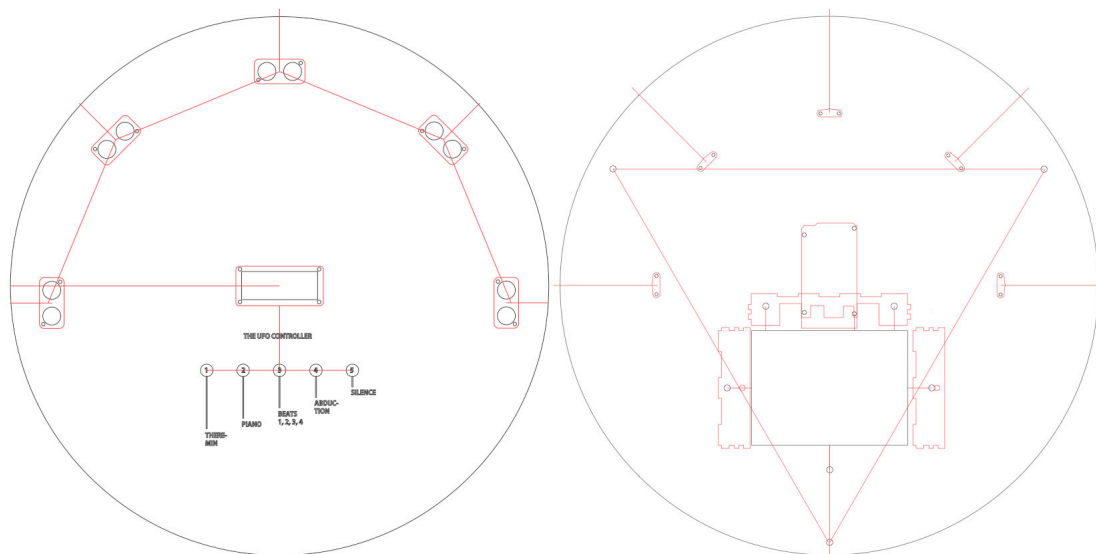


# THE UFO UFO UFO CONTROLLER

GESTURAL MUSIC PERFORMANCE



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### Abstract

This thesis introduces The UFO Controller, a free-space gestural controller for performing electronic music. It documents the design process and the main features of the UFO, analyses my experiences of performing with the controller and compares the UFO to other known free-space control instruments. The thesis also examines the domain of electronic music, critically analyzes the live performances in that field and investigates the importance of body gestures for the performances.

The UFO is a MIDI controller that uses ultrasonic rangefinder sensors for detecting the hand gestures of a performer. It is a non-tactile controller that is played without physically touching the device. The sensors measure the distance of the performer's hands moving on top of the device and convert that into control data, which can be mapped to any music software or synthesizer.

The use of body gestures, which is commonly reported lacking from the live performances of electronic music, is crucially important for engaging live music performances. The laptop computer has become the de-facto instrument of the concert stages where electronic music is performed. The UFO can help the electronic music performances to become more interesting by moving them towards a more gestural direction. This thesis aims to validate the following claims. Firstly, a novelty free-space controller makes electronic music performances more compelling both for the audience and the performer. Secondly, the use of body gestures is important for the largely disembodied electronic music performances.

The UFO has been seen and heard on concert stages all around the world with my band Phantom. The audiences have been excited and thrilled about it and the UFO has become a subject of wondering for many. Without a doubt, the UFO has raised the bar of my own live performances and helped Phantom to stand out amongst the masses of new electronic indie bands. Furthermore, the UFO has got the attention of various online technology and music blogs (e.g., TechCrunch, Create Digital Music, Synthtopia, NME and The Line Of Best Fit).

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**Keywords** electronic music, gestural interaction, live performance, MIDI controller

