free will participation seeking to generate new multidisciplinary work. *et al* comes from a Latin phrase "*et alii*" translated as 'and others'. The name works as a manifesto embracing aesthetical, scientific and technological research for artistic production under a collaborative scheme

Erhu: It is a Chinese musical instrument. It has two bowed strings.

Equalization: In sound is the process of adjusting or balancing between frequencies content.

FONCA: Stand in Spanish *Fondo Nacional para la Cultura y las Artes* [National Founds for the Arts and Culture]. It is a Mexican Governmental institution advocated to the art production in Mexico.

Geophony: Refers to the sounds that have a non-biological source like wind, rain and thunder. (Krause 2014).

Grain: a grain is a sound signal that typically falls into a range of 1-50 milliseconds (Roads 1988). In electronic music, it is a tiny sound particle of short duration. However, a “macro grain” exists, and could be exemplified with pizzicato or a short attack from an instrument.

Granular: Audio synthesis technique that generates thousounds of short sounds known as grain sounds. Composer Iannis Xenakis pointed out that granular sounds can be found in nature like the sound of wood burning. (Roads 1988).

Granulation: Sequence of grains. (Roads 1988).

Granulator: it is a machine, which makes particles bigger by moving them so that they stick together. In sound create grains of sound between 50 milliseconds to 200 milliseconds. Usually works by creating a stream of short sounds crossfading sections of the source sample. (Henke 2016).

Grüppen: Orchestral piece by composer Stockhausen. Three orchestras surround the audience. Universal Editions. (1955-1957).

HarpeX: It is a signal-processing algorithm designed to extract the maximum amount of spatial information from sound field recordings. This technology to transform sound field recordings in A-format, B-format or AmbiX into the standard surround and 3D surround formats.

Hexaphonic: Six separate sounds, or six audio signals**.**

Interpolation: The insertion of something of a different nature into something else.

Melodyne: It is an audio editor with a range of pitch and time correction. Melodyne represents audio as actual notes rather than as an amplitude waveform. The outcome is MIDI file. (Celemony Melodyne3 Audio Editor 2006).

MIDI: Music Instrument Digital Interface (MIDI). It is a protocol developed during 1980s. It allowed music devices to transmit codes that described sound. (Webster 2002).

Mikrophonie: A composition from Stockhausen (1964-65). The microphone is used actively as a musical instrument.

Mixtur: Stockhausen's work for orchestra, sine-wave generators and ring modulators surrounding the audience. Universal Editions (1967).

Mompanin: Rural region nearby Queretaro city.

Musique concrete**:** It **"**was coincieved as an 'acousmatic' practice, an approach to composition I which recorded environmental sounds were to be treated as non-signifying objects" **(**Akiyama 2010).

Nearctic: The Nearctic encompasses Greenland, Canada, the United States and parts of Mexico. It ranges from Arctic tundra and evergreen forests to grasslands and deserts.

Neotropical: Relating to or denoting a zoogeographical region comprising Central and South America, including the tropical southern part of Mexico and the Caribbean

Norteño: Popular music from northern Mexico with a fast tempo and usually featuring an accordion, bajo sexto, drums, percussion and vocals.

Nuevo Leon: Mexican state located to the north. A border state with Texas and Mexico.

Pan: the term used to describe sound motion from one speaker to the other.

Periphonic: It involves speakers at different heights so as to add a vertical distribution of sound to the horizontal one of stereophony.

Phantom images: A spatial illusion perceived as a space appears to be real, but we are listening to an illusion in stereo or multi- channel space produced through the projected sound of from two or more loudspeakers. (Barrett 2002).

Pipa: It is a four-stringed *Chinese* musical instrument, belonging to the plucked category of instruments. Sometimes called the *Chinese* lute.

PureData: PuredData was created by engineer Miller Puckette. Pure Data is a programming language for electronic music. Creating music on a computer is technically referred to as DSP (digital signal processing). (Kreidler 2009).

Prescriptive: In musical notation, prescriptive refers to using methodologies that alludes to the musician to create a sound. (Seeger 1958)

Psychoacoustic: The branch of psychology concerned with the perception of sound and its physiological effects.

Tape: It is fixed media of sound recorded on a magnetic tape. Nowadays with digital technology the term applies for a composition fixed with all its elements a characteristics unalterable.

