California Institute of the Arts

Beyond the Paradigm of Sound: Aesthetics and Methodologies in Contemporary Sonic Art Practices

by

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Abstract

The development of computational tools and media has enabled Digital Arts to become a rising topic in enquiry. It integrates the utilization of technology in art practices, opening up endless possibilities for the discovery of new and profitable synergies at the frontiers of cross-disciplinary collaborations. *Beyond the Paradigm of Sound: Aesthetics and Methodologies in Contemporary Sonic Art Practices* is an introspective to new methodologies venturing beyond the sonic domain in contemporary sonic art practice. Divided into three major approaches, namely *Data to Sonic Art*, *Algorithm to Sonic Art*, and *Hardware to Sonic Art*, the new creative processes are presented with discussions of project implementations, outlining thought processes, motivations, overviews of the systems, and workflows. The key objective is to create new works that excite our sensibilities. In doing so, this thesis proposes the use of standardized and accessible components that develop tools to facilitate the creation of stylistically individualized works.

Acknowledgments

This thesis would not have been possible without my mentor, Dr. Ajay Kapur, for his guidance, dedicated support, and encouragement to attaining my goals during my graduate tenure. I would also like to thank Dr. Jordan Hochenbaum for his valued collaboration in the realization of *VIE* and *Trièdre*, as well as Dr. Owen Vallis for his dedication and assistance. In addition, I would also like to thank Kay Adams, and Kameron Christopher, who have been with me through this journey all along and supported me through every project I undertake. Finally, I would like to thank my parents for their continual support in my creative endeavors for if not them, this fruitful graduate tenure that led me to meeting some of the greatest minds in the field of music technology would have not been made possible.

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Chapter 1

Introduction

Sonic art, or Sound art, is the exploration of dynamics relating to the experiential progress of sound with a predominant focus on notions of hearing, listening, "poetistic" perception, and aesthetic appreciation by way of various artistic applications, methodologies and practices. Typically, these are expressed through interdisciplinary processes that result in multimedia presentations and hybridized forms [1].

There has been a significant shift in the aesthetics of sonic art practices since the advancement of audio technology beginning in 1945. This began with Pierre Schaffer's *Programme de la Recherche Musicale (PROGREMU)* that manipulated tape in the late forties [2][3]; Karlheinz Stockhausen's *Gesang der Jünglinge* that used five channels and spatialization techniques to create spatial effects[4], and Edgard Varèse's *Poème électronique* that incorporated projections, and location specific sound design during the mid-late fifties [5]; David Tudor's repertoire created by electronic circuits and emergent behaviors, and Iannis Xenakis's *Unité Polyagogique Informatique CEMAMu (UPIC)* system that realized his "drawn" compositions and *Formalized Music* that integrated statistics, and physics in music in the seventies [6]. It is evident that the introduction of new technologies extends the aesthetics of performance and composition in sonic art practice.

The compositional process of sound art work has often been guided by pre-conceived inspirations in conjunction with computational thinking. The predominant focus of these processes has always been on sound, even though the processes are often interdisciplinary. However, the disciplines applied are often only within the field of the arts. In order to facilitate and free the mind from any musical, cultural, or artistic clichés, the use of metaphors through different métiers, mediums, and their perspectives can lead to the discovery of new aesthetics in composition and performance in contemporary sonic art practice. In San Francisco (1996), Brian Eno referenced *Metaphors We Live By* by George Lakoff and Mark Johnson. Eno mentions that the use of different metaphors for a situation will change one's perspective towards the situation [7]. The metaphorical representation through different métiers, outside the arts, will evoke different insights to sound, uncovering vibrant dynamics that may be clouded by our preconceived notions of sound. These representations may also extend to influence the creation of different timbres and textures, as well as rhythmic structures that one may overlook during conventional processes. *+65,* a sound installation discussed in Section 4.3.2 is a prime example of this.

In addition, researchers in the sound domain have urged for creative approaches beyond the domain of sound. Notable composers and their influential theories include: Luigi Russolo's *The Art of Noises*, Pierre Schaffer's *Solfège de l'objet*, Lejaren Hiller's *Illaic Suite for String Quartet*, John Chowning's *FM Theory & Applications*, Iannis Xenakis's *Formalized Music*, Horacio Vaggione's micromontage compositions, and Curtis Road's *Microsounds*.

1.1 Aims / Objectives

"The power of the computer to help us construct the internal architecture of sounds from first principles allows us to broaden the concept of composer to include the notion of sonic sculpture. [8]" – On Sonic Art, Trevor Wishart

Beyond the Paradigm of Sound: Aesthetics and Methodologies in Contemporary Sonic Art Practice sets out to present three methodologies for compositional processes in sonic art practice that are decentered from the predominant focus on the notions of sound. These methodologies shift away from the actual creation of sound and towards their work processes, of which sound is their by-product. The thesis should not be mistaken as a manual for the methodologies presented. It is a record of the exploration of the different possible creative processes in contemporary sonic art practice.

In addition, the thesis proposes the need for the use of technology because of its integration in our daily lives. The utilization of technology should be strategic to create works of artistic value and motivation, and should steer away from "technology for technology's sake". As contemporary sonic art practice has evolved significantly over a decade with the advent of digital technology, this thesis documents the converging processes of deriving methodologies and techniques through the utilization of standardized components (such as low-level programming languages, electrical components and hardware) while developing tools (such as specialized programming languages, software and custom interfaces) for implementation in personal artistic practices to create stylistically individualized projects. These tools are meant to assist the extension of current practices, and also encourage the development of new ones.

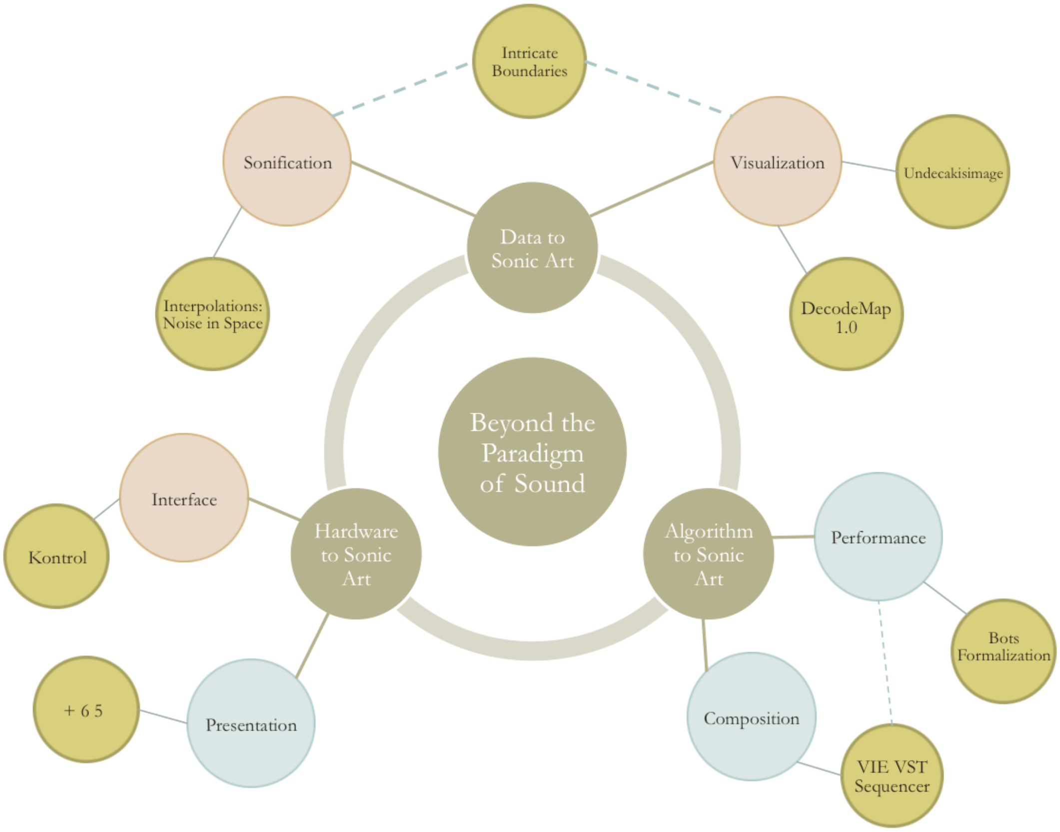

Figure 1: Overview

1.2 Outline

The methodologies in this thesis are classified in three main categories: Data to Sonic Art, Algorithm to Sonic Art and Hardware to Sonic Art (Figure 1). Each category contributes a process in the practice of sonic art beyond the sound paradigm. While in practice, these methodologies are often related and coexist within a single composition, they are discussed here independently in no particular order.

Chapter 2 introduces the methodology of using data. It centers around different techniques to obtain, transform and parse data, focusing on Sonification and Visualization. While *Interpolations: Noise in Space* focuses on the play of computer networks (WANs/LANs) as a source for sonification, *Undecakisimage* and *Decode Map 1.0* explore data visualization in a spatial augmented reality. The chapter concludes with improvisatory composition *Intricate Boundaries,* (commissioned by the Sonorous Duration Festival in Singapore), which uses techniques unifying the compositional elements above. Chapter 3 looks through the genetic algorithm, *Conway's Game of Life,* for the formalization of structures in different time scales. The research in the application of interfacing human interaction with Computers leads to the design of two systems: *Bots Formalization*, used specifically for live performance, and *VIE*: *Game of Life VST sequencer*, a tool with user-defined variables. Chapter 4 shows the applications of custom-designed hardware to discover new aesthetics by setting up new environments for interaction. *Kontrol* showcases the use of readily available microcontrollers, sensors, and machine learning to uncover emerging form and structure in gestures. *+ 6 5* explores the metaphor of an ecological system in the form of sound installation: a radical environment featuring 40 freely suspending speakers with 40 channels of discrete audio.

In all, the projects present the implementations of methodologies through the discussion of creative processes and aesthetics beyond the paradigm of sound for applications in contemporary sonic art practice. The use of these methods in conjunction with each other create a diverse range of hybridized projects that are interrelated with each other, as shown in Figure 1. The yielded result of this larger scope is what the thesis aims to encompass.

Chapter 2

Data To Sonic Art

"The craft of composition is important to auditory display design. For example, a composer's skills can contribute to making auditory displays more pleasant and sonically integrated and so contribute significantly to the acceptance of such displays. There are clear parallels between the composer's role in AD and the graphic artist's role in data visualization. Improved aesthetics will likely reduce display fatigue. Similar conclusions can be reached about the benefits of a composer's skills to making displays more integrated, varied, defined, and less prone to rhythmic or melodic irritants." – Gregory Kramer, [9].

This chapter presents the use of data in the contemporary sonic art practices. While the applications of sonification and visualization are not new in this field, the advancement in technology has shifted its implementation and aesthetics in recent times. Selected works are presented to discuss different applications and aesthetics, driven by the sonification and visualization of data. The first application, *Interpolations: Noise In Space,* presents the audification and parametrical mapping of data to sonic parameters. *Undecakisimage* explores Futurism through an interactive multimedia installation, utilizing projection mapping and visual music. *DecodeMap 1.0* is a projection-mapping tool created in *Max*[1] for a live performance setting and was used in the production, *Decoding Dreams.* Finally, *Intricate Boundaries* unify the techniques of sonification and visualization into an integrated performance of sounds and moving images.

2.1 Motivation

In this age of information explosion, advancements in information technology have significantly decreased latency while acquiring information. This increased accessibility has furthered our abilities to use this information in whatever way we demand. As the source of information could

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[1] http://www.cycling74.com

originate anywhere from the individual contributor to government authorized sources, information acquired is sometimes inconsistent and therefore should be viewed neutrally. For instance, public census data, or even online databases and references can be considered information sources. Where are the actual sources of this information? How accurate is it? Is it even possible for it to be presented in a non-subjective manner? When it is all boiled down, the contributor of the information plays a crucial role in how the information is communicated- the wording, presentation, and selective additions and omissions affects how the actual information is conveyed by those who are absorbing it. Therefore instead of treating any information in a subjective figurative manner, it is ideal to approach it in a neutral, non-biased manner to explore the form and structure embodied within it. The “absolute” use of data, or using data in the most objective neutral way possible allows latent structure to emerge. By casting these structures, augmented sonic and visual realms of information can be created. Upon examination at a lower level of abstraction, information collapses into numbers and data, which ultimately are 0’s and 1’s. Thus, organizing the “data” differently yields new meanings within them.

Taking these ideas into consideration, the following two sections focus on processing data as sonification through *Interpolations: Noise in Space*, and visualizing data through *Undecakisimage*.

2.2 Sonification

Sonification is the representation or perception of information or data using non- speech audio [10]. Most experiments in data sonification, explored by International Community for Auditory Display (ICAD), focus on scientific research, and practices using auditory perception to present and analyze data through sonic parameters such as temporal, amplitude, and frequency. An example of sonification is a Geiger counter. The rate of clicking of a counter conveys the level of radiation in the immediate vicinity of the device, while the timbre of the sound represents the intensity of radiation [10]. While there are several different techniques to formalize data as auditory displays, only the following techniques are relevant in this scope of discussion:

- Audification: The technique of making sense of data by interpreting any kind of one-dimensional signal (or of a two-dimensional signal-like data set) as amplitude over time and playing it back on a loudspeaker for the purpose of listening [9].

- Parameter Mapping: The mapping of information with auditory parameters for the purpose of data display [10].

Other techniques omitted in this discussion include *Auditory Icons, Earcons, Stream-Based Sonification,* and *Model-Based Sonification*[2].

2.2.1 Background

The application of sonification in music began as early as 1960. Often, the data used for sonification has no direct relationship with music. More often, the sonification of these data involves the transformation of inaudible data into audible sonic materials. The following related works are selected based on their relevance to the techniques discussed above.

John Cage's *Atlas Eclipticals* (1962) used a star-chart atlas, *Atlas Eclipticals,* drawn by Antonín Bečvář (astrologer) [11], as the basis of his composition, superimposing musical staves over the star charts to create the score as shown in Figure 2.

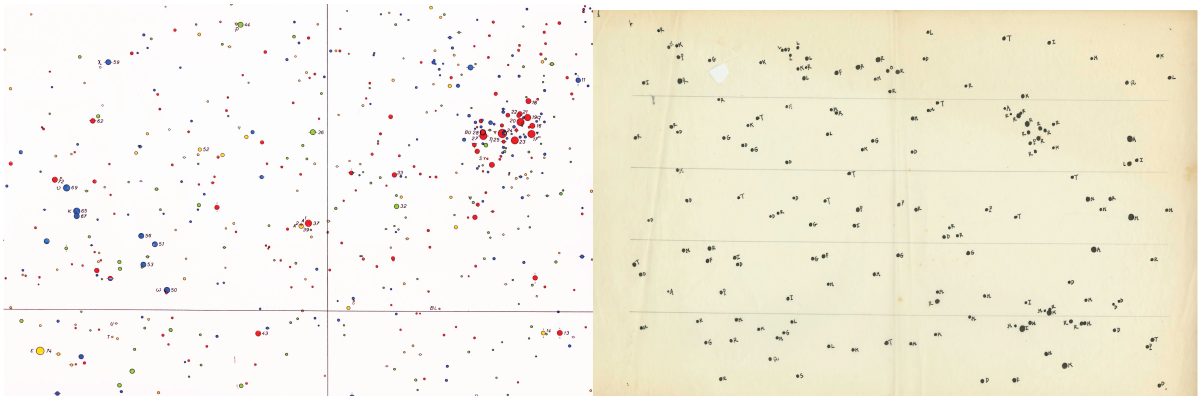

Figure 2: Becvar's (top) and Cage's Atlas Eclipticalis Sketch (bottom)

Later in 1978, Alvin Lucier composed the piece *Clocker* using data from skin resistors [12]. In 1990, David Rosenboom formalized electroencephalography (EEG) data in a self-organizing, dynamic system. Brainwave analysis techniques are used to track shifts of attention and changes in the state of consciousness of a solo performer that were concurrent with

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[2] Further reading: The Sonification Handbook, edited by Thomas Hermann, Andy Hunt and John G. Neuhoff (http://sonification.de/handbook/)

specifically identified musical events. The results are used in a feedback structure to influence the evolution of an emerging musical form, which is unique in each performance [13]. A more recent compositional example is *Guernica* by Potard. The piece sonifies war and world population data from 1 A.D. to 2006 A.D. *Guernic* uses sound spatialization to indicate the geographical locations of wars from the viewpoint of London. World population is sonified continuously in the piece by controlling the pitch of a drone sound. Other sounds are used to mark the start of millenniums and to indicate if a particular war was a civil war [14].

Interpolations: Noise in Space acquires data on the fly and present sonification in a live performance setting. It sets the definition of sonification to focus on the generation of sonic materials, and may provide insight into the data and knowledge generation about the system.

2.2.2 Interpolations: Noise in Space

Interpolations: Noise in Space is a series of audio-visual compositions that explore the sonification of data streams and visualization of sonic material, focusing on the use of inherent network qualities to induce emergent behaviors in data streams through feedback. Contrary to site-specific electroacoustic compositions that emphasize the acoustic characteristics of a location, *Interpolations* extends the play beyond the actual space itself to its local wireless network. This collaboration features multimedia artist Kameron Christopher (USA).

The piece utilizes a customized system that sends and receives audio signals over a network, specifically between two laptop musicians shown in Figure 3. The two machines are constantly sending and receiving data from one another, inducing a feedback loop. The seed of the system is a transient pulse.