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# CONTENTS

<b>1</b>	<b>Introduction.....</b>	<b>1</b>
	My background story .....	2
	Structure of the thesis.....	4
<b>2</b>	<b>Electronic music instruments and live performance .....</b>	<b>5</b>
	Brief history of electronic instrument design.....	6
	MIDI controllers, sensors and virtual instruments.....	9
	Shortcomings of Electronic music performance .....	12
<b>3</b>	<b>Fabrication of the controller .....</b>	<b>16</b>
	Coming up with the idea.....	17
	Working on the first prototype .....	19
	The more robust prototype 2.0 .....	25
	The Program .....	30
<b>4</b>	<b>Going gestural with The UFO Controller.....</b>	<b>31</b>
	Sensor space and gestures for interaction .....	32
	Airplay mode .....	35
	Performance mode.....	38
	Scenes mode .....	39
	Potential usability problems and resolutions .....	41
<b>5</b>	<b>Gestural free-space instruments .....</b>	<b>44</b>
	Theremin .....	45
	Radio Baton and Conductor .....	47
	Laser Harp .....	49
	D-Beam .....	50
	Moog Theremini .....	51
	Microsoft Kinect.....	52
<b>6</b>	<b>Preparing the UFO.....</b>	<b>56</b>
	Importance of body gestures in music performance .....	57
	Effective mapping strategies.....	59
	Mapping example 1: Conducting sound levels .....	61
	Mapping example 2: Theremin .....	63
<b>6</b>	<b>Performing with the UFO .....</b>	<b>65</b>
	The story of Phantom .....	66
	Feedback from the performances .....	69
	Media quotes .....	72
<b>7</b>	<b>Future &amp; conclusions .....</b>	<b>74</b>
	The bright future of new music controllers .....	75
	Next destination for the UFO .....	77
	Final conclusive thoughts .....	80
	<b>REFERENCES.....</b>	<b>82</b>
	<b>LIST OF FIGURES .....</b>	<b>86</b>
	<b>GLOSSARY.....</b>	<b>91</b>

# 1 Introduction

This thesis presents the development and outcome of my sensor-based performance instrument, The UFO Controller, which has, at the time of writing, been under development for over three years. Additionally, the thesis documents my findings about the performances with the controller and argues that there is a need for new musical interfaces to ‘humanize’ the electronic music performances of the digital era. My idea with The UFO Controller is to bring liveliness and excitement with impressive physical gestures to the live performances of electronic music, as the performances of various electronic music genres are commonly seen as motionless, minimal and too restrained. As an example, the performances of electronic music currently represented at the clubs and concert stages usually consist of a single person playing music from a laptop computer with the aid of one or two extra devices called MIDI (Musical Instrument Digital Interface) controllers. These controllers can be used to affect the sound synthesis and playback handled by the computer.

The UFO Controller is a sensor-based (i.e., ultrasonic distance sensing) MIDI controller for digital music performances allowing the player to use simple waving hand gestures to affect the performance. The sensors are actively measuring the distance of the hands of the player, and that data is converted into musical MIDI messages. The controller allows mapping the gesture data from the sensors to any particular digital instrument with a MIDI receiving capability (e.g., a synthesizer or a laptop running a music software). It also provides visual feedback about the gestures to the performer and audience by flashing LED lights and displaying relevant information on the LCD screen.

## My background story

I consider myself a computer musician born in the 80s. My natural enthusiasm for computers, gaming, demoscene and music led me to discover the world of electronic music production when I was a teenager in the late 90s. Back then, my creations started with highly non-musical and absurd 'collages of audio' made with primitive tracker sequencer software running on my PC. It was only some years later that I discovered the world of live electronic music and club culture that instantly had an inherent traction on me. The power of the music was so captivating to hear from a loud and crystal clear PA sound-system, and, for the first time in my life, I understood how different frequencies and rhythms in the music altered the mood and the energy of the audience. Thereafter, I developed the highest respect for the sound designers and artists who marveled us with their sonic crafts. The thought of being in control of those frequencies led me to learn more about the nature of sound, music theory, production and performance of electronic music. Making observations of what other electronic music artists did on the stage was naturally an important part in my process of learning. The thought of performing as a DJ (and playing tracks made by others) had crossed my mind, but it had no strong appeal on me and, besides, it seemed everyone was doing it already. However, playing my own music and performing it live struck a major chord in me.

The excitement carried me reasonably far in the world of electronic music, but at some point along the way it also seemed to lose some part of its magic. After a few years of doing production and performances and seeing electronic music acts perform, I began to understand even more what the performances were commonly lacking. They seemed to lack the excitement and energy of a real band, and usually the shows consisted of a single person tweaking the sounds with a laptop or DJ decks. This stage setting of a performer being placed behind a table with a computer and disembodied controllers that have very technical interfaces were not delivering too much of excitement to audiences. Both Hugill (2012: 153) and

Collins (2009: 347) argue that too often electronic music acts (whether there is a single person or more people) play hiding behind their laptops or even behind curtains. In some occasions this is a desired effect but more commonly a result of lacking performance skills (Hugill, 2012: 153-154). Collins (2011: 347) has coined a term 'almost immobile laptop artist' for such performers. I can well relate to these arguments after years of concert-going and performance experience. Altogether, humans seem to be possessed by the primitive impulse to have social contact and expressive behavior (Collins, 2009: 347). And even people like me, musicians of the computer-era with no real skills to play the guitar while looking cool, want to play live.

