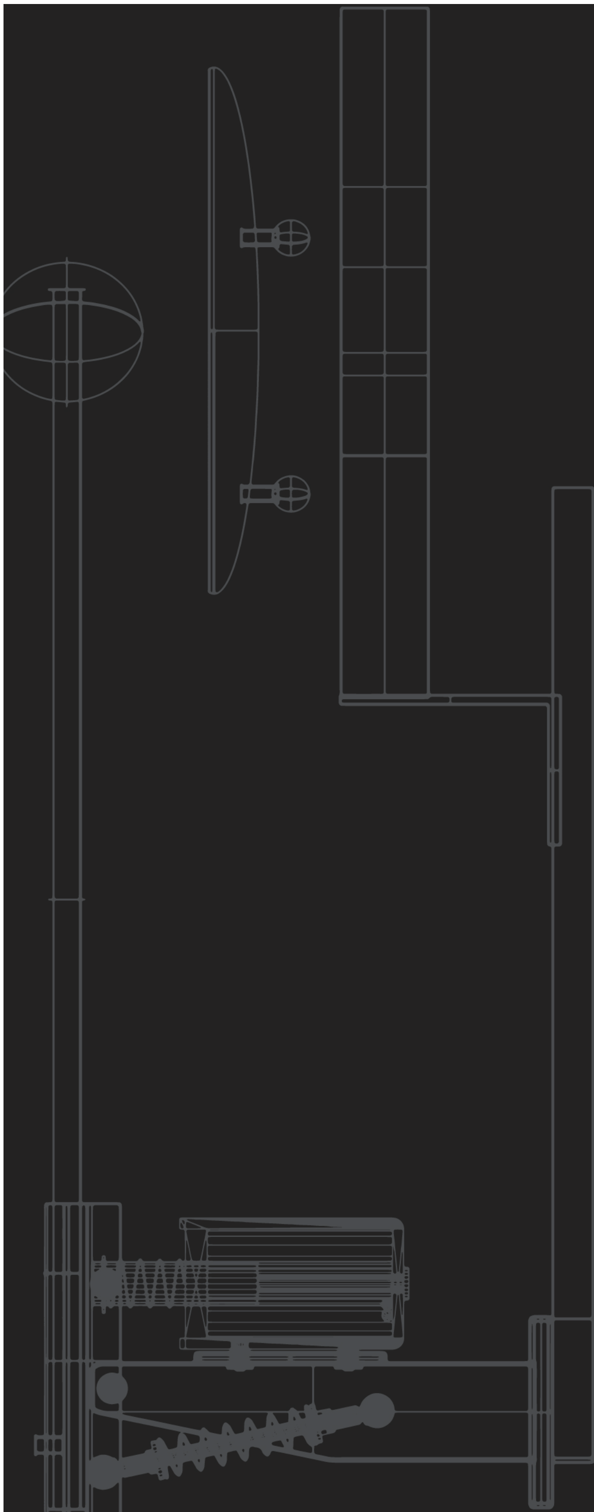

Embodied Expressions

An Audiovisual Performance

A Masters of Fine Arts Thesis by

Afaq Ahmed Karadia

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An Audiovisual Performance

by

Afaq Ahmed Karadia

A thesis exhibition presented to OCAD University
in partial fulfillment of the requirements for the degree of
MASTER of FINE ARTS (MFA) in DIGITAL FUTURES

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Embodied Expressions

an audiovisual performance

Afaq Ahmed Karadia

OCAD University

MASTERS OF FINE ARTS (MFA) IN DIGITAL FUTURES 2018

Abstract

Embodied Expressions is an exploration into the possibilities of creating live audiovisual performance systems with the aim of expanding my own artistic practice. This thesis investigates how a performer could express more intuitively with physical and mechanical audiovisual interfaces, and stands in revolt against the total digitalization of live electronic music. I argue that modern electronic music performance has led to a decoupling of sound from its traditional origins in real physical objects and has created a limitation in the live performer's ability to express themselves through the embodied aspects of their live musical expression. This thesis reflects on the artistic exploration of embodied instruments made up of found objects and their control by a performer's gestural input. The final artifact of this thesis is a set of heard and seen mechanical instruments placed about the audience's environment that are controlled by the performer using a custom-designed gesture-based control system.

Keywords: Audiovisual Performance, Installation, sound, embodied, cybernetics, Gestures, New interface in musical expressions

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To my beloved family and friends around me

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1. INTRODUCTION

In the modern context of electronic live digital performance, where performance tools produce their output through purely digital means such as synthesizers, dubs, and sample playback, there is a noticeable lack of a sense of real-world embodiment for the performing artist. Unfortunately for live performers the interaction with their creative medium is limited to buttons on a computer, knobs and a tangle of MIDI interfaces, while in the past the performer had a much more embodied and intimate relationship with the instrument with which they were performing (e.g., playing with classical instruments, vocal singing, etc.). With traditional performance tools, listeners could follow a performer's emotional expression through the performer's visible embodied experience of playing their instrument. When performers are in the flow of true live artistic expression gestures, become more frenetic, rhythmic, vigorous and drawn out, and this gives the audience a much clearer and more sublime sense of the emotions the performer is expressing through their performance. In the modern age of digital music, we lose the embodied aspects of music, which can be seen in the tangible and visible physical components of instruments when compared to modern digital music interfaces. To alleviate this gap in the artist's ability to fully immerse themselves, and by extension the performer's audience, in their audiovisual expression, this thesis is focused on developing a new interface for audiovisual performance. This research project will help me to investigate and establish a qualitatively different kind of digital performance interface, that incorporates the embodied aspects of live artistic expression, by experimenting with media interfaces that enhance the physical aspect of the live performance and connect directly with repurposed tangible mechanical- and physical-based custom instruments. The result produced through this thesis project is the development of a gesture mapping software and hardware system that controls a set of custom mechanical instruments that help to create a real-time coupling between the artist's physical gestures and their performance tool, which thus provides immediate audiovisual output and leads to a stronger sense of immersion in the performance environment.

This concept of the relation between the performer's physical actions and the resultant perceptual feedback that leads to further actions is also known as the action-perception loop (Gibson 1976) because the relationship between the environment and the performer is reciprocal. The gesture mapping framework used in the artifacts of this thesis is the key feature in giving the performer a stronger sense of real-time physical expression and immersion because their physical actions directly lead to audiovisual outputs made by the responsive real world mechanical objects. This performance system gives the performer a greater sense of extended embodiment because every action they take is linked directly to the audiovisual output of the mechanical instruments.

A general outcome of this research is the greater understanding of how to create ever more personalized and customized performance systems. This kind of embodied performance system also creates a performance environment where the audience gains a much stronger sense of immersion as they can witness the real-time physical expression of the artist extending to the activity of the mechanical instruments. This general style of performance system extends the possibilities for live performance because it opens the way towards a new set of possible gestural interfaces and their interconnected mechanical instruments and outputs.

1.1 RESEARCH MOTIVATION

In the course of recent years, the significance of new interfaces in music expression has caught the attention of a growing number of performance artists. The investigation of digital technologies changes what we consider to be innovative practice, and inspires musicians to use common interactions with rich tactile performance systems to connect with viewers and other entertainers and change how they view performance arts. While the technology has advanced in recent years, it has yet to create a growing interest in more performative and improvised tools. There is an incredible variety of ways a performer can make use of new technology in their performances but the majority of digital musicians are fastened with the keyboard interface offered by the standard computers, even while a growing number of professionals have indeed begun to build custom performative instruments. My experience with the media industry is limited to the 21st century. I initially began working as an audiovisual VJ performer in 2014 and I was astonished by the work of other performance artists like Anti VJ, Play Modes, 1234 Architecture, and Alva Noto. Each performer had a very different purpose from each other, with a unique style. A few of these performers made headway with content-creation innovation delivering live content in various new media spaces. This progress changed my perspective and my performance practice. I kept pace with these progressive innovation changes in performance technology, inspired to modify my practice, and begin this thesis research because the constant change in the industry made it difficult to adapt over and over again. Sorting through the collective of technological changes, specific vital tools and practices emerge as exciting new opportunities in live audiovisual performance, but each technology change requires time and investment to learn the new specialized software. I began my audiovisual performance practice by going to various festivals and observing how innovations fit into the performance arts. The Geneva Mapping Festival was one such example in Switzerland that profoundly influenced my work.

The Geneva Mapping Festival is a worldwide festival devoted to live audiovisuals, performances, and VJing. Held yearly in Geneva, this festival highlights experimental media and VJ exhibitions in both dance club settings and as installations in exhibition spaces. The festival advances performers from media organizations and provides the opportunity to experience new interfaces in musical expression giving artists a chance to feature their work. I attended this festival in 2016 where I met many performers, artists, and producers, and left motivated with new ideas on how to enhance my practice. I also left feeling irritated that there were too few ways to differentiate myself as a performer. At the time, my practice was limited to generative visualization without novel sound. Several performers featured generative music in their creations and I was keen to know how they produced their experimental sound. The key technologies in 2016 were Kinect and Leap Motion, both motion tracking hardware sensors. Some of the Geneva Mapping Festival artists started using these tools to control LED lights and projection mapping content, with Moving Head beam light movements for example. They made their performances responsive by warping and altering their live sound through their expressive gestures. The festival opened up a whole horizon of new mediums and artistic approaches and this influenced my practice with the understanding that future visual performances can't be comprised of a single kind of media. To make my performance more experiential I needed to investigate more devices and adjust to the knowledge and technology foundations these new gadgets required. I began to customize the technology I had seen and tried to imagine unique audiovisual performances and ways to fabricate an entire framework of novel instruments. This process has led to the development of my thesis project *Embodied Expressions*, which is my synthesis of the live digital performance elements I had understood to be the cutting edge of the industry.

Embodied Expressions was developed through a progression of iterative and experimental processes. Every new cycle of developing the model refined the connection between me as a performer with the performative tools in front of me, all made interactive with controllers. This approach presented theoretical questions intrinsic to all musical and visual performances. Specifically, the research developed from this investigation is composed of:

- immersive audiovisual performance
- live sound/video content generation, and
- embodied experience with tools and environment.

By logically investigating these domains through iterative examination I have built a versatile audiovisual system which takes into account an assortment of performance setups. A gestural control framework acts as the central interface of my performance system and is connected with some of the more interactive elements of my performance practice.

1.2 THESIS SCAFFOLDING

This Thesis contains seven chapters. Each chapter has a particular research emphasis, but also continues the individual research threads, as they developed in tandem. The first Chapter introduces the thesis and current problems, through working hypotheses and research questions. The second chapter focuses on the artist perspective and critical analysis of their artwork to see where my research is fitting on. The Third chapter surveys the literature and critical intent of the research. The Fourth Chapter provides a broader theoretical background on the themes underpinning the research. The fifth chapter Takes towards the Method and approach towards research and the process involved in it. The sixth chapter details a series of iterative based acoustic, material and mechanical tests, further subdividing by instrument in the research and design making process. This chapter critically analyses and summarizes each iteration.

1.3 RESEARCH QUESTIONS

The primary research questions that are the main focus of my thesis research are:

- How can physicality and mechanical audiovisual interfaces address the challenges of post laptop audiovisual performance?
- How can mechanical instruments support the performer to create an embodied audiovisual performance?
- How can the shared environment of the performer and audience be made to achieve a greater sense of immersion in this audiovisual context?

2. HORIZON SCAN

To gain a better understanding of where my practice sits within the broader context of contemporary art practice we will here inspect chosen pieces of work and analyze how they relate to and inspire my work. These selections were chosen because they relate to my work both as installation art as well as performance practice. Through the process of critically analyzing these artifacts we will gain a deeper understanding of how my practice fits into the contemporary context as well as what can be incorporated into my practice.

2.1 ZIMOUN

The artist Zimoun is best known for sound sculptures, sound architectures, and installation art making use of functional elements. Zimoun fabricates architecturally-oriented sound structures (Zimoun 2014), opening architectural acoustics up to artistic review.

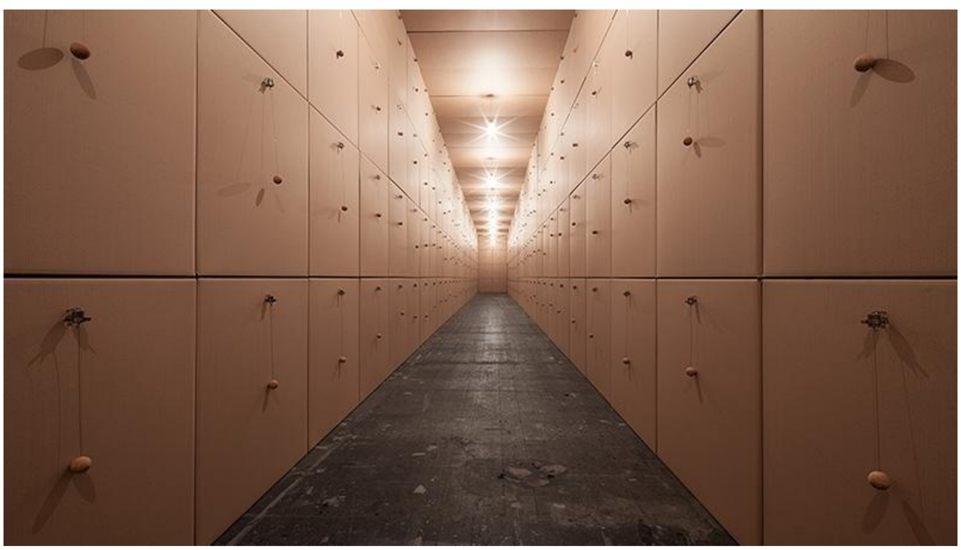

Figure 1 Zimoun 318 prepared dc-motors, cork balls, cardboard boxes

Zimoun investigated mechanical rhythm and built his aesthetic in large part by incorporating everyday industrial objects. In an exaggerated showcase of essential and useful materials, Zimoun's sculptures Illustrate a conflict between the precision of modern architectural design and the clamorous chaos of life. Zimoun is interested in creating a reflective study of architecture itself where sound is understood as an architectonic element. Zimoun works with music by making three dimensional static sound structures that can be entered and investigated acoustically, similar to walking around in a building with all of the sounds specific to that environment. He uses patterns, repetition, and spatial structures, in the form of Embodied Expressions, to inhabit a room with expressive qualities. Each module in the set carries on in its way as a part of the whole. Having multiple identical components using the same materials and systems only further highlights the different behaviours. Zimoun is interested in multiplication, and the three-dimensional soundscape that a network of dispersed mechanical systems can generate. A sound structure can get very complicated, even if it is based on many small, simple mechanical systems.

Zimoun's work relates to my ideas for developing a performance system in the sense that I am also interested in building instruments that are created from environmental, mechanical objects, which are then converted into acoustic instruments. My system is intended to similarly generate three-dimensional sound sensitive to the acoustics of the space. The shared theme between Zimoun's sculpture and Embodied Expressions is the exploration of the relationship between materiality and space. The only meaningful difference between his and my installation projects is how the two different sound sculptures are controlled. Zimoun's sculptures loop their sounds based on conditional interactive parameters through pre-assigned algorithms, whereas in my project I directly create Embodied Expressions in my performance system through explicit gestures, where I can define and adjust sonification an immersive gestural interface.