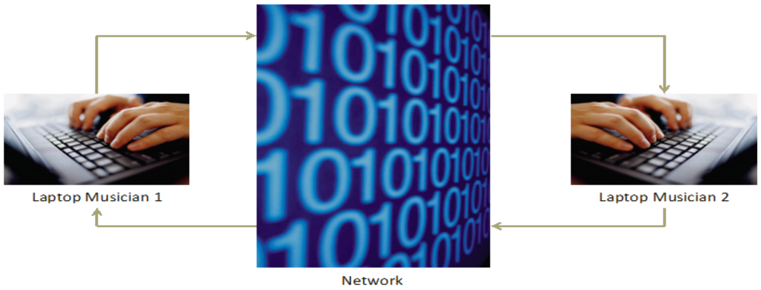


Figure 3: Interpolations – Overview

Figure 4 shows the flow of data within an individual machine. Both machines use the same flow. Audio signals are converted to data with a windowing frame of a varying size (controlled by the performers). The network exchanges these data through a User Datagram Protocol (UDP) connection. The receiver receives the streams of data and converts them into an audio signal with another windowing frame of a varying size independent from the sender.

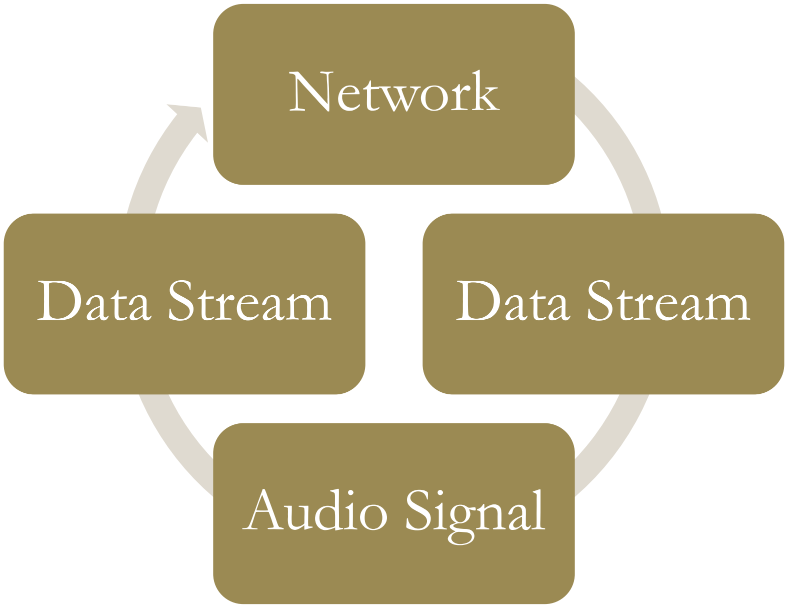
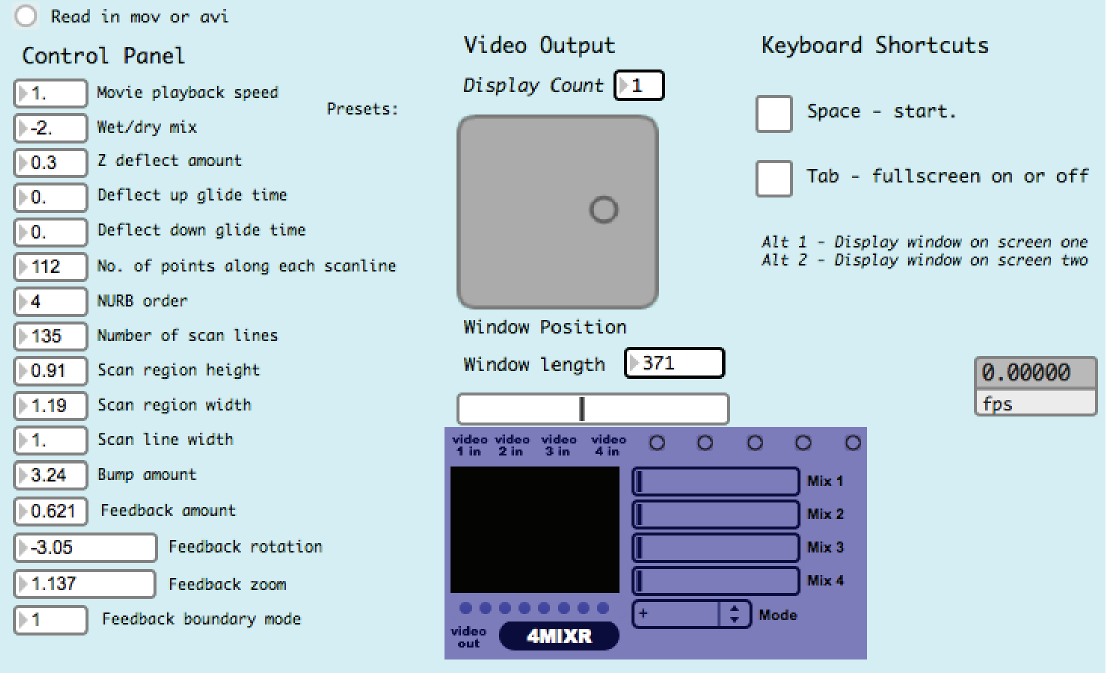


Figure 4: The flow of data

Using a UDP connection, the piece utilizes the overflow and underflow of data streams as a filter for the audio. Below are figures of *Max* patches for the compositions:



Control Panel

1. Movie playback speed
-2. Wet/dry mix
0.3 Z deflect amount
0. Deflect up glide time
0. Deflect down glide time
112 No. of points along each scanline
4 NURB order
135 Number of scan lines
0.91 Scan region height
1.19 Scan region width
1. Scan line width
3.24 Bump amount
0.621 Feedback amount
-3.05 Feedback rotation
1.137 Feedback zoom
1 Feedback boundary mode

Display Count 1

Window Position

Window length 371

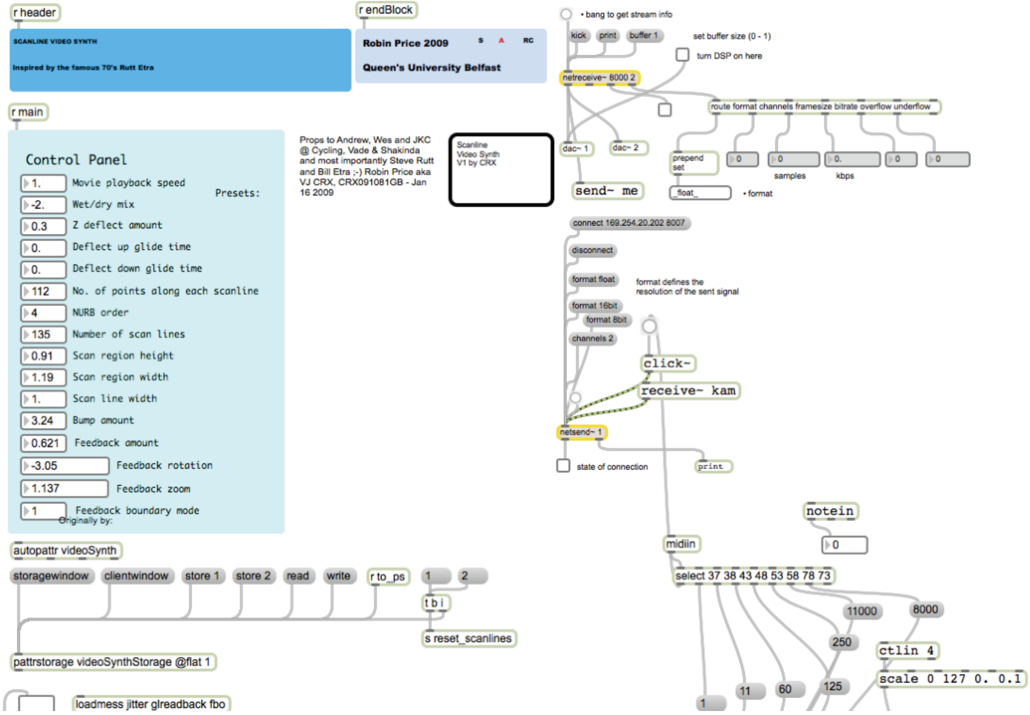
☐ Space - start.

☐ Tab - fullscreen on or off

Alt 1 - Display window on screen one
Alt 2 - Display window on screen two

0.00000 fps

Figure 5: User Interface for Performance



Control Panel

1. Movie playback speed
-2. Wet/dry mix
0.3 Z deflect amount
0. Deflect up glide time
0. Deflect down glide time
112 No. of points along each scanline
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1.19 Scan region width
1. Scan line width
3.24 Bump amount
0.621 Feedback amount
-3.05 Feedback rotation
1.137 Feedback zoom
1 Feedback boundary mode

Props to Andrew, Wes and JKC @ Cycling, Vade & Shakinda and most importantly Steve Rutt and Bill Etra ;-) Robin Price aka VJ CRX, CRX091081GB - Jan 16 2009

format defines the resolution of the sent signal

Figure 6: Inside the Patch-1

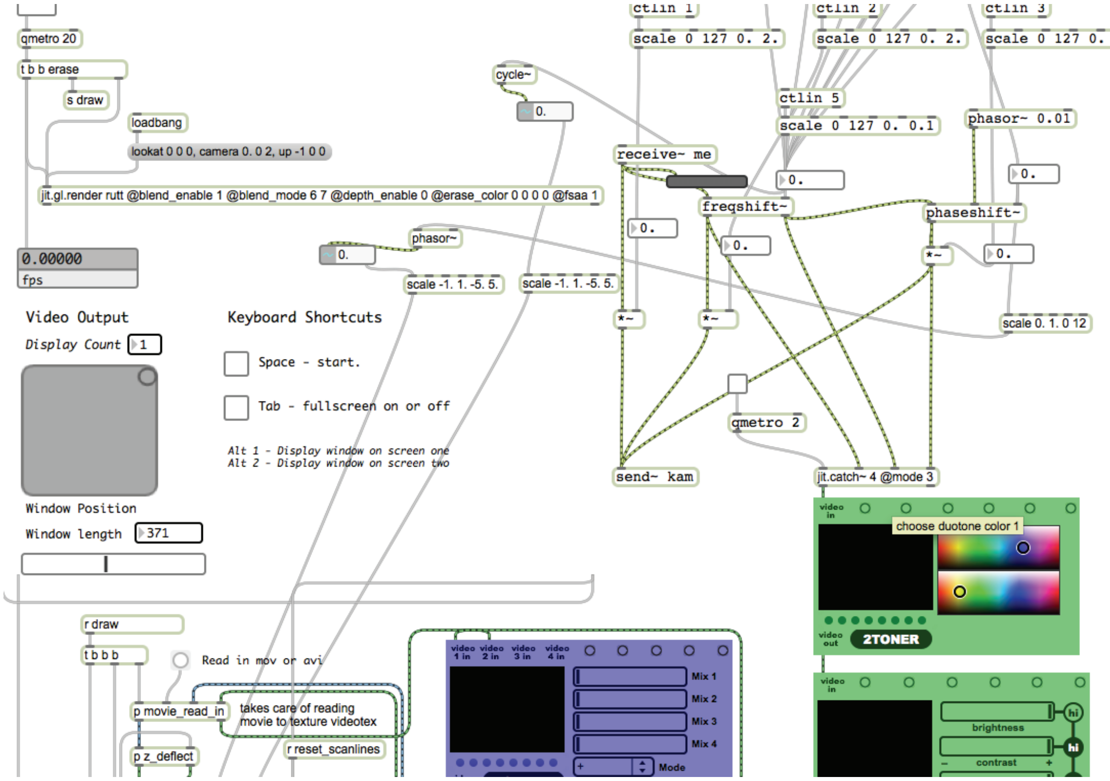

Figure 7: Inside the Patch-2

The piece *SS-0010.110011111011* (Media File 1) marks the outset of this series of compositions, with an emphasis on intuitively generating a rich palette of sonic materials. Following that, *Planar Chaos* (Media File 2) builds upon these techniques, focusing on the control of timbres as well as the compositional form and structure induced by the feedback. *I-II* (Media File 3) (Media File 4) features the almost consolidated performance of intuitive music, spatial acoustics and network. *After Sessions* (Media File 5) removes the performers and establishes itself as a generative music player through the induced feedback between the network. *SS-0010.110011111011*, *I –II,* and *After Sessions* were performed in the same venue. All of this uses the concepts of data to sonic art to realize the composition.

2.3 Visualizations

With the rise in technology in the 20th century, the construction of visual music systems has shifted towards using electro-mechanics and computers. This advancement in audio-visual technology urges and allows for lower-level understanding, while prior works encourage higher abstraction of the relationship between sound and visuals. Norman McLaren directly hand-drew on films to create sounds, introduced in the film, *Pen Point Percussion* in 1951. Laurie Spiegel created Video and Music Program for Interactive Real-time Exploration/ Experience (VAMPIRE) [15]. Artists have also furthered the exploration of the sound-color relationship.

The relationship between music and colors began in the 18th century. It started with the first color organ, *Clavecin Oculaire,* created by Louis Bertrand Castel. The music-color relationships were realized through the association of color with notes by using mechanical systems to build devices that produced visuals to accompany music [16]. Because the color association of notes is subjective, many mapping of colors to notes have been proposed (Figure 8).

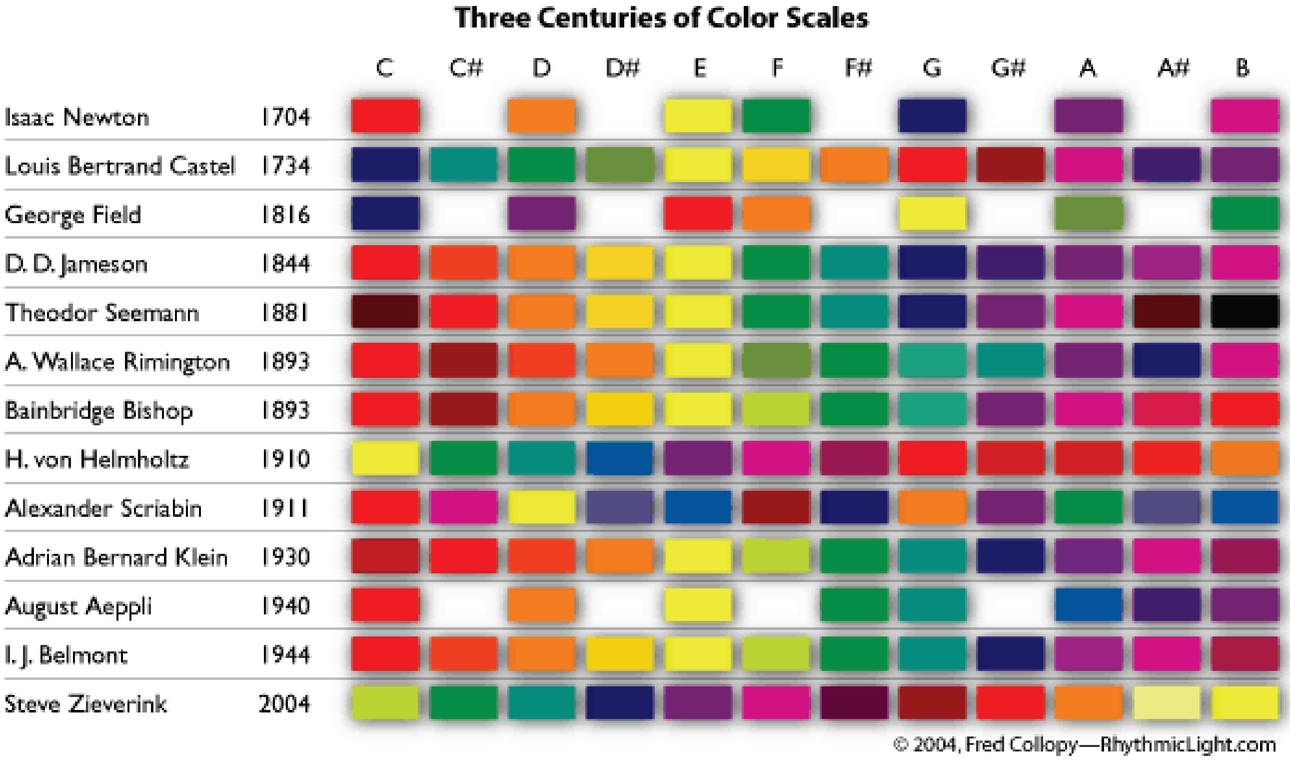

Figure 8: Color Scales that haven been proposed [17].

More recently, artists have gone much further to create interactive music systems, implementing complex video synthesis techniques, and projection mapping. *Projection mapping*, also known as *Spatial Augmented Reality* [18], started in the 60s even though the technique's presence in art and advertisements has only recently increased significantly. *Projection mapping* is essentially the technology to make irregularly shaped objects a display for video projection by spatially mapping an object, which is to be projected on, in specialized software. This allows any desired image to fit onto the surface of the object. *Projection mapping* technique is often used to add extra depth and dimensions, optical illusions, and movements onto static objects [18].

The first known projection mapping is the opening of the *Haunted Mansion* ride in *Disneyland*. Film recordings of singers' heads singing were projected on objects, which created the optical illusion of disembodied heads [19]. Notable *Projection Mapping* include *V Squared Labs* produced *Amon Tobin: ISAM* and *Datsik: Firepower Tour* [20], and *Apparati Effimeri* produced *Vis Elettronica* [21]. *Projection mapping* is often realized in a visual programming environment such as *Quartz Composer*[3], *Processing*[4], and *Max*. Some of the specialized mapping software includes *MadMapper*[5], *Resolume Arena*[6] and *VPT 6.0*[7].