Learning from these past experiences I argue that the stage presence and skills to communicate with the audience are valuable to learn if you desire to be an exceptional performing musician. These days, lacking performance skills are usually ignored by putting the focus of the audience elsewhere; Electronic Dance Music (EDM) shows bombard their audiences with blinding and deranged visual projections. However, I argue that there is more to blame than the performance skills of the musicians or the flamboyant visual projections; could it be that the disembodied interfaces and controllers (not encouraging the use of your body) are the cause? Davidson (2009: 374) claims that the use of the body and bodily motion are naturally involved with the mental representations necessary to build up musical performance abilities. Furthermore, Davidson claims these abilities reflect the aspects of performing fluently and expressively.

I have no classical training in music; most of the things I have done in the field of music are an outcome of disciplined self-learning. Nevertheless, I had come to the conclusion that my pre-learned way of composing and performing electronic music needed a change. I felt my way of working with music in the studio and on stage should be taken to a new level, which would take my background into account and, by doing so, allow me to be more expressive and creative. For me that meant building a new controller that would enable me to perform music in a completely

different way. I also thought that the “immobile laptop artist” needed an injection of bodily motion to come alive. **These notions condensed into two questions to be researched:**

- Is it possible to make electronic music performances more interesting and exciting both for the audience and the performer with a novelty controller that makes use of your body gestures?
- Is the use of body gestures important for largely disembodied electronic music performances?

My experiments with creating the new control interface for electronic music composition and live performances started in 2011 when I got accepted to study in the Media Lab Helsinki in Aalto University.

## Structure of the thesis

The remainder of this thesis is divided into two parts. The first part constitutes an overview of digital music instruments and electronic music performances, explains the fabrication process of the controller prototype and describes the functionality, technology and design of the device. The second part continues by examining gestural free-space instruments with similarities to the UFO Controller and proceeds to reveal my experiences with the UFO in action. Furthermore, it describes some of the UFO-based sound design and software mapping strategies for live performances. The final chapters unfold the lessons I have learned from using this controller and, ultimately, conclude with my predictions for the future of the UFO and the domain of new musical controllers.



## 2 Electronic music instruments and live performance

This chapter gives a brief walk-through of the history of the electronic music instruments, explains how we came about to perform electronic music as seen today and what can be regarded as the shortcomings of present-day electronic music performances. Laptops with the backlit fruit logo and MIDI controllers of all sorts are the de-facto instruments (instead of actual synthesizers) of the contemporary electronic music. Almost everyone reading this thesis has seen, without a doubt, a band or an artist performing on the stage with a computer and controller setup. Where did the electronic music with the “real instruments” go?

## Brief history of electronic instrument design

Since the invention of electricity, musicians have envisioned ideas of the most unimaginable music instruments utilizing electrical energy (Singer, 2008: 204). In the beginning of the 20<sup>th</sup> century, some of the first electronic music instruments were realized, and they began to challenge our predominant views on the definition of a musical instrument. The radio transmission technology created the basis for the first generation of synthesizers and initiated a trend to facilitate innovations in the field of instrument building. Prior to this era starting in the 1910s, some of the leading composers in Western culture shared a notion of the stagnant state of contemporary music (Singer, 2008: 204). The classical music orchestras that dominated the music scene relied heavily on the mechanical instruments that were finalized in their known form in the late 19<sup>th</sup> century (Emmerson, 2000: 206). Moreover, these orchestras often were unenthusiastic towards novelty instruments that had no traditional placement in their ranks.

Early explorations of the electronic music technology were often pioneered by musicians and composers who needed better tools for creating music (Leman, M., Styns, F. & Bernardini, N., 2008: 36). However, the renaissance of electronic music instruments began as inventors and engineers introduced their electronic instruments to the public of the civilized world; In 1919, Léon Theremin was one of the first inventors to astonish people with his novelty instrument the Theremin, which was played without physically touching any part of the instrument and created an astonishing yet primitive howling sine-wave sound. This instrument that discarded all the traditional interfaces contributed not only to the origin of electronic music culture but also to the design thinking of future generations of music instrument builders (Glinsky, 2000; Tanaka, 2009). The Theremin, which is a great inspiration for my own work, is covered in Chapter 5 of this thesis.

In the following decades, although new electronic music instruments were introduced to the world, few of these managed to become adopted by a wider user

base and to succeed commercially. Nevertheless, instruments such as the Hammond organ (1935), the electric guitar (1930s) and the modular analog synthesizer (1960s) certainly got the full attention of musicians and made a permanent mark in the history of popular music (Byrne, 2012: 110-112; Théberge, 1997: 45-47). In the late 1970s, digital microcontrollers and integrated circuits changed fundamentally how the synthesizers were designed and manufactured (Théberge, 1997: 57-58). The market for electronic music instruments, such as synthesizers, drum machines and other digital keyboards, was booming in the 1980s as new innovative and cost-effective products began entering the market. Despite the innovation happening in the domain of instruments, the old-fashioned piano keyboard interface continued to dominate the electronic music instrument design in the 20<sup>th</sup> century.

