SOUNDS OF UNSEEN BOUNDARIES: A DIGITAL PORTFOLIO DISSERTATION OF SEVEN ORIGINAL COMPOSITIONS FOR DATA-DRIVEN INSTRUMENTS

by

ZACHARY JAMES BOYT

A DISSERTATION

Presented to the School of Music and Dance
and the Division of Graduate Studies of the University of Oregon
in partial fulfillment of the requirements
for the degree of
Doctor of Musical Arts in Music Performance of Data-driven Instruments

March 2023

DISSERTATION APPROVAL PAGE

Student: Zachary James Boyt

Title: Sounds of Unseen Boundaries: A Digital Portfolio Dissertation of Seven Original Compositions for Data-driven Instruments

This dissertation has been accepted and approved in partial fulfillment of the requirements for the Doctor of Musical Arts in Performance of Data-driven Instruments degree in the School of Music and Dance by:

Dr. Jeffrey Stolet	Chairperson
Dr. Akiko Hatakeyama	Core Member
Dr. Jon Bellona	Core Member
Colin Ives	Core Member

and

Krista Chronister	Vice Provost for Graduate Studies

Original approval signatures are on file with the University of Oregon Division of Graduate Studies.

Degree awarded March 2023

DISSERTATION ABSTRACT

Zachary James Boyt

Doctor of Musical Arts in Music Performance

School of Music and Dance

March 2023

Title: Sounds of Unseen Boundaries: A Digital Portfolio Dissertation of Seven Original Compositions for Data-driven Instruments

Sounds of Unseen Boundaries: A Digital Portfolio Dissertation of Seven Original Compositions for Data-driven Instruments is presented as a Digital Portfolio Dissertation of seven compositions for data-driven instruments. The entirety of the Digital Portfolio Dissertation consists of video documentation of each piece, software and score material used in performance, and a text document serving as an accompanying analytical guide to each composition and its respective data-driven instrument. This document contains definitions related to the conceptual frameworks of data-driven instruments, an analysis of the design and implementation of each instrument, data mapping strategies used, compositional structures, and issues and practices in their performance. The compositions included in this Digital Portfolio Dissertation are: *unFamiliar, Within the Tallest Tree, Things Look Different Here, A Need to Be Free, A Musical Interpretation on the Findings of Voyager 2, family, friends,* and *Virtualability.*

SUPPLEMENTAL FILES

The supplemental material included in this Digital Portfolio Dissertation consists of digital videos of performances of the portfolio compositions, the custom software used to perform the works, and all affiliated files.

Video of performance of *unFamiliar*

Video of performance of *Within the Tallest Tree*

Video of performance of *Things Look Different Here*

Video of performance of *A Need to Be Free*

Video of Performance of *A Musical Interpretation on the Findings of Voyager 2*

Video of performance of *family, friends*

Video of performance of *Virtualability*

Software and affiliated files for *unFamiliar*

Software and affiliated files for *Within the Tallest Tree*

Software and affiliated files for *Things Look Different Here*

Software and affiliated files for *A Need to Be Free*

Software and affiliated files for *A Musical Interpretation on the Findings of Voyager 2*

Software and affiliated files for *family, friends*

Software and affiliated files for *Virtualability*

CURRICULUM VITAE

NAME OF AUTHOR: Zachary James Boyt

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:

University of Oregon, Eugene, Oregon
Western Michigan University, Kalamazoo, Michigan

DEGREES AWARDED:

Doctor of Musical Arts in Music Performance: Data-driven Instruments,
2023, University of Oregon
Master of Arts in Music: Technology,
2014, Western Michigan University
Bachelor of Music in Music Performance: Cello,
2010, Western Michigan University

AREAS OF SPECIAL INTEREST:

Electronic Instrument Design and Performance
Electroacoustic Composition
Augmented String Instruments
Digital Arts

PROFESSIONAL EXPERIENCE:

Graduate Employee, School of Music and Dance, University of Oregon,
Eugene, OR, 2020 – 2023

Technical Director, Festival Ramificaciones,
Zacatecas City, Zacatecas, 2017 – Present

Graduate Teaching Assistant, School of Music, Western Michigan University
Kalamazoo, MI, 2010 – 2014

GRANTS, AWARDS, AND HONORS:

Graduate Teaching Fellowship, Music Technology, University of Oregon,
2020, 2022
Future Music Oregon Travel Award, University of Oregon, 2020

Graduate Award for Research, Western Michigan University, 2015
Academic Travel Award, University of Oregon, 2014

CONFERENCE PRESENTATIONS:

Society for Electro-Acoustic Music in the United States (SEAMUS), 2014, 2018, 2020
New York Electro-Acoustic Music Festival (NYCEMF), 2019
International Computer Music Conference (ICMC), 2019
Festival Cultural Zacatecas (FCZ), 2019
Kyma International Sound Symposium (KISS), 2018
Society of Composers, Inc. (SCI), 2014
Toronto International Electroacoustic Symposium (TIES), 2014
Electroacoustic Barn Dance (EABD), 2014
Electronic Music Midwest (EMM), 2012

PUBLICATIONS:

Boyt, Zachary. "Gesture-Sensing Technology for the Bow: A Relevant and Accessible Digital Interface for String Instruments." Master's thesis, Western Michigan University, 2014.

ACKNOWLEDGMENTS

I would like to express my sincere appreciation to my dissertation committee, Jeffrey Stolet, Akiko Hatakeyama, Jon Bellona, and Colin Ives, for their support and guidance in the crafting of not only this dissertation, but of me as a human being and artist.

Special thanks as well to John Park, Jeremy Schropp, and Chet Udell for their invaluable knowledge, instruction, and assistance.

To all of my friends and family, who have supported and encouraged me along the way, thank you.

TABLE OF CONTENTS

Chapter Page

VIDEO: Performance of *Within the Tallest Tree*

VIDEO: Performance of *Things Look Different Here*

VIDEO: Performance of *A Need to Be Free*

VIDEO: Performance of *A Musical Interpretation on the Findings of Voyager 2*

VIDEO: Performance of *family, friends*

VIDEO: Performance of *Virtualability*

SOFTWARE AND AFFILIATED FILES: *unFamiliar*

SOFTWARE AND AFFILIATED FILES: *Within the Tallest Tree*

SOFTWARE AND AFFILIATED FILES: *Things Look Different Here*

SOFTWARE AND AFFILIATED FILES: *A Musical Interpretation on the Findings of Voyager 2*

SOFTWARE AND AFFILIATED FILES: *family, friends*

SOFTWARE AND AFFILIATED FILES: *Virtualability*

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

Overview of the Digital Portfolio Dissertation

This Digital Portfolio Dissertation, entitled “Sounds of Unseen Boundaries: A Digital Portfolio Dissertation of Seven Original Compositions for Data-driven Instruments,” contains digital audio/video recordings of performances of seven real-time electroacoustic compositions employing data-driven instruments, software and score material necessary to their performance, and the following text document which serves as an analytical guide to the seven compositions. To assist in an efficient discussion of this analysis, a brief overview of the conceptual background and theoretical frameworks involved in composing for data-driven instruments is provided in Chapter II, following this introduction. Further reading on these background subjects can be found in the bibliography section at the end of this document. Chapter III will provide descriptions of the design and implementation of each data-driven instrument, the routing and mapping of data, musical challenges and opportunities presented by each instrument, and a description of the structure and articulation of each composition.

Each composition presented in this Digital Portfolio Dissertation utilizes a unique performance interface across a range of interface types. Some are repurposed or appropriated gaming devices or tools, while others are custom-built electronic interfaces made specifically for the piece composed. The variety in types of interfaces subsequently led to a variety of decisions and strategies employed in the process of acquiring and mapping data to musical parameters. Software used in the construction of my data-driven instruments include Arduino,[1] Max,[2] Kyma,[3] Processing,[4] and Unity.[5] In all the pieces presented here, Symbolic Sound's Kyma was used as the sound synthesis engine. Kyma is a sound design and musical composition environment within which sound-producing algorithms are created and controlled in real time.

The title, performance interface, data mapping software, and synthesis engine employed in each composition is listed below:

1. *unFamiliar* for Gametrak, Max, and Kyma
2. *Within the Tallest Tree* for Wacom Tablet and Kyma
3. *Things Look Different Here* for electric cello with custom-built data glove, Max, and Kyma
4. *A Need to be Free* for Kinect, Processing, and Kyma
5. *A Musical Interpretation on the Findings of Voyager 2* for custom sensor-based interface, Max, and Kyma
6. *family, friends* for iPad and Touché, Max, and Kyma
7. *Virtualability* for Oculus Quest VR system, Max, Unity, and Kyma

---

[1] *Arduino IDE*, v. 1.8.19, macOS, 2021, https://www.arduino.cc

[2] Cycling 74', *Max*, v. 8.2.1, Cycling 74', macOS, 2021, https://cycling74.com/products/max/

[3] Carla Scaletti and Kurt Hebel, *Kyma Seven*, v. 7.39f4, Symbolic Sound Corporation, macOS, 2021, https://kyma.symbolicsound.com/

[4] Benjamin Fry and Casey Reas, *Processing*, v. 4.0 beta 2, macOS, 2021, https://github.com/processing/processing4

[5] *Unity*, v. 2020.3.25f1 LTS, Unity Technologies, macOS, 2020, https://unity.com/.

Boundaries as a Conceptual Lens for the Portfolio Compositions

Boundaries are everywhere. Ubiquitous and omnipresent, they help define everything about our lives and our relationships with the world around us. Boundaries can be physical, psychological, or imaginary. They can be temporal or spatial, natural or artificial. The Oxford English Dictionary defines a boundary as "that which serves to indicate the bounds or limits of anything whether material or immaterial; also the limit itself."[6] In the study of thermodynamics, a boundary is defined as "a real or imaginary volumetric demarcation region drawn around a system across which quantities such as heat, mass, or work can flow."[7] The American Psychological Association defines a boundary as a "demarcation that protects the integrity of an individual or group or that helps the person or group set realistic limits on participation in a relationship or activity."[8] Obviously, boundaries are many different things in different contexts. The definition and understanding of boundaries has been a subject of debate in philosophical writings throughout history and continues in the complexity of today's world. While a complete discussion on the subject of boundaries is beyond the scope of this dissertation, further exploration on the philosophical debate defining boundaries can be found in the bibliography section of this document.

In the context of contemporary music composition, boundaries of all types have often been a source of inspiration or facilitated compositional process. Throughout my studies of music composed within the last century, a handful of pieces stand out in

[6] "boundary, n.," OED Online (Oxford University Press), accessed November 8, 2022, https://www-oed-com.libproxy.uoregon.edu/view/Entry/22048.

[7] Pierre Perrot, *A To Z of Thermodynamics by Pierre Perrot* (Oxford University Press, 1998), 25.

[8] "Boundary," American Psychological Association (American Psychological Association), accessed November 14, 2022, https://dictionary.apa.org/boundary.

particular as landmarks of personal inspiration. Perhaps the most directly relevant in title is Mieko Shiomi's <*boundary music*>. In this work, performers are invited through a simple text prompt to "make your sound faintest possible to a boundary condition whether the sound is given birth to as a sound or not."[9] What may seem at first a simple exercise in the threshold of perceived sound is quickly muddied in the context of staged performance, bringing into question the boundaries in relationships between performer and audience. Is the boundary condition of perception applied to only the performer making the sound, to other participating musicians, or to the audience member sitting in the furthest row of the hall? A more concrete example of boundaries used in a compositional process is the often referenced *I Am Sitting in a Room* by composer Alvin Lucier.[10] The process of this piece is centered on the repeated playback and re-recording of a narrated text within a room. With each iteration, the resonant frequencies of the room create an emphasis or attenuation of certain frequencies. Eventually, the sonic characteristics of the room, defined by the boundaries of the walls containing it, overwhelm any intelligibility of the original narration. As a final boundary inspired example, composer Jon Rose's series of "fence projects" takes a more hands-on approach through his treatment of various fences around the world as enormous string instruments.[11] Rose's accompanying writings and liner notes are rich with commentary on the social, political, and environmental effects of the man-made boundaries he performs.

---

[9] Mieko Shiomi, "< boundary music >" The Museum of Modern Art, accessed November 7, 2022, https://www.moma.org/collection/works/127554.

[10] Alvin Lucier, *I am sitting in a room*, Lovely Music, Ltd., 1990.

[11] Jon Rose, "Great Fences of Australia," The Jon Rose web, accessed November 21, 2022, https://www.jonroseweb.com/f_projects_great_fences.php.

In reviewing my own work collected in this digital portfolio dissertation, it became clear that I too have often focused on subjects of boundaries, particularly those that are unseen, invisible, or imaginary. In *unFamiliar* I explore the boundaries of human perception of sound through the manipulation of ambisonic recordings. *Within the Tallest Tree* presents a fantasy of crossing boundaries in communication with surrounding nature. *Things Look Different Here* stands as a representation of crossing my own personal boundaries from a classically trained cellist to a data-driven instrumentalist. *A Need to Be Free* presents a musical metaphor to the unseen boundaries of anxiety and depression. *A Musical Interpretation on the Findings of Voyager 2* is centered on literal unseen boundaries, using data representing planetary magnetic fields in various ways throughout the composition. In *family, friends* I present a narrative of the recalibration of social boundaries during pandemic induced isolation. Finally, *Virtualability* strives to blur the boundaries between the interior and exterior spaces inherent to a virtual reality environment.

As much as the subjects of each piece are related in some way to my perspectives on boundaries, the preparation and performance of a musical work is itself the crossing of a boundary, as an idea or concept is manifested into an observable, performable composition. The point of translation in this medium of staged musical performance centers on the performer's articulation of a musical instrument. There are many unseen parts to the crossing of this boundary which I will reveal in this document; data mapping techniques, sound design, and the challenges and opportunities that arose through the compositional process.

CHAPTER II

CONCEPTUAL BACKGROUND AND THEORETICAL FRAMEWORKS

To facilitate an efficient discussion and analysis of the compositions presented in this Digital Portfolio Dissertation, an overview of concepts and definitions I use is provided here.

Definition of the Data-driven Instrument

Data-driven instruments are inherently modular systems in that they are complex, interconnected systems constructed from smaller, less complicated systems or objects. A definition of data-driven instruments can be understood as being divided into three layers or systems as described below:[12]

1. An interface, by which data is acquired or created by means of human performance.
2. A data mapping layer, in which data streams from the interface are analyzed and/or transformed into more appropriate ranges or messages, and then output to:
3. Sound producing algorithms, which use this transformed data to control musical parameters.

The number of sub-modules within each layer can be few or many, varying greatly in the type of interface and compositional or musical intentions.

The traditional acoustic instrument predecessors of data-driven instruments have much in common with this basic structured definition. A piano for example, contains an interface of keys, a mapping layer which transforms the downward action of depressing the keys into an upward action of a striking hammer, and a sound producing layer as the vibration of a string or strings. The main difference between data-driven instruments and

[12] Jeffrey Stolet, *Do: Notes about Action in the Creation of Musical Performance with Data-driven Instruments.* (Morrisville: Lulu Press, 2021), 23.

their traditional acoustic predecessors is the replacement of physical energy with data as the main driving force directing sound production.

Data Sources

A functionally effective interface of a data-driven instrument must have some form of sensory input to translate performative actions into data. There are two types of devices by which this can be achieved: sensors which generate momentary packets of data, and sensors which generate a continuum of data over time. These two types of sensors are commonly referred to as buttons and faders.[13] Buttons are generally either momentary in function, producing a state change only while actuated, or maintained, switching states when they are actuated. Faders come in a variety of dimensions and proportions. A one-dimensional fader is most commonly known in the form of a linear slider or a rotating potentiometer. Two-dimensional faders produce two streams of data, most commonly described as an x and y location on a plane. A three-dimensional fader produces three streams of data from its input and is most commonly expressed as a spatial coordinate of values x, y, and z. The symmetry of a multidimensional fader is determined through a comparison of spatial equality between its axes. A Wacom tablet[14] is an example of an asymmetrical fader in that the x-axis of the interface is spatially larger than the y-axis.

[13] Ibid, 33.

[14] The Wacom Intuos Pro tablet is a high-resolution, multi-input tablet device originally designed for digital illustration use.