2.3.1 Undecakisimage

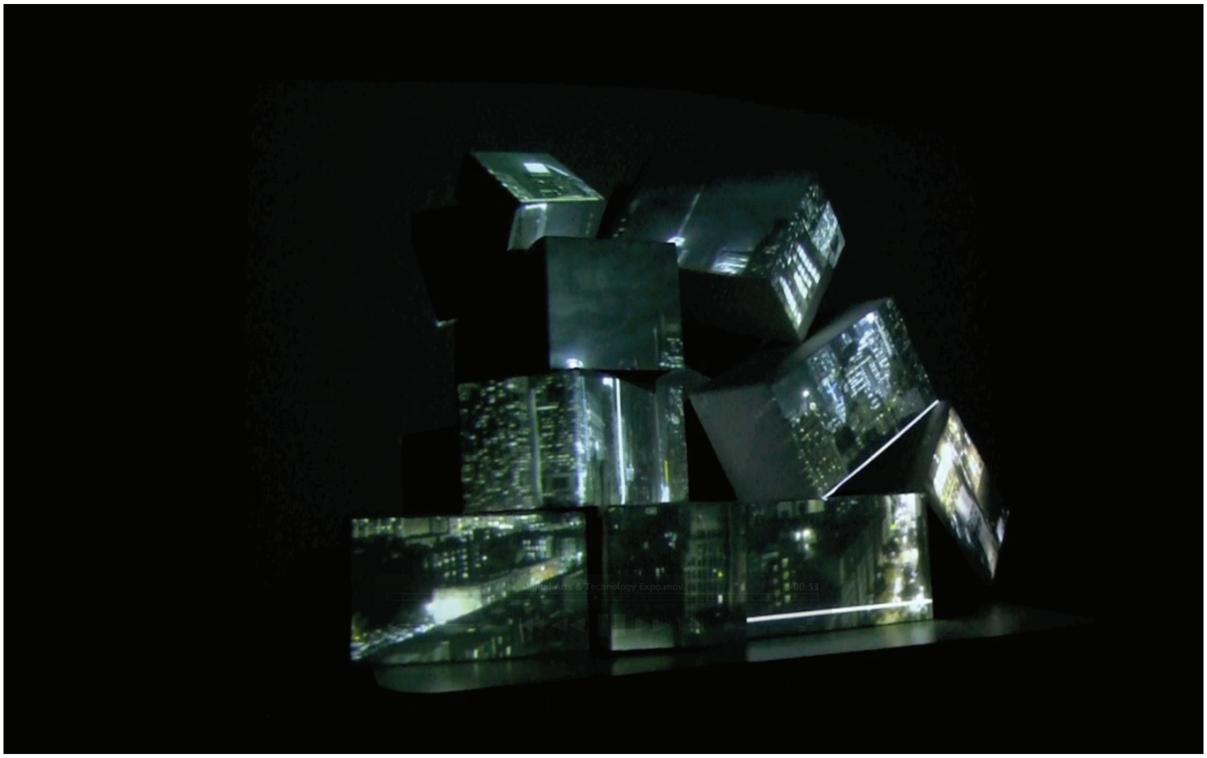

Figure 9: Undecakisimage at the Digital Arts Expo 2012, California Institute of the Arts

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[3] http://developer.apple.com/technologies/mac/graphics-and-animation.html
[4] http://processing.org
[5] http://www.madmapper.com
[6] http://resolume.com/software/
[7] http://hcgilje.wordpress.com/vpt/

Undecakisimage (Media File 6) is an interactive multimedia installation created in collaboration with Kay Adams and Kameron Christopher (Figure 9). The installation features an 11-plane projection mapped sculpture that interacts with the users via a Musical Instrument Digital Interface[8] (MIDI) controller. Inspired by the Futurist movement, the sculpture abstracts the tower of Babel from Fritz Lang's *Metropolis*. This Futurist tower embodies the ideas of a utopic urban environment, which eventually collapses due to the powers of Capitalism. This unbalance and collapse is physically symbolized in the construction of the sculpture, as the sculpture is held together without any reinforcements (i.e. tape or glue), and with a gentle knock could fall over any moment. On the other hand, when the equilibrium of forces is maintained, the structure could stand in this intricately balanced position for millennia. This juxtaposition of forces (both literal and metaphorical) captures the essence of the utopian/dystopian argument, as utopia only exists until the balance is broken, as once the scale is tilted the utopia immediately becomes a dystopia. The skyline projected is a digitally manipulated photograph of New York City, the center of Capitalism. The buildings captured were specifically those related to businesses. The users being able to manipulate these planes in conjunction with sounds, states that in both Capitalism and utopian societies, the power is in the hands of the individual people. Yet when the installation is in "idle" mode, the installation literally shows that when the people are "idle" and non-participatory in matters, the environment will move with free will with those who control the structure of it (i.e., the program in the sense of this installation).

The sounds chosen for this installation are mechanical, shimmering drones, conceived using advanced synthesis techniques in digital signal processing. The projection mapping was realized in *Processing*. This serves as a foundation to understanding the fundamentals of projection mapping and as a conceptual model for DecodeMap 1.0, a fully customized projection mapping system for the Decoding Dreams production. *Undecakisimage*'s audio and user interface programming were done in *Max*, utilizing 8 buffer players as seen in Figure 10.

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[8] http://www.midi.org

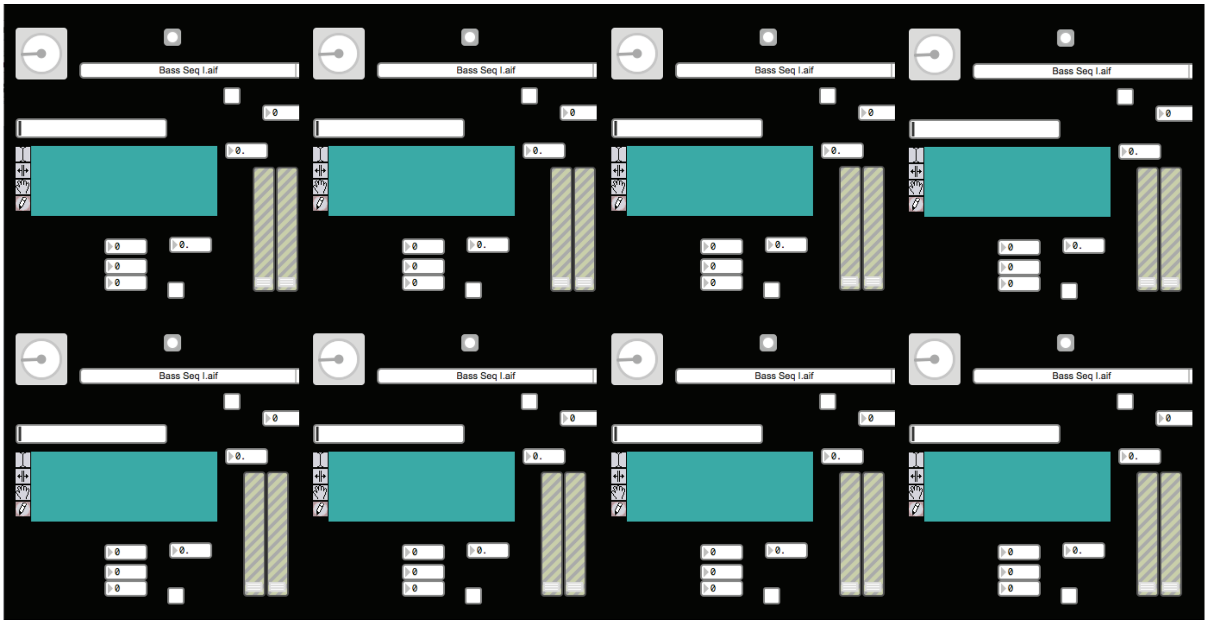

Figure 10: Undecakisimage Audio Programming of 8 buffer sample players in *Max*

2.3.2 DecodeMap 1.0

DecodeMap 1.0 a fully customized projection-mapping tool developed in collaboration with Kameron Christopher specifically for live performances. It is used in two productions, *Decoding Dreams* at California Institute of the Arts and *KarmetiK*[9] *Dreamspace: Decoding Space*, at University of California, Irvine. Developed in the *Max* environment, *DecodeMap 1.0* bridges audio feature visualization and projection-mapping utilities into a consolidated system. *DecodeMap 1.0* features a user-interface utilizing *bpatchers* in *Max* that allows users to add and/ or remove modules according to their needs. *DecodeMap 1.0* currently supports network control using Open Sound Control (OSC) [22], and both Musical Instrument Digital Interface (MIDI) and OSC locally. All modules have independent control maps, and utilize OSC (supports local and network), MIDI (local only) or a hybrid of both protocols. Table 1 shows the main modules and their functions.

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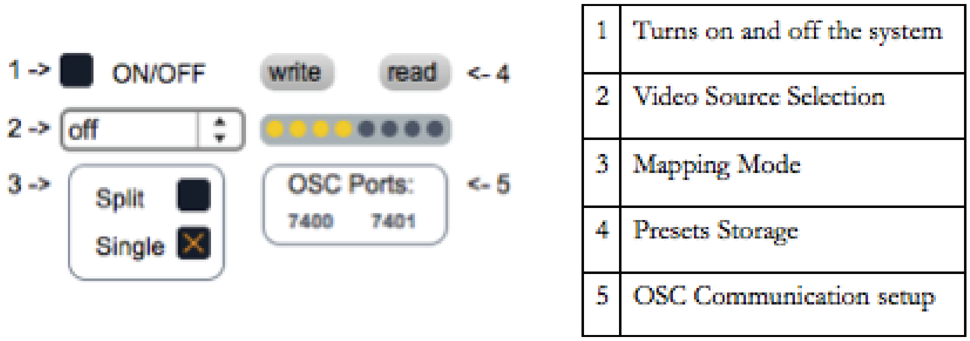
[9] http://www.karmetik.com

Table 1: Overview of Module Types

Module Type:	Function(s):
Global	Settings for the overall system.
Planar	Provides independent control and mapping settings for each projected-on surface.
Visual	Provides settings and controls for rendering visualizations

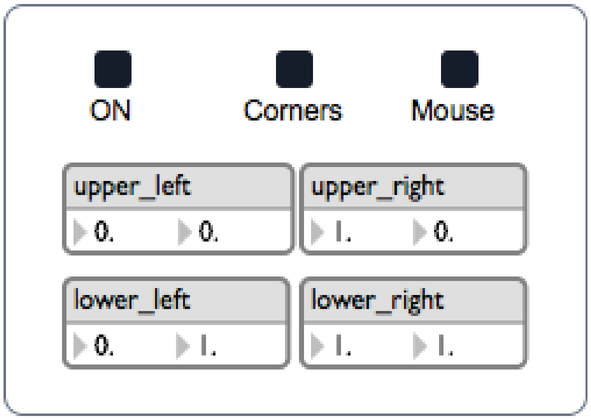
Global modules are utility modules that provide overall controls and settings for the mapping tool as shown in Figure 11. There are two kinds of mapping modes. While Single-mode keeps the original visualization and duplicates itself onto the number of surfaces that are to be projected on, Split-mode slices the visualization into the number of surfaces and assigns each slice to each surface.



1	Turns on and off the system
2	Video Source Selection
3	Mapping Mode
4	Presets Storage
5	OSC Communication setup

Figure 11: Overview of global modules

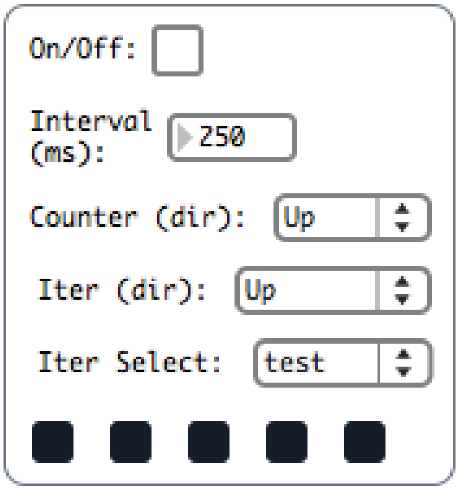
There are two kinds of Planar modules, namely Plane and PlaneSequencer. Plane provides absolute independent control for each designated mapping surface. The user can add the plane module (Figure 12), according to the number of surfaces that are to be projected on. The plane module has 3 toggle switches. ON toggles the mapping guide. The Corners button shows the corner points of each plane, and the Mouse button enables or disables mouse activity such as clicks or drags on the output screen. The labeled number boxes show the position of each corner on the output screen.



upper_left: 0. 0.
upper_right: 1. 0.
lower_left: 0. 1.
lower_right: 1. 1.

Figure 12: Plane module

PlaneSequencer is a sequencer that either enables or disables a plane. It can recall preset sequences on the fly. PlaneSequencer can also be synced to the tempo of any host, such as Digital Audio Workstations (DAWs), through MIDI clock or OSC (Figure 13).



On/Off: ☐
Interval (ms): 250
Counter (dir): Up
Iter (dir): Up
Iter Select: test

Figure 13: PlaneSequencer module

There are two kinds of visual modules – generative and video. The generative visual module allows the user to use any generative visualization patch created in *Jitter*[10]. Figure 14 shows examples of generative modules that have customized user interfaces of two generative

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[10] http://cycling74.com/products/max/video-jitter/

visualization patches created by different users. The visualization patches are reactive to sonic materials through the formalization of different audio features with different algorithms.

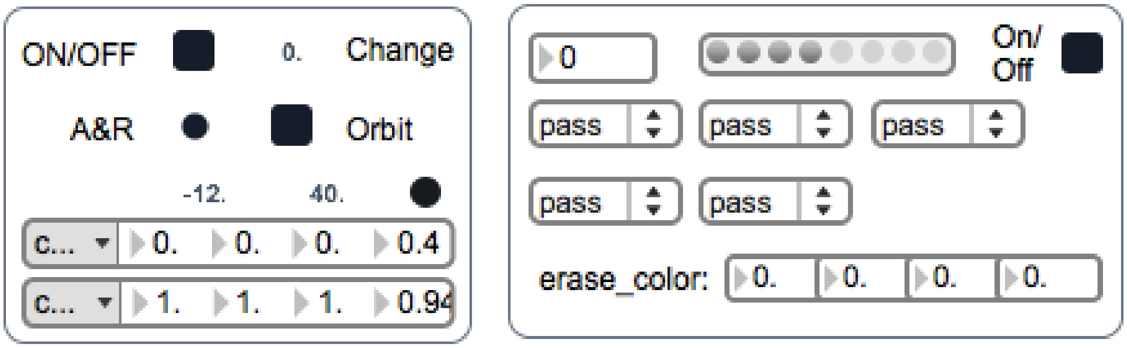

Figure 14: Generative Visualization Modules

Video module loads up movie files, alters the state and mode of playback, as well as processes the videos with effects. Figure 15 shows a video module used in the *Decoding Dreams* production.

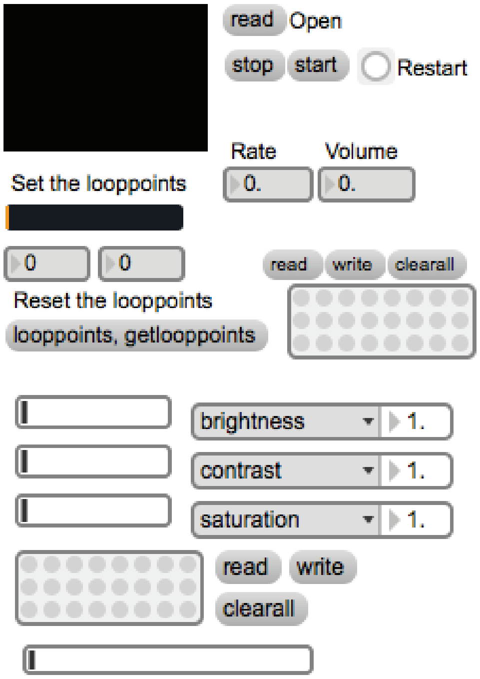

Figure 15:Video module

Users can load up to four channels of video modules for mixing and blending. Some of the features included in the video module include:

- Loading/ reading of video library folder
- Looping which allows users to set start and end loop points
- Rate of playback
- Adjusting brightness, contrast and saturation of video
- Independent presets storage for video and effects settings
- Attenuator control for mix level

All the loaded video modules are summed together in a video mixer. The video module renders video in OpenGL.

Figure 16: California Institute of the Arts (top) and UC Irvine (bottom)

DecodeMap 1.0 first premiered at *Decoding Dreams* (presented by the Music Technology department at California Institute of the Arts, Fall 2012) and later presented at to University of California, Irvine as seen in Figure 16, mapping up to 5 surfaces and the performers controlled the system over the network during the live performance.

If this were to be presented as an analogy, the tool that was used would be *DecodeMap 1.0,* which produces pieces *Decoding Dreams* and *KarmetiK Dreamscape: Decoding Space.*

2.4 Integration: Intricate Boundaries

For a long time, I have been seeking to create a multimedia performance, which is aesthetically pleasing and conceptually rich. It intrigues me how human perception is influenced and dilated with regards to sounds and moving images that are closely related to one another. I intend to explore a system whereby sound is the driving force for almost every component in the visuals, such that a refined gesture of articulation on a sound object is represented visually. - Jingyin He (2012)

Intricate Boundaries establishes a unified playing field for sonification and visualization, by the integration of both techniques to explore the relationship between sound and moving images through data.