Terretektorh: Xenakis's orchestral work for 88 musicians. The performance requires at the audience next to the musicians. (1965-1966)

Transducer: It is a device that converts energy from one form to another. In sound it is related to produce vibrations in hard surface such as wood.

Ring modulation: Audio synthesis technique related to a particular procedure of implementing a frequency mixing, performed by multiplying two audio signals.

Ruan: A plucked four instrument from Chinese culture. It resembles somehow to the modern guitar.

Sigmund: An application built-in as an object built-in PureData software. It has been adapted to diverse platforms. It analyzes an incoming sound into sinusoidal components to form a pitch estimate. (Description found it on PureData).

Soundscape: The sounds content from a landscape (Pijanowski & et al 2011).

Sonic: Adjective of or relating to sound.

Spear: Sinusoidal Partial Editing Analysis and Resynthesis. It is a software developed by Michael Klingbeil. SPEAR is an application for audio analysis, editing and synthesis. The analysis procedure (which is based on the traditional McAulay-Quatieri technique) attempts to represent a sound with many individual sinusoidal tracks (partials), each corresponding to a single sinusoidal wave with time varying frequency and amplitude. (Klingbeil 2006).

Spatialization: It is the audio synthesis that allows to create, modify the aural perception of an acoustic spaces and spatial properties of sounds. (Peteres & et al 2011).

Spatium: It is a set of free, open source and modular software tools for sound spatialization. (Pehna 2013).

Sweet spot: The ideal physical position of a listener. “In stereo reproduction, the sweet spot is equidistant from the two loudspeakers and set back to form an angle of 60º.” (Kendall 2010).

Quadraphonic: Relating to, or using four channels for the transmission, recording, or reproduction of sound.

Queretaro: An inland state of central Mexico.

Visiones Sonoras: It is a musical festival in the city of Morelia. It is advocated to new music that uses novel technology.

Vectorial: Adjective of, or relating to, or characterized by a vector.

Yangquin: Instrument that is an adaptation of the Persian Santur. Introduce in Chine during the Ming Dynasty.

Zapoteco: It is a language that belongs to a group of around closely related indigenous Mesoamerican languages. It is spoken by the Zapotec people from the southwestern-central highlands of Mexico

Zheng: Also known as a Chinese zither. It is a Chinese plucked string instrument.

Bibliography:

- Akiyama, Mitchell. “Transparent Listening: Soundscape Composition's Objects of Study.” *RACAR: Revue D'art Canadienne / Canadian Art Review*, vol. 35, no. 1, 2010, pp. 54–62.

- Amacher, Maryanne. “Maryanne Amacher.” *Maryanne Amacher :: Foundation for Contemporary Arts*, 1998, www.foundationforcontemporaryarts.org/recipients/maryanne-amacher. (last accessed January 25th 2019).

- Barrett, Natasha. “Spatio-musical composition strategies.” *Organised Sound*, 7, (2002). pp 313-323 doi:10.1017/ S1355771802003114

- Battier, Marc. Describe, “Transcribe, Notate: Prospects and problems facing electroacoustic music.” *Organised Sound* / Volume 20 / Special Issue 01 / April 2015, pp 60 - 67 DOI. Published online: 05 March 2015

- Behrman, David. “What Indeterminate Notation Determines.” *Perspectives of New Music,* Vol 3 No. 2 (Spring - Summer, 1965), pp. 58-73

- Braasch, Jonas, et al. “A Loudspeaker-Based Projection Technique for Spatial Music Applications Using Virtual Microphone Control.” *Computer Music Journal*, vol. 32, no. 3, 2008, pp. 55–71.

- Burt, Warren. “Listening to Ten Tape Pieces by Kenneth Gaburo.” *Perspectives of New Music*, vol. 33, no. 1/2, 1995, pp. 148–161.

- Cage, John. “Cage Silence.” *Hearing Voices*, August 1992. Transcript of the interview with John Cage in the film “Ecoute” (Listen) by Miroslav Sebestik. Web publish 3 Feb. 2010, hearingvoices.com/2009/09/cage-silence/. (last accessed May 4, 2019).

- Camilleri, Lelio. “Shaping Sounds, Shaping Spaces.” *Popular Music*, vol. 29, no. 2, 2010, pp. 199–211.