Modularity

One great advantage of data-driven instruments is the instrument's inherent modularity. Modularity refers to the compartmentalization and interrelation of the different components within a system. Data-driven instruments are generally more flexible in construction than traditional acoustic instruments as the three main components; interface, mapping layer, and sound production, are often physically separated rather than housed within the same body. As data is the sole driving force communicated across the different modules of the data-driven instrument system, each layer can be individually adjusted or replaced. While replacing a module within a data-driven instrument may require adjustments in the way data is treated and used in interconnected modules, doing so is clearly easier than replacing the mechanical equivalent of an acoustic instrument.[15]

Mutability

The programming capabilities of the data mapping layer also provides an inherent mutability, the ability of something to change. Throughout the temporal context of any given composition, the same or similar performative actions can produce drastically different results. While traditional acoustic instruments share a similar quality, the muting of a brass instrument or the preparation of a piano for example, data-driven instruments are distinct from acoustic instruments in the extreme and instantaneous ability of change provided by the flexibility of the software mapping layer.[16]

---

[15] Stolet, *Do*, 25-27.

[16] Ibid, 81.

Methods in Communication

The communication of data between modules of the data-driven instrument can be achieved through a variety of means. The two main subjects involved with the communication of data in a data-driven instrument are 1) the physical means by which connections are made for the transfer of data and 2) the protocols or communications standards that are used to communicate data accurately and effectively.

The means by which modules of the data-driven instrument are connected include physical wiring and peripheral connection schemes such as USB, Firewire, Ethernet, or MIDI cables. Data can also be transmitted wirelessly by means of Wi-Fi, Bluetooth, or other transmission protocols.

The protocols or communication standards used in effectively communicating data between modules varies as well, and choices are often based on the composer or instrument designer's preferences regarding what works best with the instrument at hand. Standard communication protocols used in the implementation of data-driven instruments presented in this document include serial transmission of data over USB, MIDI, and Open Sound Control (OSC).

Data Mapping

In the context of the data-driven instrument, data mapping is the intentional transformation of a set or series of data into a different set of data for the purpose of controlling and shaping musical parameters.[17] This is often a necessary procedure, as the data provided or acquired by the interface is usually not within a useful range for the controlling of musical parameters. A standard MIDI controller interface for example, will

[17] Ibid, 67.

most likely output a stream of control change values within a range of 0 to 127. If the designer of a data-driven instrument using this interface wishes to use this data stream to manipulate the cutoff frequency of a high-pass filter, some form of manipulation would be necessary in order to make effective use of this data stream in a more appropriate range. The data stream would need to be transformed into a more usable range related to values more likely used by the frequency cutoff of a filter, usually within the range of audible frequencies, 20 to 20000 Hz. Shifting and scaling the incoming data stream into this range would be an appropriate data mapping.

There are many possible approaches in data mapping techniques. The most commonly used data mapping techniques in composition involving data-driven instruments are scaling, offsetting, smoothing, quantizing, reordering, thinning or limiting, and the process of analyzing incoming data for particular events.

Observability

Data-driven instrumentalists share many of the performance techniques valued by performers of traditional instruments. However, the audience's unfamiliarity with the construction of the data-driven instrument, and the novelty of observing unique instruments, requires particular attention by the performer towards the subjects of observability and musical connections to performative actions. Ideally, in the process of composing for the instrument, the appropriate mapping of data to musical parameters allows for ease of observability for the audience, that is, the ability to relate particular actions to musical responses. Performative actions that cross between non-performative and performative space (the space which engages the interface to the point of producing usable data), can help enhance and illuminate observability in performance.[18]

Technological Embodiment

The embodiment of a data-driven instrument relates to the embedding of the interface into a physical object and/or using the interface in a way that evokes a collective understanding of familiar actions by the performer and audience.[19] Utilizing traits of embodiment in the composition of a data-driven instrument provides clarity to the performer on the natural range of performative actions, while also providing a familiar set of actions that the audience can easily understand and interpret. The way in which a particular interface looks or feels, for example, can define a restriction or freedom of movement in performative actions and an expectation of resulting sounds. Effective articulation of embodiment in performance provides a familiar set of actions-to-sounds that the audience can understand and to which they can relate. The audience's collective understanding in the embodiment of the data-driven instrument can provide increased appreciation in the composer's choice of interface, and the way in which the performer engages that interface in performance.

[18] Ibid, 21.

[19] Ibid, 60-62.

CHAPTER III

PORTFOLIO COMPOSITIONS

III.1 *unFamiliar*

Overview

unFamiliar is a multichannel real-time interactive composition for Gametrak, custom software created in Max, and Kyma. The Gametrak's unique dual three-dimensional faders, combined with a large, observable performance space, provided an exceptional tool for sonic exploration.

The conceptual intention of *unFamiliar* was to take a familiar sonic environment and stretch and explore the sounds of this environment on a micro-level to create a series of soundscapes. The inspiration for this process came from my own curiosity and study of imagery produced by scanning electron microscopes. These tools allow for the crossing of the boundary between the seen and the unseen, producing familiar, yet often very foreign visual landscapes. *unFamiliar* seeks to evoke a similar sense of a foreign, yet recognizable feeling by crossing boundaries of human perception of sound. Sonic material used for this piece is comprised of recordings of a local market taken with a custom-made ambisonic microphone. The natural spatialization provided by an ambisonic recording of a common place, combined with a recapitulatory compositional structure provide the sense of familiar, while the extreme manipulation of time with the analysis and resynthesis using Kyma's unique *TauPlayer* help cross the boundary into the unheard and unfamiliar.

Design and Implementation of Data-driven Instrument used in *unFamiliar*

The complete data-driven instrument used in the performance of *unFamiliar* is comprised of In2Games's Gametrak, custom software created in Cycling 74's Max, and Symbolic Sound's Kyma. A diagram of the complete structure of this instrument can be seen in Figure 1.

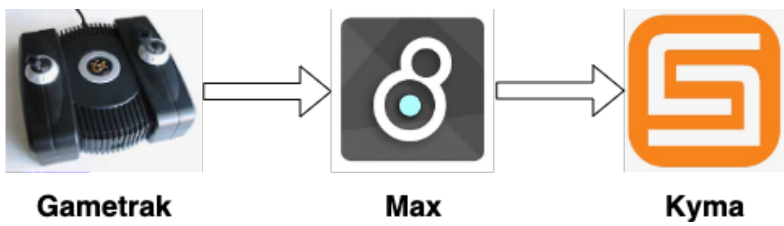

Figure 1. Diagram of data-driven instrument used in the performance of *unFamiliar*

The Gametrak provides two three-dimensional faders in the form of two joystick elements with retractable z-axis strings encased in a weighted base. A diagram of the three axes provided by each joystick element of the Gametrak can be seen in Figure 2. Each axis of the dual three-dimensional faders is output by the device via USB as individually addressed data streams in 12-bit resolution with a range of 0 – 4095.

The custom-made Max patch for *unFamiliar* receives data streams provided by the Gametrak using the *hi* object. These data streams are then scaled and smoothed in Max before they are sent as OSC messages via Ethernet connection to Kyma. OSC messages received in Kyma are then mapped to various musical parameters to be controlled in real time performance.

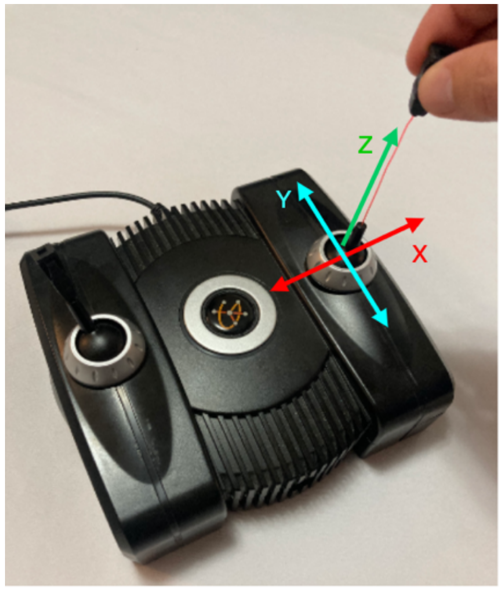

Figure 2. The three-dimensional axes of the Gametrak

Musical Challenges and Opportunities

One challenge presented by this data-driven instrument is its inherent lack of button functionality. In its natural operational state, the Gametrak outputs six continuous streams of control data for each axis of its three-dimensional joysticks. The presence of only continuous control data makes it difficult to articulate the starting or stopping of musical events, or messages meant to advance to the next section of the composition. To overcome this challenge, at various points throughout the composition, analysis of the data streams for the breaching of set thresholds effectively translates the functionality of a continuous fader into that of a button.

The large variation in the length of the extractable z-axis string included in each joystick mechanism allows for a wide range of performative action in a potentially large observable area. Throughout this composition, I take advantage of this opportunity by coordinating the variance in performance space with musical material. The introductory motive maintains a small area close to the base and can be performed by standing just over the Gametrak. The development of the second section however, requires large physical movement across the stage surrounding the base of the Gametrak in coordination with much more dense sonic material.

Data Mapping Strategies

Data mapping techniques employed in *unFamiliar* primarily include scaling, offsetting, and threshold detection. The first point of data mapping occurs in Max just after acquiring data streams from the Gametrak. The Gametrak's 12-bit value range representing each axis is scaled in Max from 0 – 4095 to a range of 0.0 – 1.0. These data streams are then processed through a smoothing algorithm in Max to help filter out any jitter inherent to the output of the device. Data streams corresponding to the z-axis strings of the Gametrak are scaled again in Max before being sent to Kyma. This second stage of scaling helps confine the resulting performative space required to perform the piece. At some point early in the compositional process for this piece I decided the ten-foot length of the z-axis strings was slightly more than was necessary to articulate the exploration of sounds that I was working with. Using the *scale* object in Max, data representing the first seven feet of the z-axis string was scaled to a range of 0.0 – 1.0.

Throughout the piece, continuous data streams are converted into button events by a process of analysis for the breaching of thresholds. This process occurs both in Max and Kyma. For the introductory motive at the beginning of each major section of the piece, a small subpatch receives the data stream corresponding to the z-axis of the left joystick, analyzes this data stream for values greater than 0.2, then counts the number of times this threshold is breached (see Figure 3). At each sequential breach, individually addressed OSC messages are sent to Kyma opening a gate for each voice used in the introductory motive. This process effectively turns one fader into four individual buttons based on the repeating breach of the designated threshold.

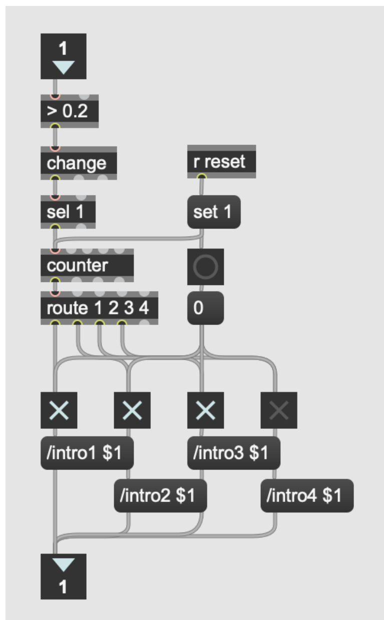

Figure 3. Max subpatch used for threshold detection in *unFamiliar.*

Essential to the original concept of this composition was the process of exploring familiar soundscapes on a micro-level to the point of unrecognizable or interesting results. To help achieve this, I mapped the data streams from the Gametrak to a resynthesis of an ambisonic recording of a familiar sounding space using Kyma's unique *TauPlayer*. To "zoom in" on subjects of interest within this ambisonic recording, data from the Gametrak was scaled and offset to specific ranges and then applied to the *TimeIndex* parameter of the *TauPlayer* (see Figure 4). This mapping formula of scaling and offsetting the z-axis data is repeated with different values throughout the piece, allowing for variance in the range in exploration of the ambisonic recording.

Figure 4. Scaling and offsetting the values of the Gametrak before application to the *TimeIndex* parameter

Compositional Structure

unFamiliar is comprised of two main sections, the second of which provides a varied restatement and development of the first. At the beginning of the first section, found at 00:30 of the accompanying video, the performative actions of quickly pulling a string of the Gametrak upward, combined with a mapping of the z-axis to a selectively low range of the *Frequency* and *TimeIndex* parameters within the *TauPlayer* provides an effective combination of action to sound, creating the illusion of a revving or ratcheting up of the instrument itself. With each pull of the string a new voice is added, spatialized equally throughout the multichannel performance space. A circular motion through the x- and y-axis of the Gametrak's joystick spatially pans each voice around the audience.

After a short development of pulling the Gametrak's string increasingly further from the base, a breach of a z-axis threshold advances the composition into more sonically dense textures. In this first section the hands are divided, the right hand exploring an alternation in harmonic material, while the left interjects with sounds similar to the introduction material. After a breach in the x-axis of the right joystick, a rhythmic motive emerges in the background and a short interplay between two voices, one in each hand, plays out in a call and response fashion. The first section concludes with a coordination of shorter and shorter statements from the alternating voices and a fade to silence.

The second section begins with an identical sound structure as the first with one exception, the offset value in the mapping of the z-axis string places the focus of the *TimeIndex* at a different time place of the ambisonic recording. This results in a similar, but slightly more expansive sounding introductory motive. After the breach of the threshold in this section, each hand is mapped to a series of four *TauPlayer*s, providing a development in increased density of the explorable soundscape. In my performance of this section, I move within a semi-circle around the Gametrak's base, exploring different sections of this "zoomed in" portion of the ambisonic recording. After approximately one minute of this section, I return to the center of the stage, just over the Gametrak's base and alternate slow pulling motions with each hand as the piece fades to silence.

III.2 *Within the Tallest Tree*

Overview

Within the Tallest Tree is a multichannel real-time composition for Wacom Intuos Pro tablet[20] and Kyma. Conceptually, this piece embodies the theme of unseen boundaries as a representation of the limits in communication between humans and surrounding nature. The narrative of *Within the Tallest Tree* presents a fantasy of crossing this boundary, posing the question, if we could speak to the trees, what would they say? The piece moves from a broad, ambient soundscape setting the stage, through a

[20] "Wacom Intuos Pro: Creative Pen Tablet," Wacom, accessed November 22, 2022, https://www.wacom.com/en-us/products/pen-tablets/wacom-intuos-pro.

conflicted dissonant section representing frustration with a communication barrier, and arrives in resolution in which spoken words are slowly revealed at the end of the piece.

Design and Implementation of Data-driven Instrument used in *Within the Tallest Tree*

The complete data-driven instrument used in the performance of *Within the Tallest Tree* consists of the Wacom Intuos Pro tablet and Symbolic Sound's Kyma. A diagram of the complete structure of this instrument can be seen in Figure 5.

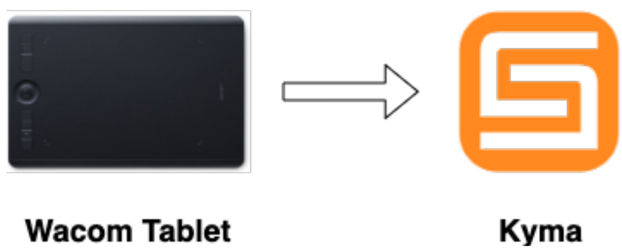

Figure 5. Diagram of data-driven instrument used in the performance of *Within the Tallest Tree*

The Wacom Intuos Pro tablet is a high-resolution, multi-input tablet device originally designed for digital illustration use. While traditionally used with an accompanying pen device, the Intuos Pro line of the Wacom tablet introduced multi-touch finger input, allowing for up to ten individually addressable data sources beyond the input of the pen. For this piece, I chose to focus on this new multi-touch input as the sole data-generation source. Only the x- and y- axis of a maximum of five fingers are used at any given time. These data streams are sent via USB to the computer.

Kyma provides native integration of the Wacom tablet, allowing for all data acquisition and mapping of this data-driven instrument to happen within the Kyma software environment. When the Wacom tablet is used in continuous controller mode, as it is throughout this piece, Kyma receives, indexes, and creates event variables for incoming data streams representing the input of each finger as it engages the x-y plane of the device. Variables used in the composition of this piece include the event of each finger engaging the tablet and its position on the x- and y-axes of the performative space. This essentially provides a button and two faders for each finger engaging the device.

Musical Challenges and Opportunities

As described in the description of this data-driven instrument, I made a choice to abandon the pen that usually accompanies the Wacom tablet and limit myself to using only the multi-touch finger input of the device. While the pen provided a decent amount of additional sensory input, in this case I felt the embodiment of the pen worked against the nature of the composition as well as my process of exploring different sounds with the tablet. The act of applying the pen to the tablet brought suggestions of drawing or writing to the observer, ideas which I felt obstructed the more abstract musical narrative that I was attempting to present.

Kyma's process of data acquisition provides individually addressed data streams for each finger engaging the device. As a result, each finger's digital representation can be individually mapped to different sound producing algorithms while occupying the same performative space. I take advantage of this opportunity in the third section of the piece in which the first finger detected controls variability of a repeating rhythmic subject, while the second and third fingers control variables related to frequency and timbre of two upper voices. However, the order in which each finger is detected by the device determines its index value, so care needs to be taken in performance to articulate the intended response. In this third section, for example, the upper voices will not be triggered unless the first finger is already engaging the device.