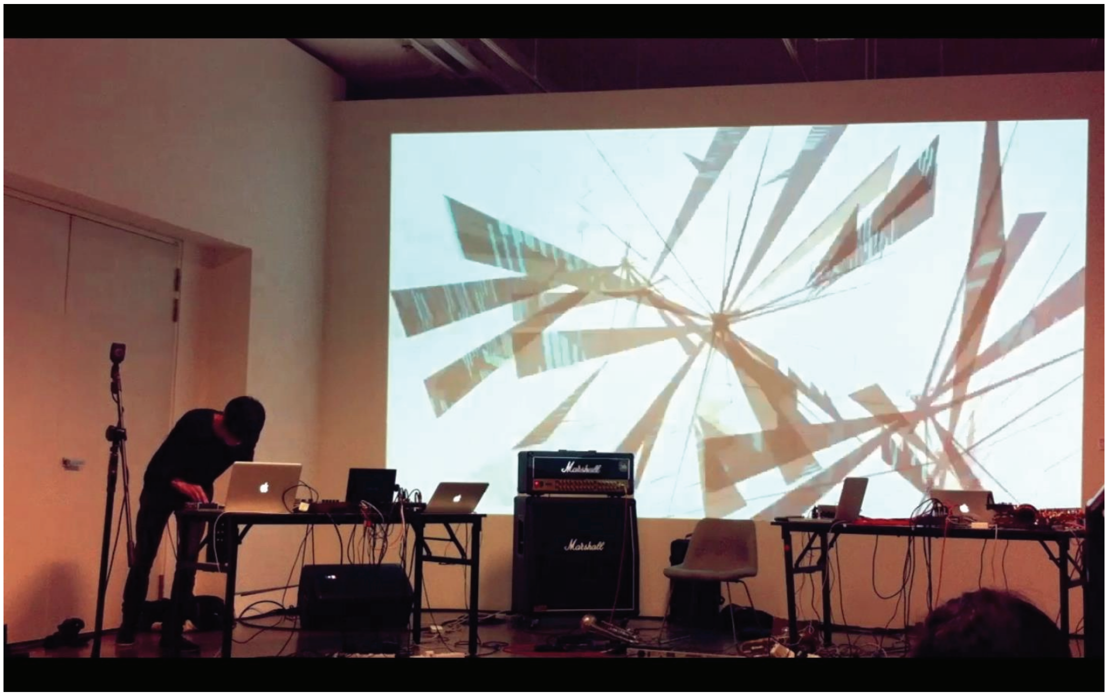

Figure 17: Intricate Boundaries at Sonorous Duration Festival 2012

"To attempt to render visible what is unseen and to make audible, what cannot be heard through different plains of intensities and vibrations." - 2012 Sonorous Duration Festival

Written for and presented at the 2012 Sonorous Duration Festival (LASALLE College of the Arts), *Intricate Boundaries* (Figure 17) (Media File 7) responds to the theme of the festival in the form of a multimedia composition. It features an audio-visual system in which the audio has a direct relationship to the generative images in a live performance setting. This piece critiques the separation of stylistic practices in different métiers by blurring the distinction through the exchange of methodologies between contemporary visual and sonic art practices.

Intricate Boundaries utilizes a customized *Max* patch and the Monome controller, *grayscale64*. The patch casts visual matrices into audio (adopting methods from *Interpolations*), and vice versa. The performer controls parameters of both visual and audio processes using the grayscale64. The strategic use of the grayscale64 and its gestural control hardware (the accelerometer) is the key to yielding an expressive performance. The grayscale64 is programmed to function as seen in Figure 18.

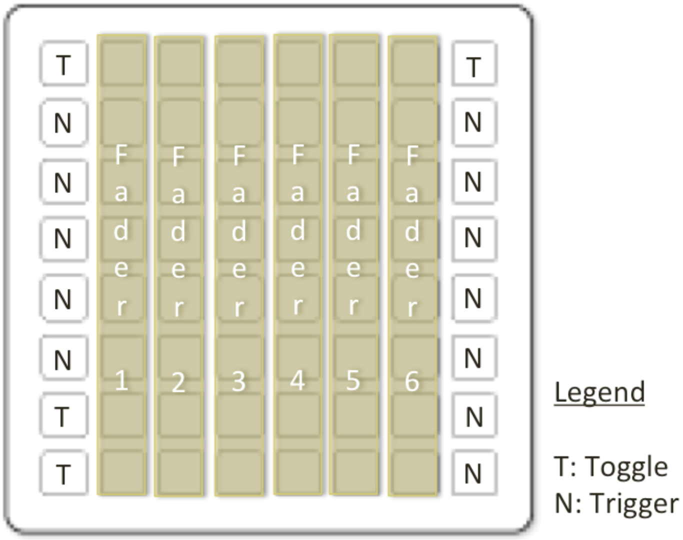

Figure 18: Grayscale64 setup

Using data as the neutrally shared medium, *Intricate Boundaries* engages sonification and visualization in an organic conversation. What gets sonified is being driven by what is visualized, and what is made visible is driven by the sonified data. This sets the data to go into a feedback loop of data exchange and destructive (i.e. unchangeable) transformation.

The system architecture (Figure 19) of *Intricate Boundaries* is essentially a feedback loop of audio and data. Similar to the sonic architecture used in *Interpolations: Noise in Space* (Section 2.2.2), the seed of the system is a square pulse. The square pulse is sent out to the audio ouput and is simultaneously transformed by audio effects (a frequency shifter, a delay, and a phase shifter). The modified audio signal is also sent to the audio output.

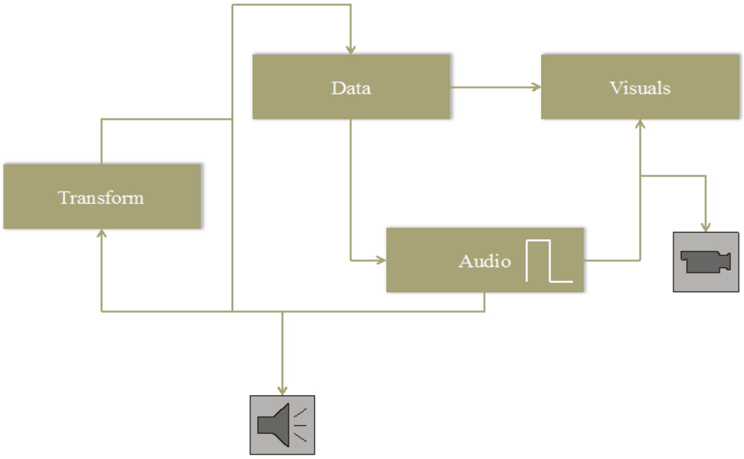

Figure 19: Intricate Boundaries System Architecture

Using a look-up table to describe a shape's geometry in three-dimensions (x, y, z), the sum of the unmodified and modified audio signals are cast into a matrix, which is used to effect spatial coordinates in OpenGL. Concurrently, audio signals are converted into a three-plane matrix, using a self-organizing map based on luminance to create a video frame that occurs at 33.3333 milliseconds per frame (Figure 20). This is a simple method for creating multiple non-uniform yet relative values for each matrix cell, which is used as a GL texture.

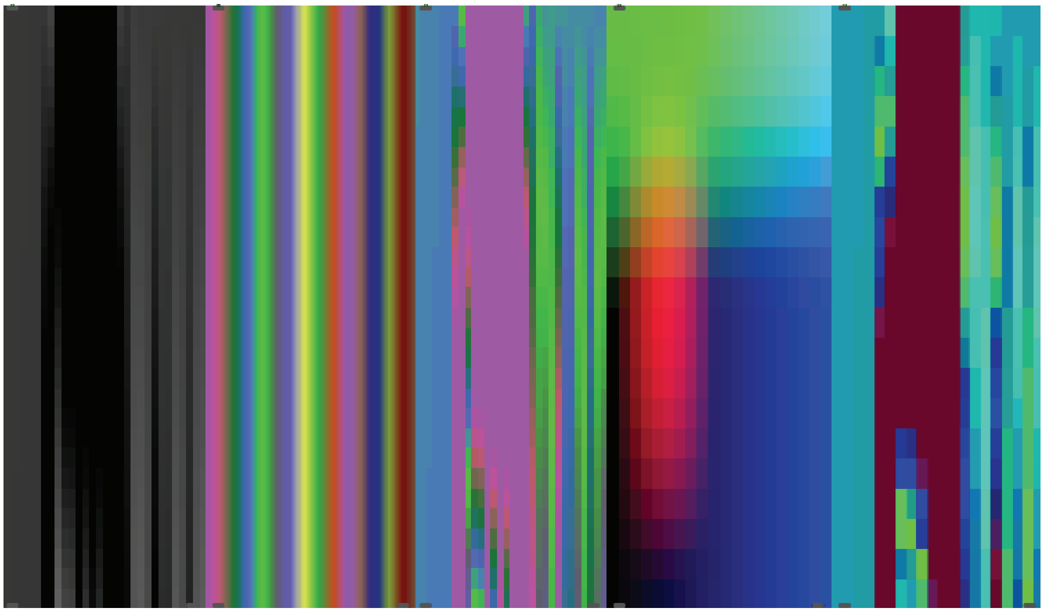

Figure 20: Three-plane matrix using self-organization based on luminance

Figure 21 shows a screen-shot of the implementation when the system is running in performance.

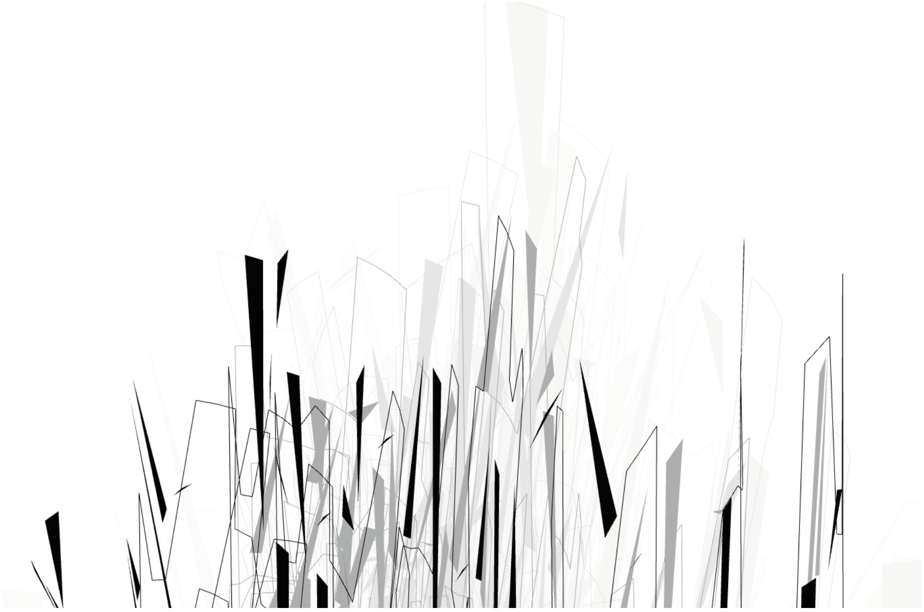

Figure 21: Screenshot of a visual frame during test-run

2.5 Summary

This chapter presented the project implementations of utilizing data in creative processes that encouraged new methodologies, focusing on data transformation and manipulation. These new methodologies defer the composer's attention away from the dominant focus of sound in sonic art practice to the parsing of data, which opens up new possibilities and perspectives for aesthetics and compositions.

The investigation of forms and structure hidden within data led to the realization of four applications, showing the different methodologies and outcomes. While *Interpolations: Noise in Space* (Section 2.2.2), and *Undecakisimage* (Section 2.3.1) look through different perspectives to find form and structure, *DecodeMap 1.0* (Section 2.3.2) was realized to render visible data structures as spatial augmented reality that cannot be heard through sonification. *Intricate Boundaries* (Section 2.4) brings together the ideas of the projects, presenting definitive intent and focused aesthetics.

Chapter 3

Algorithms To Sonic Art

"Formerly, when one worked alone, at a given point a decision was made, and one went in one direction rather than another; whereas, in the case of working with another person and with computer facilities, the need to work as though decisions were scarce—as though you had to limit yourself to one idea—is no longer pressing. It's a change from the influences of scarcity or economy to the influences of abundance and—I'd be willing to say—waste." – John Cage, [23].

In the previous chapter, the thesis addressed the idea of using data objectively to create processes that encouraged new methodologies, focusing on data transformation and manipulation. In this chapter, the focus is on using algorithms with the creative process in order to explore yet another method of reaching beyond the paradigm of sound. This chapter presents the application of Conway's *Game of Life* within the field of sonic arts, addressing concerns such as live performance, aesthetics, and control. It examines musical parameters of algorithms in live performance such as temporal and dynamics parameters. The first section (Section 3.1) discusses the motivation that drives the application in the case studies. The second section (Section 3.2) reviews the *Game of Life* algorithm, and examines its relationship to musical parameters in further details. The third section (Section 3.6) presents selected works that identify the limitations in hardware and software when using the *Game of Life* in a live performance, and explains the approach to these constrains to the realization of a customized systemization, veering back to the original ideologies of the thesis. The final sections present a series of projects that all use the *Game of Life* algorithm, concluding with a MIDI VST sequencer that finalizes the exploration of the algorithm.

3.1 Motivation

Methodologies to formalize compositional materials have often been steered by the composer's school of thought and inspiration. Throughout the history of western music, the organization of pitch and duration is often formalized by a composer's own computational thinking – tuning systems, tonal harmony, Serialism, etc. These systems of organization are also often relevant in their own contexts and not in others. The formalization of composition using genetic algorithms allows the composer to have a different perspective of music that can lead to discovery of new aesthetics in composition and performance. With the use of a computer, it also offers the ability to generate endless permutations and possibilities by tweaking user-defined variables.

3.2 Background

Algorithmic composition is the process of making music, using formalizations with minimal human intervention. The use of algorithms in music composition dates back to the 18th century with Mozart's *Anleitung zum Componieren* using *Musikalisches Würfelspiel,* a system using dice to select small sections of music and putting them together. More recent works include Brian Eno's *Music For Airports (1978)* and English electronic music duo, Autechre's *Coinfield (2001).* Within the field of generative music and the use of biological algorithms in composition, the aesthetics has been shifting towards its ability to self-organize and generate emergent behaviors [24]. The use of artificial intelligence in musical systems allows us to explore the new and unexpected from the known [25]. This may also be applicable in uncovering new aesthetics within the practice of contemporary sonic arts.

The game made Conway instantly famous, but it also opened up a whole new field of mathematical research, the field of cellular automata… Because of Life's analogies with the rise, fall and alterations of a society of living organisms, it belongs to a growing class of what are called 'simulation games' (games that resemble real life processes). [26] – Martin Garnder, 1970

Since the publication of the *Game of Life* in 1970, there have been many variations of the system and its integration in other disciplines. One example of the integration of the *Game Of Life* is by a philosopher and cognitive scientist, Daniel C. Dennett. In his book, *Consciousness Explained*, he used the *Game of Life* as an analogy to illustrate how human's philosophical constructs, such as consciousness, can evolve based on the physical laws of our universe [27]. Within the field of music, *Cellular Automata Music generator (CAMUS)* uses *Conway's Game of Life* to determine the two intervals between three notes [28]. *Automaton* by Audio Damage uses the *Game of Life* to drive modulation effects onto audio signal. Other musical applications that feature the *Game of Life* algorithm as a pattern generator include *Game of Life Sequencer Bank* by Grant Muller, *Newscool* in *Reaktor* by LazyFish, *GlitchDS*, *Runxt Life, sonicLife* by hexler and Brian Crabtree's *Conway's life* for Monome.

3.3 Aesthetics

It is important to note that one has to have a good understanding of the *Game of Life* to utilize it strategically within compositions [28]. With the mastery of theory and practicum, one can alter the system to do the following: prolong or shorten the generations of births and deaths, resume lives, or put the system to a stop. If one is able to control the system amidst chaos, one should be able to manage a series of events, or in musical terms, articulate musical gestures eloquently. In such cases, the theory refers to the grammar and vocabulary of *Conway's Game of Life*, while the practicum refers to its performance – the deliberate strategy of making choices that are aesthetically successful within the composition and the *Game of Life* in a live performance.

The main aesthetic of using *Conway's Game of Life* is driven towards the search and discovery of new aesthetics in contemporary sonic art practices. The use of *Game of Life* establishes a unified and equal field, setting decisions free from the boundaries of stylistic influences. The performers *are able to* perform music in the analogy of the *Game of Life*, blurring rhythmic rigidness, structure, while disregarding the unwavering radiance of tonality and harmony. The criterion of musicality is two-fold. The first is how two or more sonic materials interact with one another to create different sonic textures and timbres. The second is how these different sonic textures interact with one another. As such, the classification of music as being either 'ugly' or 'beautiful' is disregarded. This also implies that any interaction between two or more sonic materials can be considered musical. However, this should not be taken for granted, as the strategic choice of play used for the organizations and interactions are crucial points to yield valid musicality.

3.4 Conway's Game of Life

The *Game of Life* is a two dimensional cellular automaton[11], devised by mathematician John Horton Conway. It is a simulation based on the births and deaths of living organisms in a system [26]. It also has the power of a universal Turing machine [30]. A two dimensional cellular automaton is a mathematical model, in which cells are assigned a particular state, which then changes by turn according to specific rules conditioned on the states of the neighboring cells. Two-dimensional simply notates the movement of the cells in both x and y-axis [31].