2.2 WINTERGATAN

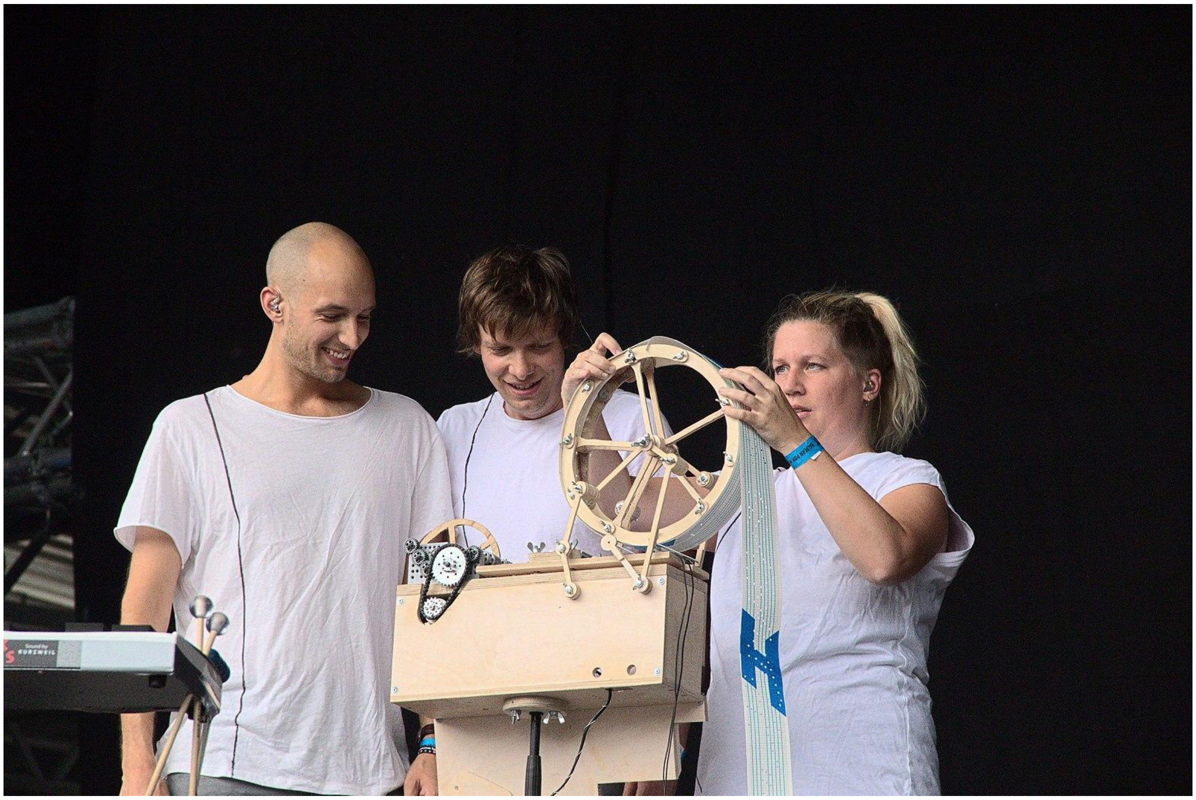

Figure 2 Wintergatan at Haldern Pop Festival 16

Marble Machine is a singularly unique musical instrument designed by Swedish musician Martin Molin. While the concept of a marble machine isn't novel there is an entire marble machine subculture where, for example, Molin has created a programmable and complicated mechanical contraption that generates sound via the collisions of marbles with sound-making objects that are thrust about by the machine. The Marble Machine is a handmade music box that powers a kick drum, bass, vibraphone and different instruments utilizing a hand wrench and 2,000 marbles. Inspired by early wheel driven church bells, Molin's machine is made up of ringing preprogrammed melodies, laser cut intricate wooden cogs, wheels, tracks, pulleys, and channels for collecting and redirecting spent marbles. Molin's marble machine Wintergartan has imbued his unique vision of machine music with his particular artistic flair.

"The marbles behave like water. The nature of water is that it just breaks through everything. After 100,000 years, it can make a hole in the stone. The marbles act like that." (Woodllaston and Michael 2017)

.

The machine itself is mechanically programmable, where its central wheel is a 32-bar loop and the key of the song can be adjusted while playing. The machine works on a grid system that follows a pattern to make a beat. In the ancient time before the digital era the common occurrence of music boxes used a similar looping grid setup. Machines that generate mechanical sound and allow for a more in-depth and expanded exploration of the boundaries of music are a direct inspiration for my work on Embodied Expressions. My intention however, is not to create a predefined beat, but to leave the composition and pace of my machine music to the spontaneous expressions of my phenomenological state. Molins's embodied experience came pre-defined as he knew he had to make a beat for his particular song choice. In contrast, my machine will incorporate Embodied Expressions between environments and audiences in order to function as a live performance system in a way that is missing from Wintergartan. Molin is very much engaged with his performative tool but the audience cannot fully immerse themselves because the relationship between the audience and performer is not fully clear. In contrast, *Embodied Expressions* is meant to provide a stronger relationship between performer, performative tool, and audience.

2.3 ORCHESTRION

Figure 3 Pat Metheny Orchestrion

The Orchestrion Project is an experimental work by American Jazz guitarist Pat Metheny. This studio album was recorded in 2009 and released by Nonesuch Records in 2010. As an artist, Pat Metheny was interested in recontextualizing musical composition and solo performance (Marsh 2013). Methany used this project to create a platform to explore mechanically controlled musical instruments and their integration into a live improvisational guitar performance. The Orchestrion was built in collaboration with a team of artists and technologists. This included custom-fabricated acoustic and acoustic electrical instruments using computer-controlled hammers, solenoids, pneumatics, etc. Performing as a single musician, this automated system allowed Methany a certain degree of autocracy to which he added a layer of improvisation by playing his conventional electric guitar to a musical composition. This ensembleoriented musical composition redefined the meaning of the solo record. However, the automation of the instruments brings too much focus to the relationship of the mechanical objects to one another and to the mechanical sounds they produce. The improvisational guitar being played adds another layer to the composition, but the artist's improvisational activity is limited entirely to responding to the mechanical music framework, as opposed to guiding it entirely. In my project, I want my gestures to influence the broad composition of mechanical instruments directly and allow the environment to play a role in the evolving live composition itself.

2.4 FELIX'S

Figure 4 Felix's Thorn Felix machines

"Felix's Machines" are an orchestra of audio instruments producing a mix of pianos, motors, LED's and improvised scrap metal instruments, all controlled by a central program. Felix composes music for his machines and then performs them to an audience. Felix's machines were first thought to facilitate live music experiences by transforming sound into a three-dimensional visual show, with digitally controlled mechanical instruments. At the beginning of his work, Felix started building stand-alone sound sculptures which played mechanical sounds based on predefined code scripts. In one of his interviews, Felix said that

> "Although my medium focuses on the development of acoustic sounds, I am continually inspired by electronic music - the countless abstractions act as blueprints for the construction of its acoustic counterparts. I aim to build a space where artificial and dream-like environments can become a reality." (Thorn 2008)

Felix's projects were not initially too focused on incorporating human control elements, but rather to test the advantages and boundaries of mechanical instruments themselves. Later on, in 2014 however, Felix and Uberact drew attention from Microsoft's Kinect team to develop an installation using a Kinect sensor, which would give human users an element of control over the musical piece. The idea branched off from the standard Kinect control of computer-generated content like video games, and was adapted for his custom musical contraption. Uberact decided to collaborate with Felix to turn his machine into an interactive installation controlled by Kinect. They initially intended to make an installation piece rather than a performance piece. The installation was programmed in a way that assigned pre-defined loops to each instrument and when an audience member pointed at an instrument it started playing. As a performer, it's really important to place musical instruments in a way that gives a feeling of the embodiment of performance. In Felix's Machine, the placement gives a participant limited access to his performance space. In contrast, *Embodied Expressions* is intended to create an intuitive relationship with the space, bringing the mechanical instruments out into the audience environment to then become an immersive aspect of the performance. In his work, Felix plays with design and form factor to draw out the mechanical aspects of his instrument, but the static placement reduces the essence of the immersive scenario and lacks a sense of an embodied performance.

2.5 PATRICK SAINT-DENIS

Figure 5 Patrick Saint-Denis Wave photo by Arsenal Montreal

As the title suggests, Saint-Denis incorporates gestural waving with performative technology using two myographic (muscle) sensors developed by Thalmic Labs to catch the orientation and electrical movements of the muscles of his lower arm. In Saint-Denis' project, custom programming transposes his gestures to a movement, not unlike the Theremin or air guitar (SaintDenis 2016). On another level, "Wave" investigates the digital context of a gesture-sound relationship. For a long time, gesture and sound were firmly connected and limited only by the physicality of musical instruments. In instruments like the Theremin, the Hammond organ or the electric guitar, artists just "control" sound while the energy to create it originates from electricity. This detachment is most evident in the computerization of instrumental music, where the computer clarifies and renders a mechanical instrument. When Patrick built a musical instrument, he tried to separate himself from the original relationship of gesture with sound. Patrick brings originality in instruments that work on their own. However, this project focuses more on performance with the body as an instrument but all the actual sound is generated synthetically, thus creating an element of separation between performer and performance tool. In this particular project, Patrick explores how gestural output maps with computer-generated sound but looking at his performance, it's hard to visualize music and appreciate the embodied aspects of performance in the context of being in the audience. The computer-generated sound has more internal consistency within each sound than controlling mechanical instruments allows for. This project creates an interesting context for mapping gestures but limits the performer's ability to engage with their performative space because his live performance is limited to being controlled by a cryptic interaction between his muscle contractions and the wearable device. *Embodied Expressions* creates a more metaphorical relationship with gesture, spatial parameters, and the performance environment.

2.6 LAETITIA SONAMI

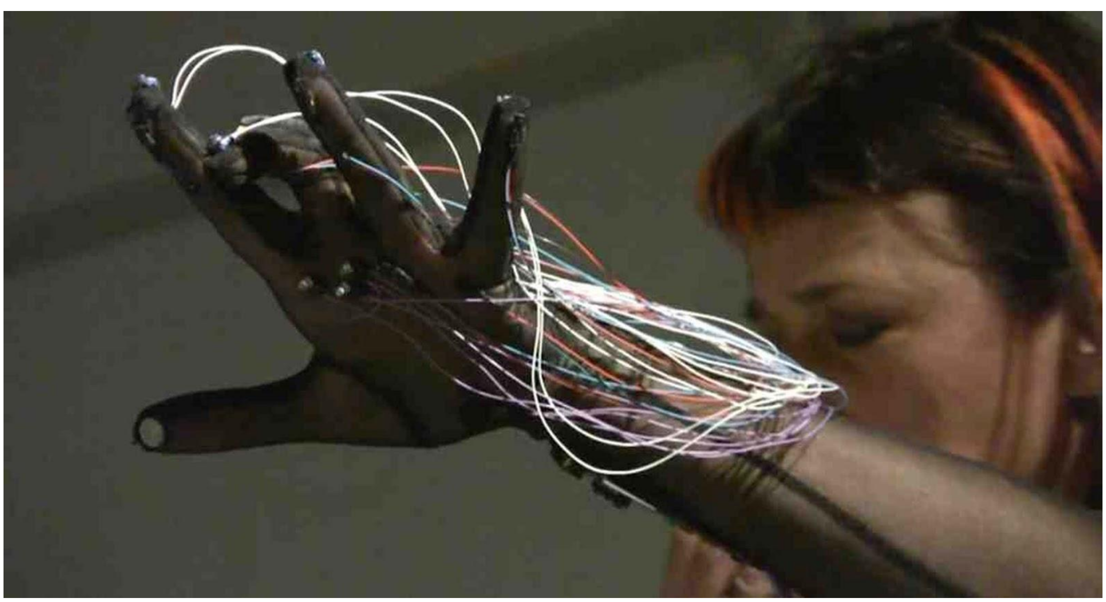

Figure 6 Laetitia Sonami lady's Gloves

The Lady Gloves by Laetitia Sonami adds a complete understanding of gesture control in audiovisual performance. Laetitia Sonami is an audiovisual artistic pioneer working with sound installations and kinetic art, developing her own custom performative tools like the "Lady Gloves." Sonami first built her gloves in 1991 for a performance at the Arts Electronica festival in Germany (Sonami 1991). She began with a couple of elastic kitchen gloves and five hall-effect transducers attached to the fingertips with a magnet on the right hand. By touching the fingers on the magnet differing voltages sent signals to a Forth board, which were then converted to MIDI signals made into sound using different synthesizers and samplers. Sonami wanted a more fluid way to perform with the computer and these gloves let her experiment with and respond to substantial masculine norms in virtual reality. The performance gloves were arm-length with sensors, magnets slotted inside the thumb, with a connection to micro switches on the tip of the fingers. Sonami hid the wires inside the gloves, leaving a big patch coming out at the wrist visible enough at close range to give a cybernetic aesthetic, but not so apparent that the audience could see it from a distance. Sonami's right hand controlled a mixing board. To add an aesthetic element Laetitia made the third iteration of the gloves more glamorous with golden lycra. The golden gloves had a resistive strip (twist sensors) and power lines sewn along the fingers and wrist. These sensors connected on the inside, collecting two channels of information for every strip, and followed along every finger's contours. A pressure pad sewn along the forefinger with an ultrasonic transmitter in the palm transmitted the signals to receivers in the right arm and left foot. These sensors calculated the distance between both hands and the height of the left hand from the ground. The objective was to translate the signals contrastingly given the separation of the hand to the body and ground. The two subsequent iterations of the Lady's Gloves were built by Bert Bongers in Den Haag, Holland in 1994 and were sponsored in 2001 by the STIME Institute of Amsterdam (Sonami 1991). The 4th and 5th iterations of the gloves had the same sensors sewn on the top of a thin black, arm-length lycra mesh glove custom-fitted in Paris. Added to the five micro switches, four Hall effect transducers, pressure pad, resistive strips and two ultrasonic receivers, was a mercury switch on the top of the hand and an accelerometer which measures the speed of motion of the hand. Version 5 added two accelerometers on the right wrist band, some more hall effects, a light sensor, extra switches, LEDs and more recently a miniature mic. The mapping and sonic material changes each composition while gestures control sound processing parameters. Laetitia can control motors and other objects via these gloves. She intended for the gloves to allow her to create meaningful gestural movement inputs, without spatial constraint, and to enable multiple, simultaneous controls of different components. Sonami's process was iterative and she built her gloves based on personal phenomenological performance practice. In performative musical tools, it is essential that the artist can express their own experience with complete freedom, and not be constrained to a limiting set of translatable actions. Tools like the Lady Gloves can help performers communicate their phenomenological state in a very intuitive way, and this will be an important element in inspiring my practice.