Throughout the piece, there is a focus on tension and release, which provides a challenge in observability in performance. While data-streams provided by the x- and y-axis of the tablet have been mapped to certain timbral parameters of the sounds, without any data generation related to force exerted into the tablet, there is a possibility for an observable disconnect between performative actions and a sense of "digging in" to the sound. In my performance of the piece, I help give the illusion of this quality with more forceful actions than are necessary to produce the sound, an observable follow through of performative actions, or with a faster motion in general.

Data Mapping Strategies

A variety of mapping techniques are employed in *Within the Tallest Tree* including scaling, offsetting, and analysis for particular conditions. Kyma's native support for the Wacom Tablet conveniently scales the high-resolution x- and y-axis output of each finger engaging the tablet to a range of 0.0 to 1.0.

One of the main approaches to mapping the Wacom tablet for this piece is the analysis for the breaching of thresholds. In the first section of the composition, I essentially split the performative space of the Wacom tablet into two separate control surfaces, one part controlling a pair of granular synthesis modules, the other part controlling a filter and amplitude of the resulting sound. To accomplish this threshold breaching strategy, I use Kyma's greater than (gt:) and less than (lt:) Capytalk[21] expressions. The gate of the envelope manipulating the granular synthesis modules is controlled by the Caypytalk expression: !FingerDown * (!FingerX lt: 0.85). Similarly, the portion of the tablet designated for control of the low-pass filter is defined through the Capytalk expression: (!FingerX gt: 0.85) trackAndHold: (!FingerY) smoothed. The values produced by this second expression are then scaled by a value of two thousand and offset by one hundred fifty when mapped to the frequency parameter of the low-pass filter.

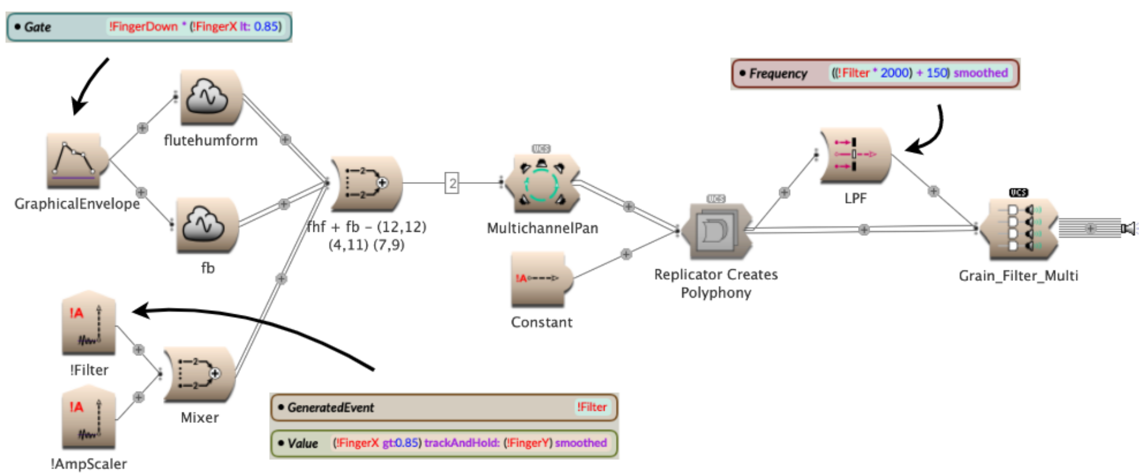

Figure 6. Mappings within a Sound structure used in the first part of
Within the Tallest Tree

The use of the *Replicator* Sound here, and in other Sounds used in *Within the Tallest Tree*, is an essential data mapping technique employed throughout the piece. The

[21] Capytalk is a real-time musical parameter control language for Kyma. Capytalk can be used to create interface components in Kyma's *Virtual Control Surface* or to generate algorithmic control of musical parameters.

Replicator allows for a variable amount of duplication of any modules being sent to its input. Additionally, any *EventValues*, variables that can be controlled in real time, can be renamed with the addition of incrementally numbered prefixes or suffixes. In my use of the *Replicator* throughout this composition, *EventValues* of *!FingerDown*, *!FingerX*, and *!FingerY* are renamed when duplicated with incremental suffixes aligning with the default *EventValue* names that Kyma provides corresponding to each fingers input.

Compositional Structure

Structurally, *Within the Tallest Tree* is divided into three sections. The first section begins with the triggering of an accompanying ambient rainfall soundscape. The main voice performed on top of this ambient soundscape consists of two low-pass filtered granular synthesis Sound objects. The first eighty five percent of the x-axis of the Wacom tablet, from left to right, is mapped to allow frequency control of the granular synthesis Sounds spanning two octaves. The remaining fifteen percent of the performative space is dedicated to a y-axis mapping of a low pass filter. This naturally divides the hands of the performer; left hand triggering the envelope and manipulating the frequency of the granular synthesis, and right hand manipulating the timbre of the resulting sound through the low-pass filter. In my performance of this section, I generally alternate between the combined activation and frequency manipulation of the granular synthesis Sounds, and broad filter sweeps of the resulting sound.

After a dramatic build into a sudden silence, the second section of the composition emerges featuring a sound reminiscent of a small organ. In this section, the full range of the x-axis is mapped to frequency control, while the y-axis is mapped to the

TimeIndex parameter of a resynthesized spectral analysis of a harsh, buzzing, bell-like tone with a long decay, creating variance in timbre and amplitude (see Figure 7). I begin this section with small, gentle performative actions in the upper half of the performative space corresponding to quieter, more pure sounding moments in time of the resynthesized sample. As my performative gestures approach the lower portion of the tablet, the timbre of the sound becomes harsher and louder in amplitude corresponding to the sonic characteristics of earlier points in time of the original sample. This second section is an improvisation on the contrast between these two sonic textures, with a gradual increase in material towards the harsher characteristics of sound representing a feeling of building frustration.

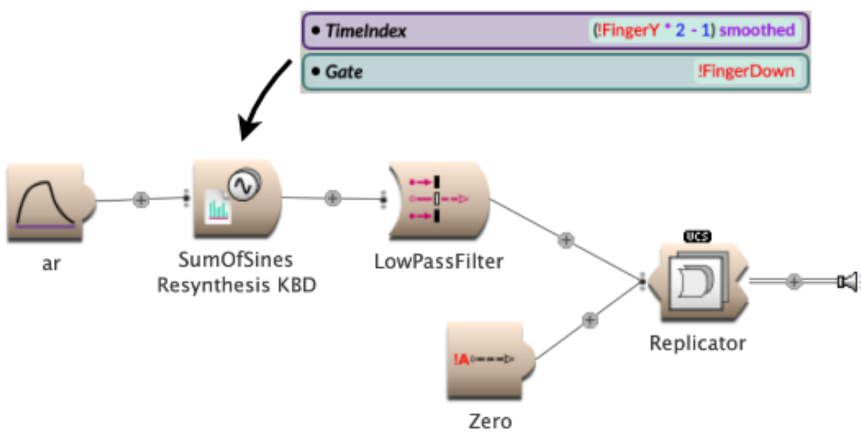

Figure 7. Sound structure used in the second section of *Within the Tallest Tree*

The third section of the piece features two main sounding voices, a performed ostinato-like subject in the lower frequency range, and a doubled resynthesized vocal sample in the upper range. While the full range of the performative space of the tablet is used to control both musical subjects, the lower voice is always controlled by the first finger detected by Kyma, while the upper voices are controlled by the second and third detected fingers. An automated sweep of a high-pass filter applied to the ostinato sound shapes this final section while an improvisation exploring the upper two voices plays out. The piece ends with a clear articulation of scrubbing through the resynthesized sample, revealing the words “things seem to move around me.”

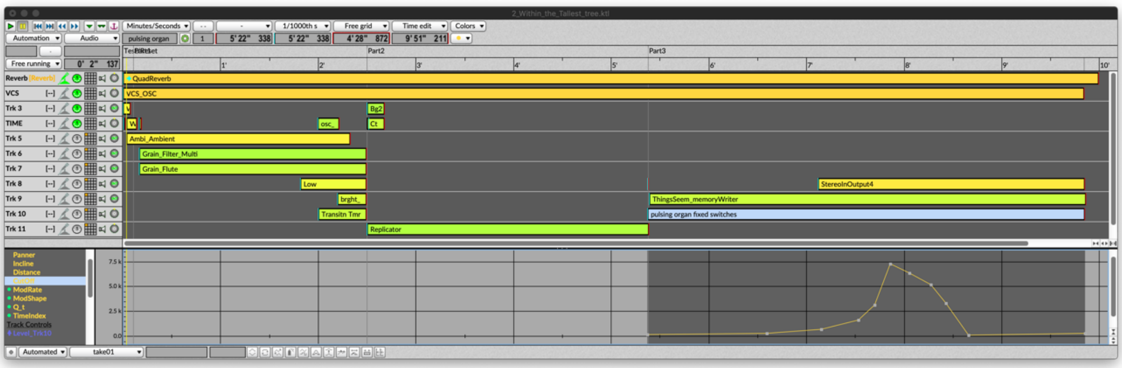

Figure 8. Automation of the cut-off frequency of a low-pass filter using Kyma’s parameter control editor

III.3 *Things Look Different Here*

Overview

Things Look Different Here is a multichannel real-time composition for an electric cello system with modified foot pedal, a custom-built data glove, Max, and Kyma. As a composer, performer, and social being, *Things Look Different Here* represents the personal crossing of many unseen boundaries. In the process of relocating from Michigan to Oregon and in recent travels in Mexico, I have experienced many unseen boundaries of state lines, geographical regions, and differences in regional social customs. This piece also stands as a landmark in my transformation from a traditionally trained cellist to a data-driven instrumentalist, crossing unseen boundaries of musical practices along the way. This transformation is manifested through changes in treatment of sound from the cello and a shift in the role played by performative actions utilizing the bow.

Design and Implementation of Data-driven Instrument used in *Things Look Different Here*

The complete data-driven instrument used in the performance of *Things Look Different Here* consists of an electric cello with a modified foot pedal system, a custom-built data glove, Cycling 74's Max, and Symbolic Sound's Kyma. A diagram of the complete data-driven instrument can be seen below (see Figure 9).

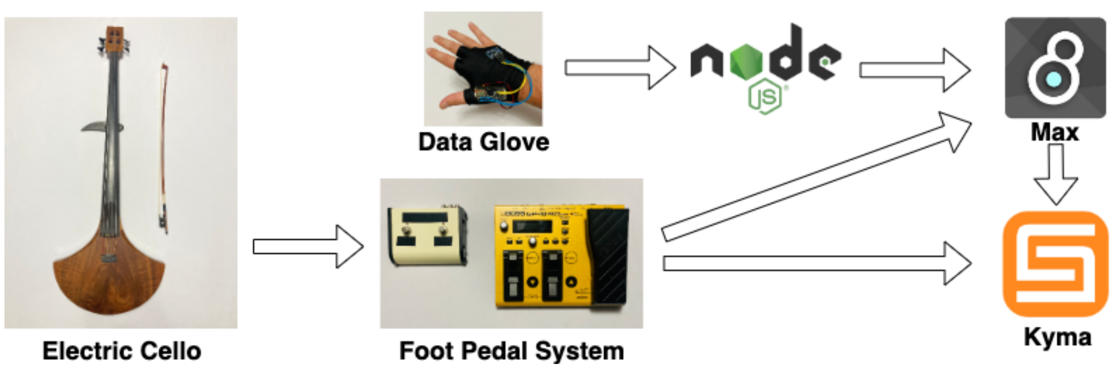

Figure 9. Diagram of data-driven instrument used in the performance of *Things Look Different Here*

The electric cello used in the performance of this piece is an Orion model made by the Seattle based instrument maker Eric Jensen.[22] It is equipped with an RMC Polydrive IV polyphonic pickup system providing individual audio signals for each string

[22] "Orion Series Cellos," Jensen Musical Instruments, accessed November 22, 2022, https://web.archive.org/web/20180506110853/http://www.halcyon.com/jensmus/ocello.htm.

out a 13 pin DIN cable.[23] These signals are received by a modified Boss GP-10 foot pedal system.[24] The GP-10 provides two footswitch buttons, a rocking "wah-wah" style fader, and performs a frequency to MIDI analysis of the incoming signals from each string, all of which is sent via USB to Max. Audio signals from the electric cello are also passed through the GP-10 to a custom-built breakout box to facilitate the direct audio signal input of each individual string into Kyma.

A number of different options were attempted in acquiring data representing the movement of the cello bow, including attaching sensors directly to the bow, wearing sensors in a wrist worn housing, and optical sensing devices. A lightweight glove form proved to be the best option as it was the least obtrusive to the performer with the most accurate digital representation of movement. The custom-built data glove houses an Adafruit made Feather 32u4 Bluefruit LE Arduino based microcontroller, a Bosch BNO055 nine degrees of freedom sensor (9-DoF), and a small battery. The glove itself is fingerless and is made from a lightweight mixture of polyester and spandex (see Figure 10).

Data streams from the 9-DoF sensor are sent as serial data over Bluetooth, received by custom JavaScript Node module running in Terminal, where they are parsed, addressed, and sent as OSC messages to Max. In Max, data streams from the 9-DoF sensor are scaled before being sent as OSC messages via Ethernet connection to Kyma. MIDI messages from the GP-10 are passed as MIDI to Kyma.

---

[23] "Poly-Drive IV," RMC pickup Co., accessed November 22, 2022, https://www.rmcpickup.com/polydriveiv.html.

[24] "GP-10: Guitar Processor," BOSS (Roland Corporation), accessed November 22, 2022, https://www.boss.info/us/products/gp-10/.

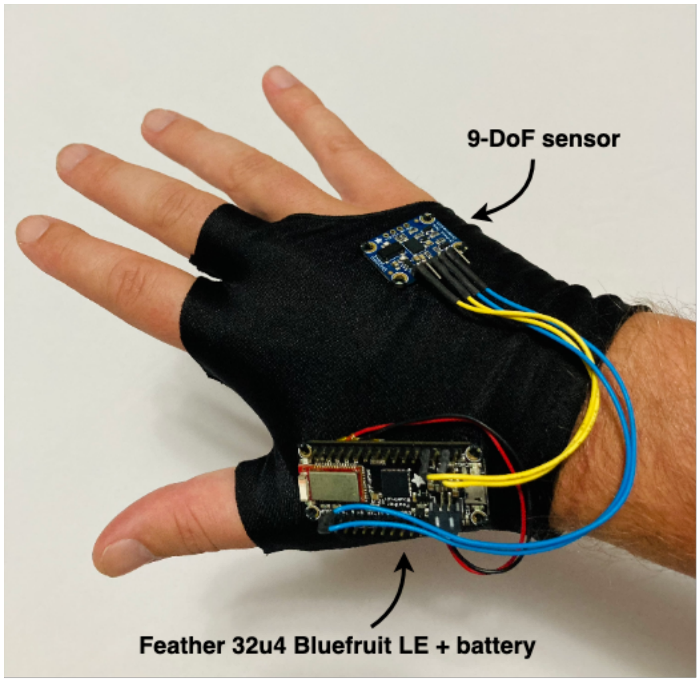

Figure 10. Custom-built data glove used for the performance of
Things Look Different Here

Musical Challenges and Opportunities

The embodiment of the 9-DoF sensor within the bow hand of a performing cellist is an essential component to the articulation of this piece. While there is an expected understanding of the physical energy exerted with the bow to vibrate the strings of the cello, the mapping of accelerometer data provided by sensors embedded in the glove to additional sound-producing algorithms provides an extra musical layer that goes beyond the expected sounds produced by performative actions of a cellist. This was utilized in different ways within different sections of the piece, controlling the amplitude of different Sound objects, as well as *TimeIndex* variables within Kyma's *TauPlayer* Sounds.

The design and implementation of the data glove provided many challenges in early stages of development. I set out three main goals in the development of this module of the interface: the sensors had to be lightweight and unobtrusive, the device had to be wireless, and it needed to take advantage of every data stream available. After exhausting options of attaching sensors to the bow or around the wrist of the performer, influenced substantially by the obstruction that such placement of the sensors would have on the natural performative actions of playing the cello, I settled on a lightweight fingerless glove with a microcontroller and sensors sewn to the top.