Theoretically, the cellular automaton is based on an infinite square grid lattice; however, the size of the board is usually defined so that the number of cells present in the arrays is finite. In the automaton, a cell has two possible states: living or dead. These states are usually represented by colors. Black counters usually represent living cells, while white counters represent dead cells [26]. The state of the cells is determined by the state of the 8 neighboring cells surrounding it at every generation. The rules that determine the state of the cell for the next generation are as follow: [26]

Let the number of neighboring cells be n,

1. A dead cell becomes alive if $n \equiv 3$. **(Birth)**
2. A living cell becomes dead if $n \leq 1$ **(Death by exposure)**
3. A living cell becomes dead if $n \geq 4$ **(Death by overcrowding)**
4. A living cell stays alive if $n = 2$ *or* 3 **(Survival)**

The automaton begins with an initial pattern. Rules of birth and death are applied throughout the array to form the next generation. These rules are applied to the new generation that results from the initial pattern again. Here is an example of a simple pattern:

Let generation be g, hence at initial pattern, $g=0$

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[11] Cellular Automaton is created by John von Neumann and Stanislaw Ulam to study the process of reproduction and growth. [29]

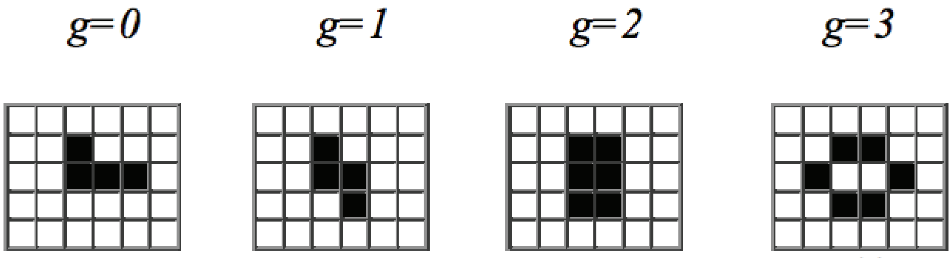


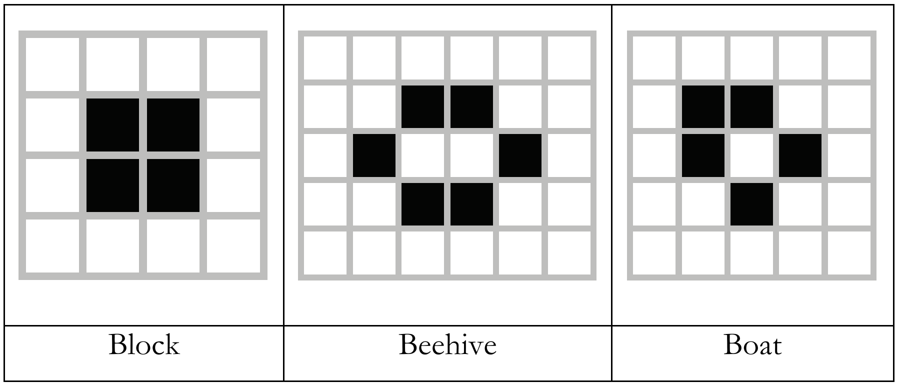
Figure 22: Illustration of the 'life history' of a simple pattern (Gardner 1970)

Figure 22 (above) shows the life history of a simple pattern of tetrominoes, four rookwise-connected counters [26]. At *g=3,* the automaton ceases. This is because the resultant pattern of the cells in the subsequent generations is constant. This pattern produced is called a still life. The automaton will cease, when any of the following occurs [26]:

1. All the cells on the board are dead.
2. The cells settle into a stable pattern that remains unchanged in the subsequent generations.
3. The cells oscillate in a cycle of two or more periods.

3.4.1 Patterns and Structures

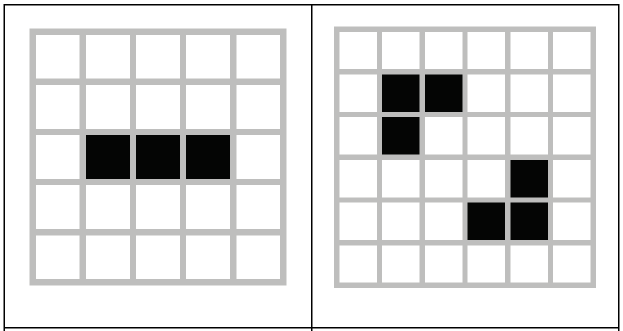
The most interesting aspect of the *Game of Life* is patterns. Patterns in *Game of Life* are configurations of cells that bring about deterministic behaviors in subsequent generations. This section will look at several common patterns and the interpretation of their behaviors in the morphology of sounds.



Block | Beehive | Boat

Figure 23: Still life

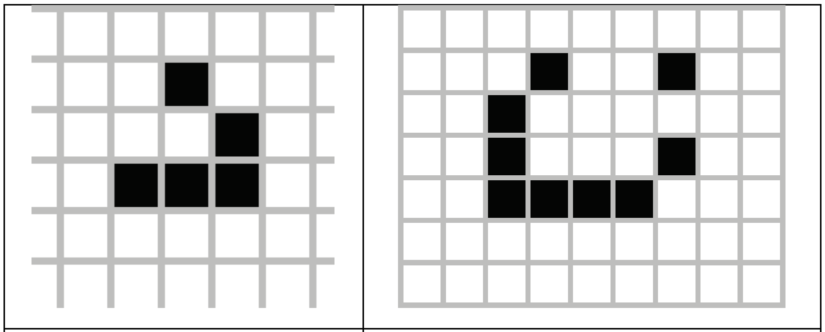
Still life is a pattern of cells that is static. This means that the pattern configuration settles into a stasis that has no births and deaths from one generation to the next. Figure 23 shows examples of common still life [32]. Its behavior can be interpreted as a group of sound objects with a complex texture that is consistent over a period of time.



Blinker | Beacon

Figure 24: Oscillators

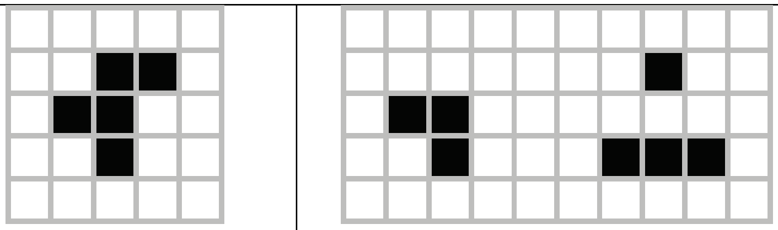
Oscillators are patterns that change from an initial pattern to other patterns and back to itself over a number of generations (Figure 24) [32]. A fairly simple sound pulsing between two different spectral typologies will be a sonic example of the *blinker*.



Glider | Lightweight spaceship (LWSS)

Figure 25: Spaceships

The Spaceship configuration is a pattern that translates itself across the board over time. Figure 25 shows the simplest form of a *spaceship* configuration known as *glider*. This translation across the board can be sonified as the shifting of textures of a sound object towards a destination over time.



R-pentomino

Diehard

Figure 26: Methuselahs

Methuselahs is a special class of configuration that is made up of fewer than 10 cells, but takes more than 50 generations to stabilize (Figure 26). The name is derived from the Biblical reference of Methuselah who is purported to be the oldest person to ever live (969 years). Methuselahs' emergent behaviors can be interpreted as short pieces of compositions in macro timeline or phrases of meso structures.

3.5 Related Works In Musical Applications

"Because of Life's analogies with the rise, fall and alterations of a society of living organisms, it belongs to a growing class of what are called 'simulation games' (games that resemble real life processes) [26]." – John Horton Conway

Since the publication of the *Game of Life* in 1970, there have been many variations of the system and its integration in other disciplines. These variations have been listed above in Section 3.2.

Most of these applications focus their time in the use of *Game of Life* as a tool for composition and in post-production works, focusing less on its live performance aspect. Furthermore, a review [28] has been written on the historical and technical aspects of cellular automata in generative electronic music and sonic art. The following section will be a discussion of projects that explore and research the aesthetics and methodology on utilizing *Conway's Game of Life* in a live performance setting, addressing crucial elements in performance such as dynamics, and temporal parameters.

3.6 Applications

This section describes the use of *Conway's Game of Life* in several musical applications, reviewing and addressing temporal parameters, mapping strategies, and dynamics in a live performance setting. This cumulative discussion concludes with *Bot Formalization* and a designed systemization.

3.6.1 FD-2.111209

FD- 2.111209 is a musical application that examines the *Game of Life* in live performance (Media File 8). Created in 2009, *FD- 2.111209* is an electronic composition based on the organization of musical motifs using *Conway's Game of Life*. (Figure 27) While this work focuses on the compositional aspect, it also set the foundations of studying the *Game of Life* in a performance setting.

The main objective of *FD- 2.111209* is to explore how events in the *Game of Life* relate to the intensity of musical events that takes place, and how parameters from the *Game of Life* can be mapped to musical attributes such as spatial location and pitch. In this work, two gliders set in a head-on collision path is used as the initial seed configuration, in an 11 by 11 grid array. The sequence lasts for 12 generations and ends with a 2 by 2 still life, more commonly known as *"*the block*"*.

FD- 2.121109 further ascertains the importance of how certain cell configurations bring about different musical outcomes, as each surface or plane has its own sound. *Parametrical Thinking* involves the use of variables from a systemization to control the values of musical attributes that are bounded by upper and lower limits. (Cope 1991) It brings to attention that *Parametrical Thinking* is an essential element to integrating the *Game of Life* in musical applications.

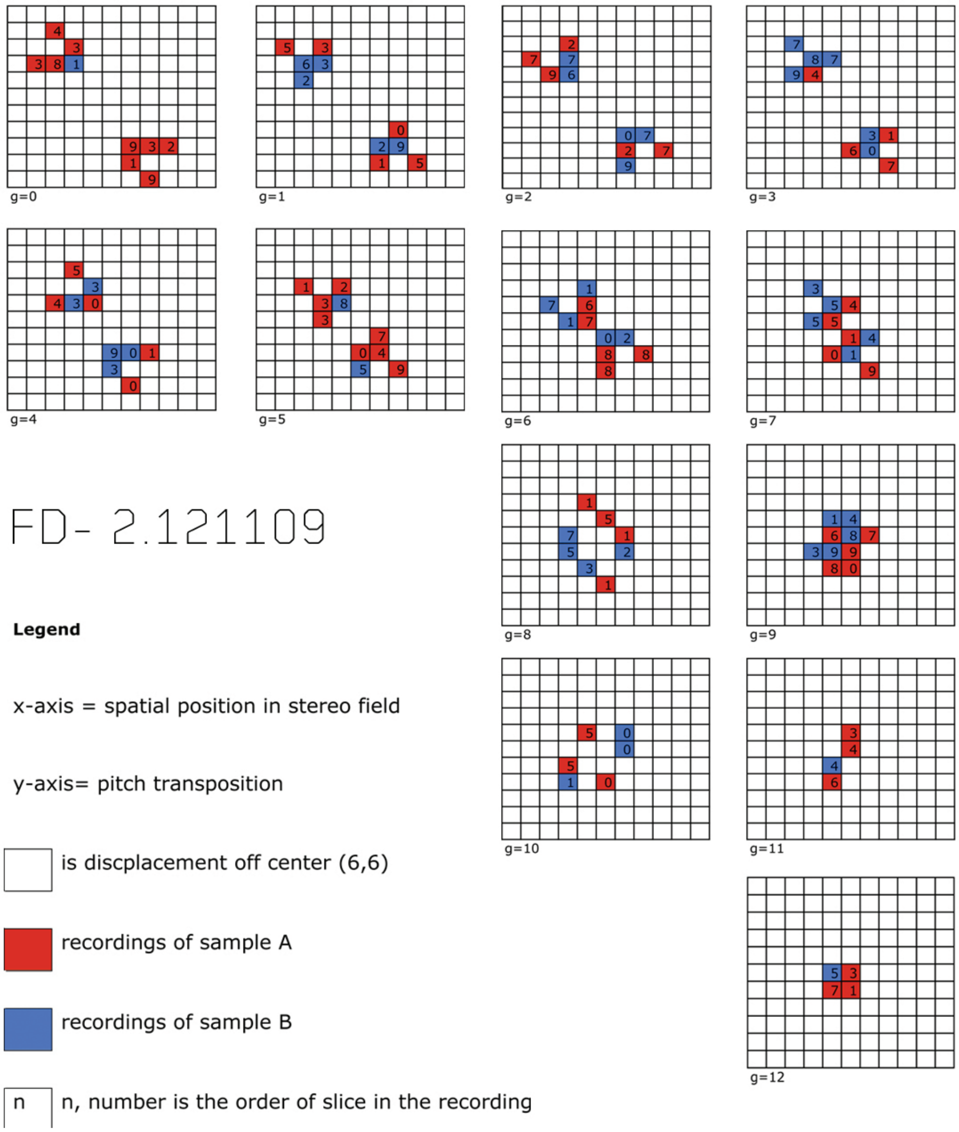


Figure 27: FD- 2.121109 Score Sequence

3.6.2 Déboulerait

Prior to designing a unique system for performance utilizing the *Game of Life*, *Déboulerait* (Media File 9) utilizes the commercially available MIDI controller, Novation's Launchpad[12], and a port of the *Game of Life* algorithm (which was originally created for the Monome (Carbtree 2008)). Based on the Monome's version of the code, a version specifically for the Launchpad was ported in *ChucK*[13]. *ChucK* is a new (and developing) audio programming language for real-time

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[12] http://us.novationmusic.com/midi-controllers-digital-dj/launchpad

[13] http://chuck.cs.princeton.edu

synthesis, composition, performance, and analysis [33]. It is chosen for its highly precise scheduler that has no compromise on the dynamics and expressiveness of the control rates. *Ableton Live*[14] is used as a host for sound generation and signal processing, as well as to regulate MIDI clock sync over the Local Area Network between the two performers.

Premiered at *COLAB 2010* (LASALLE College of the Arts Graduation Showcase, Singapore) with two performers, *Déboulerait* features the *Conway's Game of Life* as an instrument and focuses on its ability to play *the game of life as an instrument* during the piece. It consists of a sequential track of events that guides the performers in their improvisation by sending visual cues to the performers' instruments. *Conway's Game of Life* performs the role of an instrument in this piece. An overview of the system setup is shown in Figure 28. The motivation drives towards the discovery and exploration of using the algorithm and the rules of an organic mathematical model as the basis of an instrument.

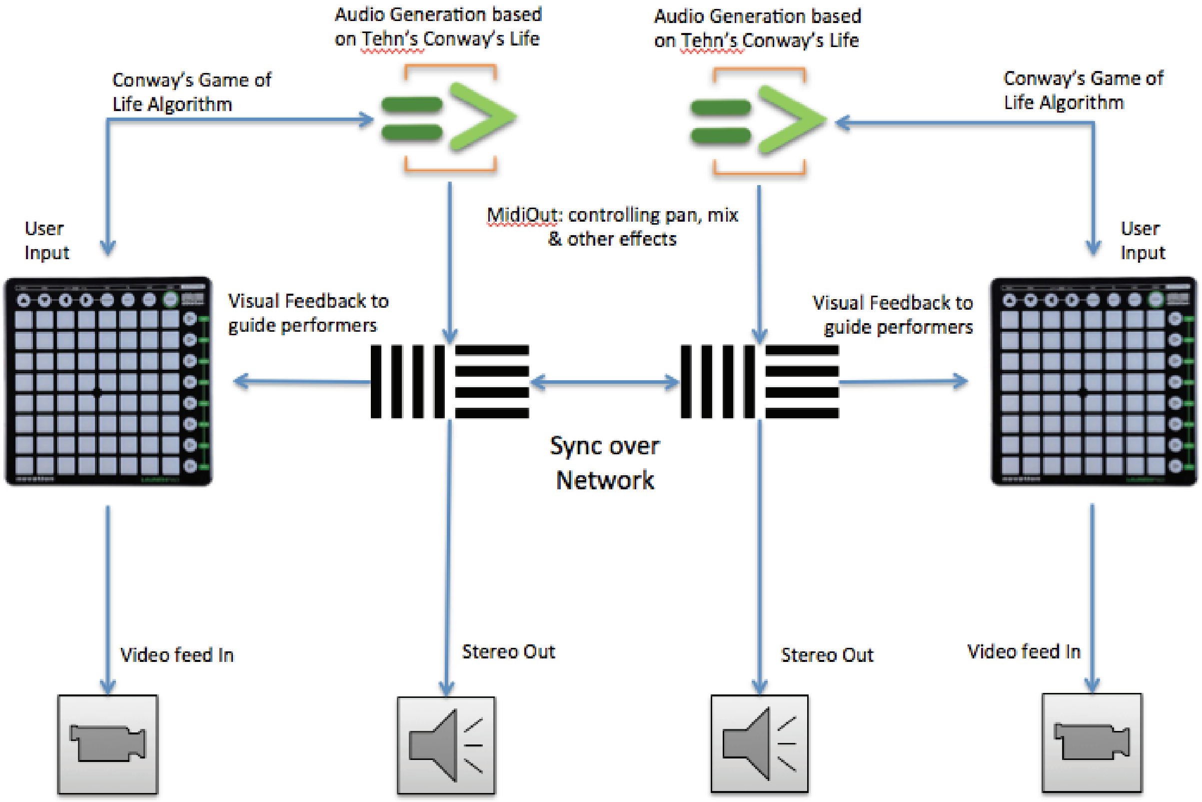

Figure 28: Overview of the system: Déboulerait

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[14] http://www.ableton.com

While in most electronic performance, the audience does not get to see what is happening on the screens and controllers of the performers. Déboulerait features a projected live video stream showing the performers on their instruments. This adds an additional element of visual performance aesthetics, as well as draws attention to the performers' aesthetic choices in the *Game of Life* during the structured improvisation. The following limitations were found in the progress of working within this piece:

1. The interval between each generation is too consistent, resulting in the rigidity of rhythmic structure and texture.
2. The dynamics are either too consistent or chaotic (if a random function is in place), resulting the performance to be musically bland in color or too incoherent.
3. The grid array is finite, therefore limiting the performers in precision and diversity in control.
4. Only one instance of the *Game of Life* can be run on a singular device.

Henceforth, the above limitations became guidelines to the realization of a new performative setup in the most recent performance, *Bot Formalization*.

3.6.3 Bots Formalization

Bot Formalization sets out to test the newly customized performative system that integrates *Conway's Game of Life*. It explores the perform-ability through the formalization of custom-built robotic musical instruments. A designed systemization interfaces the mechanical onsets of actuators to a controller that breathes the *Game of Life*. This is similar to the agent-based system for robotic musical performance [34], but in addition to that, extends it to an array of robotic musical instruments with the use of the *Game of Life* cellular automata.