Older analog synthesizers used control voltage (CV) signals to control various parameters such as clock synchronization, pitch modulation and gate input<sup>1</sup>. CV is a purely analogous signal. For example, in the control voltage modulating the pitch, a difference of one volt equals a change of one octave. CV modulation was usually done with patching cables, from an output to an input. This solution, however, failed to meet the requirements set by a new wave of studio musicians using multiple synthesizers and computers to create music in the 1980s (Théberge, 1997: 84). Prior to this, most of the manufacturers had implemented their own proprietary systems and protocols for synthesizer-to-synthesizer connectivity, which prevented communication compatibility with electronic instruments made by other manufacturers. (Théberge, 1997: 85)

A nonproprietary standard to address this issue was proposed in 1981 by Dave Smith from Sequential Circuits (a company famous for manufacturing the legendary Prophet synthesizers). The standard was released as MIDI in 1983 and it was one of the most notable inventions in music technology around the time as it

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<sup>1</sup> See the glossary at the end for explanations of the technical terms

solved the issue of synthesizer-to-synthesizer connectivity. It is a communication protocol standard that connects all of your MIDI-compatible digital studio equipment together. MIDI can be used, for example, to send data from your computer to a synthesizer and back. Furthermore, MIDI allowed you to interface your synthesizers to your digital sequencer device or computer running DAW (Digital Audio Workstation) software. Each and every DAW application has nowadays an established sequencer that is not only a multi-track recorder but also a fully capable MIDI editing suite (Figure 1). Even though MIDI has faced criticism due to the outdated capabilities of the standard (i.e., very limited messaging bandwidth and precision) it still remains as a leading communication protocol used in the industry (Théberge, 1997: 86-87).

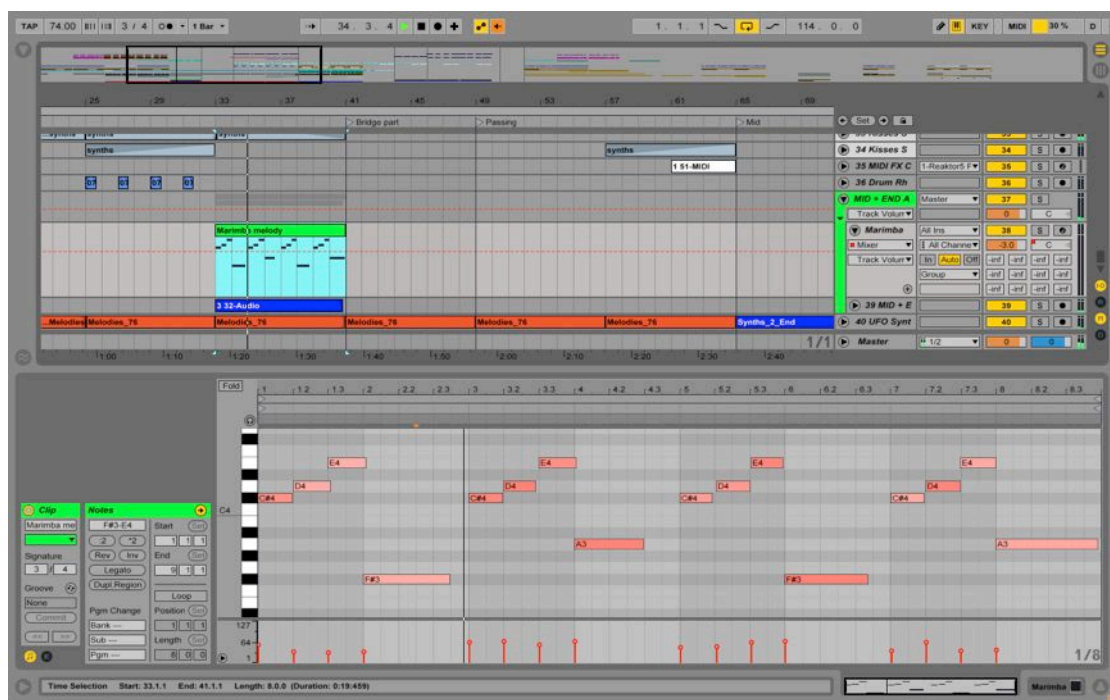


Figure 1. MIDI clip editing in the popular DAW Ableton Live 9

## MIDI controllers, sensors and virtual instruments

Sensor-based music controllers are devices that can be used to translate physical action into digital musical data. A standard MIDI controller is basically a sensor-based device that reads, for example, the turning of a knobs (i.e., potentiometer interpreting voltage changes, see Figure 2), translates the event into MIDI signals and sends them to another device for processing a

sound. MIDI controllers are not capable of producing a sound on their own, but they can be used to control, for example, external synthesizers or virtual musical instruments running on a computer. They are basically tools for sending musical data and they need to communicate with an additional device creating the sound. They can easily be mistaken with synthesizers (or other electronic keyboards) that also can act as MIDI controllers. What separates a synthesizer from a MIDI controller is the fact that a synthesizer is capable of creating sound independently (i.e., acting like a real instrument). The decoupling of the sound source and the controller has inspired me to create a device like the UFO.