2.7 MICHEL WAISVISZ

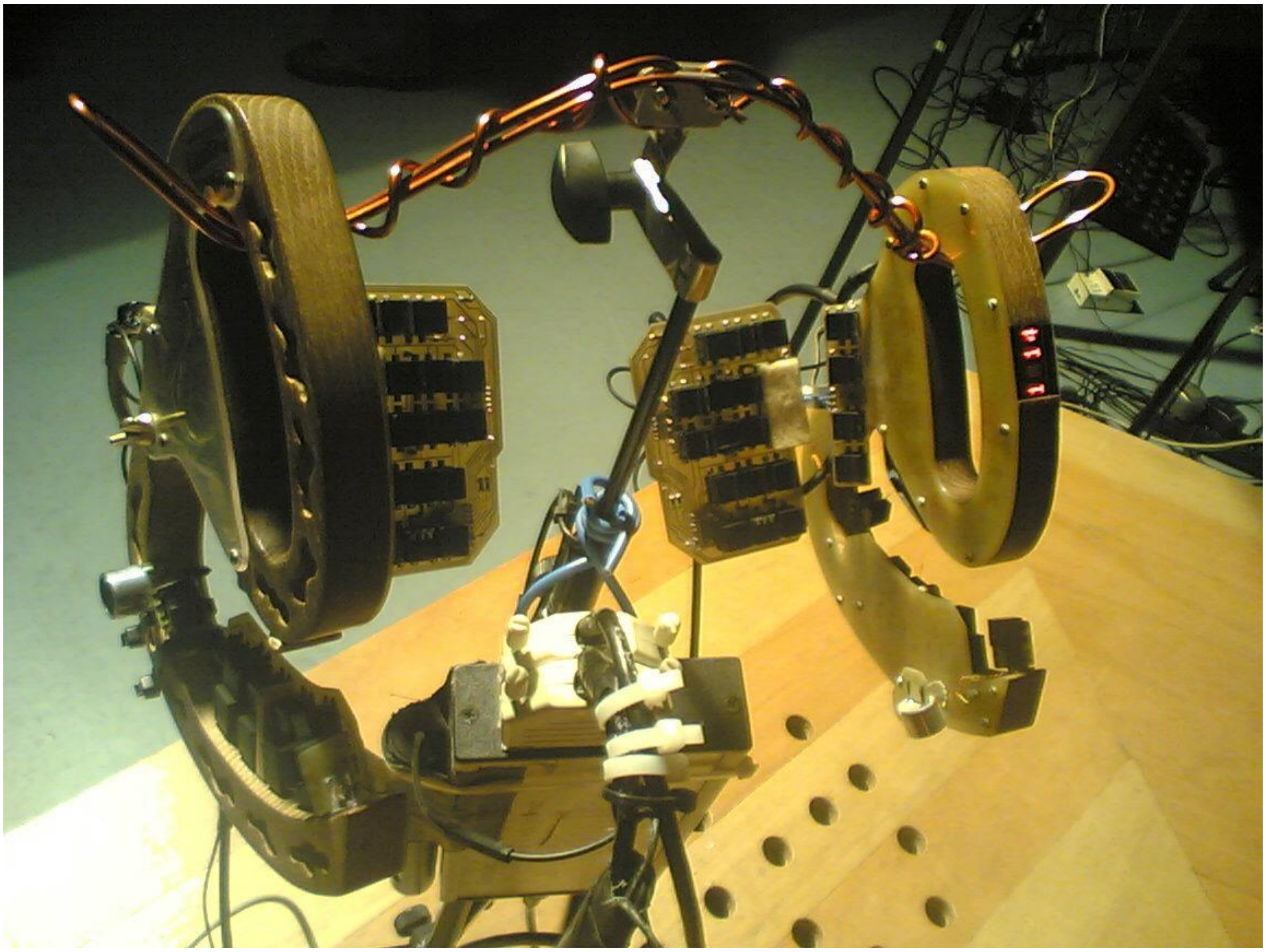

Figure 7 The Hands, electronic instrument Micheal waisvisz

It took Michel Waisvisz three months after the arrival of his first DX7 midi synthesizer to build his first prototype of his tool “The Hands”. This project was first featured at a concert in the Amsterdam Concertgebouw in June 1984. The Hands instrument was used to remote-control three Yamaha DX7's modified with extraordinary and extremely responsive sounds. The Hands also followed an iterative development process based on Michel’s performance practice, in which he considered himself a composer. During an interview, Michel said he was “a composer of timbres”, and went on to explain that

“Due to the state of technological developments in the current era, I'm a composer using electronic means because of their differentiated and refined control over timbre.” (Volker Krefel 1990).

He considered the creation of a specific electronic music instrument a natural part of the compositional process, and the already high modular setup of MIDI instruments expanded this scope. The Hand emerged from years of work experience in which Waisvisz saw the hands as an immediate part of the brain, and not a lower instrument of it (Waisvisz 1990). One can see the hand as a transmitter and sensor where in the cognizance of a performance it directly extends the will, and more crudely can be seen plainly as an extension of the user’s brain. Waisvisz considered the hand as part of the larger system responsible for gathering data and sending it to the computer. Building the Hand prototype came second nature to Michel’s perception of music and helped him develop a more intimate gestural experience. In the context of *Embodied Expressions*, the hand will play a vital role in creating a customized audiovisual interface that will add intimacy to the performance and even the development process.

SUMMARY

To achieve more intuitive control, it is essential to understand how to optimize a performative system. Michel Waisvisz and Laetitia Sonami had a complete understanding of gestural control in their audiovisual performance and both used a similar iterative process of self-study, but their product focused strictly on controlling the hand. Also interesting is that their system took years of iterative development to reach a mature product. In the case of *Patrick Saint-Denis*, his gesture was also focused on the hand, but he could use his whole arm freely and was not limited to one direction. The paradigm of using mechanical instruments for audiovisual creation is shown in Zinoun’s and Martin’s musical structures work, the *Wintergatan and Orchestrion* machine ensemble performances, and *Felix Thon’s* machine interactions. *Embodied Expressions* is inspired by the performance qualities of these artist’s projects in a few ways. *Zinmoun’s* experiments with amplification added an exciting element to the performance environment.

Michel Waisvisz focused on the embodied gestural aspects of his hands to create a flexible solution to control amplified tools. Finally, *Felix Thon* gave performers the opportunity for an embodied experience without the aid of an instrument with a tactile interface. In *Embodied Expressions,* I intend to merge all of these highlighted qualities in order to experiment with and develop an interface for musical expression and live performance.

3. LITERATURE REVIEW

Most musical activities like performance, conducting, and dancing involve bodily movements or gesture. Gesture involved in musical performance can be understood by its spatial aspects, functional aspects, and their use in performance as a means of communication and controlling tools (e.g., bowing a violin string). Often, gestures in music express some metaphorical artistic statement. As technology advances, new options are now available in computing, electronics and sensor technology that allow for increasingly customizable audiovisual interfaces. The possibility of easily creating music has become a reality since the advent of computer-generated sounds. However, the ability to make new interfaces and unique instruments that produce sound does not mean that all these new tools are intuitive and embodied.

A well- developed performance system supports the ability to play music by allowing the performer enough control freedom to explore the audiovisual and special elements in an experiential way. These interfaces allow artists and music researchers to address performance uniquely. The perspective taken in this thesis is the desire to develop a performance system which defines a relationship between me and my performative tools, as well as my relationship with the performance space. Both of these elements are interconnected and play a vital role in live performance practice. The context which I will be looking at is more about developing a system rather than developing a performance piece. By unpacking the theoretical and logical elements from the available literature, I will draw attention to ideas related to customize an audiovisual technology that will help to underline the constraints of current audiovisual interfaces in order provide a more embodied method of control for performative tools.

3.1 NEW INTERFACES IN MUSICAL EXPRESSIONS

User-centered design has become a more widely accepted methodology across industry and academia. Developers have come to understand that the active participation of users is necessary to bridge the gap between a user's intentions and their actual art practice. Making musical technology and instruments for the computer is a difficult yet exciting endeavor where the field of Human-Computer Interaction (HCI) intersects with art (Magnusson 2006). In their field, digital musicians already face HCI issues when working with spatially laid out studios, mixing boards and equipment littered with buttons and sliders, the logical processes of music production are designed with careful attention to the ergonomics of the temporal and spatial workflow. Simulating professional studio setups for new amateurs on the computer screen has been problematic in some cases and often results in frustrating and disembodied sense of work for musicians using these physical devices. Over an extended period, digital musicians and artists have trained themselves to play their instruments via these processes, and the tools in a sense consequently become part of the artist's body as an extension. Finesse in motor control and knowledge of the subtleties of the instrument define an excellent instrumentalist (Magnusson 2006), where learning an instrument is a highly-embodied action in which the musician incorporates knowledge of the instrument theoretical musical knowledge. When creating digital musical instruments much of the embodied knowledge of playing the instrument is lost. The instrument becomes virtual, and the control of it can vary from software-based control structure, with devices like computer mice or "qwerty" keyboards, to MIDI controllers for keyboards, wind-instruments or percussion (Beaudouin-Lafon's 2000). None of this fully satisfies musicians, and this has resulted in debates over new interfaces in musical expression. There is a real tension between the task and technology of interface design. Designs based primarily on the features of the new technology are often technically aesthetic but functionally awkward. Even with designs based primarily on users' current articulated needs and tasks potential innovations available with new technologies can still be overlooked.

“We must understand the needs and abilities of prospective users. But equally, we must understand the capabilities and limitations of technologies to know the possibilities they offer for design” (Gaver 1991). Unlike with traditional acoustic instruments, the control devices and sound sources of digital instruments are arbitrarily related. The control mechanism used to play music always effects the character and the style of the playing. For example, we might not hear the difference in whether a piano in a song is real piano or synthesized piano, but we would immediately recognize a synthesized trumpet played on a keyboard. Playing trumpet with three fingers and the mouth is a very different control mechanism from playing a synthesized trumpet with ten fingers on a keyboard where there is no “embouchure”, or functional control by the mouth (Magnusson 2006). The growing importance of digital interfaces in musical expression opens up conversations about how performances can be enhanced with these flexible new tools. Experimental interfaces have technological constraints that impose gestural limitations on classical instrument performers (Mulder 2000), and these become contribute to the array of decisive constraints related to electronic musical instruments (Michael Gurvich 2010).

Fortunately, these constraints inspire user studies and creative research of musical interaction design, producing interfaces that are fun, intuitive and practical. Most artists feel limited by general purpose interfaces that demand customized solutions suitable to their individual performance set ups. Because modern technology changes quickly and often, digital musicians require time commitments to stay up to date. Modern customized interaction systems can play a vital role in catalyzing adoption of new technology for performance. Speaking on my own behalf, designing customized audiovisual interfaces creates more intimacy with my performative tools in a way that my previous laptop interfaces left me unsatisfied. Put simply, it allows me to perform in a more embodied way that allows me to add new gestural elements as they become apparent. As a performer, this gives me a more excellent range of expression and more flexibility towards content production.

3.2 PERFORMER BODY AND EMBODIMENT IN PERFORMANCE

What is the role of the performer in live performance? Videographer and lecturer, Mia Markela, defines performance art as:

"art in which the actions of an individual or a group at a particular place and at a particular time – It can happen anyplace, whenever, or for any period. Performance art can be any circumstances that included four fundamental components: time, space, the entertainer's body and a relationship between performer and audience." (Makela 2008)

There is an extraordinary variety of ways audiovisual entertainers interface with their instruments. The vast majority are stuck with the keyboard interfaces offered by conventional computers. However, a developing number of professionals are working to bridge the gap between them and their instruments, by developing gestural, instinctive and direct interfaces. This gives precise and nuanced access to the various layers of interaction and content that the artists set up in their video mixing software. This trend is moving towards gestural multi-modular sensor inputs organized like instruments. In most laptop performances, the audience sees the entertainer standing or sitting behind the PC, mindfully watching the screen, moving the mouse and squeezing keys on the console (Makela 2008). The laptop performer looks more like an administrator carefully performing tasks with the machine than a traditional performer. German Electronic Festival Organization Club Transmediale 2004 described the trend in an official 2004 statement

"The laptop hype is over. Laptop performers, who resemble a withdrawn scientist publishing results of laboratory research, are now just one role-model amongst many. Electronic music takes a turn towards being more performance-based, towards ironic playfulness with signifiers and identity, and to being a more direct communication between the public and the artists." (Makela 2008)

There are fundamentally different approaches to performance. The foundational skills of a performer can range from visual design and classic film to live-electronic audio mixing and improvised forms of audio-visual media. Performers tend to be less body cognizant and focus on the execution of their work without considering the physical disengagement they express visually throughout their performances. Performance artists with a traditional music background tend to be more conscious of their stage presence and carry over-emphasized instrumental gestures to their performances. Both styles of expression impact the way audiences perceive a performance or musical piece, either through the absence of expressive qualities or through the distracting overuse of showmanship. The physical position of the entertainer in the live performance space also has an impact on audiences. Some performers choose not to be seen, and expect their work to justify itself without showmanship. Other performers put themselves behind their workstation, positioning their screen as the visual focal point of attention between them and their audience. These more inhibited performers hide the expressive signals that viewers could glean from their body language.

Laptops are inadequate devices to incorporate expressive body gestures into performance. Laptops draw performers' attention to their screen, spatially and cognitively limiting their physical activity. Moreover, moving mouse cursors and turning knobs on a MIDI controller holds less interest and inherent skillfulness for audiences to watch and appreciate. This same need to "demonstrate" their performance artistry can overemphasize the live quality of their show, turning that "liveness" into the content of the show. An MIT graduate produced similar research on gesture in real-time audiovisual performance tools with a specialized glove-controlled system called cinema Fabrique (Manor 2003). The glove allows performers to control audio and video content continuously through gesture capture. French performance artists Cecile Babiole, Laurent Dailleau, and Atau Tanaka formed a band called Sensors Sonics Sights (S.S.S.) (Cecile Babiole 2016), and surpassed laptop performance via an array of body sensors to create expressive audiovisual worlds with nuanced movements and gestures. Their system adds one more example to the growing number of performance tools that incorporate the body in performance, along with visual instruments, information suits, performance gloves and motion capture sensors. These new physical interfaces help performers create their performance language and engage better with their audiences and environment. *Embodied Expressions*, as a technological focus and artistic paradigm shift is poised to disrupt and replace traditional laptop interface rules, and to bring our bodies out into the conscious space of our audiences. Embodied technology showcases my expressive gestures adding a key missing visual element for more intimate performances.

3.3 PHYSICAL AND MECHANICAL AUDIOVISUAL INSTRUMENTS

Most computers supported with gestural input systems are hampered by their inanimate nature, which does not give performers and audiences the physical or visual vocabularies essential to making musical interactions expressive. For example, a common physical language includes the size and position of gestures. Movement size often corresponds to loudness, and gesture location associates with pitch (Weinberg and Driscoll 2006). Conductors demonstrate these gestural norms enough for other musicians to follow. Similarly, these gestures create a loop giving visual feedback to the performer, allowing them to predict and shape their performance. The communicative gestures also command more attention from the audience by giving them a visual connection to the sound. Interactive musical gestural-input systems are also limited by the electronic reproduction and amplification of sound through speakers, which do not fully capture the richness of acoustic sounds. One way to address this limitation could involve a mechanical contraption that converts physical and visual gestures into digital musical instructions that physically generate acoustic sound. In other words, a mechanical musical instrument that physically creates sound based on gestural movements. Mechanical instruments make use of mechanical parts such as motors, solenoids, and electronic gears. Early trendsetters in scholarly, entertainment and art circles have contributed algorithms and designs for musical mechanics for decades anticipating the rise of computer music culture. From the historical point of view using mechanical instruments might be an old trend, but in 1909 Italian poet Filippo Tommaso Marinetti proposed a policy that is known as the Manifesto of Futurism. The manifesto expressed an interest in the experience of “simultaneity”, or in other words, the experience of a varied combinations of sensations all at once. Another critical idea in this manifesto was the focus on old versus new, personified by the differences in various places and machines. The futurist was interested in transforming machines into vehicles for producing sound. Based on this manifesto in the 19th century, the Futurists were trying to break the rules of traditional orchestra performance. With the advent of machinery and the vast expansion of the urban world today's noises reign over traditional human sensibility. Before this recent development musical art typically looked for the soft and limpid purity of sound, which it then amalgamated into soundscapes intent upon caressing the ear with sophisticated harmonies (Russolo 1913). In contrast, musical art nowadays aims at the shrillest, strangest and most dissonant amalgam of sound. In other words, the futurists were approaching artistic sound with noise, and the increased proliferation of machinery in the world paralleled this revolution of music (Russolo 1913). This evolution towards noise sound is thought to only be possible today, the air of an eighteenth-century man could never have withstood the discordant intensity of some of the chords produced by an old orchestra (Russolo 1913). The musical performance Intonarumori is a result of this futurist movement, which is composed of a group of experimental musical instruments invented and built by Luigi Russolo. Russolo built these artefacts to perform the music outlined in his art of noises manifesto. Russolo's manifesto argued that:

"we must break at all cost from this restrictive circle of pure sounds and conquer the infinite variety of noise-sounds."

He was interested in the infinity of sound. According to him all of us have liked and enjoyed the harmonies of the great masters but we are now we are fed up with them (Russolo 1913). He felt that we could get infinitely more pleasure imagining the combinations of sounds made by trolleys, autos and other vehicles, loud crowds, etc., then listening once more, for instance, to the great heroic and pastoral symphonies of the past. In present time, many artists are working on mechanical instruments and they have different reasoning behind their built specifications and the skills needed to play the instruments. Despite their differences between musicians, computer scientists, and electronic engineers, these professionals all have shared a common desire to create new protocols for more exciting performances. Artists working in the field have their own biases and reasoning for developing mechanical instruments. In an interview with the Director of Music Technology at CalArts Ajay Kapur, musician Eric Singer said:

"I couldn't play with humans anymore, humans have too many problems, like drugs, egos, jobs.... I figured I could make a band that I could play with until I die, and not worry about if anyone in the band was going to quit and kill the band." (Kapur 2005)

Early work on musical robotics primarily addressed mechanical keyboard instruments such as the Pianista (1863) by French inventor Jean Louis Nestor Fourneaux (See Kapur 2005 for a comprehensive historical review of musical robots). The field has gotten significant artistic and academic interest in recent years and has grown to include anthropomorphic designs (Rosheim 1995) and several mechanical instruments like chordophones, aero phones, membranophones, and idiophones. String instruments have also recently evolved as can be seen in such examples as the Guitar-Bot (Singer, Larke and Bianciardi 2003), which is a mechanical guitar with four strings where each is outfitted with a sliding scaffold, a damper solenoid, and is played by plucking, bowing, and otherwise exciting the system using various mechanical and electromagnetic actuators. The sliding and picking instruments work with DC servomotors under closed-loop feedback control, and the whole framework is controlled utilizing a MIDI protocol. The resulting instrument looks nothing like a traditional guitar as can clearly be seen in Figure 9.