At around the time that I was developing this instrument, Adafruit had just released the first of their Feather series of PCBs that combined an Arduino based microcontroller with a Bluetooth module in one small, lightweight form factor. My adaptation of this device attached to the glove solved the first two goals I had set out, however, taking full advantage of the 9-DoF sensor still proved problematic. Early experiments in transmission of data streams from the sensor as standard MIDI data proved to be far too low of a resolution for the small performative actions I wished to acquire. The limited processing power of the Atmel ATmega32u4 chipset also provided undesirable results with experimentations of high-resolution MIDI transmission. I decided to abandon MIDI as a communication protocol and instead send the data streams as serial data over Bluetooth. This process certainly provided the resolution I desired, but at the cost of significant variable delay. Later experiments with more advanced microprocessors eliminated any perceptible delay in serial transmission of data, but for the device used in the implementation of this instrument, the delay of these data streams is an inherent characteristic. While at first I found this frustrating, throughout my process of composing this piece I embraced this characteristic of the instrument and began to anticipate its effects in performance. In the end, the challenge of this delay in the system provided a compositional opportunity, often creating an antiphonal effect at different points of the piece between the sound of the cello and sounds produced as a result of delayed data streams from the glove.

The polyphonic pickup system on board the electric cello combined with the custom-built breakout box module of the foot pedal system allowed for individual audio signal input to Kyma that corresponded to each string of the electric cello. This provided an opportunity for the routing and application of separate audio effects for different strings of the instrument within Kyma. An example of this can be seen in the first section of the composition within a Sound structure on the timeline titled *Direct with TauPlayers*. Within this Sound structure, all four audio inputs corresponding to each string of the electric cello are routed to one destination, while inputs corresponding to the upper two strings are additionally sent on a separate path for frequency and amplitude analysis to then be mapped to variables of a replicated *TauPlayer.*

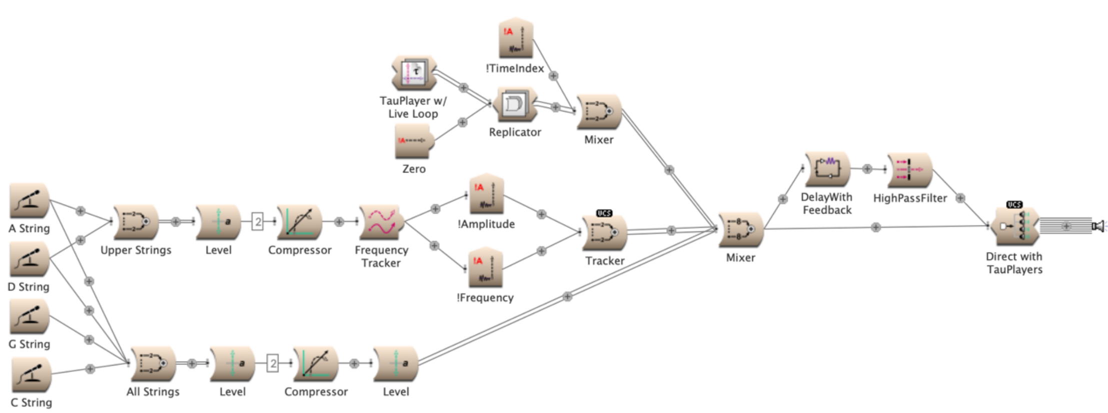

Figure 11. Input routing of audio signals corresponding to each string of the electric cello

Data Mapping Strategies

A variety of mapping techniques are employed for each module of the interface. MIDI data from the foot pedal system is scaled to a range of 0.0 to 1.0 and sent as OSC messages via Ethernet connection to Kyma. These signals are used as simple triggers for two main functions – to advance the composition from one section to the next, and to trigger recording and playback of the electric cello input within Kyma's *MemoryWriter* and *Sample* Sounds. When triggered, the *MemoryWriter* Sound writes incoming audio signals to the RAM of Kyma's signal processor, which can then be used in various other Sound modules when referenced by the same name. This mapping scheme allows for the articulation of layering and looping of the cello's sound in performance. An example of this process can be seen in the Sound structure titled *memory* present throughout the second and third sections of the composition (see Figure 12).

Data provided by the glove is used in two different ways. Accelerometer data is first routed through an averaging algorithm in Max which helps produce a smoother, more unified control signal before being sent to Kyma (see Figure 13). In Kyma, this data stream is mapped to the amplitude of two different Sounds, a high frequency granular synthesis module in the first section, and a simple oscillator of lower frequency in the later two sections.

Data streams from the orientation sensor are passed directly to Kyma from Max and scaled and offset before they are mapped to the *TimeIndex* parameter of a series of *TauPlayers*. The result is an effect of scrubbing through a resynthesized sample driven by data from each movement of the bow hand.

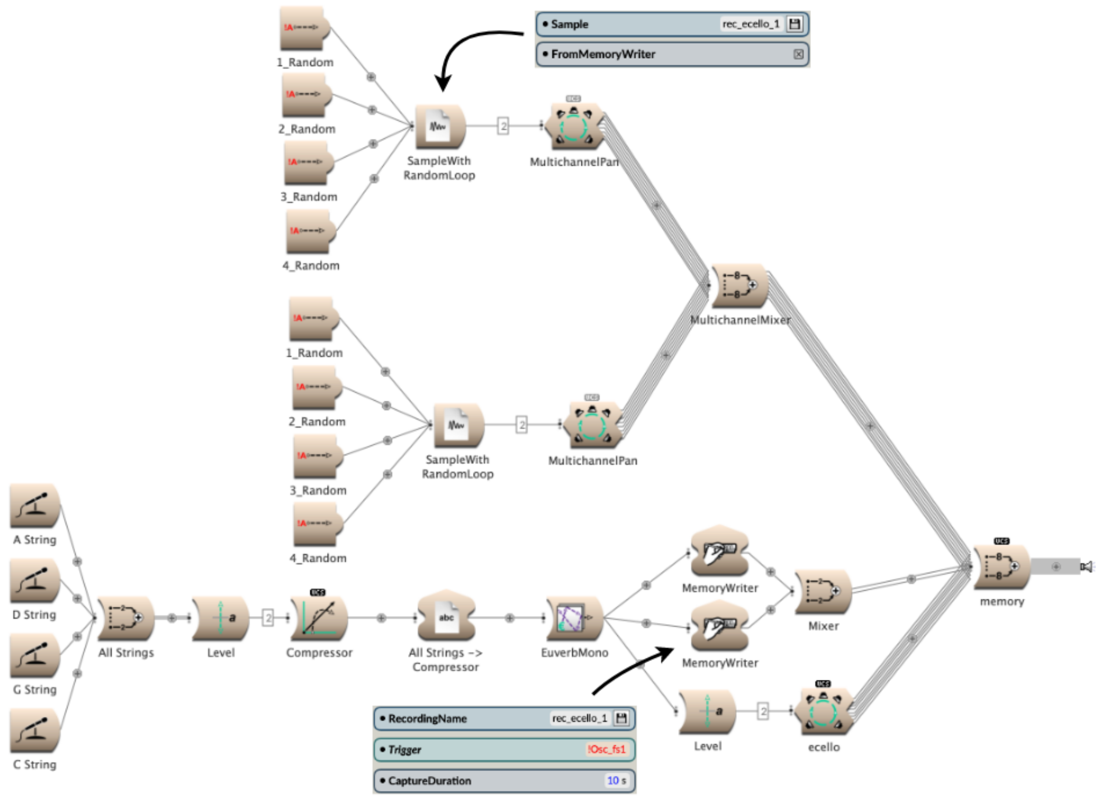

Figure 12. OSC messages corresponding to the footswitch inputs triggering the *MemoryWriter* Sounds in Kyma

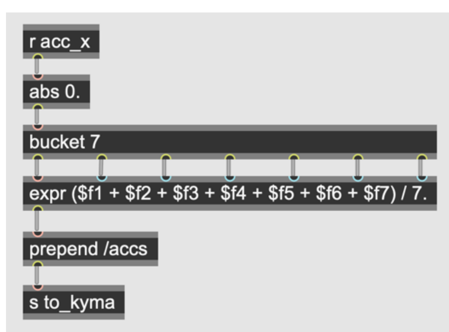

Figure 13. Averaging algorithm in Max used to smooth accelerometer data

MIDI data provided by the frequency to MIDI conversion of the GP-10 foot pedal system is mapped to the *Frequency* parameter of the same series of *TauPlayers*. The result is a duality of control over this Sound, the pitches produced by the electric cello controlling the modification of frequency, while the movements of the bow hand vary the resulting timbre (see Figure 14).

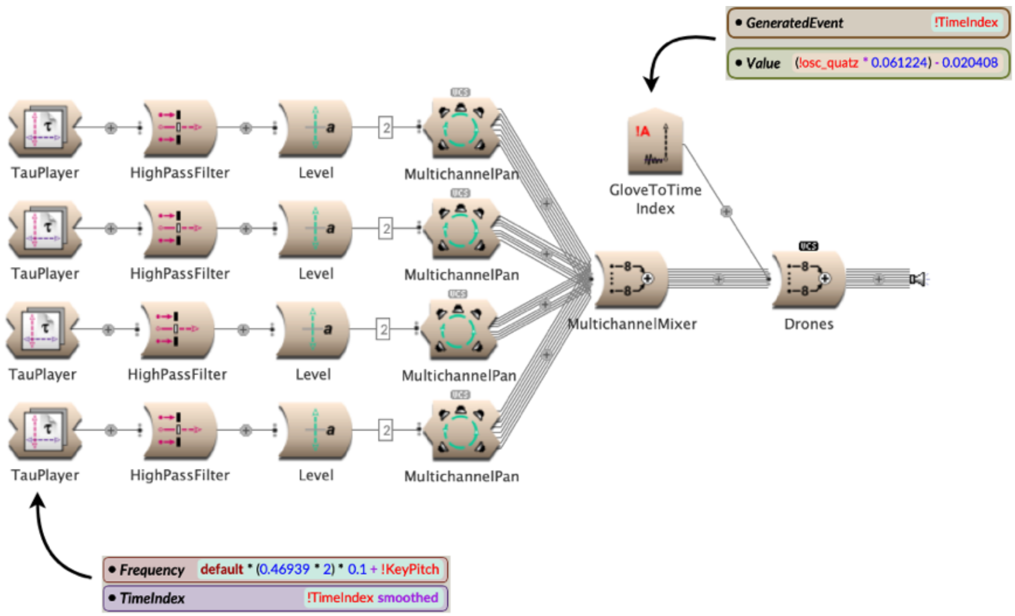

Figure 14. Orientation data streams from the glove and MIDI data from the pedal system mapped to *TauPlayers* in Kyma

Compositional Structure

The composition is divided into three main sections, an introductory section, which builds into a more tranquil middle section, and which then evolves into the more aggressive final section. Musical material was largely improvisatory within each section, though certain thematic material has been solidified with each performance of the piece.

In the first section, I begin with a simple string crossing motive on the first two strings of the cello. Accelerometer data from the glove and MIDI data from the foot pedal system is mapped to the envelope and frequency of a granular synthesis Sound structure creating a chime like texture in coordination with increased motion of the bow hand. This simple opening introduces the observer to the mappings available with this instrument.

The upper two strings of the electric cello undergo a process of frequency and amplitude tracking in Kyma, the results of which are mapped to the resynthesis of an analyzed sample of the sound of a viola. The simultaneous frequency tracking of two strings at once can sometimes produce erratic results. As the first section develops, I take advantage of this unique outcome by playing two different pitches with increasingly dissonant intervals. The first section ends with an increase in dissonance and string crossings across all four strings of the instrument.

At the climax near the end of the first section, the second section is triggered by the activation of a footswitch on the GP-10. This section heavily features the use of Kyma's *MemoryWriter* Sound. The input of the electric cello is sent to two *MemoryWriter* Sounds, each one set to record a sample of ten seconds of audio when triggered by the footswitches. The recordings from the *MemoryWriter* Sounds are played back with randomly generated variables manipulating the looping functionality of two *Sample* Sounds. At the beginning of this section, I primarily perform harmonics on the strings of the cello, but gradually incorporate fully stopped pitches with the approach of the final section.

The third section of the composition slowly emerges as more dissonant sonic material fades in. The most striking addition in this section is a Sound comprised of four *TauPlayer*s equally spatialized around the listening space, the *TimeIndex* variables of which are controlled by a mapping of the z-axis of orientation data provided by the glove corresponding to the action of rotating the wrist. While playing the strings of the cello with the bow, wrist rotation is minimal, creating only slight variations in the *TimeIndex* parameter. Performative actions involved in the release of the bow from the strings or preparation in engaging the strings with the bow, however, produce much more dramatic results in variation of the *TimeIndex* parameter. After a period of interacting with this Sound structure in an improvisatory manner, the section ends with an engagement of the footswitch triggering the *MemoryWriter* one final time while the piece fades to silence.

III.4 *A Need to Be Free*

Overview

A Need to Be Free is a multichannel real-time composition for the Microsoft Kinect with custom-built fabric interface, Processing,[25] and Kyma. In this composition, the notion of boundaries is, perhaps, most literally expressed through my performative actions engaging the fabric portion of the interface. Through this piece I sought to capture the feeling of insurmountable struggle with unseen boundaries of mental anxieties and depression. These conditions can often lead to feelings of entrapment or separation from others, feelings which I have manifested through performative actions of clawing and straining against the fabric which obscures the performer from the audience's view.

Design and Implementation of Data-driven Instrument used in *A Need to Be Free*

The complete data-driven instrument used in the performance of *A Need to Be Free* is comprised of Microsoft's second version of the Kinect optical gaming device paired with a custom-built fabric interface, the Processing software environment, and

[25] Processing is a computer programming language based on Java and optimized for the visual arts. Processing was initially developed the Aesthetics and Computation Group at the MIT Media Lab in 2001 and continues to be developed as open-source programming environment.

Symbolic Sound's Kyma. A diagram of the complete instrument can be seen in Figure 15.

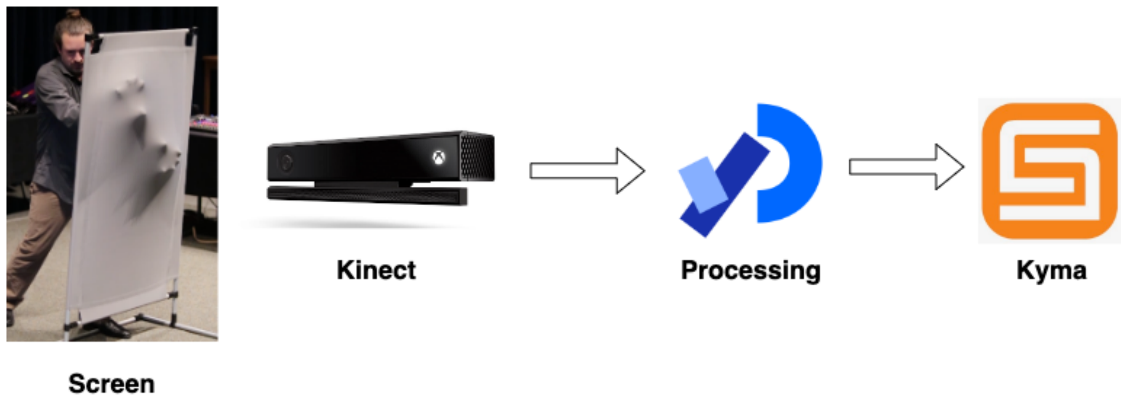

Figure 15. Diagram of data-driven instrument used in the performance of *A Need to Be Free*

The custom-built module of the interface is constructed from a metal frame one by one and a half meters made from electrical conduit pipe suspending a surface of flexible fabric material. The frame is connected using a series of t-connector pieces called Maker Pipe designed specifically for construction with electrical conduit pipe.[26] This was an essential consideration in the design of the interface as electrical conduit pipe is affordable, standardized, and easily accessible. This allowed me to easily rebuild the interface when traveling by acquiring conduit pipe at the location while traveling with only the connector pieces and the fabric.

The Kinect is oriented towards the fabric surface at a height of two meters at a distance of approximately two meters. Data and images from the Kinect's optical sensors are sent via USB to the computer for analysis.

[26] "Structural Pipe Fittings for DIY Builders," Maker Pipe, accessed November 22, 2022, https://makerpipe.com/.

A Processing program utilizing a modified software library developed for interpreting the proprietary formatted messages from the Kinect analyzes designated ranges of the Kinect's visual field corresponding to the space occupied by the fabric. A blob-detection algorithm in the Processing program analyzes for the x-, y-, and z-axis as well as the width and height of the first two blobs detected which breach a threshold of the z-axis of the visual field. A separate algorithm calculates the average three-dimensional position of any space breaching the z-axis threshold. Data streams produced by this analysis are scaled and output as OSC messages via Ethernet connection to Kyma where they are further scaled and mapped to appropriate ranges to effect musical parameters.