Figure 2. Potentiometer

The most common MIDI controller is a “piano” keyboard, which can be found in various octave sizes (i.e., 24, 49, 61 keys and so on). The piano keyboard layout has a strong historical background in Western music and still remains a dominating interface in the market of electronic music instruments. Nonetheless, there are MIDI controllers that are adaptations from other traditional instruments, such as wind instruments, violins and guitars. The more typical controllers for electronic music production and performance are, for example, electronic drum pads, DJ mixer controllers and hybrid controllers (that usually combine keyboard with drum pads, faders and knobs) (Figures 3 and 4). Andrew Hugill (2012: 152) claims that the nature of a controller can be anything: brainwaves, motion, sound, gesture, weather and so on. Almost any real-life event can be tracked with a sensor

and converted into digital data, thus we could argue that there is infinite amount of options for an input of a controller.

Whatever the sensors of the controller are, Simon Emmerson (2000: 209) indicated that the devices can be divided into two categories: controllers with either **tactile** or **non-tactile interfaces**. In reality, they can be both as a device with distance sensors (non-tactile) and can also contain, for example, buttons (tactile), like The UFO Controller. Even though the controllers are still largely based on tactile interfaces, I argue that we are already experiencing a new phase bringing more innovation and disruption to the electronic music instrument market.

Being aware of the separation of the controller device and the source of the sound, I could easily argue that all you need is a computer, a DAW and a MIDI controller to produce and perform music on a professional level. The fact is that the music production has been largely virtualized due to more powerful computing offered by the development of personal computers. The modern DAWs include a variety of high quality virtual instruments and effects to create almost any kind of music or sound. Computer, as a composing and performance tool, can be regarded as an interactive music system with limitless possibilities. Paine (2009: 216) describes it as ‘the iconic instrument of our time, eschewing the traditional composer/performer model for a real-time authoring environment’. There is no more a prerequisite to own expensive synthesizers, drum machines or effect units. These virtual instruments (ranging from samplers, synthesizers and drum machines to physical modeling of acoustic instruments) can nowadays do everything the hardware can do (Earl, 2012). Essentially, a virtual instrument is able to perform any sound and can be controlled by anything. Moreover, the ever-growing market of mobile applications (e.g., software running on an iPad tablet computer) has already introduced hundreds of inexpensive and easy-to-use music apps. They range from DAW software, experimental sound design apps to MIDI controllers and virtual musical instruments (Figure 5).



Figure 3. Typical hybrid MIDI controller ReMOTE 25 from Novation



Figure 4 Left: Lady Gaga playing a huge custom-made Keytar MIDI Controller on her Monster Ball UK Tour. Top right: Onyx Ashanti playing a MIDI wind controller. Bottom right: Roland Octapad MIDI drums on display at the NAMM 2010



Figure 5. Modern MIDI controller solutions (Left: Livid CNTRLR MIDI Controller, Right: Lemur controller app on iPad)

## Shortcomings of Electronic music performance

Most of the acoustic instruments have been copied or virtualized to the digital domain either by sampling or physical modeling synthesis. These counterparts are mimicking the acoustic qualities of the acoustic instruments, and some of them do it surprisingly well. Nowadays though, the electronic music is filled with sounds that have no counterpart in the acoustic world. The contemporary music culture has weakened the link in music to individual instruments as they are connected into sounds created inside the computers and electronic instruments. That leads us to the fact that musicians have **difficulties identifying their musical identity** and practice in electronic music (Hugill, 2012: 138). I would argue that the domain is still so new that it will take more time and practice for the identities to emerge. Eventually, people want to make classifications in their heads; I have encountered some members of audience labeling me as the UFO player after they have seen me performing with The UFO Controller. I firmly believe that when electronic music instruments and controllers get more character their musical identities will follow. Meanwhile, acoustic instruments are justly used to label the musicians playing them (i.e., guitarist, pianist and so on).



The lack of musical identity is not the only concern for the performers of electronic music, but also the fact that **audiences struggle to find connection between electronic sounds they hear and their sources**. Simon Emmerson (2000: 206) argues that usually audiences have no clue what ‘action’ results in what ‘sound’ in electronic music live performances. Moreover, Emmerson claims that as there is no real human control, but rather electronic instruments being in control, it causes the audience to lose their impression of live performance. Fortunately, this concern has been realized in the research of new music tools during the last decade, and more attention is paid in creating **interfaces that couple perception and action** (Leman et al., 2008: 30). I consider that the UFO is able to mitigate both of the aforementioned problems with the gestures and the sound design. Live performance with the UFO can be designed in a fashion that the gestures made with the UFO alter every audible element in the live set. The gestural technique of performing with the UFO is very similar to a conductor of an orchestra raising or lowering his or her hands. I also argue that this kind of gesture will altogether be far more visible to the audience than, for example, a keystroke on a controller.