Figure 8 Guitar- Bot Lemur

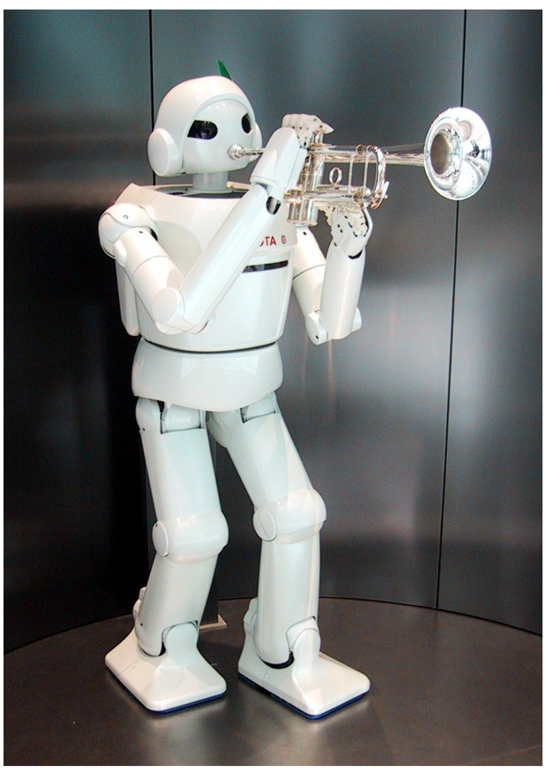

Figure 9 Toyota robot

Incorporating the idea of the perception-action feedback loop I intend to make mechanical instruments part of my performance in order to address the gap I see in electronic music production. Is it necessary to understand where the sound is coming from to perform intimately? I argue here that perceiving the output of the custom musical machines I aim to develop will help create a more dynamic relation to these performance tools. This is still an unresolved question for now, and requires further development of the tools and an exploration of materiality in mechanical instruments. I believe that the process of gauging my spontaneous output from these machines will help me create a more dynamic relationship with them in my performance.

3.4 IMMERSIVE ENVIRONMENT IN ARTISTIC PRACTICE

One prominent part of interactive arts is the idea of immersion. Immersion has been intensely investigated by abstract and film theorists and more recently by virtual reality (VR) professionals (Kwastek 2013). Immersion is characterized as the viewer "forgetting" the present world outside of the virtual environment as they are embedded within an imitated world simulated with computational hardware and software. Most research on immersive experiences has been led from the scientific point of view. The scientific research method standardizes and objectifies results and immersion researchers have largely used quantitative experimental techniques, like measuring physiological data and conducting surveys to capture participants' experiences (Slater and Usoh 2008). In tandem with computer science research, numerous interactive artists have investigated immersion within VR environments in collaboration with computer scientists. Artists have investigated full-body sensory immersion through their expressive creations (Davies 2005, Brenda and Tow 1994) with their methodologies countering the disembodied stereotypes of virtual reality simulations and aesthetics. In other words, the artistic exploration of immersion, focused on making immersive experiences more compelling, has used qualitative rather than quantitative methods in gaining a deeper understanding of the immersion experience.

Despite years of research there is still not a singular definition of immersion, as various approaches have been used to refine and develop a greater understanding of this idea from different knowledge areas. The term “immersion” commonly depicts compelling experiences in immersive virtual reality, installation art, and video games, but common to each of these is the connotation of being absorbed, engaged and embraced. Various disciplines utilize the various definitions and adaptable qualities of immersion depending on context (Deweppe 2017). Physically immersive environments extend the limit of our vision and bring out unspoken emotions from materials that effect our impression of dimension and depth. Physical installations are not based on normal architectural spaces or rooms that we encounter in our everyday lives. It is unclear whether we can call the experiential phenomenon immersion when we are habituated to a space and mindful of our associations with its true nature (Seo 2015). Gaining on the psychological power of immersion, contemporary artists have made immersive spaces that empower the audience to indulge in different domains. This helps us as researchers to appreciate the passionate excitement for imaginative illusions in addition to the complex human desire to create worlds within realities (Mitchell 2010). Immersive virtual realities allow us to suspend our disbelief of our physically arranged world and accept artificial constructs. Our obsession with video games, short films, and animated films demonstrates our desire to enter symbolic space and actively engage with alternate realities. In the Metaphysics of Virtual Reality, Michael Heim asks, “Are not all worlds symbolic? Including the one we naively refer to as the real world, which we read off with our physical senses?” (Heim 1993). While computer scientists and artists look to make virtual spaces with the computer, traditional artists have also abandoned the clean white dividers and pedestals of exhibitions in favor of initiation into the space between these divided worlds. Poème Électronique, as shown in figure 11 below, is a collaborative work between Edgard Varèse, Le Corbusier, and Iannis Xenakis exhibited at the 1958 Brussels World Fair. This piece consisted of 400 loudspeakers, projected film, colored lights, and architecture. This seminal work was the first fully immersive environment that combined electronic music, projections, and architecture for the purpose of creating a total work of immersive art (Varese 1958).

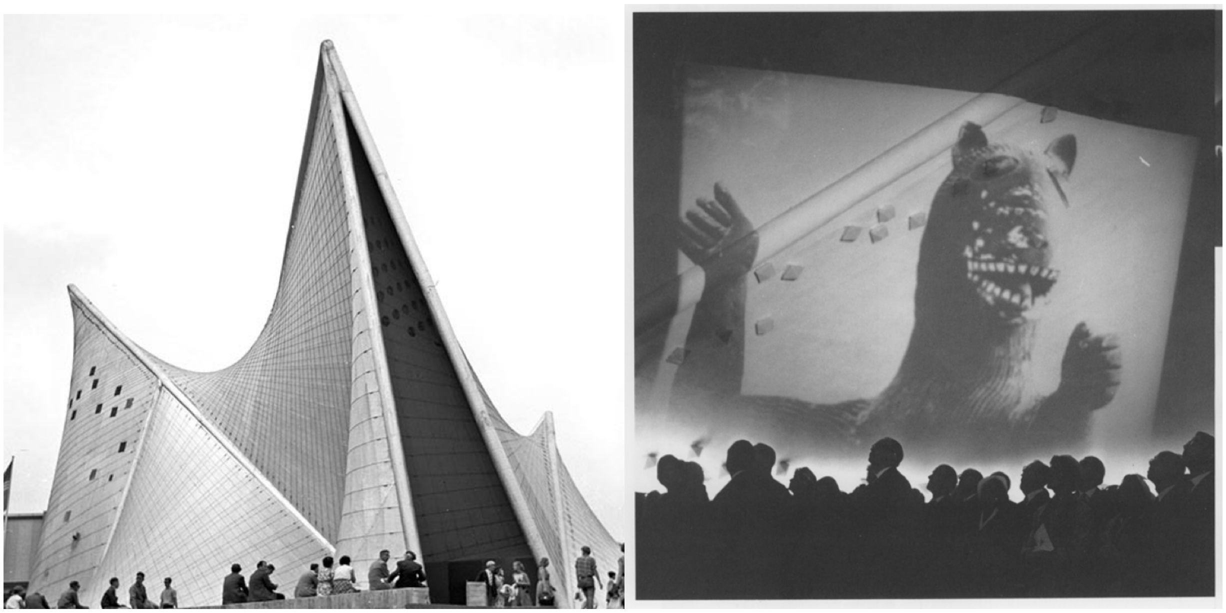

Figure 10 Poème Électronique Expo 1958 Philips Pavilion

The physical space that these installation artworks are presented in are frequently considered as important as the single art object itself and as such the installation artist takes into score the viewer's entire sensory experience. We should have in mind the factors of the set-up area are not art objects themselves but that the participant's experience is still based fundamentally on the focal art piece. Based on this argument, *Embodied Expressions* is intended to bring the physicality of sound in a live performance space for audiences to experience a sense of immersion as a component of the performance's overall meaning. In my project *Embodied Expressions*, custom mechanical artifacts will be built in order to generate custom sounds within the same environment as audience members during live performance in order to create a sense of immersive feeling.

3.5 AMBIENT AND AUDIENCE AMBULATORY RELATIONS

Is the audience considered part of the performance? In any performance art practice the audience co-presents the performance. During a performance, the performer occupies the same space, time and air as the individuals making up the audience in a theatre. Normally the stage belongs to actors or their defined characters to distinguish themselves from the viewer, but in performance art there is no distance. During a performance art piece, the performer is both the subject and the object of the art piece and the audience is included in this relationship (Meyer 2009). From the mid-twentieth century onwards, many theorists have acknowledged that works of art manifest within sight of the viewer, where they are often referred to as the receiver or spectator (Leon 2016). In the context of film, directors address their viewers directly through the presentation of the entire piece, but it is the actors and performers that must primarily build empathy and understanding with their audience. Embodied Expressions considers the meaning that audiences form about the performances they witness and asks what can add significance to the audience's experience? Wolfgang Lser and Stanley E. Fish have a response to this question in which they recommend that we should interface with our surroundings through investigating, playing and talking, and any other interaction that might help us find out more about our surroundings. To summarize, in a statement by Fish referred to by Leitch in `The Norton Anthology of Theory and Criticism' it is the observer's `need to know' that drives them to connect with a text. In Fish's own words:

Intention (authorial) is known when and only when it is recognized (by the reader); it is understood as soon as you (the reader) decide about it; you decide about it as soon as you make a sense, and you make a sense as soon as you can. (Fish 2001)

Substituting the word "reader" for "audience," we take the point that the audience's curiosity drives them to look for meaning in performances (Leon 2016), which then forms the core of their experience. Instead of communicating any meaning explicitly in my art practice I intend to engage my audience in drawing their own meanings and interpretations by influencing their perspective through audiovisual performance techniques. The conscious reasoning of my audience is not specifically important for their interpretation of my work, but what is important is their attempt to follow my performance and gather their own subjective interpretation of its meaning. I do not judge individuals on how much they engage as active audience members, but I define active consumers of audiovisual performance as those who draw comparisons to content and metaphors that they know, rather than passively engaging with the material. For example, the audiovisual orientation of the performer within a performance space helps create the context of the *Embodied Expressions*. The idea that the audience is part of the performance environment is supported by the viewpoint of James Gibson's ecological approach, which shows that we perceive an environment *"not just with the eyes but with the eyes in the head on the shoulders of a body that gets about"* (Gibson 1979).

Gibson emphasizes that the embodiment of a viewing experience highlights the connections among ambient and ambulatory visual perception, both of which are part of the environment where the performer is actively perceiving environmental and expressive information that they can incorporate into the performance.

SUMMARY

Does presenting physical gesture with electronic music influence the performer's ability to feel an embodied relationship with sound? I argue that having a relationship with their performative tools is an essential factor for live performers. Using customized tools helps performers understand the architecture of their performance system, and the growing need for new interfaces in musical expression has raised greater awareness of customized performative tools. Most focus on getting the body out of the performance system in order to merge with the audience and performance environment directly. As of now, expressive performers realize that audiences are not the only environmental factor, and that the performer and their performative tools also add to the environmental factors of live performance. Through new tools and technologies, the performer's body becomes the instrument. With gestural control technology, a performer can express and present themselves through their performative tool as well as with the contextualization of their environment. The intention of *Embodied Expressions* is to combine the varied wisdom and experiences of other artists and their custom performance systems in order develop my own custom performance system that will successfully embed me as an inseparable part of the performance itself. Confronting these ideas has helped me envision and articulate the layers of my ideal performance system in order to make it more responsive to my perceptions. This creates an open dialogue about the future of audiovisual performance interface development.

4. THEORETICAL FRAMEWORK

This chapter includes two concepts around embodiment and perception that form the foundation of both the conceptual model and the experimental framework of this thesis. The two concepts are Body as a Mediator and Action Perception Coupling. These concepts create the foundation of embodiment and physicality in audiovisual performance and together develop application domains for *Embodied Expressions*.

4.1 EMBODIMENT

Interactive audiovisual systems are comprised of two main parts, a technological component and an experimental component. Using technological tools to translate human actions into performance content is getting attention where researchers are designing new interface in musical expressions. The experimental element is more related to the control of these tools, which can be achieved with gestures. Stanford philosopher Taylor Carman expands on consciousness “phenomenology” theory from Husserl and Ponty telling us that the body “is a natural go-between, for musical experiences and the physical environment” (Carman 1999). This makes physical gestures an obvious input for audiovisual performances and illustrates how important physical cognition is in appreciating music. This is where embodiment took birth. Here, embodiment has put the emphasis on the role of the human body as mediator for meaning formation. Its purpose in meaning formation can be seen as grounded in the idea of extended cognition. The concept of extended cognition implies that the human mind and body can incorporate external effectors in such a way that they effectively become a part of itself. In this sense, it can be said that the human motor system plays a vital role in music perception, as the artist’s mind, body, and performance system become united as a cohesive whole. The important idea here is that an intentional level of musical interaction is developed through material articulations which leads to feedback in the form of impressions of sensed physical information provided by the musical environment. This environment and factors in the environment further create a sense of embodiment for a performer in live audiovisual space. (Godoy and Leman 2010, Leman 2007)

4.2 THE BODY AS MEDIATOR

If our bodies mediate our experience of music, how do we differentiate between what our mind perceives and our body senses? How do our cognitions and senses effect expressive interfaces, built around body motion and gestures?

> "Cognition depends upon the kinds of experience that come from having a body with various sensorimotor capacities, and–" "these individual sensorimotor capacities are themselves embedded in a more encompassing biological, psychological and cultural context." (Francisco j. Varela 1993)

The concept of embodiment serves as a vantage point for consciousness of the body and how we perceive our body in space. Embodied cognition here represents our broad subjective understanding of reality. We see the world through our cognitive sense of it, filtered through our sensory organs (i.e. retinas, ear drum, taste buds, etc.). Contrary to this, Rene Descartes argued that our mind and body have a dualistic nature, where there is a fundamental theoretical separation between mind and body. Popular since the 17thcentury, Descartes theory of mind points out that our body is divided into different senses, while our minds (perception, identity, fears, inner monologue etc.) are all wrapped up into a single conscious entity (Descartes and Lafleur 1979).

The dualist notion of the disembodied mind flourished for centuries, asserting that our intellect is disembodied from our senses because the mind is categorically separate from the physical world we experience. If reason is universal and pure and the appreciation of music is purely intellectual, then according to the idea of dualism, reason, and by extension the perception of music, must somehow transcend our bodies. However, since the advent of psychiatric medication and famous mind-altering brain damage cases like Phineas Gage, the popular theory of dualism has slowly evolved into a more blended understanding called weak dualism (Beloff 1994). In this interpretation, the body is thought to shape the mind (Gallagher 2005). We see evidence of this common ground between our body's experiences of events and our social understanding of them, through shared neurological activity throughout the embodied experience (Gallese 2005). George Lakoff and Rafael Núñez further challenged the entire philosophical worldview of dualism, arguing that "the mind arises from the nature of our brains, bodies, and bodily experiences–the very structure of reason itself comes from the details of our embodiment" (McNerney 2004). Thus, to understand our cognitive understanding of what we perceive, we must understand the details of our visual system, our motor system, and the general mechanism of neural binding, where it can be said that our cognition is not confined merely to our cortices. Our experiences in the physical and sensory world influence our cognition of it. We define and understand perceptual systems by exploring the physical world. Our senses are necessary to create a cognitive understanding of how sensory experiences like music work. The nervous system has specific sensory organs dedicated to each sense. So, when we react to something new, like mechanical instruments for example, our senses feed our brain new cognitive information to help build a mental model and conceptual structure. In his 1968 book *The Senses Considered as Perceptual Systems,* Gibson (1968) suggests that animals naturally explore their environments to collect information, and that sensory impressions are just a casual coincidence. Here, environments and spaces become an unignorable means to feed our senses information and our experiences and understandings develop as a result of this interaction.