- “Celemony Melodyne3 Audio Editor.” *Computer Music Journal*, vol. 30, no. 4, 2006, pp. 132–133.

- Cope, David. *Notes*, vol. 36, no. 4, 1980, pp. 987–988., www.jstor.org/stable/939787.

- Dennis, Brian. “Xenakis's 'Terretektorh' and 'Eonta'.” *Tempo*, no. 82, 1967, pp. 27–29.

- Dooling, Robert J. “Ontogeny of Song Recognition in Birds.” *American Zoologist*, vol. 22, no. 3, 1982, pp. 571–580.

- Dunn, David D., and James P. Crutchfield. “Entomogenic Climate Change: Insect Bioacoustics and Future Forest Ecology.” *Leonardo*, vol. 42, no. 3, 2009, pp. 239–244.

- Dunn, David. “Speculations: On the Evolutionary Continuity of Music and Animal Communication Behavior.” *Perspectives of New Music*, vol. 22, no. 1/2, 1983, pp. 87–102.

- Dunn, David. *David Dunn :: Foundation for Contemporary Arts*, 2012 www.foundationforcontemporaryarts.org/recipients/david-dunn. (last accessed April 1st 2019).

- Dunn, David. *The Sound of Light in Trees: Bark Beetles and the Acoustic Ecology of Pinyon Pines*. EarthEar. 2006.

- Dunn, David. "Wilderness as Reentrant Form: Thoughts on the Future of Electronic Art and Nature." *Leonardo*, vol. 21, no. 4, 1988, pp. 377–382.

- Dunn, David, and Michael R. Lampert. "Environment, Consciousness, and Magic: An Interview with David Dunn." *Perspectives of New Music*, vol. 27, no. 1, 1989, pp. 94–105.

- Dunn, David, and René Van Peer. "Music, Language and Environment." *Leonardo Music Journal*, vol. 9, 1999, pp. 63–67.

- Feisst, Sabine. "The American Southwest as Muse: Maggi Payne's Sonic Desertscapes." *Contemporary Music Review*, vol. 35, no. 3, June 2016, pp. 318–335. *EBSCOhost*, doi:10.1080/07494467.2016.1239384.

- Fenn, John. "The Building of Boutique Effects Pedals—The 'Where' of Improvisation." *Leonardo Music Journal*, vol. 20, 2010, pp. 67–72.

- Henke, Robert. "Granulator II." *Granulator by Robert Henke*, Ableton, Dec. 2016, www.monolake.de/technology/granulator.html.

- Gauthier, Philippe-Aubert, and Philippe Pasquier. "Auditory Tactics: A Sound Installation in Public Space Using Beamforming Technology." *Leonardo*, vol. 43, no. 5, 2010, pp. 426–433.

- Hoose, Shane. "Creating Immersive Listening Experiences with Binaural Recording Techniques." *College Music Symposium*, vol. 55, 2015.

- Hofstetter, Richard W, David D. Dunn, Reagan McGuire, and Kristen A. Potter. "Using Acoustic Technology to Reduce Bark Beetle Reproduction." *Pest Management Science*. 70.1 (2014): 24-27.

- Hron, Terri. Useful Scores: Multiple formats for electro acoustic performers to study, rehearse and perform. *Organised Sound* / Volume 19 / Special Issue 03 / December 2014, pp 239 - 243 DOI: 10.1017/S1355771814000223, Published online: 13 November 2014

- Hubble, L. Roy. "U&I / Arboretum Systems MetaSynth for Mac OS." *Computer Music Journal*, vol. 22, no. 4, 1998, pp. 87–88.

- Hünniger, Martin. (2015). The Audio-Granulator. Acta Acustica united with Acustica. 101. 1-6. 10.3813/AAA.918817.

- Ingram, David. "'A Balance That You Can Hear': Deep Ecology, 'Serious Listening' and the Soundscape Recordings of David Dunn." *European Journal of American Culture*, vol. 25, no. 2, June 2006, pp. 123–138. *EBSCOhost*, doi:10.1386/ejac.25.2.123/1.

- Jaap Blonk, and René Van Peer. “Sounding the Outer Limits.” *Leonardo Music Journal*, vol. 15, 2005, pp. 62–68.