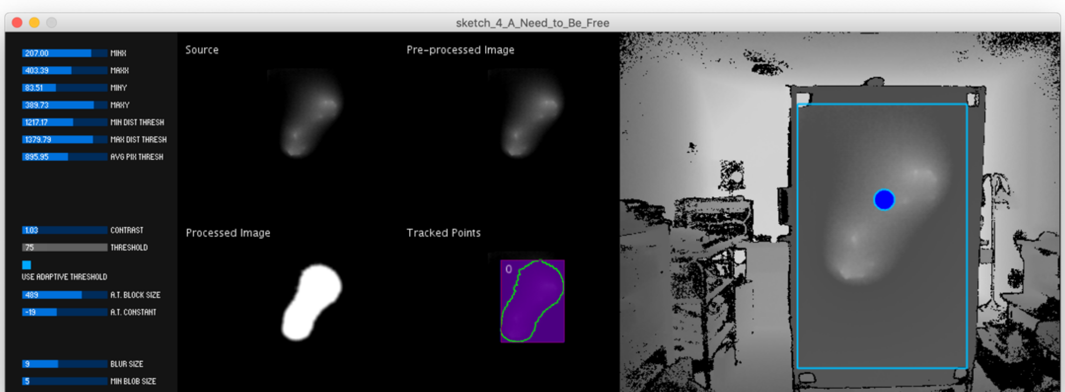

Figure 16. Screenshot of Processing program used in the acquisition of data

Musical Challenges and Opportunities

My first interactions with the Kinect as a musical interface prior to *A Need to Be Free* left me feeling unsatisfied and exposed. Performative actions used to manipulate the data streams from the device were nebulous and undefined. Additionally, I felt this lack of definition created a disconnect with the audience in the understanding of the interface of the instrument, and that I was placing too much responsibility on the audience in understanding the invisible nature of the Kinect interface. To help mitigate this issue, I created the flexible fabric screen. The screen gave me, the performer, something tangible to engage and operate, while also giving the audience something to focus on and relate to. The kinetic qualities of the flexible fabric provided an opportunity for a better understood and more sympathetic response from the audience, the embodiment of the Kinect's optical tracking capabilities into the flexible fabric creating a sense of entrapment and a struggle to break free.

While the screen provided something tangible to perform with, and provided a visual target for the audience, the fairly large fabric interface also obscures the performer from view of the audience. At first, the obscuring of the performer seemed problematic, and I considered different orientations of the instrument in order to compensate for the lack of visibility of my performative actions, particularly those actions of performative preparation in engaging the interface. I chose instead to focus on this obstruction of view from the audience as a main attribute to the instrument and a driving force in the compositional process. The concept of the piece is centered on a feeling of struggling to break free from depression and anxiety. Often, a large part of this struggle is an overwhelming feeling of being unseen, unheard, or misunderstood. The obstruction of the performer by the screen provides a visual layer and literal boundary to this concept.

Similar to the challenges faced with the Gametrak in *unFamiliar*, data acquired by analysis of the optical tracking capabilities of the Kinect only produce streams of continuous control data, lacking any button functionality. This makes it difficult to articulate the starting or stopping of musical events, or messages meant to advance to the next section of the composition. To overcome this challenge, at various points throughout the composition, analysis of the data streams for the breaching of set thresholds effectively translates the functionality of a continuous fader into that of a button.

Data Mapping Strategies

Data mapping strategies involved in the composition of *A Need to Be Free* include scaling, offsetting, smoothing, and analysis for particular events.

Scaling, offsetting, and smoothing of data streams is most often applied when mapping to parameters controlling frequency, amplitude, or the *TimeIndex* of some form of resynthesis. The example below (see Figure 17) is of a Sound structure from the third section of the composition. In this example, data streams representing the depth, y-axis, and width of the first blob analyzed by the Processing program are mapped to control the *AmpScale*, *Frequency*, and *TimeIndex* parameters of Kyma's *PsiPlayer*.

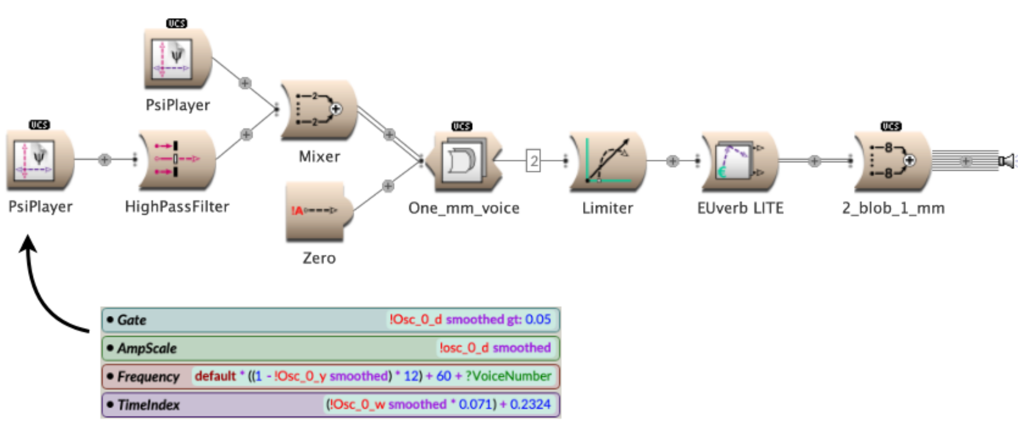

Figure 17. Sound structure from the third section of *A Need to Be Free.*

The mapping of data related to depth to the scaling of amplitude is quite direct, allowing for the action of pushing or straining the fabric forward to scale the amplitude of the resulting sound. Kyma's smoothing algorithm is applied to this data stream by the use of the keyword *smoothed* following the statement of the *EventValue*. The mapping of data related to the y-axis to manipulate frequency involves a number of parts. The output of data from the Processing program related to the y-axis provides an orientation of data in which lower values are located at the top of the interface and higher values are located at the bottom. This orientation was reversed from my desired mapping to manipulate frequency. After applying the smoothing function to the y-axis, the values are subtracted from a value of one in order to flip this orientation. These values are then scaled and offset to a desired range for the manipulation of frequency. The resulting values are additionally offset by a Kyma specific variable *?VoiceNumber*. This variable refers to the index value of the portion of the Sound structure that has been duplicated by the *Replicator* Sound. The addition of this variable offsets each replicated voice by an incremental amount, resulting in a slightly more dense, fuller sound.

The use of the "greater than" function in the mapping of data representing the distance or z-axis of the space detected by the Processing program is an example of the transformation of the fader-like functionality of the interface into that of a button. In the above example, the sound is gated by a crossing of a threshold of 0.05. Similarly, in other Sound structures throughout the piece, the breaching of a threshold in the opposite direction is used to trigger events. In the Sound titled *Jar_Drum* for example (see Figure 18), data representing the z-axis of the interface is analyzed for a crossing of a threshold using the "less than" function to simultaneously trigger the playback of a drum-like sample and the envelope of a simple oscillator. The resulting effect of this mapping is the triggering of these Sounds as the flexible fabric returns to its resting state at each release of my performative actions.

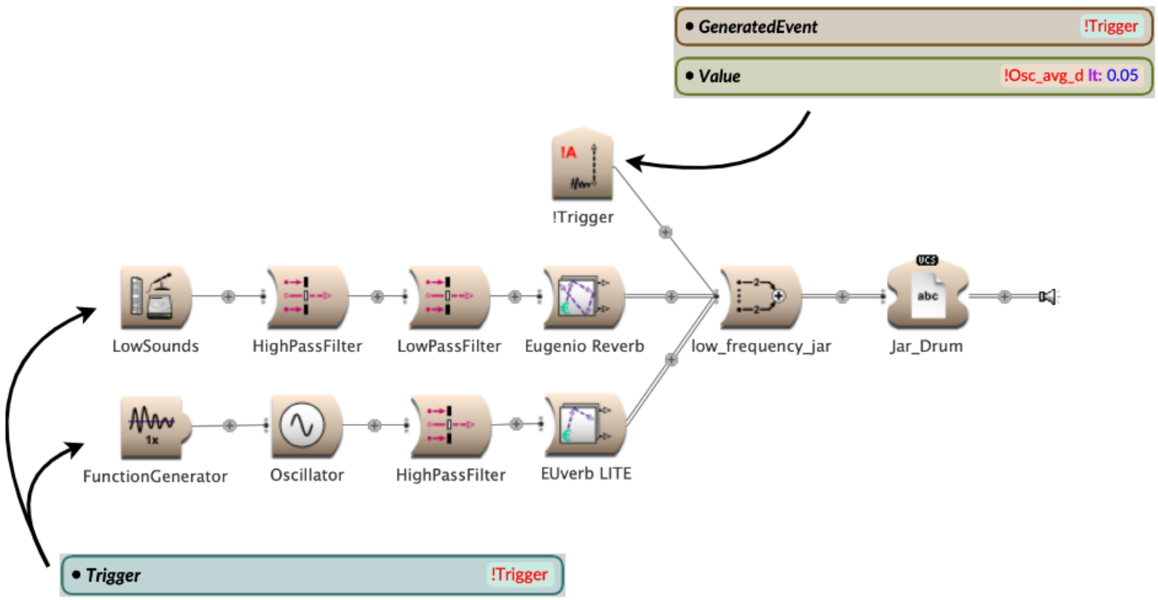

Figure 18. Threshold detection used to trigger musical events in *A Need to Be Free*

At other points in the piece, this same threshold detection process is used as a mechanism to generate random values. In the Sound structure featured most prominently in the opening and closing sections of the piece, the detection of the return of the fabric to its resting state produces random values which are then scaled and set to the *Frequency* parameter of replicated granular synthesis Sounds (see Figure 19).

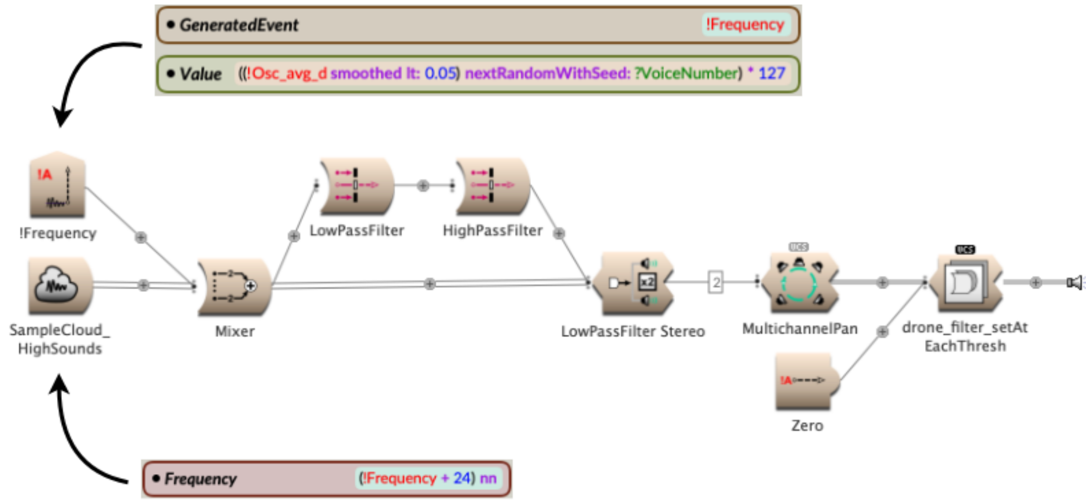

Figure 19. Threshold detection used to generate random values

Compositional Structure

A Need to Be Free has four sections. In the opening section, the z-axis of the flexible fabric plane, that which is perceived as distance by the Kinect sensor, is mapped to control variables of a granular synthesis algorithm and a low-pass filter. I begin the section by slowly applying force and stretching the fabric towards the Kinect with both hands. When I release my hands, the fabric returns to its original state, breaching a threshold which triggers the playback of a sample of a drum-like sound. This action is repeated, slightly increasing in intensity throughout the first section. After approximately one and half minutes, two repeating bell tones enter, one after the other, producing sounds reminiscent of alarm bells, helping to build tension into a climax at the end of the first section.

The second section emerges out of the climax of the first with an accompaniment of softer, more reverberant tones produced by a series of granular synthesis Sounds. My performative gestures in this section change to a poking or prodding of the screen, triggering resynthesized spectral analysis of a sample of a bell. The y-axis of the space breaching the z-axis threshold is mapped to control the frequency of the bell sounds.

After approximately two minutes of improvisation emphasizing the bell tones, the second section gives way to the third with the addition of a repeating low rhythmic pulse followed by a reverberant granular tail. In this section, data representing each of the two blobs detected by the Processing sketch are each mapped to the resynthesis of a sample of a human voice using Kyma's *PsiPlayer*. While a similar mapping scheme of the y-axis of each blob is used to control the frequency of the resynthesis, the second voice is significantly offset into a lower frequency range. The use of the human voice as a sound source combined with my antiphonal articulation of the two voices, are meant to provide a sense of conversation, as if someone were talking to themselves. The predominant upper voice frequently switches between character of sorrowful and frantic.

The final section is marked by a slow fade in and return of the same granular synthesis Sound structure featured in the opening of the piece. My performative actions throughout this section differ from the first with increased force and less space between moments of engaging the interface, a sense of increased urgency and anxiety. This final section builds over the course of approximately one minute into a climax ending with a final trigger of the drum-like sample.

III.5 *A Musical Interpretation on the Findings of Voyager 2*

Overview

A Musical Interpretation on the Findings of Voyager 2 is a composition for variable instrumentation of data-driven instruments, Max, and Kyma. This piece has been written to accommodate an indeterminate number of performers with varying types of data-driven instruments with previous performances ranging from one to up to twelve performers. For my performance of this piece, I have built a custom interface comprised of four force-sensing resistors (FSRs) and three linear touch faders mounted to an acrylic base (see Figure 20).

In this piece, audio samples of material included on the golden record, a kind of "message in a bottle" affixed to the Voyager 2 probe,[27] are combined with sonified data acquired by the probe's encounters with the outer planets. Data accessed through NASA's online database was used to create wavetables for various sound synthesis techniques, as well as the creation of graphic scores for musical interpretation by the performer.[28]

Much of *A Musical Interpretation on the Findings of Voyager 2* is centered on literal unseen boundaries. Most of the data used in the creation of this piece focused on the interaction of planetary magnetic fields with solar radiation. The clashing of these invisible barriers is at the very core of the composition. The interpretation of data visualizations used as graphic scores towards the creation of a musical result also speaks to the line crossed between pure scientific observation, and the human desire to affix extra meaning to the planetary bodies we can observe.

[27] "Voyager - The Golden Record," accessed January 5, 2022, https://voyager.jpl.nasa.gov/golden-record/.

[28] "NASA Open Data Portal," DATA.NASA.GOV (NASA), accessed January 12, 2023, https://data.nasa.gov/.

Design and Implementation of Data-driven Instrument used in
A Musical Interpretation on the Findings of Voyager 2

The complete data-driven instrument used in the performance of this piece consists of a custom-built, multi-sensor interface, Cycling 74's Max, and Symbolic Sound's Kyma. A diagram of the complete instrument can be seen below (see Figure 20).

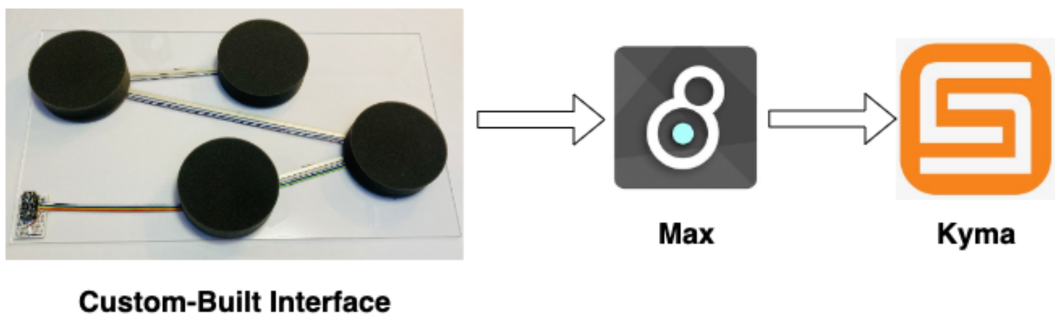

Figure 20. Diagram of data-driven instrument used in the performance of *A Musical Interpretation on the Findings of Voyager 2.*

The custom interface built for the performance of this piece is comprised of four FSRs, three linear touch faders, and a small Arduino-based microcontroller mounted to a sheet of clear acrylic. Four short cylindrical pieces of flexible foam are affixed over the FSRs. The obstruction from direct contract with the FSRs by the foam cylinders provides an increased dimension in both performative action and observability. The analog to digital converter aboard the Arduino microcontroller produces data streams analogous to each sensor's varying resistance. Each data stream is given a unique identifying value before being sent as serial data via USB to Max.