Gibson argues that there is enough information in our environment to make sense of the world in a direct way and rejects the need for processing information. Gibson believes that sensation is perception and the information received is adequate to interact directly with the surrounding environment.

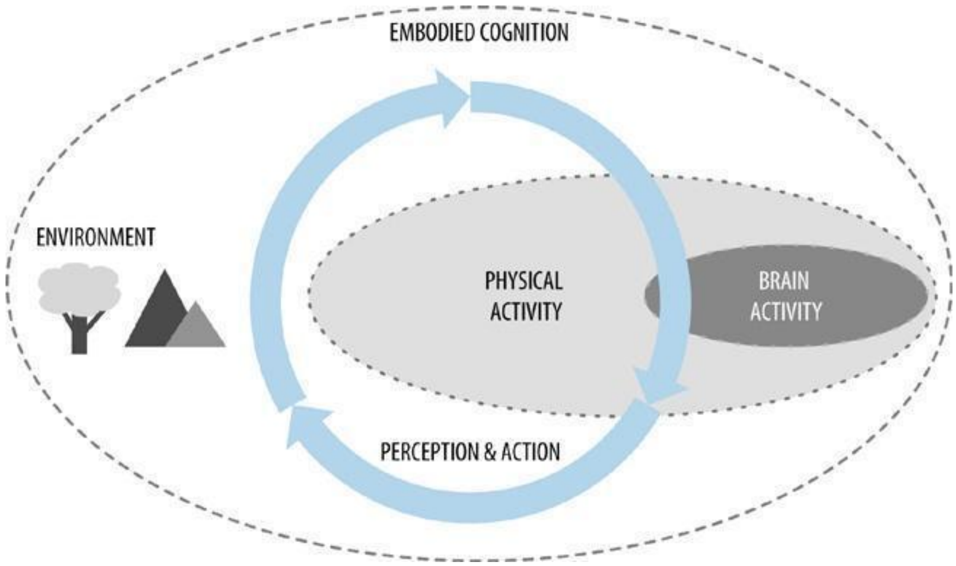

Figure 11 A model for Embodied cognition

The action perception loop developed by James and Eleanor Gibson (Hinton n.d.), describes a framework where perceptual faculties use environmental information to construct our cognition. The relationship between our actions and our perception of the environment is reciprocal, where physical explorative actions facilitate perception and vice versa. In other words, the concept of embodiment closely represents human physical action. Human physical actions play an important role in facilitating perceptual activities. The body of a person can be considered as the mediator between the person's environment and their subjective experiences of the environment (Deweppe 2017). In this case the body generates action, and perception creates experiences that the body responds to. From this point of view it is clear that embodiment and cognitive representations of human experiences are connected in nature and closely linked to one another. Specifically, within the scope of virtual environments and devices there is a need to implement objects and represent some of the physics of the world the body is instinctively accustomed to by using embodied metaphors in physical and digital environments. For example, most mobile phone applications simulate the physical buttons, switches and grips we have already grown accustomed to, in order to take advantage of their perceived affordances, which make the transition to smartphones and touch screens easier (e.g. sliders, knobs, grips, switches, etc.). When the body acts as a mediator between our environment and the direct experience of it, a range of gestures and gestural-actions are often the result. This range is called a gesture/action-oriented ontology (Leman 2012), which is the set of commands and perceived outcomes that are kept in memory and used to prompt the next action and predict future perceptions and interpretations of the next system output. This idea is based on the notion that humans interact with the environment on the basis of physical actions, as we do in gestural musical performances (e.g. aggressive drumming). In such performances, movements are made to achieve certain goals and produce certain emotional effects on the audience. Marc Leman (2012) calls this mechanism action-perception coupling.

4.3 ACTION PERCEPTION COUPLING

From Gibson and Leman’s arguments, it is clear that our gestures and physical actions form parts of a more complex perceptual mechanism that controls the interaction between our environment and subjective experiences. Given our modern expanded technological landscape, embodied music cognition research has focused on the shift from traditional music perception to physical musical actions (i.e gestures). I argue here that creating live music showcases the dualism of embodiment perfectly, in that the experience of performing as a musician is simultaneously combined with the physical aspects of playing the instrument with the perception of hearing and visualizing the sonic content. It is hard to get the same experience with the electronic music production process because sound is coming out of a disembodied speaker system and there is less available information that can be related to direct interactions with the body and physical world. In order to create a more embodied experience it is better to understand the sound producing elements in a live performance. Technological protocols can extend the range and complexity of what the human body can do. Traditional instruments already create a loop between action and perception. Traditional instruments include string (violin), wind (flute), brass (trumpet), percussion (drum), and keyboard (piano) instruments. Just as in dance and tradition musical, the paradigm of embodied music cognition sees the human body as a natural proxy between musical experiences and the environment. Technologies like Kinect and other motion sensors are not just a direct interface to facilitate playing. One of the goals of mediation technologies like these is to achieve the illusion of non-mediation. Mediation refers to the mappings between the intentions and desires on the part of active musical participants and the technology that renders the music (Leman 2012). The subject must view the technology as part of the traditional musical instruments rather than a bridge to them. The exploration of embodied interfaces for musical content has become an important topic in music over recent decades. Mediation technologies such as motion capture take advantage of the flexible relationship between musical experience and the physical environment, allowing the body to function as an "augmented" mediator (Deweppe 2017). If mediating technologies are meant to become an extension of the body, the same way a weapon or physical tool can be said to become an extension of one's arm, how does a gestural interface improve on traditional instruments? Effective gestural systems are inherently flexible. They redirect the energy of the human motor system onto an expandable protocol without limiting the performer's direct physical input on one fixed mode of musical interaction (Eduardo R. Miranda 2006). Ideally, by employing gestures for whole body interaction the body could become its own form of instrument, rather than a loose analogous protocol (e.g. Playing the "air guitar" or tapping surfaces with your fingers like a drum). In an ideal instantiation, the embodied musical interaction becomes a cognitive extension (Magnusson 2009).

Consistent with the perception action loop, the communication process that results from mediation technologies should ideally occur between multiple participants, and within an interactive environment that allows for social musical interaction. The ideal setup should closely resemble the ensemble of a band. In my performance, the multiple *"participants"* are mechanical instruments, extending my perception through my interactions with them. This will allow my mind to create a relationship with the environment and create a more fully Embodied Expressions. I use action perception theory as a guiding principle to build a customized audiovisual system that creates an intuitive relationship with my performative tools and helps me outgrow and replace the traditional laptop interface system.

5. METHODOLOGY

In this chapter, we discuss what working methodologies were applied throughout the research span, how they evolved, and how methodological model was ascertained. We first take a close look at the various elements in methodology that were used throughout the different stages of the research project and what end they were investigated and incorporated.

5.1 AUTOETHNOGRAPHY

The research conducted for Embodied Expressions is based on an autoethnographic research approach. Autoethnographic research is used in a variety of disciplines typically including anthropology, sociology, and education (Anderson, 2006; Ellis & Bochner, 2000; Etherington, 2004; ReedDanahay, 1997; Roth, 2005). The characterizing feature of autoethonography is that it involves the researcher or specialist performing a narrative analysis examination relating to himself or herself as personally identified with a specific phenomenon. Autoethonography involves writing about oneself as a researcher-practitioner, yet it isn't the same as personal autobiography in the literary sense. Autoethnography is not simply the telling of a story about one's life but rather a form of critical investigation embedded in theory and practice.

5.2 EXPERIMENTATION PROCESS

Throughout the application of these methods, a number of stages and concepts has been applied. These are consequently presented as iterative processes and incremental developments. For this research, my use of autoethnography involved careful critical notation of design changes, system learnings and performance problems. In the subsequent conceptual model that is derived from these methodological considerations and design guidelines, the most important concepts are then summarized and in turn operationalized as a number of assessment parameters. This was sought by a combination of methods including artistic creation practice and theoretical research motivated by the practical ordinated knowledge acquired during the creation process. This knowledge is then fed back into the iterative process giving place to a reflective loop where practice and research connect with each other. First, the research began with designs for a simple performance system, and later evolved towards a more complex model of performance and interaction. The performance research of each design iteration has been documented with video, sketches and theoretical critiques. A critical system was drawn out through these methods where each stage improved upon its predecessor with new interaction elements, rules and language, leading to a more complete, intuitive performance system. Each round of design solutions was tested by implementing them into the performance and design making process. I documented my intuitive behaviors and responses to each design as a performer, analyzing gestural data in relation to the musical instruments. Mapping data to the desired instruments proved more difficult than capturing the gestural data. The research was done in a way where the system, instruments and performance complemented and communicated with one another, and defined me, both as a performer and as a visual element of the larger performance piece. Each set of results informed a redesign, which moved things closer towards the singular purpose of a more embodied relationship with my performance system. Information was gathered at each cycle with the following methods:

- Planning and mapping goals.
- Capturing video data from performance.
- Reviewing and annotating each performance video critically.
- Planning and considering the overall user experience.
- Instrument design through mechanical objects.
- Experimenting with different gestural interactions, to control the system.
- Revised process in context more improved output.

6. RESULTS

Embodied Expressions evolved through a performance and testing process. I Initially started with a performance, and began with gestural research using digital and analog manifestations of sound where I tested the flexibility of the sensors with my gestures and movements. The next study involved reflection and evaluation of the previous performance. This study focused more on exploring the material textures of sound in various objects where questioned how to get better mechanical sounds, and how to develop a better system for controlling these objects. The third study evaluated results from the previous test and the focus was to develop a relationship with my tools and with the acoustics of the performance environment. Building on previous mechanical instruments refined the complex final form factor, allowing the audience to better visualize sound, which helps the audience immerse themselves in the embodied elements of the performance system and environment.

6.1 OBSCURE SPACES

The idea of Embodied Expressions began with an accumulation of potential ideas and scattered technologies starting in 2014. The ideas ranged from interaction hypotheses through to extensive design sketches. Discussing the ideas with HCI and design experts helped me to develop a critical position on expressive machine music, which gradually solidified into a final solution for my performance system. Some technologies and ideas had more potential for growth in audiovisual performance. I aimed to establish a practice rather than a singular custom musical piece, as the idea of Embodied Expressions was already pioneered. The birth of the first design was inspired by a happy accident during a performance of my show titled “Obscure Spaces” held at OCAD’s 2016 Open Show. I made a mistake with the live sync controls and accidentally mixed the signals of the audio and visual content and to my surprise found the result artistically compelling.

Obscure Spaces transformed my VJing performance practice and inspired me to perfect the artistic use of sound in my practice. During this performance, I shared a live stage with OCAD University professor and researcher Dr. Adam Tindale.

Figure 12 OCAD Obscure Space jam session

The performance centered on audio visualization and I coordinated the visualizations. I prepared some animation presets and used processing methods to make the sound reactive to my visualizations, with the projection mapping tool Resolume Arena. Using Resolume as the VJ media software I mapped my animations on to environmental surfaces while Dr. Tindale mastered all sound content for the performance. Some of the live content from my end did not generate properly, and I noticed that my animations did not synchronize well with the mechanical sounds Dr. Tindale produced, but these sounds were very fascinating to me. In our post-performance discussion, we examined the current VJ practice and considered which novel content tools could potentially improve the live performance experience. This formalized the first design of *Embodied Expressions*.

6.2 PERFORMANCE ("STAND BY AND")

The first performance for *Embodied Expressions,* which took place after my initial experience with Dr. Tindale for Obscure Spaces, was tested to get familiar with the initial components of the performance and to explore the live content creation process and embodied relationship with performative tools. The first round of study was an exploration of sound-making materials and the possibilities of controlling them via physical gestures.

6.2.1 OBJECTIVES

The goal of the performance was to discover and address issues in my current performance practice using conventional digital tools. Looking back at my previous performances, the connection between my laptop and most of my performative tools was not intuitive, leaving me feeling disconnected during my performances. Anyone using this or a similar system would experience the same lack of direct control. This inspired the idea to replace my laptop with a custom interface triggered by physical gestures. Creating a direct link between my body's gestural movements and my audiovisual output would create a more intimate relation with my tools. Another goal was that I wanted to improve sound production, as I recognized the potential for physical sounds paired with visualizations. I thus decided to explore more about mechanical sound creation, common in DJing and audio remixing, and discovered a large group of artists using mechanical objects in their audio performances. Bringing the elements of both real mechanical sounds with live gestural control would yield my first real experiment in producing my custom live performance system.

6.2.2 MATERIALS AND INSTRUMENT EXPLORATION

The next round of performance research examined the physicality of found objects that I could use to create sounds. I began my exploration of live mechanical sound content by testing the physical musicality of found objects and environmental sounds. I tested the sounds produced by striking metal, wood, liquid and plastic objects with one another, and small hammers and drum sticks.

Figure 13 Found Object Test

These sounds were captured by audio recording and evaluated to see which would could be used to make live performance more compelling and appealing. To create a flexible and versatile instrument setup I various selected objects that could produce different and exciting sounds when struck together in different combinations. I collected a few specific objects, as shown in figure 14, and assembled them into a combined rig that allowed me to see how they reacted when struck against one another. I discovered that plastic and metal knocked together created a subtle crackling and scraping glitch sound. This sound and several other particular mechanical sounds left a powerful feeling of materiality in my test performances. I selected three objects to rebuild as instruments before adding more as I wanted to better understand the interchangeable connections between them. This whole process helped me to understand the array of potential sounds that I could work with, as well as to better understand how natural objects in the everyday environment could be activated to contribute to an artistic audio expression.

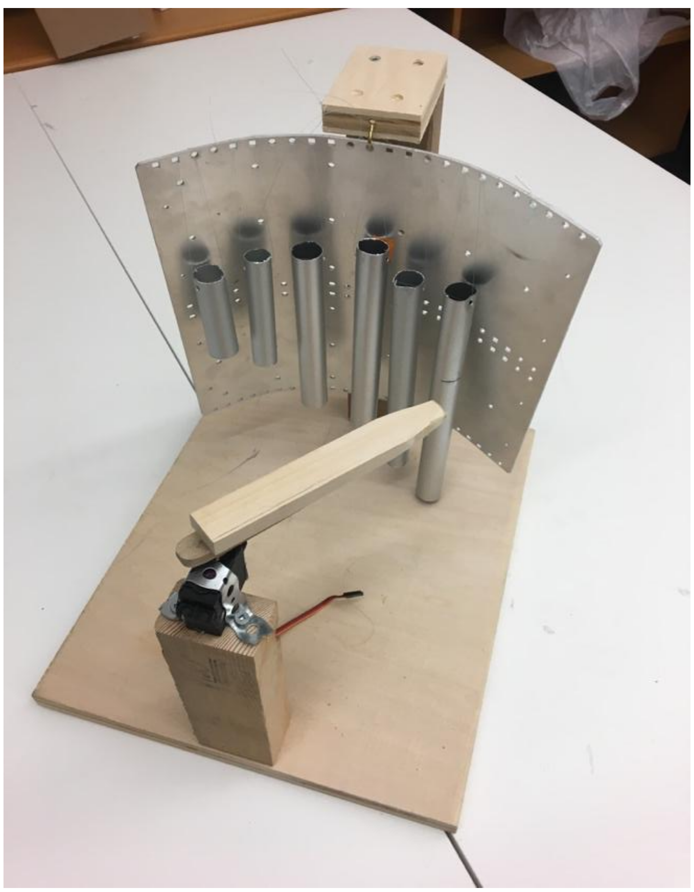

Figure 14 Customized Chime Instrument

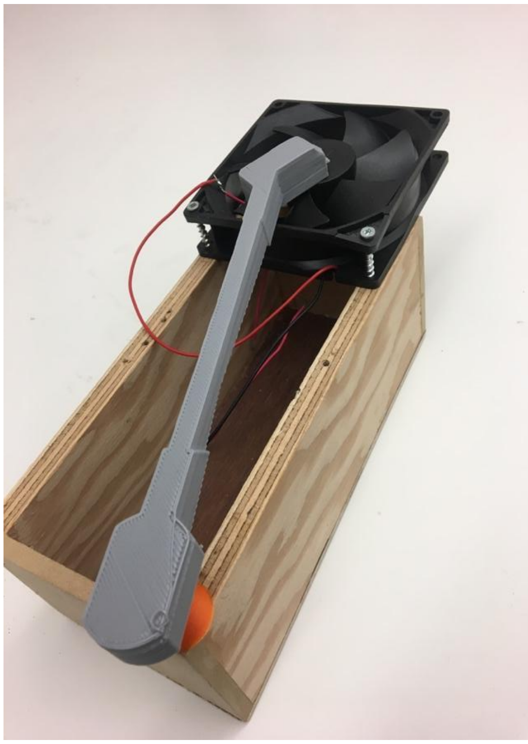

Figure 15 Fan and Stylus bar

6.2.3 GESTURE STUDY AND SENSORS

From the point of view of autoethnographic research, I began with a series of intuitive and free-form gestures that could be captured by motion sensors. I played sequences of electronic machine sounds, and video documented the gestures I improvised in response, in order to discover any spontaneous gestural patterns or connections that could be made with the mechanical sounds (see figure 17 below). This music research yielded a few distinct gestures, with some seemingly natural and automatic responses to specific sounds such as the glitchy sound effects. After exploring some of the relationships between my bodily responses to the mechanical sounds I intended map my gestures as cleanly as possible to the performative tools available, such as the ZX distance sensor and motion sensors. After applying the autoethnographic approach towards the performative tools I mapped out a few interesting standard gestures, but soon realized my sensor system lacked the ability to sense these gestures effectively.