The custom-built robotic musical instruments (Figure 29) residing in the Machine Lab at California Institute of the Arts [35] include seven independent robotic units that have a total of 170 actuators, consisting of idiophones and membranophones. They are connected to a main server, communicating with the users in *Musical Instruments Digital Interface (MIDI)* through a Local Area Network.

Figure 29: MahaDeviBot and GanaPatiBot

The most important basis to the successful utilization of the *Game of Life* is mapping the automata's parameters to musical attributes as mentioned in the earlier section. These parameters from the *Game of Life* and the robotic instruments are shown in Table 2.

Table 2: Parameters from Game of Life against robotic musical instruments

Game of Life		**Robotic Musical Instruments**	
State of cell	On / Off (0, 1)	No. of Actuators	170
Coordinates of cell	x- axis/ y- axis (integer)	Volume	soft - loud
Interval between generations	time (float)	Speed	slow - fast

The *Game of Life* is setup in the program to send and receive either MIDI or Open Sound Control (OSC) [22] messages. The outcome of each cell can either be its position coordinates and current state (x, y, state) or a cumulative message consisting of position coordinates converted to MIDI notes and the state scaled to MIDI velocity (MIDI note, velocity).

This allows the communication between the Game of Life and an external device. The use of a controller interface bridges the user and the game itself, while enabling the performer to figuratively "play" away from the computer screen. The interface controller used in this setup is the grayscale64 by Monome. It consists of 64 buttons and an accelerometer that registers 2 axes (Figure 30).

Figure 30: The Monome grayscale64

To further extend the compatibility of the controller closer to the number of actuators in the robotic instruments, the controller is setup to run 2 instances of *Game of Life* synchronously and independently.

Table 3: Overview of Mapping

Controller	**Game of Life**	**Robotic Instruments**
Buttons (64 x 2)	Cells	Actuators (128)
Accelerometer: x- axis	Duration of each generation / State	Speed of Actuators / Hitting Velocity
Accelerometer: y- axis	State / Duration of each generation	Hitting Velocity / Speed of Actuators

In summary, the buttons are mapped to the cells in the *Game of Life*. The additional accelerometer sensors in the grayscale64 allow us to add further control to the *Game of Life* system. In this case, the x- axis is mapped to the time duration of each generation and y- axis is mapped to the *MIDI* velocity. The mapping of the axes is switched in the second instance of the

Game of Life. The state of each cell also acts as a gate to allow the passing of accelerometer data for MIDI velocity. (Table 3) These mappings give the user additional control to dynamics and rhythm, which increases the articulation.

In *Bot Formalizations* (Media File 10), the musical aesthetic is driven by the notion of *organized sound*. *Organized sound* is a term coined by French composer, Edgard Varèse to describe his definition of music when certain timbres and rhythms are grouped together. This notion is reinterpreted in this musical performance of the piece by robotic musical instruments, which are formalized by *Conway's Game of Life*. The piece is driven towards a structured improvisation of the analogy in Xenakis's quote:

> *"The perfect rhythm of the last slogan breaks up in a huge cluster of chaotic shouts, which also spreads to the tail. Imagine, in addition the reports of dozens of machine guns and the whistle of bullets adding their punctuations to this total disorder. The crowd is then rapidly dispersed, and after sonic and visual hell follows a detonating calm, full of despair, dust and death." –Formalized Music, Iannis Xenakis (1971)*

This composition explores the usage of traditional instruments in conjunction with robotics, enabling these instruments to reemerge in current performance repertoire. A designed systemization interfaces the mechanical onsets of actuators to a controller that breathes the *Game of Life*. This is similar to an agent-based system for robotic musical performance, but in addition, extends to an array of robotic musical instruments with the use of the *Game of Life* cellular automata.

The system used in *Bots Formalization* overcame the limitations mentioned in Section 3.6.2. Dynamics and the fluidity in rhythm and structure are achieved by mapping the temporal and velocity attributes to a volatile parameter in the *Game of Life*. By increasing the number of instances of the *Game of Life* that runs synchronously and independently, the restriction of diversity in control is reduced. These improvements in musicality and aesthetics are all derivatives from the previous project, and the next project, *Vie*, would have further improvements derived from this project.

3.6.4 V I E

"... Life's analogies with the rise, fall and alterations of a society of living organisms..." – Martin Garnder, 1970.

V I E is driven by the notion of formalizing multiple depths of structure through an organic systemization. It reciprocates the metaphor of music onto *Conway's Game of Life*. The system, built to receive midi notes and events, renders a visual feedback of a standard keyboard as a *Game of Life* array (Figure 31). V I E aims to give a different perspective to the music, which we are familiar and comfortable with. It explores their formalization in terms of the *Game of Life's* rules, and perhaps influences the discovery of new methods for organization that could redefine the definition of harmony and dissonance in music.

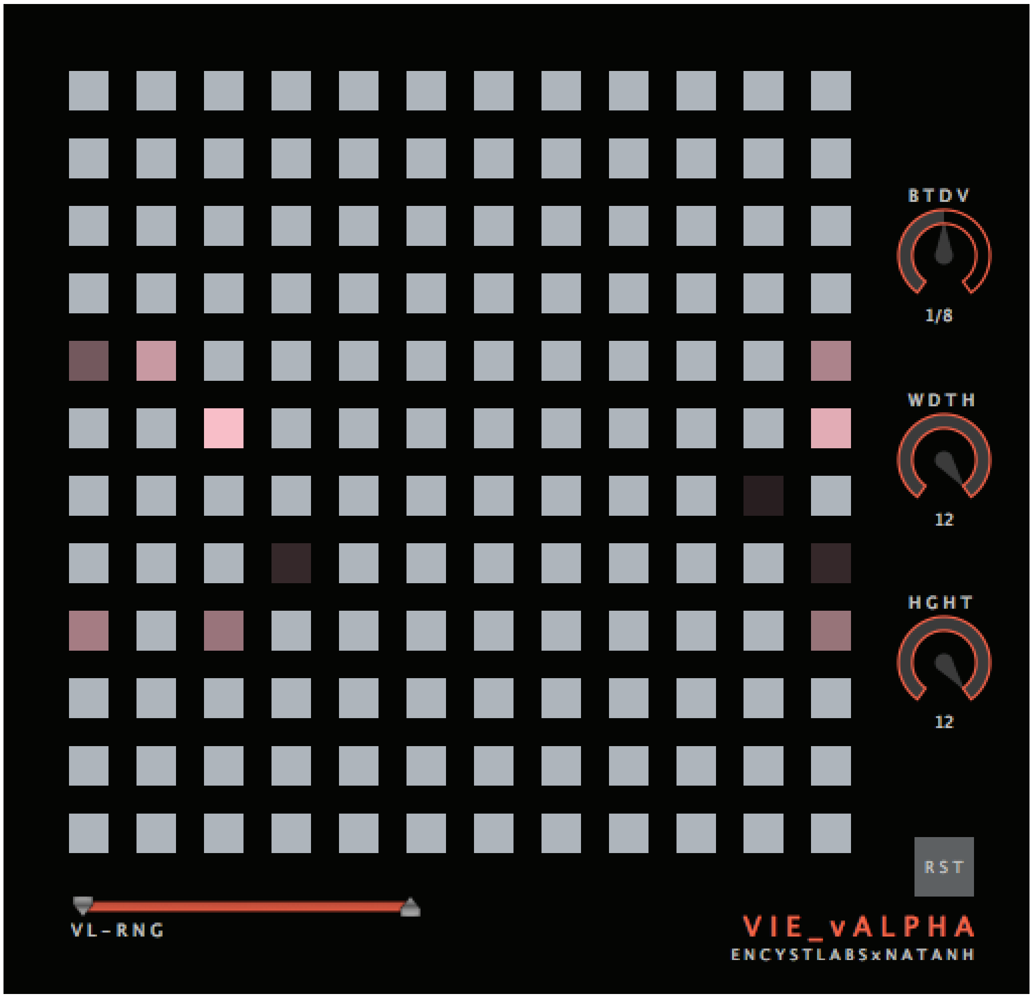

Figure 31: VIE VST Sequencer

The main features of VIE include: Sync to DAW's transport, quantization of generations to note duration, variable width and height, static and dynamic velocity, and automation for all parameters. The sequencer is realized in C++ programming environment, using *JUCE* library[15], in collaboration with Dr. Jordan Hochenbaum.

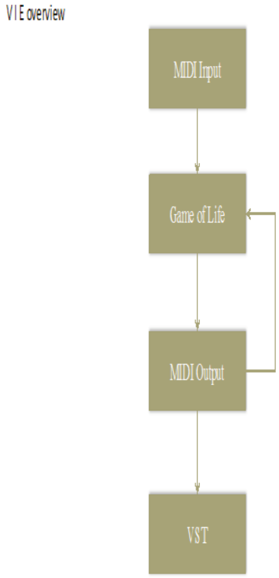

Figure 32: VIE System Architecture

The overview system architecture is as shown in Figure 32. MIDI from any input interface is formalized into the *Game of Life* instance as cells, using the algorithm shown in Table 4:

Table 4: Formula to convert MIDI notes into a *Game of Life* cell

Midi note = m,
X-coordinate that m will be cast onto = x,
Y-coordinate that m will be cast onto= y,
$y = m$ / width of *Game of Life's* grid lattice
$x = m$ % width of *Game of Life's* grid lattice

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[15] http://www.rawmaterialsoftware.com/juce.php

As the sequencer is synced to host, the user can setup an initial pattern before running the *Game of Life*. Each subsequent generation output MIDI notes through a conversion algorithm shown in Table 5. The interval between each generation is quantized to note duration, from as long as a whole note to as short as a triplet of a thirty-secondth, of the host's tempo. The MIDI output is then feedback into the *Game of Life* algorithm. Synchronously, they can be routed to any desired sound-generating VST as midi messages.

Table 5: Formula to convert a Game of Life cell into MIDI notes

Midi note = m,
X-coordinate that m will be cast onto = x,
Y-coordinate that m will be cast onto= y,

$$m = (y * \text{width of } \textit{Game of Life's} \text{ grid lattice}) + x$$

At any point in time, the user is still able to modify the system by inputting MIDI notes. Additionally, if the user wishes to clear the array and start afresh, the "R S T" button removes all "live" cells present, and sends "note-off" messages to all MIDI notes. The velocity of each MIDI note is generated randomly within a desired range determined by the user, using a two-headed slider. The velocity parameter of each note is reflected visually but the alpha value of each "live" cell.

Media File 11 shows an example of VIE triggering *Battery*[16] by *Native Instruments*[17] in *Ableton Live*. Media File 12 formalizes the first five seconds of Edgard Varèse's *Amériques* using granular synthesis, built in *Max for Live*[18]. The initial seed used is a variation of a *Die Hard* methuselah configuration, which settles into a stable pattern that remains unchanged in subsequent generations.

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[16] http://www.native-instruments.com/en/products/komplete/drums/battery-4/
[17] http://www.native-instruments.com
[18] http://www.ableton.com/en/live/max-for-live/

3.7 Summary

This chapter addressed the live performance aspect of using the *Game of Life* automata, bringing crucial elements such as dynamics and temporal parameters into discussion. Focusing more on the perspective that resulted when using the *Game of Life* in a live performance, a discussion of works in Section 3.6.1, and 3.6.2 leads to the realization of a designed systemization in Section 3.6.3 that addresses the limitations of array size, dynamics and rhythmic structures.

The metaphorical representation of living organisms evoked different insights to performance, uncovering vibrant dynamics within human-*Game of Life* interaction. This also extends to influencing the creation of different timbres and textures, as well as rhythmic structures that one may overlook during the conventional process. Section 3.6.4 presented a tool for composition and live performance, packaging the *Game of Life* in a fairly universal VST format, further encouraging the use of metaphors in sonic art practice to steer the focus away from the sound domain.

Chapter 4

Hardware to Sonic Art

"To excite our sensibility, music has developed into a search for a more complex polyphony and a greater variety of instrumental tones and coloring…" – Luigi Russolo, [36].

This chapter presents the use of hardware in the applications of sonic art practices. The use of custom-built hardware for the specific purposes of accomplishing an artistic intent has been significant within the field of new media art. This is very much similar in musical applications, especially after 1945. The performances and fixed media works of sonic art extend to multimedia performances, and interactive installations. The first section (Section 4.1) discusses the proponents of the new modes of expression and presentation in performance and installations. The second section (Section 4.2) briefly reviews prior works and influences to two projects, which are presented in the third section (Section 4.3).

4.1 Motivation

More often than not, composition techniques and methodologies revolve around the paradigm of content, also known as compositional materials. Instead of the orthodox approach, it is more intriguing to address compositional methodologies from the hardware perspective – by way of constructing new interfaces for expression, communication, and presentation; new aesthetics in performance and composition can be discovered. By dropping all inclinations to known theories and practicums, the artist sets out on an unstable yet converging compositional process of uncovering unexpected dynamics within different influences from various métiers.

4.2 Background

The father of Futurism, Luigi Russolo, stated in his Futurist's Manifesto, *L'arte dei Rumori (The Art of Noises)*, written in early 20th century, that the human ear has become "accustomed to the speed, energy and noise of the urban industrial soundscape" [36], and therefore new compositional techniques (such as the creation of new timbre and orchestration techniques) are in order. To realize this order of new timbres, Russulo created noise-generating instruments called *Intonarumori.*

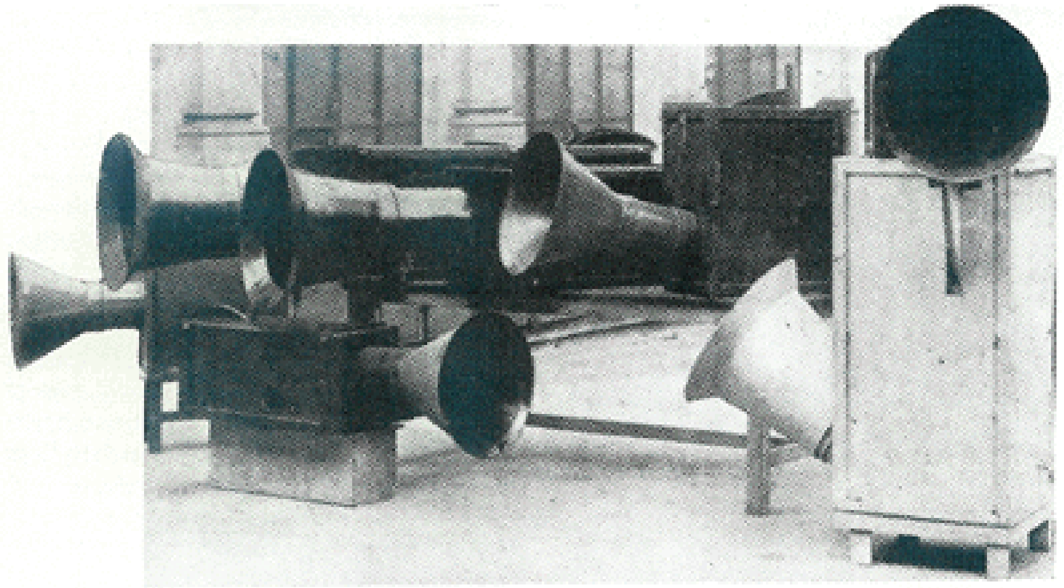

Figure 33: Intonarumori (1919) [37]

The advancement of audio technology since 1945 and its shift in aesthetics since then has further encouraged the creation of new compositional techniques and instruments. This includes Pierre Schaffer's search for *Musique Concète*, which resulted in the creation of phonogenes by Studio d'Essai [3]; the *Philips Pavilion* designed for *Expo '58 in Brussels*, whereby Edgard Varèse's *Poème électronique* was presented [5]; the *Unité Polyagogique Informatique CEMAMu (UPIC)* system was devised by Iannis Xenakis to exploring "drawing" sounds and compositions [38].

In today's digital age, the traditional performing artist (instrumentalist or dancer) is faced with an ever-growing interest in extending their media. There is a long history of using micro controllers and sensors to create interface that interact in ways that appear more embodied. Many in the field of music have longed to create devices for musical control that function in a way that is more expressive, and allows for alternative expression. Tod Machover was an early innovator in these musical technologies with his idea of hyper-instruments[39].

Hands are an important form of non-verbal communication, in which humans rely on for interaction. They help relay emotions, emphasize concepts, and often help in explanation. Hands are the basis of sign language, which rely heavily on movements and gesture for daily communication. A skilled musician's hand movements can provide useful information on what the musician is playing, how they are playing it, and possibly what they intend to do next. Musicians develop complex muscle memories in order to execute various performative tasks in the most efficient and effective way. Many of these movements have become intuitive, and often have developed naturally and have become intrinsic and include many subconscious motions.

In 1984, Michael Waisvisz brought popularity to the idea of hand based musical controllers with his introduction of *The Hands* [40]. The hands were constructed of numerous sensors and attached to the users arms, hands, and pants and allowed the control of music. Since then, many gesture-based designs for musical control have been created [41]. Simultaneously, numerous hand-based devices were being developed for non-musical uses, such as communication, computing, and gaming [42]. Gold's *Power Glove* was the first attempt to create a commercially available glove input gaming device and was being developed at the same time as the *DataGlove* [43], [44]. Stanford produced the *Thumbcode* as a digital sign language device in 1998 [45]. The development of hand-based devices have continued to grow in these fields [42]. Additionally, methods for gesture recognition in musical application continue to develop [41].

All of these gloves were historical benchmarks in how engineers approached the task of employing what they wanted their hand interface to do: aiding gaming and signing, both of which are tasks for niches that are outside of the arts. *Kontrol* (Section 4.3.1) is different from these in that it utilizes machine learning to achieve gesture recognition, that alone differentiating it from its predecessors. On top of that, *Kontrol* is specifically created for the performing artist, even though its use is not exclusive to them. The wide range of usability is also what sets *Kontrol* apart from the rest of these hand-interfaces.