- Johnson, Colin G. “Exploring Sound-Space with Interactive Genetic Algorithms.” Leonardo, vol. 36, no. 1, 2003, pp. 51–54.

- Kendall, Gary S. “Spatial Perception and Cognition in Multichannel Audio for Electroacoustic Music.” *Organised Sound*, vol. 15, no. 3, 2010, pp. 228–238., doi:10.1017/S1355771810000336.

- Kendall, Gary S. “The Decorrelation of Audio Signals and Its Impact on Spatial Imagery.” *Computer Music Journal*, vol. 19, no. 4, 1995, pp. 71–87.

- Keim, Brandon. "Decoding nature’s soundtrack.” In *The Eye of the Sandpiper: Stories from the Living World*, 37-44. Ithaca; London: Cornell University Press, 2017.

- Klingbeil, Michael. “S P E A R.” *SPEAR Homepage*, 2006, www.klingbeil.com/spear/. (last accessed February 21, 2019).

- Krause, Bernie. “Transcript of ‘The Voice of the Natural World.’” *TED*, May 2014. www.ted.com/talks/bernie_krause_the_voice_of_the_natural_world/transcript#t-156303. (last accessed March 1st 2019).

- Kreidler, Johannes. “Programming Electronic Music in Pd.” *Programming Electronic Music in Pd*, www.kreidler-net.de, 27 Jan. 2009, www.pd-tutorial.com/english/index.html. (last accessed April 25th 2019).

- Malham, David G., and Anthony Myatt. “3-D Sound Spatialization Using Ambisonic Techniques.” *Computer Music Journal*, vol. 19, no. 4, 1995, pp. 58–70.

- McClure, Christopher J. W., et al. “A Multi-Scale Analysis of Competition between the House Finch and House Sparrow in the Southeastern United States - Análisis De Competencia En Múltiples Escalas Entre *Carpodacus Mexicanus* y *Passer Domesticus* En El Sureste De Estados Unidos.” *The Condor*, vol. 113, no. 2, 2011, pp. 462–468.

- McKinnon, Dugal. “Dead Silence: Ecological Silencing and Environmentally Engaged Sound Art.” *Leonardo Music Journal*, vol. 23, 2013, pp. 71–74.

- Mitilineos, Stelios & POTIRAKIS, Stelios & Tatlas, Nicolas-Alexander & Rangoussi, Maria. (2018). A Two-Level Sound Classification Platform for Environmental Monitoring. *Journal of Sensors*. 2018. 1-13. 10.1155/2018/5828074

- Murphy, Damian. “Spatial Audio Measurement, Modeling and Composition.” *Leonardo*, vol. 39, no. 5, 2006, pp. 464–466.

- Oliveira, João Pedro, and Pehna, Rui. Spatium, uma abordagem modulare e open source ao software para esoacuakuzação, *IV Seminário Música Ciência Tecnologia: Fronteiras e Rupturas*. 2012, S.Paulo

- Oliveira, João Pedro, and Pehna, Rui. SPATIUM, TOOLS FOR SOUND SPATIALIZATION, *Proceedings of the Sound and Music Computing Conference 2013,* SMC 2013, Stockholm, Sweden

- Otondo, Felipe, and Natasha Barrett. "Creating Sonic Spaces: An Interview with Natasha Barrett." *Computer Music Journal*, vol. 31, no. 2, 2007, pp. 10–19..

- Penha, Rui. "Spatium." *Spatium*, 2013, spatium.ruipenha.pt (last accessed February 28th 2019)

- Peteres, Nils, et al. "Current Technologies and Compositional Practices for Spatialization: A Qualitative and Quantitative Analysis." *Computer Music Journal*, vol. 35, no. 1, 2011, pp. 10–27.

- Pijanowski, Bryan C., et al. "Soundscape Ecology: The Science of Sound in the Landscape." *BioScience*, vol. 61, no. 3, 2011, pp. 203–216.

- Reardon, Sara. "Listening to the Landscape." *New Scientist*, vol. 213, no. 2857, Mar. 2012, p. 52. *EBSCOhost*,search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=73908241&site=ehost-live

- Reynolds, Roger. 2005. Mind models: new forms of musical experience. New York: Routledge

- Roads, Curtis. "Automated Granular Synthesis of Sound." *Computer Music Journal*, vol. 2, no. 2, 1978, pp. 61–62.