Figure 16 Gesture study

Having three sets of instruments from the material research, the next step was to connect those mechanical instruments to gestural inputs. To understand the relationship between instrument and gesture, I had to think about how a performer perceives these objects. I exaggerated any unusual qualities in the form factor of these mechanical instruments. For example, the first instrument combined a DC computer fan and a stylus. I automated the speed of the fan, and rotated the stylus to make contact with the rotating fan. The DC fans have a minimum and maximum value in rotational speed dictated by the amount of voltage supplied to them. I mapped these values to a ZX distance sensor. The distance sensor collects data from both Z and X axes, where the Z represents distance from the sensor and X represents the left-right horizontal mapping of the sensor. I made use of the Z-axis by mapping forward-backward gestural motions to the increases and decreases in fan speed. Mapping became more difficult because the ZX distance sensor proved to be inaccurate, especially along the Z-axis. Having set both the mechanical action and distance sensor I calibrated the values to see if it could produce an intimate relationship between gesture and motion in the same responsive way that traditional musicians lose themselves in their instruments. I wanted to understand better what made for intuitive and expressive control of the physical instrument in order to refine my gestural interpretation of live sonic feedback in a performance space.

6.2.4 PERFORMANCE EXPERIENCE

The first performance using this initial setup included another combined performance with Dr.Tindale. Dr. Tindale participated a second performer in this study in order to help understand how multiple sounds layered. The rig included two customized mechanical instruments and a mapped gestural control system that wirelessly connected to those instruments via a piezoelectric microphone embedded into each object in order to achieve a louder acoustic sound. The arrangement for the first live performance followed my previous VJing performance, where I now focused on gestural performative experimentation. I tested the flexibility of the distance sensors used to control the mechanical instruments in hopes to match them with Dr. Tindale's sounds. Dr. Tindale's electronically generated sound provided rhythm to try and match to, acoustically and gesturally. It was challenging for me in trying to move in sync with his sounds in a way that connected the mechanical instrument sounds with the electronic music. The projection-mapped video elements, carried over from the first collaborative performance, provided a backdrop to try and coordinate with, both for control timing and aesthetics. As intended, the test performance helped me to understand the relationship between audio visualization and my gesture tools.

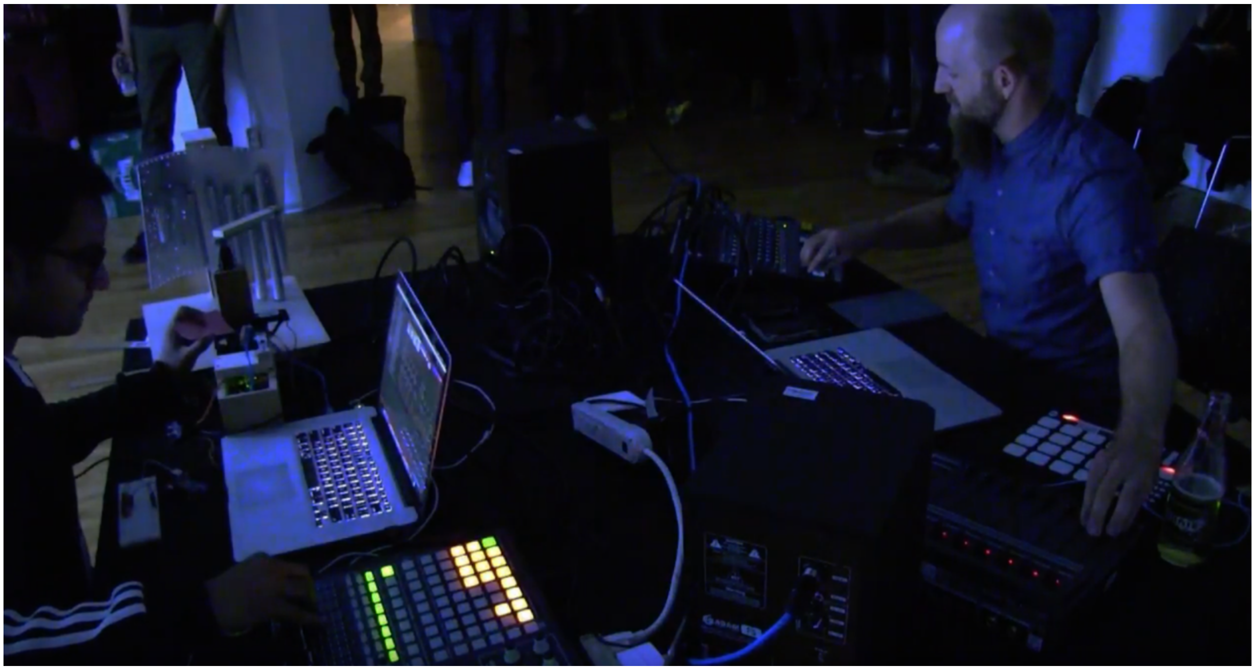

Figure 17 Stand by and Performance OCAD

6.2.5 AUTOETHNOGRAPHIC PERFORMANCE REFLECTION

The first performance allowed me to study the different components of embodied musical expression and the unique challenges that would inform later studies. The first performance helped me to understand the behaviors relating to performative tools when controlling mechanical instruments gesturally, revealing the embodied aspects of interacting with gesture sensors. The technical research revealed the practical difficulties of synchronizing sensor input with the analog fan's rotation speed, in order to achieve a smooth looping of multiple instruments at the same time. Last of all, the relationship between me and my performative environment was not optimized for embodied expressive control. I felt disconnected from the performance environment and not in tune with it. At some point I was depending on my performance partner Dr. Tindale to provide input on where I could do more to connect with the mechanical sounds. Unfortunately, the electronic sounds he produced were hard to synchronize with an analog system. The experience was frustrating but exciting, and led to the generation of new ideas to connect the mechanical instruments with different gestural output.

6.2.6 CRITICAL ANALYSIS

As a performer, the output of performance 1 allowed me to see how these instruments can facilitate an Embodied Expressions and intuitive control. Despite the technical limitations of the sensors and mechanical instruments, more profound concerns were voiced in critique period, which'd highlighted the need to make the performances more human-centered and less technology-centered. Instead of communicating genuinely with the mechanical instruments I focused on the control mechanisms of gesture capture through the sensor. At this point the sensor's precision was too limited to offer a successful and flexible control of the instruments. The most significant design change needed for the second performance involved leaving the classic laptop keyboard interface behind so as to feature my body as the central control and visual element in the performance space. It was clear that a more intimate relationship with the performative tools, and a bright and compelling visualization of the system's data could add to the audience's embodied experience as well as my own. In the first performance, my audience interaction from behind a laptop screen was weak, and my feeling of immersion seemed to disappear. I had no clear perception-action cycle and no natural flow with my tools and instruments. The sensors I used were not mapping well to my use of the mechanical instruments.

6.3 EVALUATION 2

Evaluation 2 was more about iterative processes in exploring gesture mapping techniques and its adaptability with different instruments. Reflecting on the performance "Stand by and" I set out to use my body more in the performance space and interact with the environment and audience. The exploration centered on mechanical objects to identify more expressive and harmonious. This connection between instrument and expression had to be mediated through sensor protocols to achieve an intimate relationship.

6.3.1 OBJECTIVES

The goal for this study was to evaluate new ways of reading gesture data, especially those which are not connected with the body directly. Another intension was made to achieve a more complex system for connecting gestures and sound together within flexible framework that could be linked directly with software instruments. The major goal for this study was to bring my body out of the traditional laptop situation where I am sitting in a position instead of exploring more possibilities in using the space as my playground for performance. The overall objective was to link my body with instrument and environment together in order to understand the prominent aspects of my live performance.

6.3.2 MECHANICAL INSTRUMENTS DESIGN

This section details the materials used to create the instruments, their evolution throughout the research, the methods used to increase embodiment, the quality of sound, and how the different sounds could be mapped with my gesture parameters. The first study made me realize that I needed sturdier materials and more mechanical objects. I started with sketches based on found materials and decided which form factors and consequently, which sounds, felt more sharp and distinct yet aesthetically pleasing. Solenoids and DC motors proved to be the best electromechanical tools that could be linked with the various found mechanical objects.

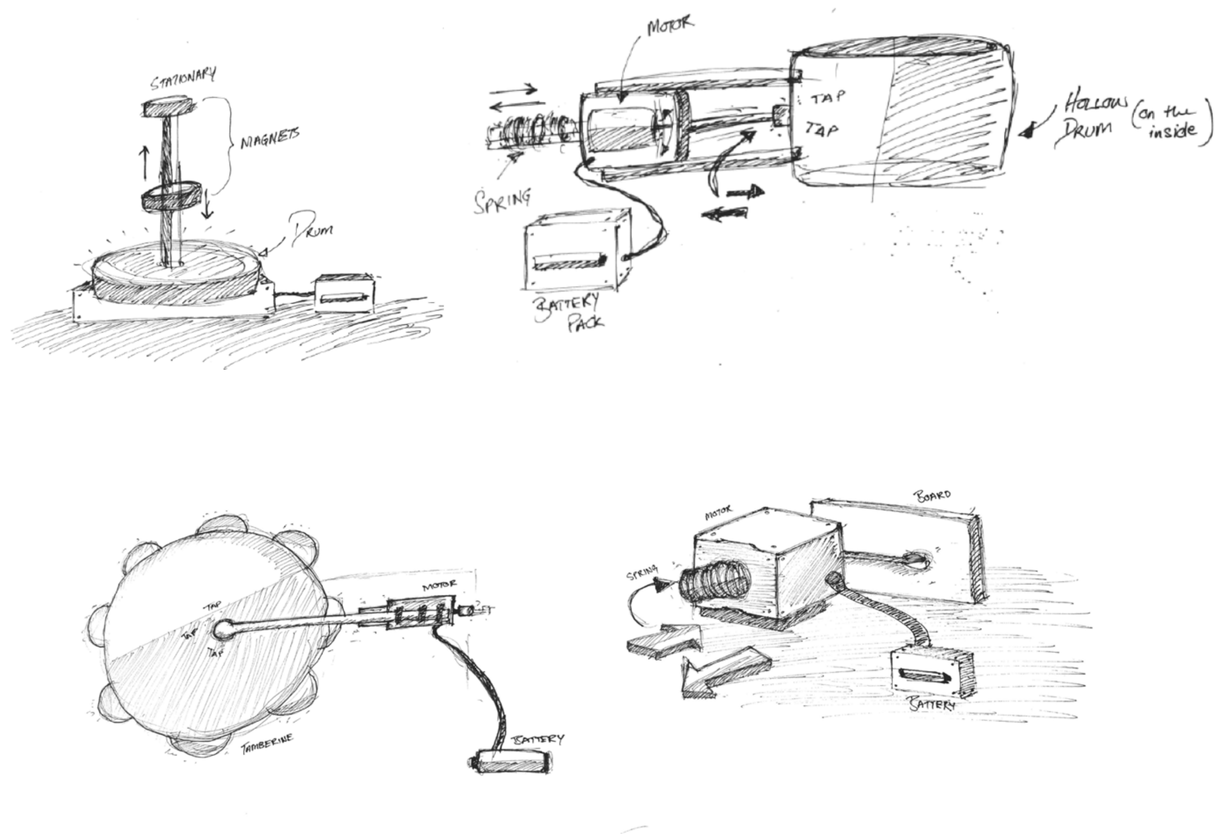

Figure 18 Initial mechanical instruments sketch

From conducting direct material research with found objects I designed a few instruments. I took inspiration from objects like record players, flutes, and xylophone, in order to apply electromechanical output (scrapes, taps, pressure) via solenoids and DC motors to these objects until I was satisfied with the sounds they produced. A solenoid is a special type of motor which creates linear motion. A solenoid consists of a coil of wire wrapped around an iron shaft in the center. When supplied with current the coil creates a magnetic field that forces the shaft away. When the current is removed, the magnetic field is no longer present and the shaft returns to its original position. Solenoid valves can repeat this quickly, but for most typical solenoids the time between supplying and not supplying current must be short to prevent the solenoid from overheating. The more voltage supplied to the solenoid the harder it will strike. Thus, solenoids can be used in conjunction with Pulse Width Modulation (PWM) in order to supply variable control of striking power. My objective was more mechanical sounds and I thus designed four different instrument prototypes based on the initial sketches. The first mechanical instrument illustrated a push solenoid pressing/tapping against an iron plate. I built a form where the solenoid had direct contact with the iron plates and controlled the speed of solenoid movement via gestures. The second instrument resembled a phonograph (i.e. record player). Record players reproduce sound from phonograph records, comprising a turntable that spins the record at a constant speed and a stylus that slides along in the groove and picks up the sound, amplified using a loudspeaker. My instrument worked similarly in a more mechanical and analog way. Instead of using the typical vinyl record I mounted a textured found object, in this case a coarse round sheet of sandpaper, to the record player, and I pressed a square tin sheet against it that clipped to a bent aluminum rod that helped to amplify the sound. I selected a 68 grit sandpaper and focused on how the mixed sounds combined best between materials (rather than musical composition). When the tin sheet rotated around the sandpaper it created an amplified and distinct scraping sound.

Figure 19 Sandpaper Instrument

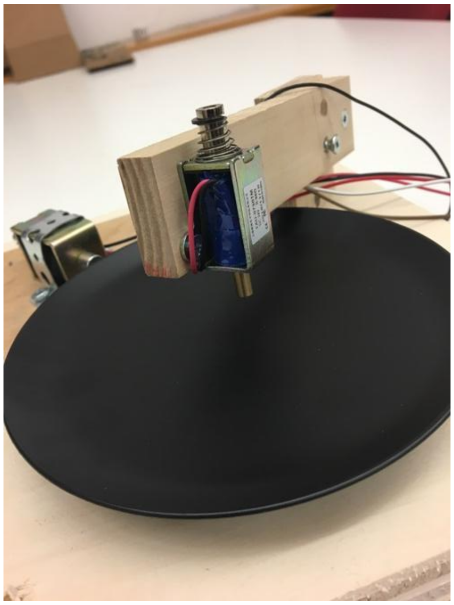

Figure 20 Iron plate instrument

Instrument 3 was inspired by a traditional flute. Flutes form open cylindrical air columns and produce sound when you blow into a sharp edge, causing the air enclosed in the flute's tube to vibrate. I wanted to achieve a pure material sound using the flute rather than making a rhythm. Using a DC blower fan, I explored the form factor and air dynamics of various pipes to see how air flowed through different kinds of materials including from plastic and metal. Aluminum pipes produced the most appealing, clear and sharp sounds. As the blower forced air to spiral down the metal tube it created a whistling sound. In order to achieve a higher pitch, I narrowed the mouth of the DC fan with a paper cone, forcing air more directly into the pipe from a sharper angle, thus producing a more flute-like sound. The 12 volts, 3000 rpm DC fan couldn't project the sound loudly enough on its own and instead produced more of an echoing whistle. In order to blow more air, I had to combine three different pipes.