4.3 Applications

This section presents two projects, *Kontrol* and *+ 6 5*. *Kontrol* is a hand interface that performers can wear without interference of their idiomatic performance styles. *+ 6 5* is a hybrid installation merging participation and performance, confronting the participants with a radical environment through the use of suspended speakers.

4.3.1 Kontrol

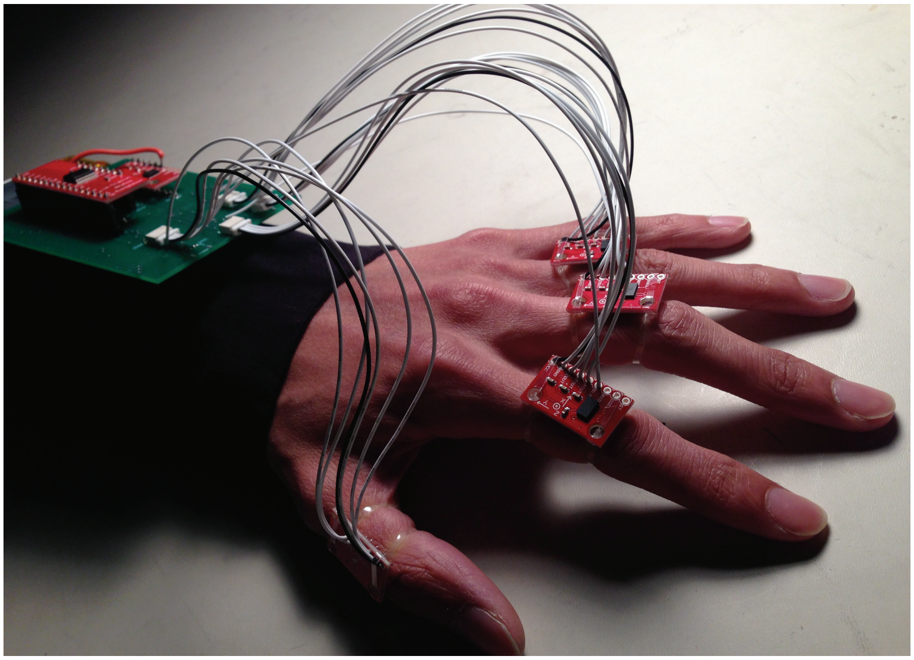

Figure 34: Kontrol

Kontrol aims to account for the traditional manner in which these artists perform, and not interfere with their ability to do so. This means that the performer not only gets to perform within the orthodox styles of their genres, but would also be able to acquire additional information about their movements. The greatest feat of Kontrol is the fact that they do not modify the instrument or the performer. In most cases of performing hyperinstruments, the performer is given the task of relearning their instruments in order to perform the additional tasks that are built in as digital artifacts. Kontrol is minimally invasive, as it is attached to the hand whereby it does not get in the way of any performance- there are no buttons, knobs or gestures that need to be integrated into the performance practice, as the gesture recognition would be mapping the original movements from the performance practice itself.

Kontrol is a hand interface built to extract the intricate expressivity of performers of various performative backgrounds. The goal of Kontrol is to provide a tool for the natural interpretation of gestures that interfaces with the performer in conjunction with the performative task. The use of triple-axis accelerometers on each finger and the hand provide high-resolution details about a performer's actions, and an ergonomically lightweight and non-intrusive design for the performer. These details are intricate: approximately 800 steps, which more than twice of an 8-bit resolution. Kontrol builds upon these findings as a tool for intuitive expression in digital music.

The sensors are carefully calibrated and designed to lay out ergonomically on the left-hand and are connect through a multiplexer to an Arduino Fio as seen in Figure 35. The use of accelerometers allow for the recognition and parameterization of the subtlest of movements.

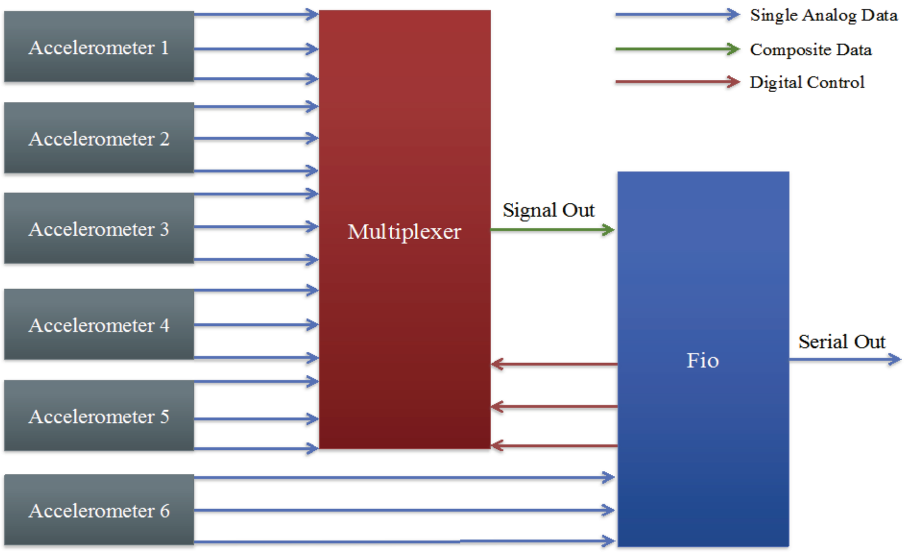

Figure 35: Overview of data handling between sensors and microcontroller

Six triple-axis accelerometers are customized to sit on the left hand: 5 on the fingers and 1 on top of the hand. The sensors are carefully calibrated and designed to lay out ergonomically on the left-hand and are connect through a multiplexer to an Arduino Fio as seen in. The use of accelerometers allow for the recognition and parameterization of the subtlest of movements. The number of accelerometers necessitated the use of a multiplexer in order to input all of the accelerometers' data into the Fio. The system is powered by a lithium rechargeable battery, which provides reliable mobility for Kontrol. The use of Xbees allows for wireless communication, sending the data from the Fio directly to the computer.

An overview of data flow from the microcontroller to the computer through wireless communications can be seen in Figure 36.

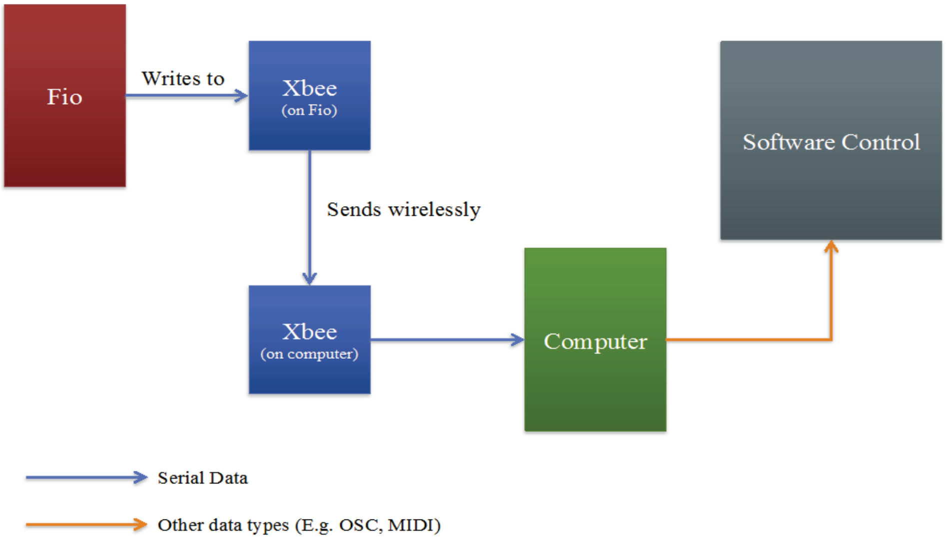

Figure 36: Overview of system communications

To achieve a compact setup, a customized PCB is designed to connect all of the components for Kontrol to the Arduino Fio. The PCB also provides a stable structure for Kontrol to sit on one's hand.

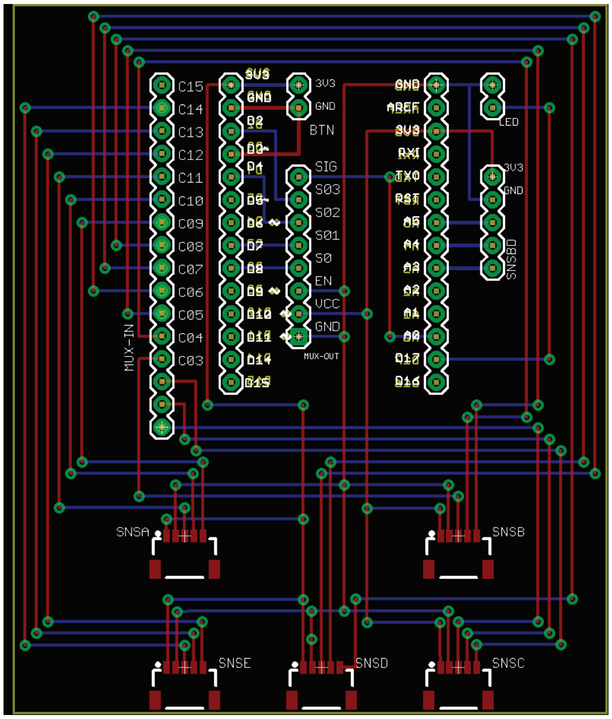

Figure 37: Customized PCB

Kontrol provides information about the performer's hand and finger movements, which can be extremely useful in determining what the performer's intentions are, and what a performer's actions should trigger. As such, a method is devised to extract the meaning of useful gestures for various types of performances. Individually addressing the data from the accelerometers into meaningful parameters is time consuming, and requires logging and processing large data sets for each performer. This inconvenience necessitates the use of machine learning to classify gestures. The classification of the data falls into two modes: Static and Dynamic.

Static classification allows us to classify single feature vectors. Theses classifiers are used when the performer wants instantaneous feedback on a given hand position. An example would be a flautist using a particular fingering as an indicator or trigger.

Dynamic classification allows us to classify a sequence of vectors. These algorithms take into account temporality, and allow us to classify gestures unfolding over time - A dancer performing a movement, which is to be accompanied by a triggered musical gesture.

Wekinator was the software used to realize the classification process. Developed by Rebecca Fiebrink, Wekinator is a tool for real-time feature extraction and on-the-fly machine learning [46]. It includes several machine learning algorithms and allows for the input of the data from Kontrol. The system allows us to easily classify data from Kontrol simultaneously in multiple modes. Using our custom-built software in conjunction with Wekinator, the incoming x, y and z values from each of the accelerometers are packed into a single Open Sound Control (OSC) message. Once Wekinator classifies the incoming data, it sends the results of the classification back to our software, which then allows it to be used for various purposes. This process is demonstrated in Figure 38 and Media File 13.

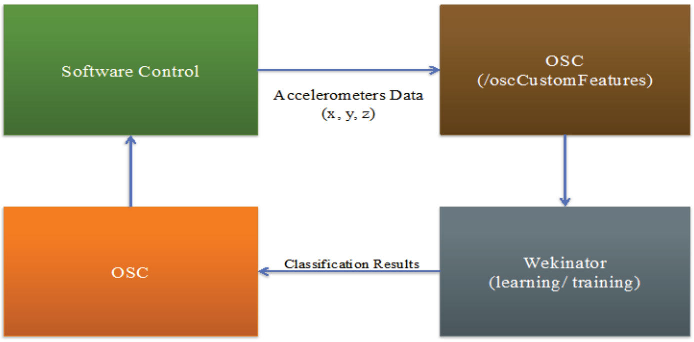

Figure 38: Overview of Feature Extraction to Wekinator

Kontrol was first used in the performance of *Gate,* an electroacoustic composition written for alto saxophone, 8-string guitar, and electronics. *Gate* explores the theme of the film *Baraka (1992)* by Ron Fricke. As the film is concurrently symbolically programmatic and pure art, the composition is formalized by structuring the form towards the literal thematic elements of the film, while playing with gestalts that first are symbolic of limpidity, growing into kaleidoscopic musical onomatopoeia of the modern world. This is shown through choices in both timbre and texture, as the limpidity is audible through purer and more continuous sound. As the piece progresses, these sounds become the kaleidoscopic onomatopoeia through the severe increase in intensity and discontinuity.

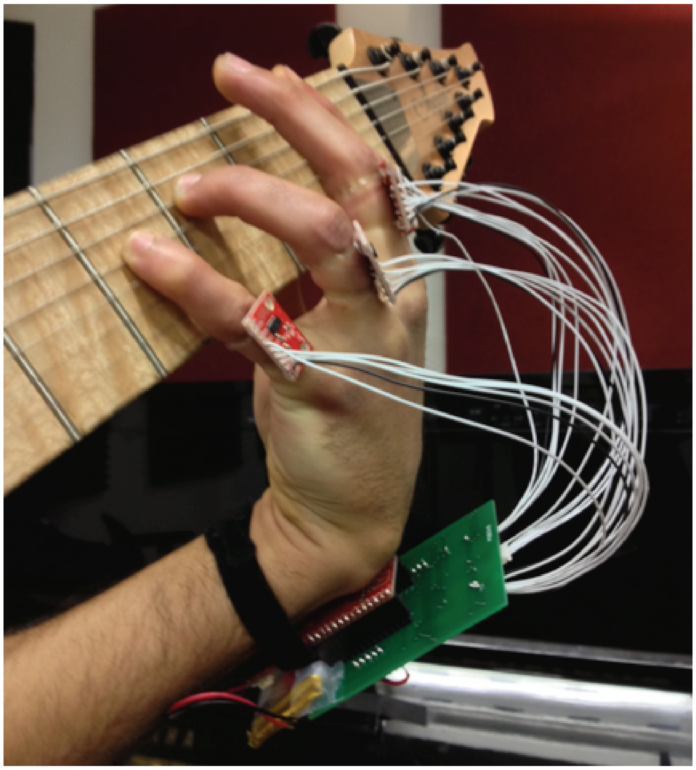

Figure 39: Guitarist with *Kontrol*

Gate (Media File 14) ties together the instruments and the electronics using a custom-built microcontroller. It extends and explores the interaction between the performers on two levels. By having an instrumentalist wearing *Kontrol*, the performers are able to musically and gesturally converse with both each other and the electronics. *Kontrol* captures micro-gestures that are otherwise non-visible and inaudible, becoming the gateway to the performers interacting on a microscopic level.

Many of the design considerations for Kontrol proved to be successful. The utilization of Xbee allows seamless and reliable wireless communication between the Fio and the computer. This provides mobility for the performers and the absence of a computer on stage, which may otherwise affect the performance aesthetics. More so, the accelerometers allow high precision in gesture recognition and provide accurate data to even the subtlest movement of the fingers. However, using readily available hardware has prevented further reduction of the overall dimensions of Kontrol. To overcome this, the newer version looks into custom-design circuits that integrates the multiplexer and Fio into a consolidated package. Furthermore, the surface mount JST-like connectors require high level soldering skills and are very fragile.

4.3.2 + 6 5

+ 6 5 takes the form of a performance-installation hybrid, confronting the participants with a radical environment through the use of spatialization and the speakers' localization. The project inquires the interrelations between performance and fixed media works, spatial acoustics and human perception, and sounds as objects. *+ 6 5* aims to challenge the individual artist to utilize techniques from multiple métiers synchronously to make new discoveries while attempting to achieve a more resolute result.

The installation represents an ecological system inspired by the hybridization of cultures. The entrance of participants will change the ecology of the system, and may re-establish itself in a new equilibrium state. It presents itself synchronously in two forms – the first involves participants observing the space as audience members, while the second presents the participants as performers in the installation space. The installation rigs 40-channels of suspended speakers from the ceiling. Figure 40 shows the artist impression of the performance-installation hybrid.

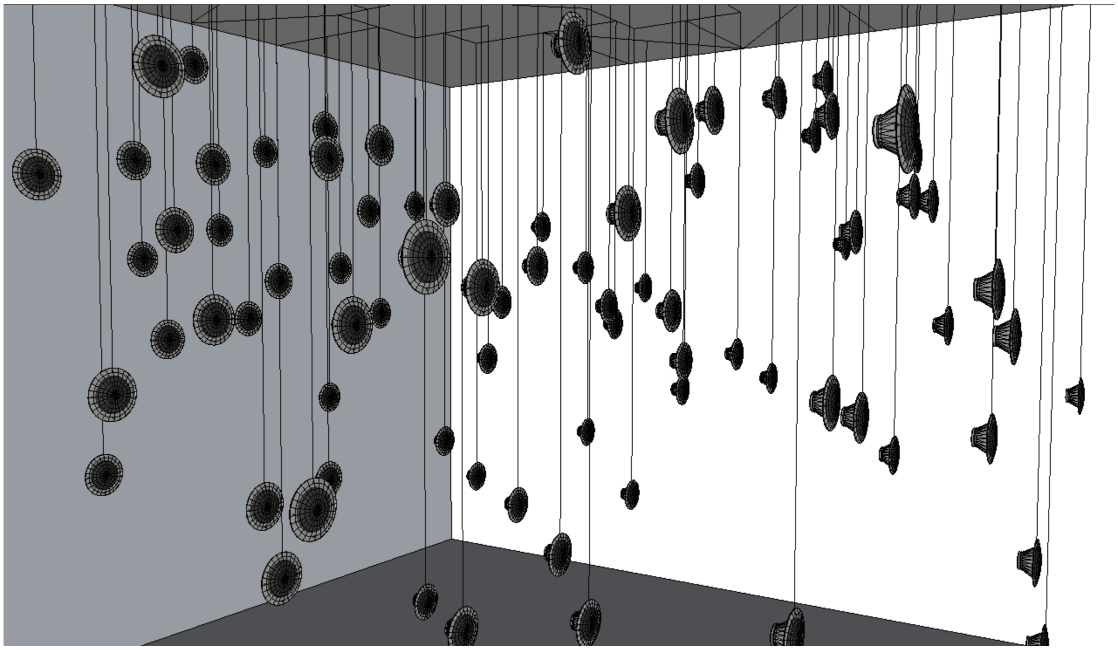

Figure 40: Artist impression of + 6 5

Prior to the installation, the sonic materials used in *+ 6 5* was presented at Playden, a space in The Arts House, on March 2nd, 2013 in Singapore. It was a commission from SouArt for the *i-AM Festival 2013*[19], the annual arts festival for social causes. Presented as *from across the pacific: time, space and density,* it adopts the aesthetics and artistic concepts of *+ 6 5*. *From across the pacific: time, space and density* uses mutated concrète sounds to describe the morphological relationship between space and people. Time is hyper-compressed from 52 years to 22' 24", while space is compressed from 704 km squared to the venue's size. The concrete sounds were contribution by the locals (Singaporeans) of either sounds is part of their daily lives, or sounds that defined them as an individual. Then, these contributed sounds are processed by Singapore's geographical and populous census data[20] post-1950's. The structure of the composition is derived from calculating population over geography, creating an abstraction of the space's density. Media File 15 condenses the four-channel performance to a stereo mix.