Andrew Hugill (2012: 138-139) analyzed the research on musicians’ opinions to acoustic and digital instruments made by Magnusson and Hurtado (2007). He discovered that the most of the musicians appreciated the ease of use, liberty and explorative sides introduced by the digital music instruments. However, they found no obvious reason for digital instruments and their interfaces to mimic the acoustic instruments, and some of them claimed that digital instruments are slaves to the history of acoustic instruments. Additionally, they felt that the **experience was disembodied** and acted without social conventions that were common to bands playing traditional instruments. Some of the interviewed musicians even claimed that they felt introverted playing digital music instruments. This strengthens the argument made by Juhani Räisänen (2011: 66) that there is a need for new electronic instruments with interfaces that come closer to the body of the musician. Musicians who play acoustic instruments are accustomed to the physical

proximity of their instruments. Electronic instruments, however, usually lack this factor, especially the most used combination of them all, the laptop and the mouse.

The mainstream of electronic music live performances nowadays seems to be more dependent on delivering a spectacle for all senses rather than demonstrating extraordinary musicianship and performance skills. Usually, there is middle ground between those two, but, for example, EDM performers are often accompanied with massive stage setups that are being bombarded by spectacular visual projections, lasers and lights. As music and visuals can be equal in their scope, **this kind of audiovisual experience can distract listeners from the ‘issues of physical engagement’** (Collins 2009: 347-348). The visual part of the show has clearly taken primary (and distractive) role in these performances and music is largely performed with a single laptop computer. I predict there will be a tipping point sooner than later that will leave the audience craving for something more. The mainstream of electronic music will realize the potential that lies in “live performance” which would include gestures and new kind of instruments and control interfaces.

I questioned 24 electronic music producers and performing musicians to collect their opinions about MIDI controllers and electronic music performances in an online survey titled ‘Research On The Use And Novelty Value Of MIDI Controllers’. The most relevant finding for my thesis project was **the fact that most survey participants were not satisfied performing electronic music with a relatively simple laptop-based setup**. They were instructed to envision a scenario watching a live set where a performer only used a computer and two ordinary MIDI controllers on stage. The results indicated that such performances are not considered to be fully ‘live’, audiences can have difficulties realizing what actions actually change the sounds, and almost all of the survey participants wished there would be something more in the live set (gestures, instrument solos or even dance). Additionally, the results indicated that 37,5% completely agreed and 45.8% partially agreed on the notion wishing there would be more performance elements

in the live sets. Paine (2009: 218) explains that ‘many laptop music performers, however, do see the need to inject a sense of the now, an engagement with audience, in an effort to reclaim the authenticity associated with “live” performance’. This builds up justification for my claim that there is definitely room for new kind of interfaces in the domain of music controllers. Furthermore, novelty interfaces with gestural interaction can bring some of the craved “live” factor, excitement and interest to the performances.

### **3 Fabrication of the controller**

This chapter explains the origin of my controller idea, how I progressed from having the original idea to the final prototype device and it explains my design process and various fabrication stages.

## Coming up with the idea

Before proceeding to explain how I designed and fabricated the controller prototype, it might be interesting to know how I ended up having the initial idea in the first place. Me, a person with absolutely no previous background in electronics or instrument building, created a controller device that would have a significant role in my future music projects. Now that I reflect back to the day when I was accepted to study in the Media Lab Helsinki (in Fall 2011) I had no idea where it would eventually lead me. During one of the initial courses I got my first contact with the world of physical computing as I discovered Arduino (a popular electronics prototyping platform) and sensor technology. By the end of the course I was using flex, light and accelerometer sensors to get interaction data from physical objects and mapped that data to virtual samplers and synthesis algorithms running on my computer.

Next step for me was to sign up to a course about Physical Interaction Design (PID). The course was about to dive deep into the domain of physical product prototypes with electronics. However, before the course I visited Cartes Flux 2011 media art festival and saw a performance that would give me the idea of my future controller. I had seen a performer use hand and body gestures with rangefinder sensors to control experimental sounds made with a custom-made MAX/MSP patch. The performer had no physical device or any structured order for the sensors. He had just an Arduino connected to his laptop with additional wires and rangefinders on a breadboard. It got me instantly thinking and considering the idea of having a stand-alone controller using similar kind of sensors.