For the last instrument, I aimed to create an echo-based sound using pneumatics, acoustics and programmable controls. A rubber membrane stretched across the end of a PVC pipe that was used to generate continuous vibration. A solenoid hit the rubber surface exactly where air and sound circulated at the mouth of the pipe and this produced vibration that ranged from sharps to flats. For this instrument, it was necessary to get control of the solenoid in a more subtle and precise way

Figure 21 Air Pipe instrument

Figure 22 PVC pipe instrument

6.3.3 GESTURE MAPPING FRAMEWORK

In order to bring my body out into the performance space I knew I needed sensors which could track the human skeleton. I decided to use Kinect as my main sensor because it combines a motion capture camera that allows for precise spatial and motion detection, with a minimum latency. Kinect's camera (v.1) provides absolute positions and can be used for skeletal tracking. By observing my gesture parameters data I was able to figure out the values of my motion. Through an autoethnographic study of my body I captured my gestures mapped them onto spatial parameters that were mostly based on my upper body parts in a fluid way (e.g. hand gestures). Through the process of reviewing the video documentation I found a pattern of curving motion in my body movements and tested whether Kinect could discern these gestures as it searches for more precise linear motions. In this section, I describe an interface which I used for routing and mapping user tracking data from Kinect. The interface consists of the software Synapse which communicates with MAX MSP from OSC (Open Sound Control) messages and is performance ready. The Synapse interface's main advantage is that it serves as a ready-made tracking tool that saves the user the time of building a mapping framework between compositions, and can more precisely act as a performance interface. Tracking users in space is not a new concept and David Rokeby's "Very Nervous System" demonstrated the possibility of computerized body tracking as far back as 1982 (David Rokeby's 1982). Kinect's true power lies in how affordable it makes tracking multiple users in 3D space, providing world based coordinates that can serve as real-time controllers. Using a steady standing protocol for getting messages provided a feasible and adaptable architecture. The Synapse interface was built for applications that support OSC, which transmit data as OSC remote-Bluetooth messages. The Synapse interface provides out of the box mapping capabilities, as all user tracked OSC messages received by MAXMSP are first unpacked into floating numbers and then accessible as sent objects. MAXMSP directly simplifies the process of mapping joint data.

As soon as a performer is identified in the tracking space the Synapse framework assigns a performer ID value. To get tracked data the Synapse must calibrate to a performer's body before interpreting and transmitting skeleton coordinates. In some cases, the Synapse framework offers auto calibration. Auto calibration calibrates a performer without any direct inputs and begins as soon as the user receives an ID.

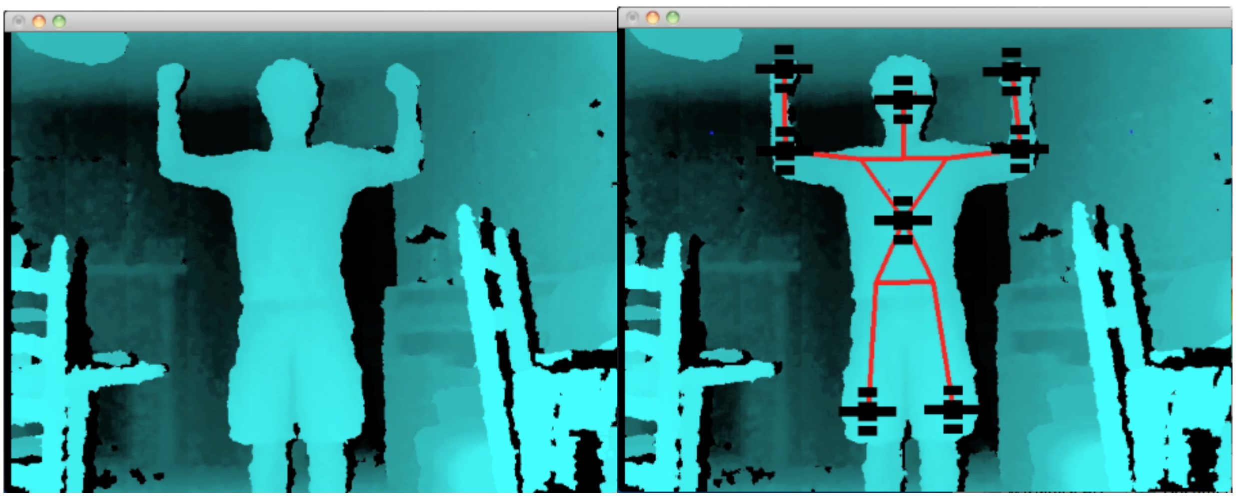

Figure 23 Psi Pose and Auto-Calibration

Through MAX MSP we would then be able to receive the OSC coordinates. To make the application more usable I built a basic patch to see if I am receiving the data (see Appendix for OSC coordinates).

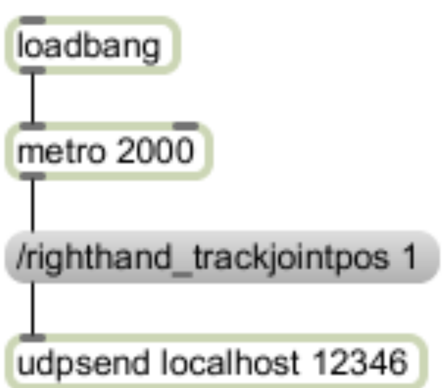

Figure 24 MAX-MSP patch data receiving

Data received from skeleton joint-tracking then sent control instructions to the mechanical instruments through a MAX MSP patch. In this test patch MAXMSP received data from the OSC route and scaled sensor values to the output values. For output, I used a solenoid which could instantiate push speeds that ranged from mapped values of 0 – 255. Testing the Kinect's responsiveness to my hand position, mapped along the Y-axis of the Kinect's detectable range, proved to be successful in that it mapped effectively to the real-time speed of the solenoids pushing behavior. During this process however, I found new issues with the spatial mappings that needed to be resolved. To illustrate, at a certain point when I was standing directly in front of Kinect I received clear positive and negative values representing activity along the x-axis (from -800 to 0, and 0 to 800), but when my body moved a few steps to the left or right along the X-axis these values became less stable. To solve the problem with tracking my body position along the x-axis I was able to set the Synapse software to compensate for changes in my body's position at any given time. Synapse offers multiple tracking modes that can generate a different set of coordinate data for a performer's joints, depending on preset coordinate mapping systems. Synapse offers three different tracking modes that include: real-world mapping, projective mapping, and a third and unique "body" mapping mode. Body mode sends coordinates as joint distance measurements relative to the torso, expressed in millimeters. All three of Synapse's modes may be switched globally or on a joint-by-joint basis, meaning that individual joints may send coordinates in different modes. Using my torso turned out to be the perfect way to map my body movement values because I could move around the trackable space without losing the synchrony of spatial mapping activity.

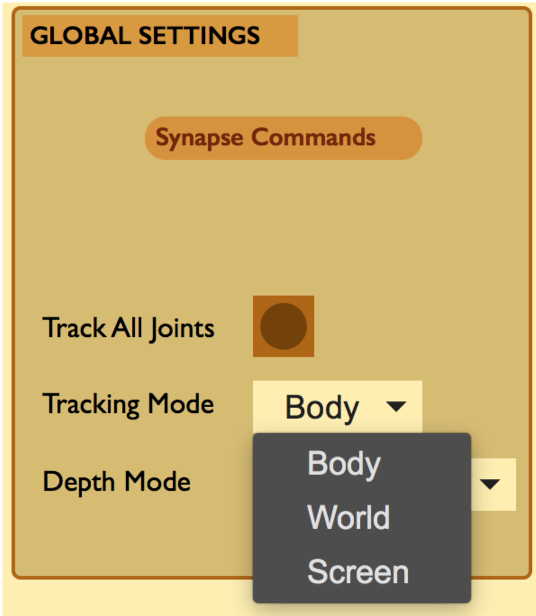

Figure 25 Synapse for Kinect Global Settings

6.3.4 AUTOETHNOGRAPHIC REFLECTIONS

This second reflective study was built on the gesture mapping capabilities of the previous study. During this process, I conducted small test performances without an audience to see how my system functioned as a whole. The resulting interactions and mechanical sounds added more depth and immersion than my original performance. My interlinked system gave me flexible and intuitive control over the mechanical instruments activated by electromagnetic objects, and I realized I could make it more precise for ambisonic (surround sound) environments by changing the physical arrangement of the instruments and a few control parameters. In other words, the *Embodied Expressions* system is more than just software, but rather a combination of three elements: the input system, instruments and environment.

6.3.5 CRITICAL ANALYSIS

Critically analyzing the current study led me to consider the quality of sound coming from my mechanical instruments and the limitations of my control system. The mechanical instruments I created were clearly leading me to my desired direction for audiovisual mechanical instrumentation, but the quality of sound thus, far has been uninspiring. The sounds coming from the interactions between the electromagnetic effectors and the found objects were not very musical (e.g., solenoid directly hitting metal) and left me wanting during my performance. This can potentially be solved by developing new mechanical instruments with a mediator between effector and found object, such as a custom-designed mallet commonly used for playing the xylophone. Another issue with the audio quality of my mechanical instruments was simply that they were not loud enough and furthermore not properly balanced relative to each other.

The second point of consideration derived from reflection on my recent study concerned the effectiveness and limitations of my gestural control system. While the development of this system was overall a success in that I was able to control the mechanical instruments using physical gesture, certain issues of the system became clear. The main point of concern was the question of how to control multiple mechanical instruments with a limited number of discernible gestures. To illustrate, how could I control a set of 3 or more mechanical instruments with the gestures of just my two hands? This is an HCI problem in my project that needs greater focus to sufficiently deal with, where gesture to effector mapping solutions will need to be explored.

6.4 EMBODIED EXPRESSIONS

The final and most refined of the prototypes developed in this thesis, detailed in this section, is titled *Embodied Expressions*. Through the development of this final prototype I tackled some tough design challenges, most of which centered on performance design and the environmental factors of the exhibition space. In this process, I realized that identifying one standard layout for a performance system is nearly impossible and that my performance system would need to adapt to novel performance venues to be most effective.

6.4.1 OBJECTIVES

The next major goal for the study was to develop a spatial mapping strategy to work with all interaction loops. Each "loop' is the combination of a performative tool (Kinect), a gesture (body) and a mechanical instrument (environment). Another goal was to find an ideal spatial mapping for the entire performance setup that would allowed me to move and perform freely in space while still staying within the field of vision of the camera and stage boundaries. To illustrate, certain instruments (e.g. sand disc, solenoid) required specific placement to create an immersive atmosphere for both the audience and performer.

6.4.2 MECHANICAL INSTRUMENT AND FORM FACTOR

In the pursuit of creating embodied instruments I had to consider the scale of the instruments and the noises coming from them in order to gain a deeper understanding of how to amplify them in open spaces. Off-the-shelf mass-produced solenoids proved to be flawed in their suitability as mechanical instruments because they unexpectedly clicked against themselves and made unwanted internal mechanical sounds that reduced their precision and musical quality. All future iterations thus included sound insulation to reduce unwanted noise. I changed the original plate and solenoid instrument and modified the punch action and transformed it into a lever a custom mallet that would be used to strike the plate.

Figure 26 Solenoid Machinimas Design

This mechanism has the three following important parts: (1) the pivot point of the hammer, (2) the place on the hammers shaft that the solenoid strikes to lever it, and (3) the mallet itself. When the solenoid hit, the mallet's rod the length of the rod, and the springs tensioned against the end of its handle, kept it under tension and created a bouncy and clumsy movement resulting in an echoing sound. Stacking multiple iron plates under the mallet mechanism successfully amplified the sound it created. Adding a hole to the bottom of the metal plate allowed sound to travel through it and improved the instrument's acoustics. Also, the mechanical action of the solenoid moving and the hammer hitting the plate added a visual appeal to the hammer instrument.

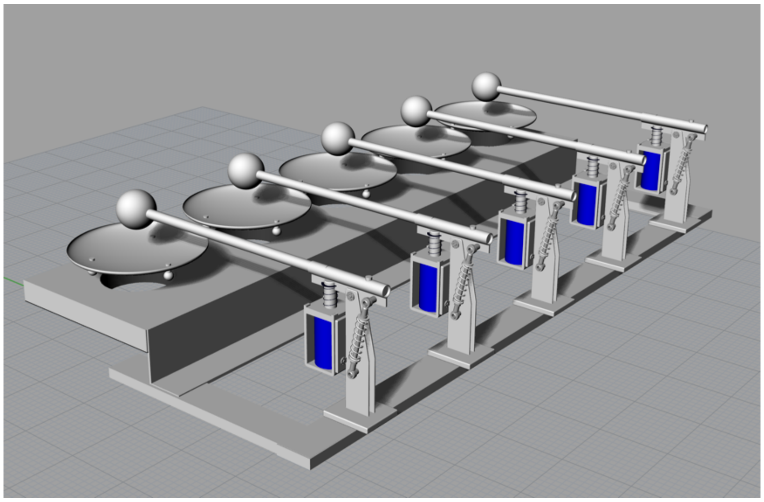

Figure 27 Plate Instrument 3D model

Figure 28 Plate instrument, Photography by Hammadullah Syed

For the sandpaper scratching instrument, I used the same DC motor as its first version. Using a 2500 RPM DC motor I attached a larger diameter disc of sand paper in comparison to the first version of the instrument. Again, the intention was to amplify the sound and provide the audience with a more aesthetic visual element for the. For the blowing pipe instrument, I changed the length of the pipe and increased it to 2 feet long. The larger pipes and the DC blower motor were also moved to a standing rack and pedestal mount. I introduced another mallet for PVC pipe instrument, replacing the steel rod with a light weight wooden one, to hit the rubber membrane. The vibrating sounds it produced were fascinating but lacked the visual appeal of the fully metal components. The fourth instrument, the air pipe instrument, needed some delicate adjustments to produce a pleasing mechanical sound, as it depended on the dynamics of airflow coming from the fan motor. The fans began with a range of high and low speed airflow, and then shifted to a narrower band of high speed settings where the sonified air created a Whistling rhythm. The fan funnel, previously modified to narrow the blower's air stream, was replaced with a 3D-printed duplicate. A new holding mechanism secured the fan inside. This fan prototype wasn't easy to visualize at first but it took form when I added six different sizes of pipes that I could target with airstreams from 4-6 different fans, all mounted to a central wooden lever and pedestal. I upgraded these fans to units with a higher RPM range for stronger airflow. Each fan had one pipe with different sizing.