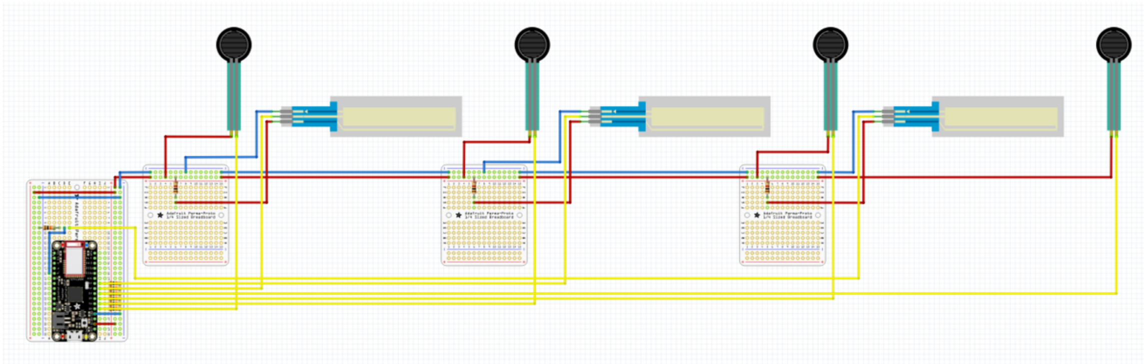

Figure 21. Prototyping diagram of custom-built interface

In Max, the serial data is parsed according to its unique identifier and scaled to a range of 0.0 – 1.0. These data streams are then sent as OSC messages via Ethernet connection to Kyma where they are mapped to various musical parameters.

My original concept in designing the interface of this instrument involved adhering some type of printed images representing each planet over the FSRs attached to the acrylic. This would create a visual analogy to the concept of interpreting the probes journey, creating a kind of map. While I liked this idea of a clear visual analogy, it was challenging to clearly articulate subtle changes in performative actions when engaging the FSRs with such a flat surface. The use of low-density foam covering the FSRs solved this issue by creating a buffer of space when translating force applied to the sensor, allowing for more nuanced control. An additional benefit of this design was the increased observability of my performative actions when engaging the sensors through the foam coverings. The circular shape of the foam components attached to the interface still help bring a visual analogy of the spherical bodies they are meant to represent.

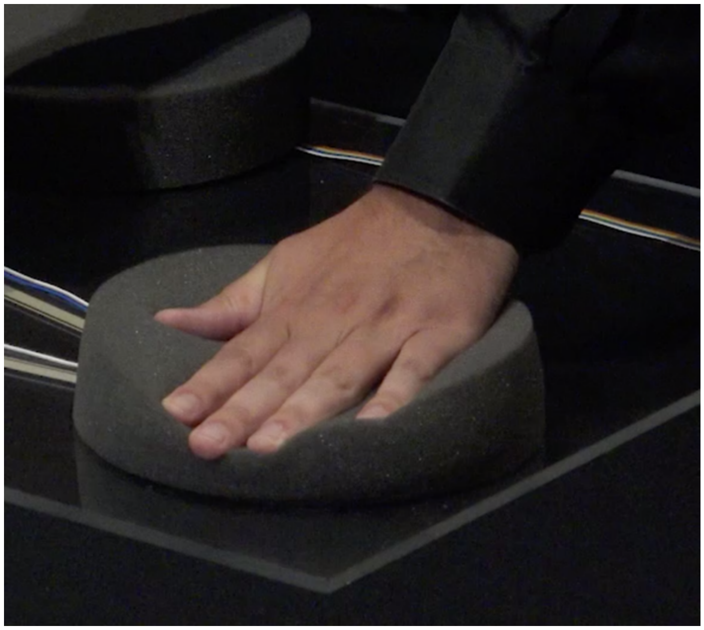

Figure 22. Low-density foam covering a force-sensing resistor

Musical Challenges and Opportunities

My goal in the process of composing this piece was to incorporate data in multiple ways that was gathered by the Voyager 2 probe. The first opportunity that arose in pursuing this endeavor was the creation of graphic scores from visualizations of data sets provided by NASA's online database. To accomplish this, I created a Max patch that would sequentially write each item of a tab delimited text file as a sample into a buffer using the *peek~* object. The *waveform~* object would then visualize this buffer (see Figure 23). Screenshots of this visualization were then printed to be used in performance of the piece. The graphic score generator patch and graphic scores generated for the performance of this piece are included in the software and affiliated files of this DPD.

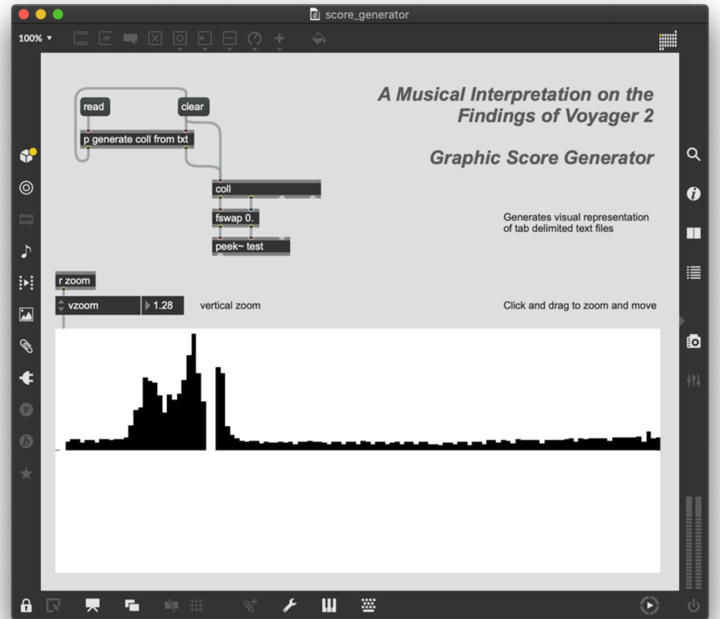

Figure 23. Graphic score generator Max patch

The second opportunity of incorporating data acquired by the Voyager 2 probe was the translation of datasets into waveforms to be used as sound sources throughout the piece. Kyma's *Wave Editor* environment provides the possibility of directly generating sample files from a tab delimited text file. These generated samples were often too short in length for the intended purpose. By applying the "make cycle" modifier in the *Wave Editor*, further samples are generated as interpolation points between those given in order to provide a waveform with the appropriate length of 4096 samples, the standard length required for use in various Kyma Sounds (see Figure 24). These waveforms are then used throughout the piece as waveform sources for oscillators and granular synthesis Sounds.

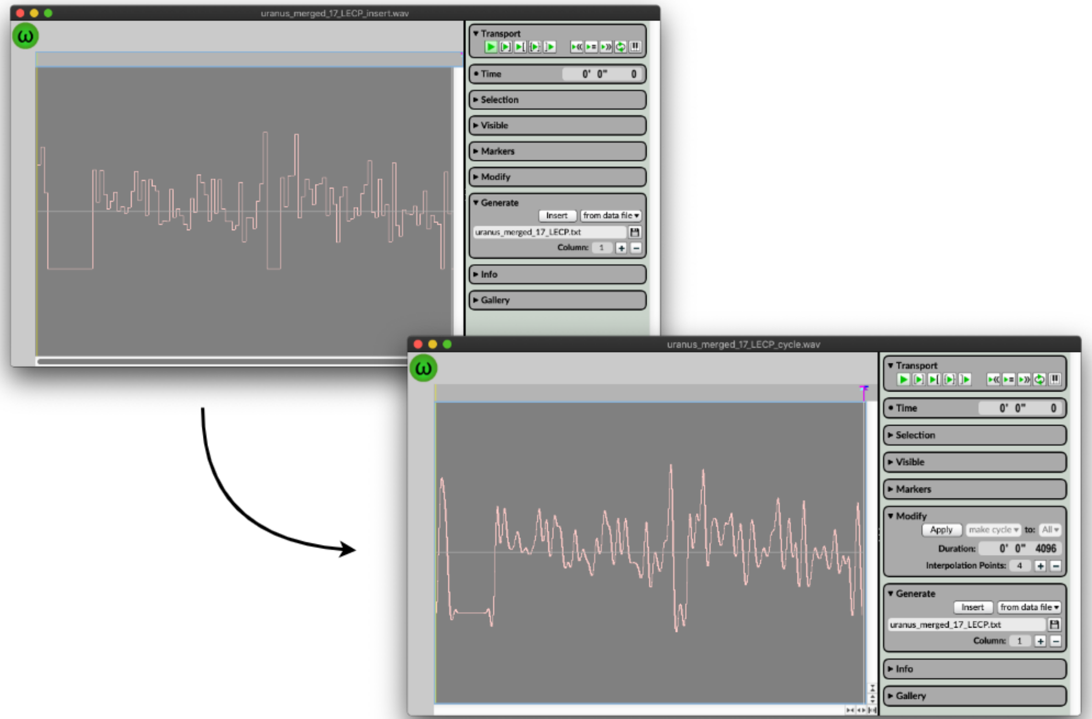

Figure 24. Translating datasets to waveforms in Kyma's *Wave Editor*

Data Mapping Strategies

Mapping techniques employed in this piece include scaling, offsetting, smoothing, and analyzing for particular events. Each section throughout the piece shares a similar mapping scheme in which a designated foam covered FSR is paired with a touch fader in controlling variables of the Sound in that section. Data acquired from force applied to the FSR is often analyzed for the breaching of a threshold, translating the fader functionality to that of a button, which is then used as a gate or trigger. The touch fader paired with the FSR is most often used to manipulate frequency of the Sound for that section. The example shown below is of a Sound structure from the middle of the composition (see Figure 25). In this instance, the amplitude of the primary sounding *GrainCloud* Sound is controlled by an envelope which is initiated by the breaching of a threshold by data from the FSR sensor. The amplitude is then scaled by the same data stream in the *Amplitude* parameter of the *GrainCloud* Sound. Data corresponding to a touch fader on the interface is scaled and offset when applied to the *Frequency* parameter of the *GrainCloud.* The output of a low-frequency oscillator further offsets the frequency by a variable amount. The wavetable source of the low-frequency oscillator was created in Kyma's *Wave Editor* using the process outlined previously.

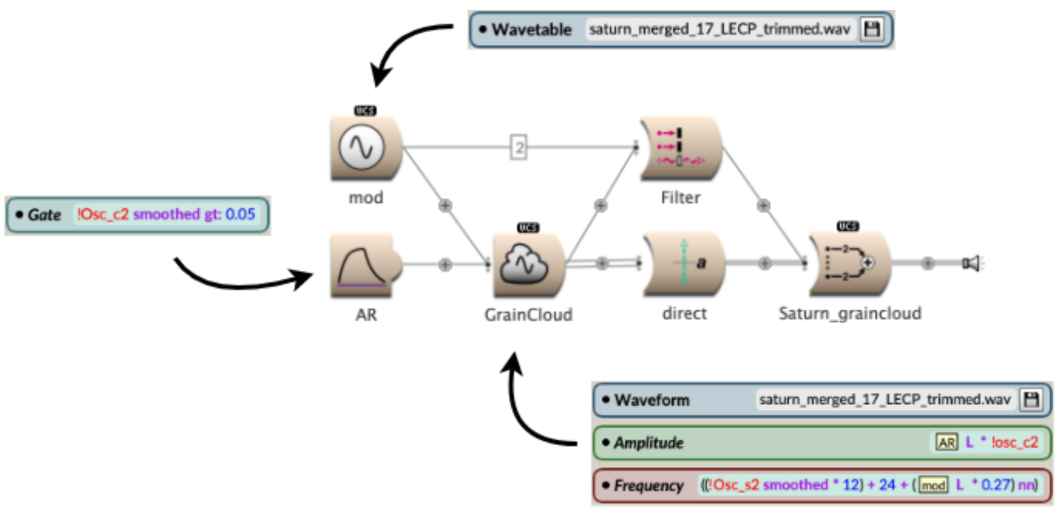

Figure 25. A Sound structure used in *A Musical Interpretation on the Findings of Voyager 2*

Compositional Structure

A Musical Interpretation on the Findings of Voyager 2 is divided into five main sections with transition periods of varying duration between. Each section represents a significant event in the journey of the Voyager 2 probe including its departure from Earth, and the close proximity to each of the outer planets. The timing of the transitions between each section corresponding to significant events is proportionately analogous to the probe's original journey. A separate Max patch titled *Time_Score* coordinates the timing of each section of the piece using a series of sequentially triggered messages sent to a *line* object. At the completion of each timed ramp provided by the *line* object, OSC messages are sent to Kyma to advance the *Timeline*. This timing data is also used to create a visual score component displayed to the performer on an iPad running Mira, an application which allows for the mirroring of a Max patch running on a standard computer operating system.[29] The *Time_Score* patch is shown in Figure 26.

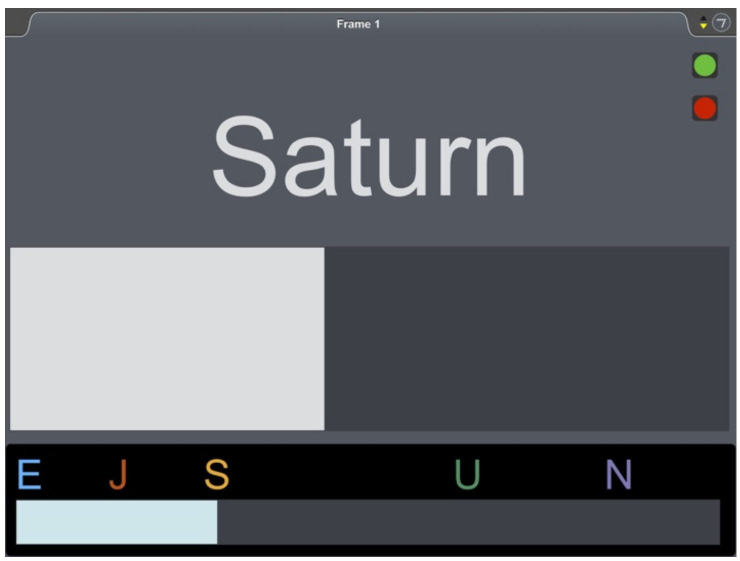

Figure 26. Visual score component displayed on an iPad using Mira

Within each section, data visualizations representing information collected at that point in time of the probe's journey are interpreted by the performer as guides in actuating and modulating various methods of sound synthesis. While the prescribed score timing and translated data is derived from data collected by Voyager 2, the piece is decidedly not a direct sonification of the probe's journey, but rather highlights the

[29] "Mira," Cycling 74', accessed October 3, 2022, https://cycling74.com/products/mira.

process of human interpretation of data collected by our technologies. In the preparation and rehearsal for this piece, the performer selects graphic scores with attention to how the shape of these data sets will most effectively shape parameters of their given sounds.

III.6 *family, friends*

Overview

family, friends is a multichannel real-time composition for Touché,[30] iPad, Max, and Kyma. The duality and contrast between the two parts of the instrument's interface provided an interesting opportunity in musical narrative.

Written over the course of the pandemic, *family, friends* explores the recalibration of social boundaries and the normalization of increased communication through screens and video calls. Throughout these last few years, this communication medium previously reserved for intimate one-on-one communication with family and friends has been invaded by the needs of education and the workplace. Our treatment of the screen as a social communication space has changed with the necessary shift from a one-to-one to a one-to-many paradigm.

Design and Implementation of Data-driven Instrument used in *family, friends*

The complete data-driven instrument used in the performance of *family, friends* consists of a 9.7 inch Apple iPad Pro running a custom software interface constructed in TouchOSC,[31] paired with the Touché, a music hardware interface made by Expressive E,

[30] "Touché," Expressive E, accessed November 22, 2022, https://www.expressivee.com/1-touche.

[31] Rob Fischer, *TouchOSC*, v. 1.0.6.122, Hexler Limited, iPadOS, 2021, https://hexler.net/touchosc.

Cycling 74's Max, and Symbolic Sound's Kyma. A diagram of the instrument can be seen below (see Figure 27).