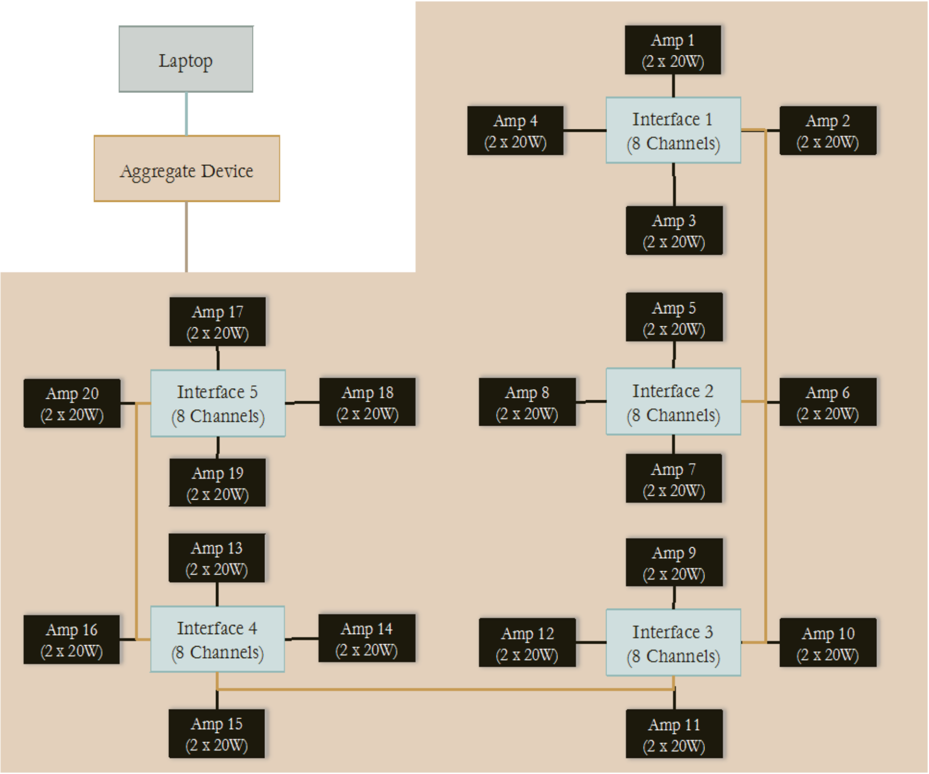

Figure 41: + 6 5 hardware setup

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[19] http://www.lasalle.edu.sg/Events/EventDetail.aspx/i-AM-2013-Arts-Festival

[20] http://www.singstat.gov.sg

Figure 41 shows the technical setup of the installation. 40 discrete outputs are achieved through daisy chaining (Firewire) 6 audio interfaces to one laptop, creating an Aggregate Device. Amplifiers of 20-Watts per channel power the individual passive speakers.

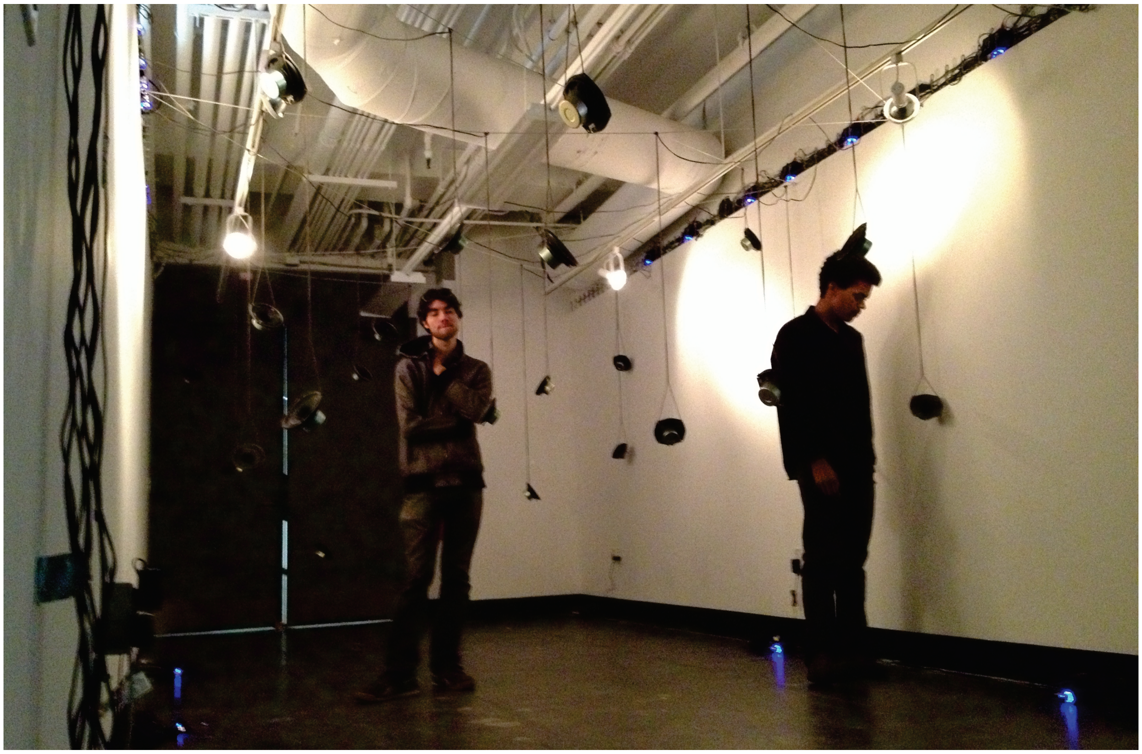

Figure 42: + 6 5 performance-installation

The performance-installation hybrid is presented at Center for Integrated Media, California Institute of the Arts as part of the fulfillment for the Integrated Media Program. *+ 6 5* features 40 freely suspended speakers, allowing the participants to intimately interact with each individual speaker to change the direction of emittance. Figure 42 shows two participants interacting with the speakers at close proximity. Media File 16 is a video with short excerpts from the installation.

4.4 Summary

On the whole, this chapter presented two projects that addressed the practice of sonic art by designing new hardware for interfacing performances and presentations. Section 4.3.1 described the design of an ergonomic hand controller that made use of sensors and machine learning to recognize and listen to gestures. Section 4.3.2 presented the idea of playing with the alteration of sound tactilely by altering the direction the sound is emitted in an enclosed space. Both these projects focused on the process of designing and engineering hardware by understanding the needs and specifying its context of use (instead of the auditory compositional process), therefore as a result produced a new direction of aesthetics created through hardware.

Chapter 5

Conclusion

"The development of computational tools and media has been radically transforming the landscape for the practice of design, the arts and numerous cultural manifestations." – xCoAx, [47].

5.1 Summary

Over the past decade, the advancement of technology has increased significantly specifically in the areas of mobile, sensor, computation, and audio-visual technology. These technological advances have become increasingly pervasive and its integration into our daily lives has altered/modified/changed/extended human perceptions and way of life. Hence, it is essential to extend further beyond the sonic and visual realms to continue exciting our sensibilities. The thesis presented a resolution - to explore and discover new approaches, specifically using new methodologies that involve creative processes beyond the familiar paradigm of sound, for implementation using accessible components to create new works that may be compositions, or tools for artistic practices, yet encourages non-conforming new art.

In the previous chapters, three methodologies were presented to explore new creative processes in contemporary sonic art practice - namely *Data to Sonic Art*, *Algorithm to Sonic*, and *Hardware to Sonic Art*. Figure 43 shows the overview of the methodologies and their relationship. As mentioned in the earlier chapters, these methodologies are often used in conjunction with one another. This is further discussed later in Section 5.3.

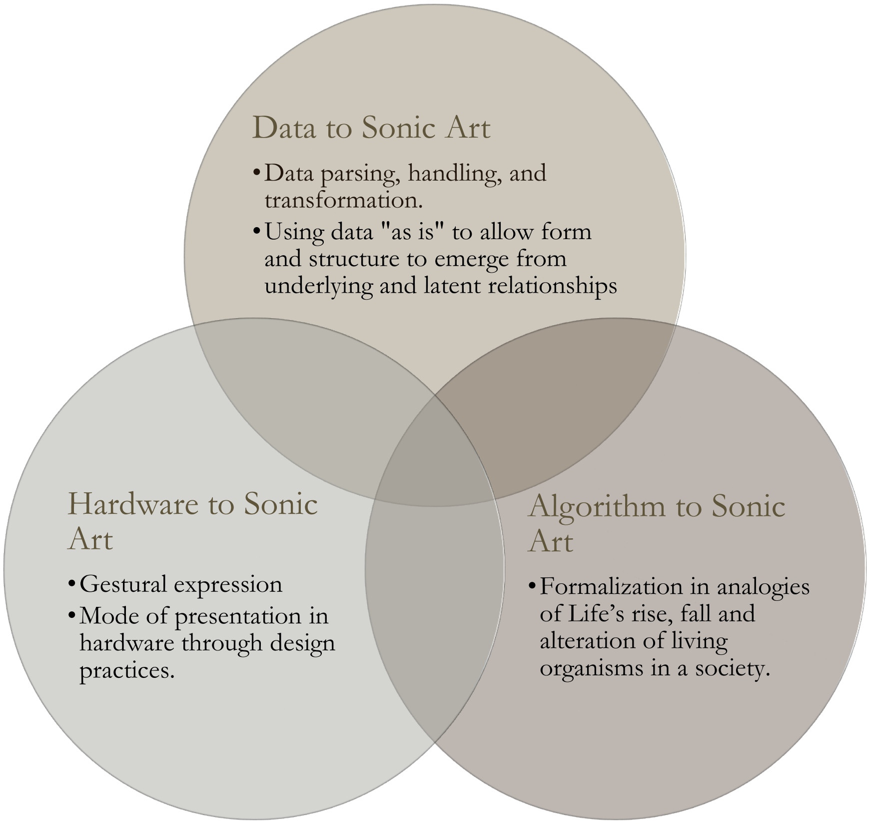

Figure 43: Overview of methodologies

5.2 Primary Contributions

In Chapter 2, the focus is recentralized to the practice of data manipulation. The approach uses techniques in data transformation such as bit shifting, and filtering, etc. Interpolations*: Noise in Space* (Section 2.2.2) uses data as the source of composition and implements sonification techniques such as audification and parameter mapping, extracting embodied structures and form within network messages. While *Undecakisimage* (Section 2.3.1) presents a figurative outlook to visualizing data and ideology in a spatial augmented reality, *DecodeMap 1.0* (Section 2.3.2) provides a unified solution to audio and video synthesis, as well as projection mapping tools in a consolidated package realized in *Max*. Bridging sonification and visualization through data, *Intricate Boundaries* (Section 2.4) free creative processes from the mind's limitations within each field. Using algorithms as described in Chapter 3, compositions are put into the perspective of societies with living organisms to drive the sonic practice. *Bots Formalization* (Section 3.6.3) extends human-robotics interaction by interfacing their formalization with *Conway's Game of Life* in a live performance setting, breathing *Life* into the mechanical robots. *V I E* (Section 3.6.4) drives the organization of sonic materials through the analogies of *Game of Life*. Finally using a hardware-design approach towards sonic art practice as presented in Chapter 4, *Kontrol* (Section 4.3.1) identifies the need for extending traditional performance techniques by focusing on gestural expressions for its use in digital media. *+ 6 5* (Section 4.3.2) addresses the platform of performance by creating a radical space using a large array of suspended speakers.

5.3 Other Discussions

As mentioned earlier in the discussion, the methodologies are more often used in conjunction with one another. Figure 44 shows a possible creative process in using the presented methodologies in contemporary sound art practice.

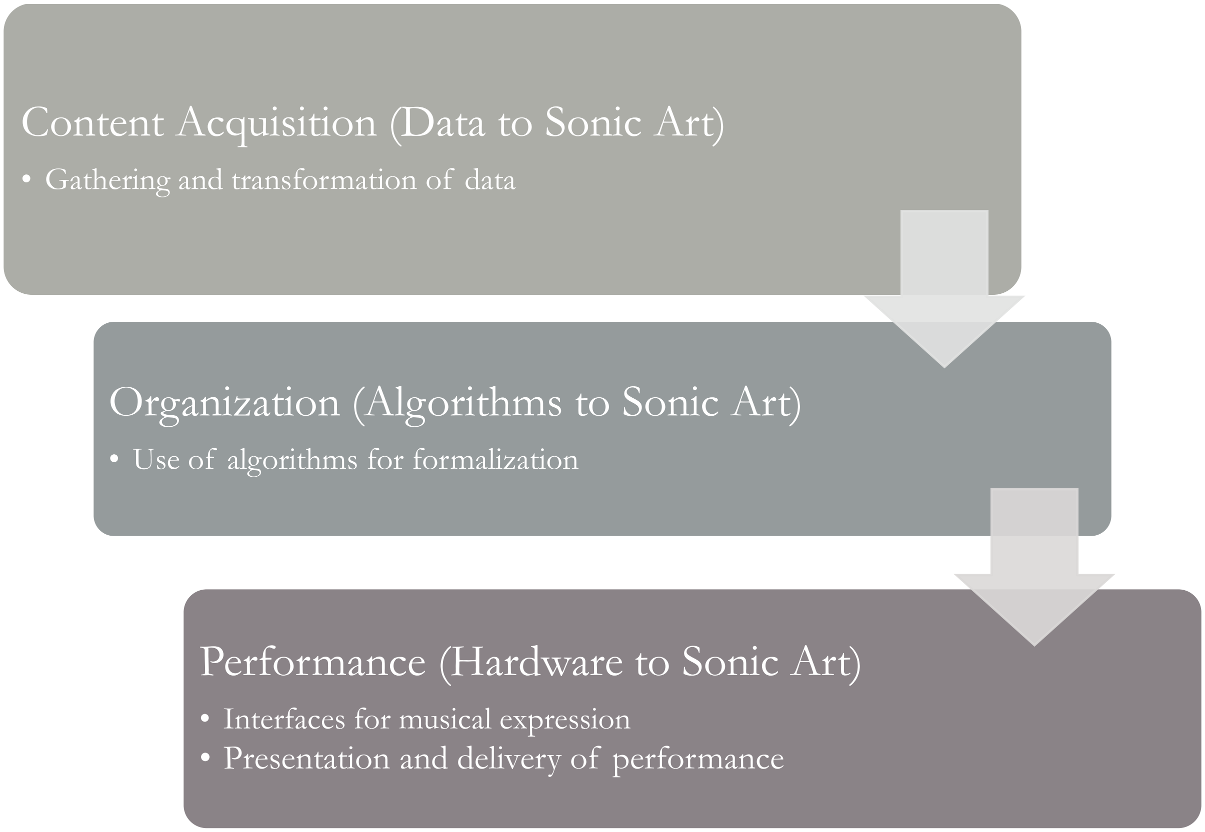

Figure 44: Creative process with new methodologies

In the electroacoustic composition parallel, the *Data to Sonic Art* approach can be viewed as the content acquisition of a composition, focusing on the gathering and transformational processes. This is very much similar to process-oriented techniques such as throwing die to determine pitch. The process of using algorithms will be the organization of sonic materials by an algorithm, while preserving the possibility for user-defined variants at a higher-level. Lastly, the hardware approach can be used for interfacing live performances and setting a platform or medium for the presentation of a composition.

5.4 Final Thoughts

Technology is the mediation between the marriages of different métiers. It provides a common platform or landing-ground for the conversation and exchanges of ideas without the limitations of theory and practicum from each field. While technology dulls human sensibilities with its progressive developments (the constant use of smartphones, instant messaging/texting, being desensitized by the internet, the death of shock value, 3D becoming a norm), it urges for art practitioners to discover new ways of performance, presentation, and aesthetics appreciation. This thesis has presented new methodologies and aesthetics that extend beyond the paradigm of sound to discover new aesthetics and excitement for our sensibilities. Through this discussion, along with accomplished projects, this thesis proved to yield profitable synergies that open new areas for considerations in contemporary sonic art practice.

5.5 Future Work

As the development of technology will not cease to progress, it is important as a digital artist to stay au courant and continue exploring the frontiers of digital arts. This shall hopefully open up new fields of research, theory, practice, pedagogy, and methodologies that may contribute to the maturity of Digitals Arts and inspire many other digital artists to be courageous in liberating one's mind from theory to explore cutting-edge technology in a diverse collaboration of métiers.

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