- Roads, Curtis. "Introduction to Granular Synthesis." *Computer Music Journal*, vol. 12, no. 2, 1988, pp. 11–13.
- Robjohns, Hugh. "You are surrounded." *Sound on Sound,* Published in SOS October 2001.

- Rothenberg, David, and Ben Neill. "Playing into the Machine: Improvising across the Electronic Abyss." *Leonardo Music Journal*, vol. 20, 2010, pp. 19–20.

- Schachter, Daniel. "Modulacion de textura y espectro en el sonido de las aves latinoamericanas aplicada a la composición musical electroacustica." *Canto electroacústico: aves latinoamericanas en una creación colaborativa*. 1a ed. Madrid ; Barcelona: Fundación Telefónica ; Ariel, 2012. xv, 161 p. Fundación Telefónica; pages 66-80.

- Seeger, Charles. "Prescriptive and Descriptive Music-Writing." *The Musical Quarterly*,Vol. 44, No. 2 Apr, (1958), pp. 184-195. Published by: Oxford University Press

- Shaff, Stanley. "AUDIUM: Sound-Sculptured Space." *Leonardo*, vol. 35, no. 3, 2002, pp. 248–248.

- Solomos, Makis. "The Complexity of Xenakis's Notion of Space." In Martha Brech et Ralph Paland, Technische Universität, Berlin, juillet 2014, publiée dans Martha Brech, Ralph Paland (éd.), Kompo-sition für hörbaren Raum. Die frühe elektroakustische Musik und ihre Kontexte / Compositions for Audible Space. The Early Electroacoustic Music and its Contexts, Bilefeld, transcript Verlag, 2015. p. 323-337., 2015, 10.14361/9783839430767-020. hal-012028

- Sterne, Jonathan. “Soundscape, Landscape, Escape.” *Soundscapes of the Urban Past: Staged Sound as Mediated Cultural Heritage*, edited by Karin Bijsterveld, Transcript Verlag, Bielefeld, 2013, pp. 181–194.

- Trochimczyk, Maja. “From Circles to Nets: On the Signification of Spatial Sound Imagery in New Music.” *Computer Music Journal*, vol. 25, no. 4, 2001, pp. 39–56.

- Truax, Barry (1992) “Musical Creativity and Complexity at the Threshold of the 21st Century”. *Interface*, 21:1, pages 29-42, DOI: 10.1080/09298219208570598

- Truax, Barry. “Acoustic Communication.” Second edition. Westport, Connecticut: Greenwood Publishing, 2001. p 237.

- Truax, Barry. “Composition and Diffusion: Space in Sound in Space.” *Organised Sound*, vol. 3, no. 2, 1998, pp. 141–146.

- Truax, Barry. “Composing with Real-Time Granular Sound.” *Perspectives of New Music*, vol. 28, no. 2, 1990, pp. 120–134.

- Truax, Barry. “Paradigm Shifts and Electroacoustic Music: Some Personal Reflections.” *Organised Sound*, vol. 20, no. 1, 2015, pp. 105–110., doi:10.1017/S1355771814000491.

- Truckenbrod, Joan. “A New Language for Artistic Expression: The Electronic Arts Landscape.” *Leonardo. Supplemental Issue*, vol. 1, 1988, pp. 99–102.

- Tuomas Eerola. (2011) “Are the Emotions Expressed in Music Genre-specific? An Audio-based Evaluation of Datasets Spanning Classical, Film, Pop and Mixed Genres.” *Journal of New Music Research* 40:4, pages 349-366.

- Webster, Peter. “Historical Perspectives on Technology and Music.” *Music Educators Journal*, vol. 89, no. 1, 2002, pp. 38–54.

- Yakutchik, Maryalice. “Composer Records Beetles to Mark Climate Change.” *NPR*, NPR, 10 Mar. 2008, www.npr.org/templates/story/story.php?storyId=88074919. (last accessed May 25th 2019).

- Verboom, Willem, and Cornelis Heij. Bird Vocalizations: “The House Sparrow (Passer Domesticus).” *ResearchGate*, 2018, doi:10.13140/RG 2.2.27778.17601. (last accessed on April 28th 2019).