My initial idea was to create a multi-effect device with free-space gestural control to apply sonic effects to my music performances. The idea was largely inspired by Korg Kaoss Pad (Figure 6), an effect synthesizer using a X/Y touchpad to apply effects on the inputted sound (Korg, 2015). The device, which created massive and

distorted sound manipulations, was operated by making gentle sweeps on the touchpad with your fingertip. Somehow I felt the gesture and outputted sound made no match for each other, and I was urged to test it with broader hand



Figure 6. Korg Kaoss Pad 3

gestures that could be detected by the rangefinder sensors. To get closer to this goal, I would only need to implement an Arduino-based MIDI controller to detect these “bigger gestures”. I was mainly using Ableton Live to produce my music and live performances and I could basically create the necessary sound and effect program inside

the software. Now that the initial idea was born, the PID course provided a perfect playground for me to start experimenting with this idea. Therefore, I proposed a project for the course called “Hand Gesture Based MIDI Controller”.

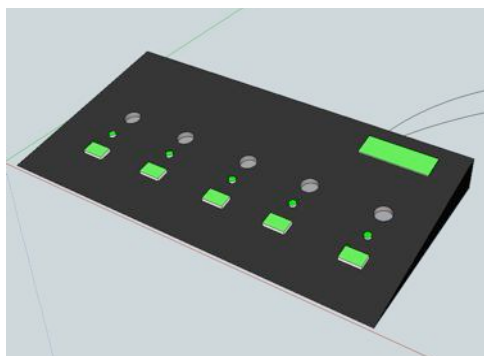


Figure 7. Early mock-up image of the controller

My project was accepted and my work on the initial prototype lasted intensively for the next two weeks. The original sketch image of a boxed unit (Figure 7) played an initial role in the design but had no resemblance to the prototype that was the outcome of the project. The mock-up design was simply a boxed unit (like most of the commercial

MIDI controllers are) with the components embedded on the top surface. However, during the early days of the course I discovered a plastic arched lampshade from the university dumpster with a perfect diameter of 50 centimeters. It immediately evoked ideas of a new kind of design. Consequently, this dome shape started to feel like it had more character and excitement to me than a simple controller in a box. I took it with me and gave it a new life.

The following subchapters focus on the stages of the work that had the biggest impact in the design of the prototype. They also briefly explain how the controller was assembled and give an overview of equipment and tools used to fabricate the parts of the prototype. The functionality of the controller is covered in Chapter 4.

## Working on the first prototype

The prototyping of electronics can be quite overwhelming. Before even going to the part of connecting your components on the breadboard, it is good to start by figuring out what you are actually trying to achieve with the project and then by splitting the project into smaller, more manageable tasks. Hence, keeping your project organized is the key. I faced this challenge when I started working on the UFO. Where to start and what to do next? I decided to solve one problem at a time: First, planning some first goals for the project and setting up the Arduino environment. Second, getting reasonable data out from a sensor. Third, showing visual feedback with a LED light when the sensor is detecting something within its range. Fourth, the list goes on. This way the project started to fall in place piece by piece, but it did require countless amount of iterations in the end. In the beginning of the project I came up with the following set of **features and requirements** for the controller:

- **Determining the distance** of the hands of a performer by using rangefinder sensors
- **Airplay mode:** The rangefinder distance data can be translated to MIDI notes in a certain root key and musical scale. There can be 5 channels (sensors) to produce the notes. Each of these channels can have a unique distribution of the notes. The Airplay mode can be considered as the equivalent of playing an invisible piano keyboard in the air.
- **Performance mode:** The rangefinder distance data can be translated to MIDI continuous controller (CC) commands that can be assigned to

control, for example, effect unit parameters, synthesizer variables or global performance controls (e.g., mixer, tempo). The Performance mode can be considered as the equivalent of playing Korg Kaoss Pad in the air.

- Ability to switch between the modes by using five buttons on the device. Each button is assigned to control mode selection of one of the sensors. Additionally, there is an option to turn off any of the sensors.
- Visual feedback: Small screen and lights to provide visual feedback for the performer.
- MIDI output: The device can be connected to any other MIDI compatible device with a standard MIDI cable. It needs to only send MIDI data out to the receiving device.