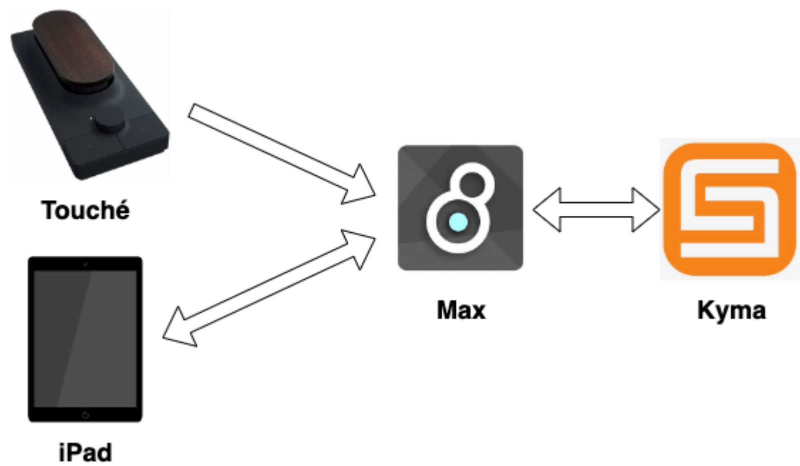

Figure 27. Diagram of data-driven instrument used in the performance of *family, friends.*

The Touché offers a unique arrangement of four sensors, engaged by moving a suspended oval-shaped piece of wood, which when released, springs back to a neutral, zero-value state. Viewed from above, two of these sensors are engaged by shifting the oval-shaped wood horizontally left or right from center along the x-axis and can only be accessed one at a time. The remaining two sensors are engaged along a z-axis, by applying force to the top or bottom of the oval shape and can be accessed simultaneously. Data streams from each sensor are sent as continuous controller MIDI messages over USB to Max where they are then scaled and sent as OSC messages to Kyma via an Ethernet connection.

The TouchOSC interface offers a variety of programmable modules which can be arranged in multiple layers or pages. Modules used in this piece include one- and two-dimensional faders, buttons, toggles, and encoders. OSC messages from TouchOSC running on the iPad are sent to Max via Wi-Fi. After some preliminary mapping the data is sent as OSC messages via an Ethernet connection to the Kyma system. OSC messages from Max and Kyma are also sent to the iPad to advance pages or modify characteristics of modules in the TouchOSC interface.

Musical Challenges and Opportunities

The ability to reveal and modify interfacial components or whole pages of components at predetermined times provides a strong visual component throughout the piece while also taking advantage of the extreme mutability characteristics of a data-driven instrument. Throughout this composition, the interface of the iPad running TouchOSC presents a variety of different interactable components ranging from full screen two-dimensional faders to a collection of encoders of variable size. While this provides a great opportunity in shaping a variety of performative actions through the piece, it also provides an opportunity for an increased presentation of narrative beyond the sonic domain. For example, the transition from the first to the second sections of this composition features a sudden change in the iPad interface from a collection of two-dimensional fader components to a visual representation of an incoming video call. The embodiment of this interactive visual metaphor within a device that is commonly used for video calls assists in the narrative of the tension in defining social boundaries in long distance communication.

Figure 28. A variety of TouchOSC interface components used in *family, friends*

Data Mapping Strategies

Mapping techniques used in this composition include scaling, offsetting, smoothing, and analyzing data to transform particular events. Data from the Touché is used throughout the piece most often to trigger samples or to induce change in parameters of *TauPlayer*s. In both cases, the fader functionality of the Touché is transformed into a button-like characteristic through the detection of the breaching of thresholds. In the example below (see Figure 29), while this threshold detection scheme is applied to two of the four faders generating two separate triggers, part of the Sound is gated by the crossing of a threshold by only one of the faders, while the other half of the Sound is engaged only when both triggers are active.

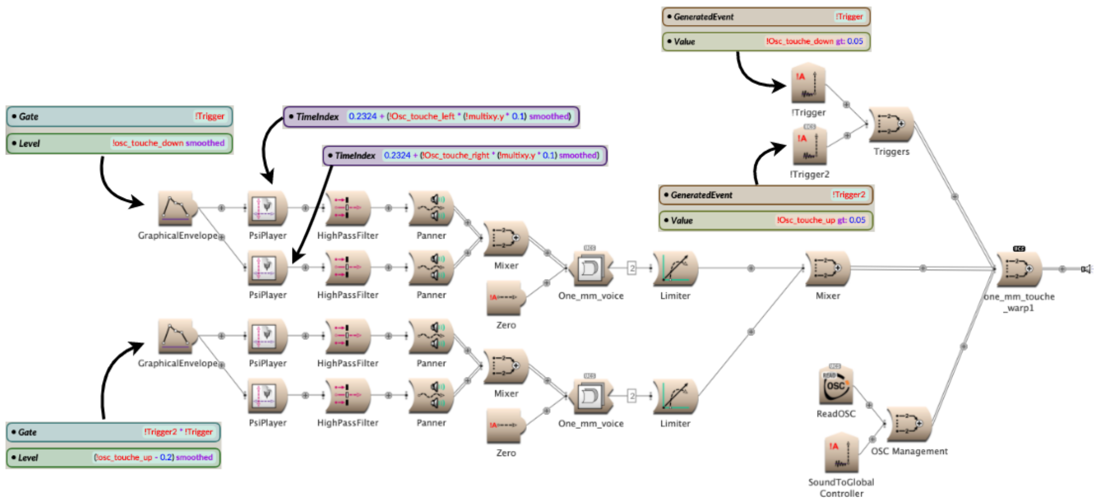

Figure 29. Sound structure used in *family, friends*

In the final section of the piece, a collection of encoder modules is revealed in the TouchOSC interface on the iPad. While experimenting with the construction of this visual portion of the interface, I was inspired to emulate the action-to-sound paradigm of gentle friction applied to the rim of glassware producing a delicate ringing tone. The input from the encoder modules, however, only reported a clockwise or counterclockwise motion as a 1 or -1 when engaged. To achieve a mapping for the desired result, I used a Kyma specific Capytalk mapping algorithm *accumulateWithHalfLife*. This algorithm allows for the increase or decrease of a resulting value by a specified amount and a diminishing half-life over a specified period of time when its input returns to zero. This essentially allowed for the input of a button-like data stream to behave like a fader. The resulting value from this process was then scaled and smoothed when applied to the envelope of a grouping of oscillators (see Figure 30).

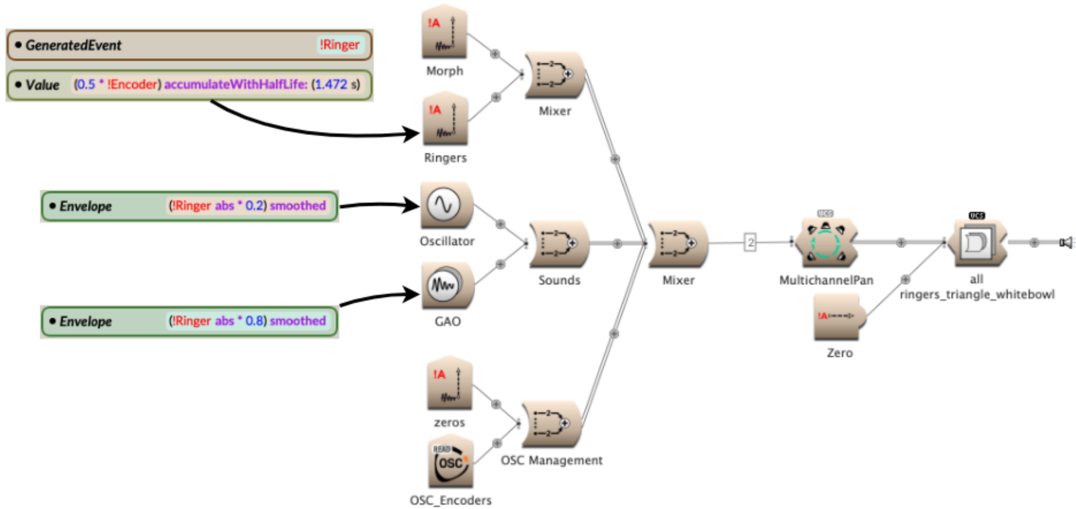

Figure 30. *accumulateWithHalfLife* algorithm used in the enveloping of oscillators

Compositional Structure

family, friends is comprised of three main sections. In the first section, both components of instrument's interface are mapped to a collection of *TauPlayers*. The vertical faders of the Touché are mapped to the enveloping of these *TauPlayers*, while the horizontal faders are mapped to slight changes in the *TimeIndex* variable. The x and y values of a collection of 2-dimensional faders provided in the TouchOSC interface are mapped to the frequency and degree of *TimeIndex* modulation.

After a dramatic intensification of dissonance, the second section employs a new collection of TouchOSC interfacial components, which are designed to look like an incoming video call. Performative interaction with the interface in this second section is restrained to just the iPad and is limited to primarily the triggering of samples.

The third section presents a collection of encoder components in TouchOSC each of which are mapped to a collection of replicated oscillators in Kyma. The Touché is again mapped to a collection of *TauPlayers* with an additional mapping of the top vertical fader to frequency modulation. A call and response interaction is played out between the two elements of the instrument's interface.

III.7 *Virtualability*

Overview

Virtualability is a multichannel real-time composition for Oculus Quest virtual reality system,[32] Max, Unity, and Kyma. This piece strives to cross the boundaries between the interior and exterior spaces inherent to a virtual reality environment. The experience of a virtual reality device can often be inspiring and provocative, but is frequently limited to an audience of one, and shared only with others utilizing a similar device. This piece is an attempt to shift this experience into the context of a staged musical performance, providing a shared experience between the performer and audience in the visual and auditory domains.

Design and Implementation of Data-driven Instrument used in *Virtualability*

The complete data-driven instrument used in the performance of *Virtualability* is comprised of the Oculus Quest virtual reality system, Cycling 74's Max, Unity, and Symbolic Sound's Kyma. A diagram of the instrument in its entirety can be seen below (see Figure 31).

[32] "Oculus Quest," accessed June 6, 2021, https://www.oculus.com/quest/.

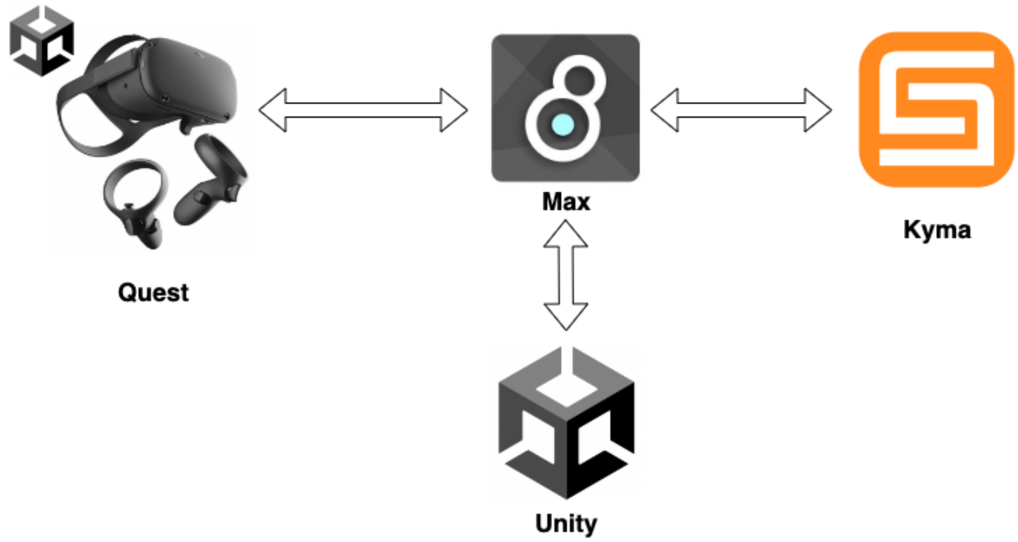

Figure 31. Diagram of data-driven instrument used in the performance of *Virtualability*

The Quest provides 6-DoF positional data for the main headset and each controller using a combination of internal sensors and an array of cameras mounted on the outside of the headset. Additionally, each controller provides input of four buttons, two faders and a two-dimensional joystick. A custom application was created using Unity for the Quest's Android-based operating system to format the various input data streams as OSC messages, which are then sent via Wi-Fi to Max. A selection of these data streams are then sent as OSC messages via Ethernet connection to Kyma where they are scaled and mapped to various musical parameters.

I created a Unity-built standalone application as an interactive visual component to the piece, projected for the audience (see Figure 32). This application is run on a separate computer so as not to overly tax any one component of the instrument. Data streams produced by the Quest interface are sent as OSC messages to Max and then passed to Unity, engaging algorithmically generated visuals. Data streams produced by the visual component are also sent as OSC messages via Ethernet connection first to Max and then to Kyma, to be scaled and mapped to musical parameters.

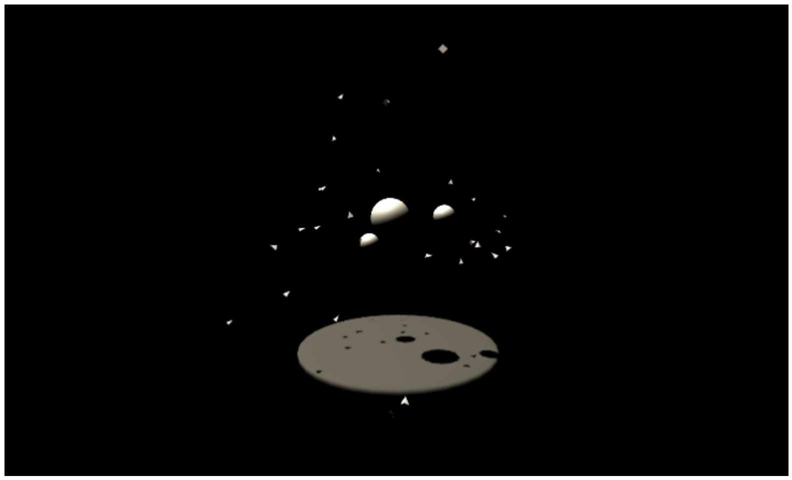

Figure 32. Visual component to *Virtualability*

In addition, both Kyma and the standalone Unity application send OSC messages back to Max corresponding to algorithmically generated visuals and audio analysis, respectively. Data streams representing audio analysis in Kyma are routed to the standalone Unity application and mapped to parameters of lighting effects within the projected virtual environment. Data corresponding to the timing of events in Kyma and positional data from the standalone Unity application are both sent as OSC messages via Wi-Fi to the Quest to provide visual feedback components for the performer.

Musical Challenges and Opportunities

My original approach in writing this composition took a much simpler and direct form in terms of data to sound from the virtual reality system directly to Kyma. However, early in the compositional process a large challenge presented itself in the inevitable feeling of withholding valuable information from the audience when wearing an immersive headset. While my performative actions would certainly be observable, some part of the relationship with the audience seemed to be missing as long as they were left wondering what I could see that they could not. I decided early on that a strong visual component was necessary that would in some way mirror both my performative actions, and the virtual environment I was engaging in. In previous staged performances of this piece, the visual component has been projected above or behind the performer. In the accompanying video of the performance of this piece, the projected visuals have been superimposed on to video of my performance with the Quest, leading to an even further symbiotic relationship with the visual component of the piece.

One great advantage of using an immersive headset as part of a musical instrument interface is the opportunity it provides in discretely communicating valuable performance instructions throughout a performance. For this piece, I created a virtual environment program with Unity, which provides visual feedback to the performer. This virtual space takes the form of a three-meter cube shaped room. On one wall of this room, text is displayed relating to connectivity information for reference when setting up the instrument. The main forward-facing wall presents information related to connectivity to the instrument, timing information, and score instruction. Throughout the performance of the piece, these mutable modules of the visual feedback system provide timely information on interaction with the interface’s inputs as well as representations of interactive objects in the visual component projected to the audience (see Figure 33).

Figure 33. The virtual cube shaped room and forward-facing wall.

Data Mapping Strategies

Mapping techniques used in this piece include scaling, offsetting, smoothing, and analyzing incoming data streams to transform particular numerical values. Data streams selected for application to sound-producing algorithms are sent from Max to Kyma and are mapped in the Kyma environment. While this composition includes many of the same data mapping strategies discussed in previous pieces within this document, there are two particular strategies that are essential to the character of the piece.

In the opening section, data streams representing the velocity of movement of each controller are offset and cyclically written at a duration of 4096 samples to a memory file using Kyma's *MemoryWriter*. These recordings are then used as wavetables in replicated collections of oscillators, creating a uniquely manipulated technique of additive synthesis. The triggering of the *MemoryWriter*'s recording function and the enveloping of the sounding oscillators are engaged by a direct mapping of a fader input located at the index finger position of the controller. This same fader input is used to trigger random variations in frequency of each replicated oscillator.