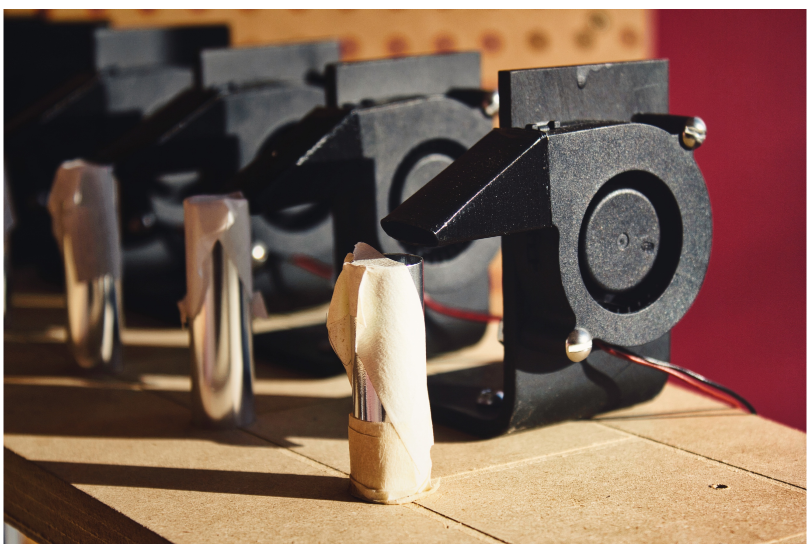

Figure 29 Air instrument, Photography by Hammadullah Syed

A fifth new instrument emerged during this second iteration of material design research in the form of a tin rattle, enclosed in a laser-cut wooden box. The most exciting part of this instrument was the collection of small grain rattles, layered on top of a tin sheet (i.e. bells, balls, pearls). When playing this instrument, a solenoid hit the tin sheet from the bottom side and the tin surface would rattle against the bouncy and grainy objects lying on top. This instrument added some missing but necessary supporting sound to the overall ensemble of mechanical instruments, and so I added 3 of them.

Installing the redesigned instruments took as much careful consideration as developing them. How do orchestras and musicians embody their expression in performance spaces? The space assigned to exhibit a mechanical ensemble is a critical space whether it is enclosed, open, situated along a wall, or at the front of a hall. As an exhibit, *Embodied Expressions* does not have to take up much space, but as part of a live performance the instruments need to be spread apart and angled so that the audience can see the visualizing element of my gestures and the instruments' mechanical actions. Exhibitions can follow a pre-defined formation while performances need to be flexible and arranged on a case-by-case basis. This is what necessitated a modular system capable of getting all inputs and sending it to outputs.

6.4.3 GESTURE AND SPATIAL MAPPING

In the previous iteration of gesture mapping I only supplied signals to one instrument, but in the current iteration the system is designed to control all five instruments in one performance space. The previous exploration using Kinect revealed a tendency for the system to map xyz data simultaneously, rather than strictly along a single plane. I used the z coordinate data for spatial depth parameters in order to specify controls for various instruments. The Kinect can support tracking as far as 26 feet away, but the functional, *stable* tracking range is much more limited. Kinect can maintain reliable, accurate body and joint tracking from a maximum depth of about 15 feet away. This was adequate for a single performer to loop five instruments, but this might not be enough for more. My mapping system uses two hands at a time, where moving my left hand from a positive to negative X coordinate would trigger instruments to begin playing, and moving my right hand from a positive to negative Y coordinate to trigger the second instrument. In order to add another instrument, while still keeping the initial instrument's playback continuous, I would need to loop that instrument using the same hand to capture negative z coordinates. This limited me to restrict my body position while I moved my hand back and forth to trigger the third instrument loop. Once the instrument begins looping, I can take another step forward and get a third instrument to trigger with the same hand but with a new z coordinate value. By integrating the Z-axis into the XY gestural control space in this way, I was able to independently trigger all 5 instrument in continuous rhythmic direction. The most challenging interaction with the system came from controlling my hand gestures precisely in stiff mid-air positions. This control constraint added some cognitive distraction as I was always trying to remember the next step in terms of hand positioning and gesture. Despite any technical issues however, the idea of using space as a mapping constraint was shown to be successful and I can still add a few other instruments to the 15-foot radius of performance space and still have room left over for expressive movement.

6.4.4 AUTOETHNOGRAPHIC REFLECTION

From an autoethnographic point of view, can I say that the current prototype met the goals of embodied control and immersion? I would argue yes because the gestural control mechanism was improved dramatically as controller-free movement in space was achieved, but the gestural interface was still limited in terms of freeform body movement. That said, while mediating between these machines and the Synapse Kinect mapping, I felt the instruments simultaneously drawing me into a fully engaged performance, where I was immersed into a continuous relationship with them. There seemed to be an analogy of my performance process to the musical-perceptual-physical loops found in the circular breathing adjustments needed to play trumpets and didgeridoos. This is why the form factor and placement of these machine instruments was so important. I began to feel as though the instruments were part of my body. As a final reflection on the study of *Embodied Expressions*, I was satisfied with the feedback, engagement, and audience participation facilitated with this project, and felt inspired to continue making more performances.

6.4.5 CRITICAL ANALYSIS

The last iteration for *Embodied Expressions* was exciting and interesting for me in that I could see a real working performance system coming together. The performance system enabled a platform for an intuitive expression but from a critical point of view, there was not always a perfect blend between the system, instrument and environment. Sometimes the environment does not really respond to actions and the engagement level in the space can be limited. Another issue was simply that mixing and matching electromagnetic effectors with the found objects led to some imperfect designs in terms of their audiovisual and responsive aspects. Finally, the amplification of sound and rhythm was a critical aspect of this last study but I was not as focused on composition so there was not a real connection between meaning and sound. These issues will be addressed in more detail for future iterations and performances.

7. CONCLUSION

Looking back at my previous art practice as a VJ, I felt the technology was lacking, and wanted to fill a few gaps between me and my performance technology. This thesis helped me to understand and improve upon those gaps, creating a context to critically address my need for a new system for audiovisual performance. The aesthetics of control are associated with an embodied system, that is, the control of the tools and environment, independent of the gestural output device provided a positive experience for me when using it. About the research question (1), the audiovisual interface developed in this thesis successfully addressed the challenge of creating a more immersive and intuitive performance experience compared to a conventional laptop performance. The artifact developed in this exploration helps bring my body out into the performance space, in contrast to previous performances where I was stuck with a laptop desk and sitting in an isolated corner sharing no expressions and relations with the audience and the content of the audiovisual performance. During my auto-ethnographic exploration, it became clear that not only was the experience enhanced for myself as a performer but observed responses from audience members were also paying attention and curious about the gestural controls and expressions coming through them. In this sense, it can be said that my thesis project was successful both regarding the performer as well as the audience experience, and showed improvement and potential for moving beyond the conventional laptop performance setup. In relation to the research question (2), the mechanical instruments support the performer in creating an embodied audiovisual experience by offering immediate feedback in the form of perceptual responses that come from directly observable physical objects. As immersion increases the performer becomes more in tune with the audiovisual feedback coming from the mechanical instruments as they begin to feel almost as part of the performers now extended embodied self. In relation to the research question (3), the shared environment of the performer and audience achieves a greater sense of immersion in the audiovisual context by providing them with much more interpretable audiovisual content that is much easier to comprehend and relate to, all the while maintaining its sense of artistic magic. I assert that this thesis contributes to the development of a personal performance practice which will lead me to serval distinctive performance out of it. This thesis helps me realize that there was a lack of practice found in my previous audiovisual performances, I can build more performances and pieces that result from the practice

8. FUTURE DIRECTIONS

One of the area of future improvement for this project is the fact that this performance setup was not designed to musical compositions, in the sense of incorporating some the conventional qualities of music such as coherent rhythm, melody, and harmony. Resolving these kinds of issues related to the audio and musical quality of the mechanical instruments will be a necessary step in future iterations and will significantly expand my performance repertoire. Another direction for future improvement, besides the basic quality of the audio and visual elements of the performance system, includes porting the system to new physical spaces, as well as tailoring performances to new political and cultural environments. Making the performance system portable for moving between different venues and locations is a basic but important issue, as many live performance artists can understand. Another more interesting issue, however, is figuring out how to arrange the system by the different physical aspects of a new performance environment, where the placement of the interface and mechanical instruments will always require a unique interpretation. More interesting however is the consideration of how to adapt the performance to different social, ecological and political dynamics germane to specific environments. The exploration of my practice in different physical and musical spaces will keep me occupied and stimulated for years to come.

BIBLIOGRAPHY

Babiole, Cécile, Laurent Dailleau, and Atau Tanaka. 2016. Sensors Sonics Sights. September 14. Accessed january 2018, 23. http://babiole.net/en/sss-sensors-sonics-sights/.

Beaudouin-Lafon, Michel. 2000. "Instrumental Interaction: An Interaction Model for Designing Post-WIMP User Interfaces". Proceedings of ACM Human Factors in Computing Systems. The Hague: ACM Press. 4.

Beloff, John. 1994. "Minds and Machines: A Radical Dualist Perspective." Journal of Consciousness Studies,. Vol. 1. 1 vols. Department of Psychology, University of Edinburgh, George Square, Edinburgh EH8 9JZ, UK.

Brenda, Laurel Rachel Strickland, and Rob Tow. 1994. "Placeholder: Landscape and Narrative In Virtual Environments." ACM (ACM Computer Graphics Quarterly) 28 (2): 118-126.

Carman, Taylor. 1999. The Body in Husserl and Merl. Vol. 27. 2 vols.

Davies, Charlotte Adele. 2005. Landscapes of Ephemeral Embrace : a painter's exploration of immersive virtual space as a medium for transforming perception. Plymouth: University of Plymouth.

Deweppe, Alexander. 2017. Moving Sounds and Sonic Moves, Exploring Interaction Quality of Embodied Music Mediation Technologies through a User-centered Perspective. Ghent University.

Fish, S. E. 2001. "Reader-response theories." The Norton Anthology of Theory and Criticism (W. W. Norton) 2067-2089.

Gallagher, Shaun. 2005. How the body shapes the mind. Cambridge University Press.

Gallese, Vittorio. 2005. "Embodied Simulation: From Neurons to Phenomenal Experience." Phenomenology and the Cognitive Sciences . Vol. 4. 1 vols. Dipartimento di Neuroscienze, Sezione di Fisiologia Università di Parma Italy.

Gaver, William W. 1991. "Technology and Affordances." CHI '91 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. Cambridge: Rank Xerox Cambridge EuroPARC, 61 Regent Street, Cambridge CB2 1AB, U.K. 79-84. https://sites.google.com/site/physicalcyber/page-1p.

Gibson, James J. 1979. The Ecological Approach to the Visual Perception of Pictures. Vol. 11. Pergamon Press Ltd.

—. 1968. The Senses Considered as Perceptual Systems. George Allen and Unwin Ltd.

Griffiths, Alison. 2013. Shivers Down Your Spine Cinema, Museums, and the Immersive View. Columbia University Press.

Heim, Michael. 1993. The Metaphysics of Virtual Reality. New York: Oxford University Press; Reprint edition.

Hinton, Andrew. n.d. Understanding Context. Accessed February 2018, 23. https://www.safaribooksonline.com/library/view/understanding-context/9781449326531/ch04.html.

Kapur, Ajay. 2005. "A History of Robotic Musical Instruments." In Proceedings of the International Computer Music Conference. Barcelona: (ICMC) . 8.

Kwastek, Katja. 2013. "Interaction as an Aesthetic Experience." In Aesthetics of Interaction in Digital Art, by Katja Kwastek, 44-69. London: The MIT Press.

Leman, Marc. 2012. "Musical Gestures and Embodied Cognition." Actes des Journées d'Informatique Musicale. IPEM, Dept. of Musicology Ghent University, Belgium.

Leon, McCarthy. 2016. Steering Audience Engagement During Audio-Visual Performance. University of Limerick.

Magnusson, Thor. 2006. "Affordances and Constraints in Screen-Based Musical Instruments." Edited by Konrad Morgan, Tone Bratteteig, Gautam Ghosh, Dag Svanaes Anders Morch. NordiCHI 2006 The 4th Nordic Conference on Human-Computer Interaction. Oslo. 4.

—. 2009. Of Epistemic Tools: Musical instruments as cognitive extensions. Music Informatics Research Lab, Department of Informatics, University of Sussex.

Makela, Mia. 2008. "The Practice of Live Cinema." Media Space Journal (ARTECH Catalogue).

Manor, Justin. 2003. Cinema Fabriqué : A Gestural Environment for Realtime Video Performance. Massachusetts Institute of Technology.

McNerney, Samuel. 04. Scientific American Blog Network. November 2011. Accessed February 2018, 23. https://blogs.scientificamerican.com/guest-blog/a-brief-guide-to-embodied-cognition-why-you-are-not-your-brain/.

Meyer, Helge. 2009. "Audience as participant in Performance Art." Inter Art Actuel. Canada . 3.

Miranda, Eduardo R. and Marcelo M. Wanderley. 2006. New Digital Musical Instruments: Control and interaction beyond the keyboard.

Gurvich, Michael, Paul Stapleton and Adan Marquez-Borbon. 2010. "Style and constraint in electronic musical instruments." Proceedings of the 2010 conference on New Interfaces for Musical Expression. Sydney. 106-111.

Mitchell, Bonnie. 2010. "The Immersive Artistic Experience and the Exploitation of Space." CAT 2010 London Conference. London: CAT. 10.

Mulder, Axel G.E. 2000. "Towards a Choice of Gestural Constraints for Instrumental Performers. Trends in gestural control of music." 315-335.

Rosheim, Mark. 1995. Robot Evolution–The Development Of Anthrobotics. New York: Wiley Interscience, John Wiley & Sons Inc.

Russolo, Luigi. 1913. The Art of Noise, Futurist manifesto . Great Bear Pamphlet

2016. Wave. Directed by Patrick Saint-Denis. Performed by Patrick Saint-Denis.

Seo, Jinsil Hwaryoung. 2015. "Aesthetics of Immersion in Interactive Immersive Installation: Phenomenological Case Study." Proceedings of the 21st International Symposium on Electronic Art. ISEA. 8.

Singer, Eric, Kevin Larke, and David Bianciardi. 2003. "LEMUR GuitarBot: MIDI Robotic String Instrument." Proceedings of the 2003 Conference on New Interfaces for Musical Expression. Montreal, Canada: NIME. 3.

Slater, Mel, and Martin Usoh. 2008. "Body Centred Interaction in Immersive Virtual Environments." (John Wiley and Sons) 22.

Sonami , Laetitia. 1991. Instruments – Lady's Glove. http://sonami.net/ladys-glove/.

Varela, Francisco J., Evan Thompson, and Eleanor Rosch. 1993. The Embodied Mind, cognitive science and Human Experience. Massachusetts Institute of Technology.

Varese, Edgard. 1958. Masterpiece's of 20th-Century Multi-channel Tape Music: Varese. http://sites.music.columbia.edu/masterpieces/notes/varese/notes.html.

Waisvisz, Michel, interview by Volker Krefeld. 1990. The Hand in the Web: An Interview with Michel Waisvisz. The MIT Press. 28-33.

Weinberg, Gil, and Scott Driscoll. 2006. "Toward Robotic Musicianship." Computer Music Journal. Georgia Institute of Technology. 30 (4).

Woollaston , Victoria, and Rundle Michael. 2017. 16 months to build, two hours to demolish: watch the Marble Machine being taken apart. March 16. http://www.wired.co.uk/article/marble-machine-video.

Zimoun. 2014. 157 prepared dc-motors, cotton balls, cardboard boxes 60x20x20cm. Studio Zimoun.

APPENDIX A : FOR SYNAPSE COORDINATES VALUES

Synapse send messages out on ports 12345 and 12347 and receives OSC messages on port 12346. The messages sent via 12345 and 12347 are identical; synapse sends messages in following ways.

- **/tracking_skeleton <bool>** - Sent with 1 when we start tracking a skeleton, and 0 when we lose it.

- **/<joint>_pos_world <float> <float> <float>** - The x,y,z position of the joint in world space, in millimeters.
- **/<joint>_pos_body <float> <float> <float>** - The x,y,z position of the joint relative to the torso, in millimeters.
- **/<joint>_pos_screen <float> <float> <float>** - The x,y,z position of the joint as projected onto the screen, in pixels.
- **/<joint> [up,down,left,right,forward,back]** - Sent when we detect a "hit" event, such as a punch forward, which would be "righthand forward".
- **/<joint>_requiredlength <float>** - The current tuning value of how far you must move in a straight line (in mm) before a hit event is generated
- **/<joint>_pointhistorysize <int>** - The current tuning value of how many points are being tracked for hit event detection.

"Righthand_trackjointpos 1" sent a data call to Synapse every 2 seconds, and prompted Synapse to generate messages like "/righthand_pos_body 150 200 400" every frame.