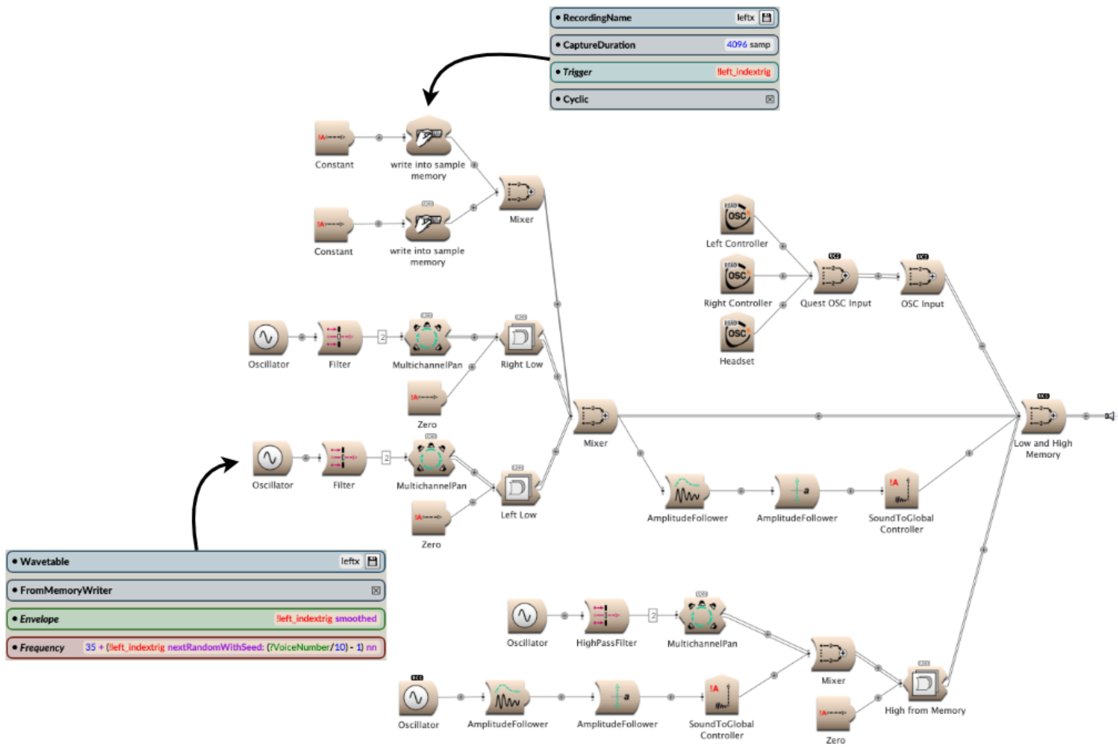

Figure 34. Translating data streams to wavetables in *Virtualability*

The second section of the composition features a flocking behavior algorithm generated in the standalone Unity application.[33] Modeled after movement behaviors of animals in nature, the flocking algorithm is based on three control principles usually described as separation (amount of difference between each of the elements), alignment (average directionality), and cohesion (overall center of mass). When mapped to musical

[33] Craig W. Reynolds, "Flocks, Herds and Schools: A Distributed Behavioral Model," *ACM SIGGRAPH Computer Graphics* 21, no. 4 (August 1987): 25–34, https://doi.org/10.1145/37402.37406.

parameters each element of the algorithm can control the individual elements of frequency distribution or distribution in space and/or time.

Data representing the three-dimensional position of each component generated in this algorithm is sent as OSC messages to Kyma. Using Kyma's *into:* function, each axis of the spatial representation of each component is translated to more appropriate values for the chosen musical parameter of a replicated *GrainCloud* Sound. In the case of amplitude, for example, as the position of each component approaches the center of the three-dimensional space the amplitude increases. Spatial location of each component is similarly mapped to grain duration, but the mapping here is inverted, creating shorter grain durations near the center of the three-dimensional space and longer grain durations further away. The angle of each component in relation to the x-axis of the virtual space is simply offset by a value of 0.5 in order to align with Kyma's default spatial orientation. Each component generated by the flocking algorithm is mapped to a replicated instance of a spatialized *GrainCloud* Sound with a maximum grain number of one, resulting in an analogous granular experience across the visual and sonic domains.

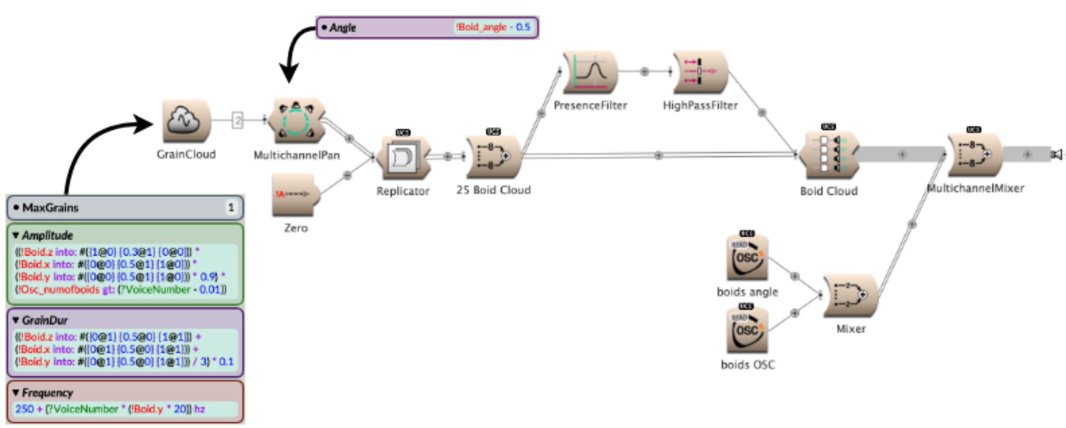

Figure 35. Mapping spatial location in *Virtualability*

Compositional Structure

Virtualability is comprised of three main sections, the third serving as a varied restatement of the second. The first section centers around an alternation between two main sounds, the unique additive synthesis structure described above, and the manipulation of two granular synthesis Sounds with vocal samples as their source. My performative actions in this section differ quite dramatically as I engage each sound. The additive synthesis structure, being directly dependent the velocity of each controller, is most effectively engaged with large swinging actions from the arms. Data representing the orientation of the headset is mapped to the *TimeIndex* and spatialization of the granular synthesis Sounds. When activated, the physical actions of turning and tilting my head simultaneously scrub back and forth through the vocal samples while panning the sound around the room. The performative gesture paired with the sounds of a voice suggests a searching or looking for someone. The first section ends with gradually smaller performative actions engaging the first sound and fading to silence.

The second section begins with an alarm-like sound, which gradually increases in tempo while shifting into a lower range of frequencies. Each press of a designated button generates an individual component of the flocking behavior algorithm, which is mapped to a replicated instance of a *TauPlayer*. The spatial location of each component is mapped to affect the amplitude, spatialization, and *TimeIndex* parameters of this Sound structure. Performative actions varying the distance between the two controllers interpolate between behavioral parameters of the flocking algorithm, in turn effecting the resulting sound. The second section ends with an abrupt elimination of the flocking components and their resulting sounds, and a brief return of the granular synthesis motive from the first section.

The third section begins with a reinitialization of the flocking algorithm, each component added sequentially when triggered by a button. While the mapping scheme is similar to the second, the replicated sound source in this section is a granular synthesis Sound using a waveform generated from data representing the velocity of a controller resulting in a harsher timbre. My performative actions through this section are slightly more dramatic and frequent, resulting in a building of tension towards the end of the piece. Similar to the second section, the flocking algorithm and resulting sounds are abruptly eliminated and the granular voice motive briefly returns. The piece ends with a final statement of the opposing additive synthesis motive.

CHAPTER IV

SUMMARY

This text document describes and analyzes the seven real-time electroacoustic compositions that are the core of the digital portfolio dissertation. This analysis has included descriptions of the design and implementation of each data-driven instrument, the routing and mapping of data, musical challenges and opportunities presented by each instrument, and a description of the structure and articulation of each composition. Each musical work presented has utilized a unique instrument interface ranging from repurposed tools, to gaming devices, to interfaces custom-built specifically for the piece composed.

The common thread throughout the seven compositions presented here is the exploration of unseen boundaries. In *unFamiliar* I explored the boundaries of human perception of sound through the manipulation of ambisonic recordings of a familiar space with the Gametrak. *Within the Tallest Tree* presented a fantasy of crossing boundaries of communication with surrounding nature. *Things Look Different Here* stands as a representation of crossing my own personal boundaries from a classically trained cellist to a data-driven instrumentalist. *A Need to Be Free* presents a musical metaphor to the unseen boundaries of anxiety and depression. *A Musical Interpretation on the Findings of Voyager 2* is centered on literal unseen boundaries, using data representing planetary magnetic fields in various ways throughout the composition. In *family, friends* I present a narrative of the recalibration of social boundaries during pandemic induced isolation.

Finally, *Virtualability* strives to blur the boundaries between the interior and exterior spaces inherent to a virtual reality environment.

While each individual musical work presented here focuses in some way on a different facet of the concept of boundaries, the presentation and performance of these works is in itself the crossing of an unseen boundary. The boundary space between the concept or narrative inspiring the musical work and the observable musical performance of the composition is the focus of this document. It is my hope, through the presentation of this analytical guide, and the exposure of the boundary space of my own compositional process, that others may be inspired in the crossing of their own unseen boundaries.

BIBLIOGRAPHY

Arduino IDE. V. 1.8.19. MacOS, 2021. https://www.arduino.cc.

Boyt, Zachary. "Gesture-Sensing Technology for the Bow: A Relevant and Accessible Digital Interface for String Instruments." Master's thesis, Western Michigan University, 2014.

“Boundary.” American Psychological Association. American Psychological Association. Accessed November 14, 2022. https://dictionary.apa.org/boundary.

"boundary, n.". OED Online. Oxford University Press. Accessed November 8, 2022. https://www-oed-com.libproxy.uoregon.edu/view/Entry/22048

Cook, Perry. “Principles for Designing Computer Music Controllers.” In *Proceedings for the InternationalConference for New Interfaces for Musical Expression*, 3-6, 2001. doi:10.5281/zenodo.1176358.

Cycling 74'. *Max.* V. 8.2.1. Cycling 74', macOS, 2022. https://cycling74.com/products/max/.

Expressive E. “Touché.” Touché. Accessed January 6, 2022. https://www.expressivee.com/1-touche.

Fischer, Rob. *TouchOSC*. V. 1.0.6.122. Hexler Limited, iPadOS, 2021. https://hexler.net/touchosc.

Freed, Adrian, Devin McCutchen, Andy Schmeder, Anne-Marie Skriver, Dan Overholt Hansen, Winslow Burleson, Camilla Nørgaard, and Alex Mesker. “Musical Applications and Design Techniques for the Gametrak Tethered Spatial Position Controller.” In *Proceedings of the 6th Sound and Music Computing Conference*, 23–25, 2009.

Fry, Benjamin, and Casey Reas. *Processing.* V. 4.0 beta 2. macOS, 2021. https://github.com/processing/processing4.

Godlovitch, Stanley. *Musical Performance: A Philosophical Study*. London ; New York: Routledge, 1998.

“GP-10: Guitar Processor.” BOSS. Roland Corporation. Accessed November 22, 2022. https://www.boss.info/us/products/gp-10/.

Hunt, Andy, Marcelo M. Wanderley, and Matthew Paradis. “The Importance of Parameter Mapping in Electronic Instrument Design.” *Journal of New Music Research* 32, no. 4 (December 1, 2003): 429–40. https://doi.org/10.1076/jnmr.32.4.429.18853.

"In2Games. Gametrak & Real World Golf PlayStation2." Accessed November 5, 2022. https://web.archive.org/web/20080610084443/http://www.deafgamers.com/05reviews_a/gametrak%26rwgolf_ps2.htm.

Kimura, Mari, Nicolas Rasamimanana, Frédéric Bevilacqua, Bruno Zamborlin, Norbert Schnell, and Emmanuel Fléty. "Extracting human expression for interactive composition with the augmented violin." *International Conference on New Interfaces for Musical Expression, NIME 2012, Ann Arbor,* 99-102, 2012.

Lucier, Alvin. *I Am Sitting in a Room*. CD. Lovely Music, 1990.

Machover, Tod. *Hyperinstruments: A Progress Report, 1987-1991.* Media Lab, Massachusetts Institute of Technology, Cambridge: MIT Media Laboratory, 1992.

"Mira." Cycling 74'. Accessed October 3, 2022. https://cycling74.com/products/mira.

Miranda, Eduardo R. and Marcelo M. Wanderley. *New Digital Musical Instruments: Control and Interaction beyond the Keyboard*. Middleton, WI: A-R Editions, 2006.

“Oculus Quest.” Accessed June 6, 2021. https://www.oculus.com/quest/.

“Orion Series Cellos.” Jensen Musical Instruments. Accessed November 22, 2022. https://web.archive.org/web/20180506110853/http://www.halcyon.com/jensmus/ocello.htm.

“NASA Open Data Portal.” DATA.NASA.GOV. NASA. Accessed January 12, 2023. https://data.nasa.gov/.

Paradiso, J. A. "Electronic music: new ways to play." *IEEE Spectrum* 34, no. 12 (Dec. 1997): 18-30.

Perrot, Pierre. *A To Z of Thermodynamics by Pierre Perrot*. Oxford University Press, 1998.

“Poly-Drive IV.” RMC pickup Co. Accessed November 22, 2022. https://www.rmcpickup.com/polydriveiv.html.

Reas, C., and Benjamin Fry. “Processing: Programming for the Media Arts.” *AI & SOCIETY*, no. 20 (2006): 526–38. https://doi.org/10.1007/s00146-006-0050-9.

Reynolds, Craig W. "Flocks, Herds and Schools: A Distributed Behavioral Model." *ACM SIGGRAPH Computer Graphics* 21, no. 4 (August 1987): 25–34. https://doi.org/10.1145/37402.37406.

Roads, Curtis. *Composing Electronic Music: A New Aesthetic*. Oxford ; New York: Oxford University Press, 2015.

———. *The Computer Music Tutorial*. Cambridge, MA: MIT Press, 1996.

Rose, Jon. "Great Fences of Australia." The Jon Rose web. Accessed November 21, 2022. https://www.jonroseweb.com/f_projects_great_fences.php.

Ryan, Joel. "Some Remarks on Musical Instrument Design at STEIM." *Contemporary Music Review* 6, no. 1 (1991): 3–17.

Scaletti, Carla. *Kyma X Revealed! Secrets of the Kyma Sound Design Language*, Symbolic Sound Corporation, 2004.

______. *The Kyma Language for Sound Design, Version 4.5*, Symbolic Sound Corporation, 1997.

Scaletti, Carla, and Kurt Hebel. *Kyma Seven.* V. 7.39f4. Symbolic Sound Corporation, macOS, 2021. https://kyma.symbolicsound.com/.

Shiomi, Mieko. "< boundary music >" The Museum of Modern Art. Accessed November 7, 2022. https://www.moma.org/collection/works/127554.

Stolet, Jeffrey. *Do: Notes about Action in the Creation of Musical Performance with Data-Driven Instruments.* Morrisville: Lulu Press, 2021.

———. "The Cinematics of Musical Performance with Data-Driven Instruments." Presented at the Kyma International Sound Symposium, Bozeman, Montana, August 9, 2015.

———. "Twenty-Three and a Half Things about Musical Interfaces." Keynote Address presented at the Kyma International Sound Symposium, Brusels, Belgium, September 14, 2013.

———. *Kyma and the SumOfSines Disco Club*. Morrisville: Lulu Press, 2012.

"Structural Pipe Fittings for DIY Builders." Maker Pipe. Accessed November 22, 2022. https://makerpipe.com/.

"Touché." Expressive E. Accessed November 22, 2022. https://www.expressivee.com/1-touche.

Unity. V. 2020.3.25f1 LTS. Unity Technologies, macOS, 2020 https://unity.com/.

"Voyager - The Golden Record." Accessed January 5, 2022. https://voyager.jpl.nasa.gov/golden-record/.

"Wacom Intuos Pro: Creative Pen Tablet." Wacom. Accessed November 22, 2022. https://www.wacom.com/en-us/products/pen-tablets/wacom-intuos-pro.

"What Is Arduino?" Accessed January 5, 2022. https://www.arduino.cc/en/Guide/Introduction.

Wright, Matthew James, and Adrian Freed. "Open SoundControl: A New Protocol for Communicating with Sound Synthesizers." In *International Computer Music Conference* 101, vol. 104. 1997.

Zbyszynski, Michael, Matthew Wright, Ali Momeni, and Daniel Cullen. "Ten Years of Tablet Musical Interfaces at CNMAT." In *Proceedings of the 7th International Conference on New Interfaces for Musical Expression*, 100–105, 2007.

Zhang, Zhengyou. "Microsoft Kinect Sensor and Its Effect." *IEEE Multimedia* 19, no. 2 (February 2012): 4–10. https://doi.org/10.1109/MMUL.2012.24.