The breakdown of the main features helped me to determine which were the main electronic components I needed for the project:

- Arduino Mega 2560 microcontroller (Figure 8)
- Five Parallax Ping ultrasonic sensors for detecting the distance of the hands of the performer (Figure 8)
- Five tactile push buttons to switch between the modes of the sensors
- Five RGB LED lights to provide visual feedback
- One LCD screen to provide visual feedback
- MIDI port for sending the data out

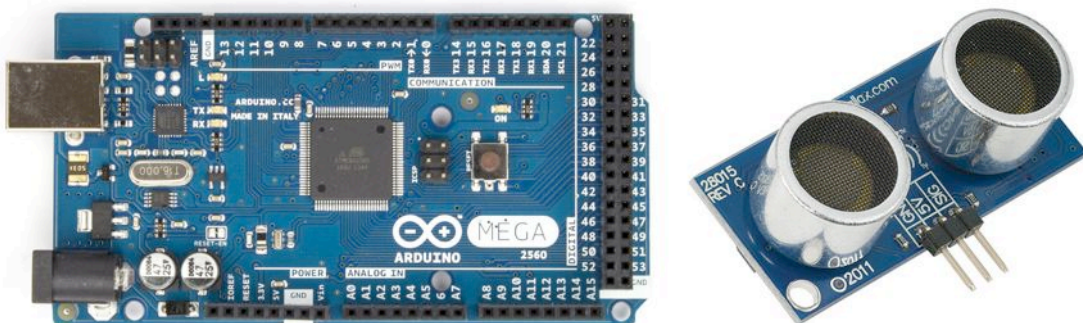


Figure 8. Arduino Mega 2560 microcontroller and Parallax Ping ultrasonic sensor



The Arduino Mega 2560 microcontroller was an obvious choice out of all Arduino boards for the project at the time of prototyping. It was the only Arduino microcontroller that had sufficient amount of analog and digital input/output pins for the UFO. The Arduino microcontroller is the most important part of the UFO as it handles the logic of the device and the real-time computing. It is running the program that is managing the following main functions:

- Receive data from the ultrasonic distance sensors and filter out all irrelevant data (i.e., errors and sensor readings from too far distances)
- Translate the sensor data to MIDI according to the selected mode
- Send MIDI data over the MIDI output port
- Control LED lights for visual feedback
- Control the contents of the LCD screen for visual feedback
- Monitor if any of the buttons are pressed and act accordingly

Receiving and interpreting the data from the sensors is one of the highest priorities of the software. The sensors repeatedly send ultrasonic sounds in 40kHz range and receive reflections (echoes) of the sounds. As we know that sound travels at approximately 340 meters per second we can calculate the distance of the reflection. The software running on the microcontroller receives a value in microseconds from each sensor that indicates the time of how long the ultrasonic sound has traveled to the point of reflection and back. Furthermore, the time value can be converted to a distance value in centimeters.

Before making the decision to use ultrasonic sensors in my project I also experimented with a few different models of infrared (IR) sensors by Sharp. These experiments revealed that the accuracy of IR sensors was somewhat lower than with ultrasonic sensors. Furthermore, the ranges of the IR sensors were not exactly suitable for my needs. Most of the Sharp IR sensors are unable to detect distances under 10 cm, and that would have caused problems for the usability.

Ultrasonic sensors, however, provided a reasonable range starting from 2 cm. Parallax Ping sensors, however, have far too long range (i.e., approximately 3 meters) that can cause other issues (more in the end of Chapter 4).

The sensors were after all plotted in a semicircle on top of the circular dome shape (Figure 9). I deviated from the original boxed design idea only not because it was less interesting but because it also proved to be impractical to place the ultrasonic rangefinder sensors next to each other in a boxed unit. The problem with the Ping sensors is that they all use the same ultrasonic frequency. This can cause the sensors to interfere and “trigger” each other if they are placed too close to each other. The ultrasonic sound signals tend to attenuate very rapidly but there is a risk that they cause ‘ghost echoes’ (Blitz & Simpson 1996).

When I built the first prototype I had no scientific calculations to support the decision behind the placement of the sensors. I simply empirically tested how the sensors would react within certain distances to each other in the circular dome shape of the controller. The top surface is arched so it can cause the beam of the sensor to be directed slightly outwards from the device. I noticed that even distribution of the sensors (Figure 9) in a semicircle on the outer rim of the dome had best results: least amount ‘ghost echoes’, an eye-pleasing symmetrical formation and it also marked a designated area for the performer. Hereafter, the sensors are referred with numbers 1 to 5 starting counterclockwise.



Figure 9. Even distribution of the five ultrasonic sensors in a semicircle ( $d$  = diameter,  $x$  = distance of the sensor from the outer edge of the device).

Symmetry ended up being present with other design decisions as well: LCD screen was placed in the middle of the dome, LED lights were placed in the same spots as the sensors (but underneath the dome) and the buttons for switching the sensor modes were aligned symmetrically below the LCD screen (Figure 10). All of these components needed to be mounted in the dome, and the original lampshade naturally had no premade holes for the components. Laser cutting was out of the question as the surface was arched; the machines at my university could only cut flat pieces. I accepted the risk of breaking the dome when it was time to use tools such as jigsaw and drill. Fortunately enough, the acrylic plastic material endured the coarse treatment and all components could be now attached to the dome.

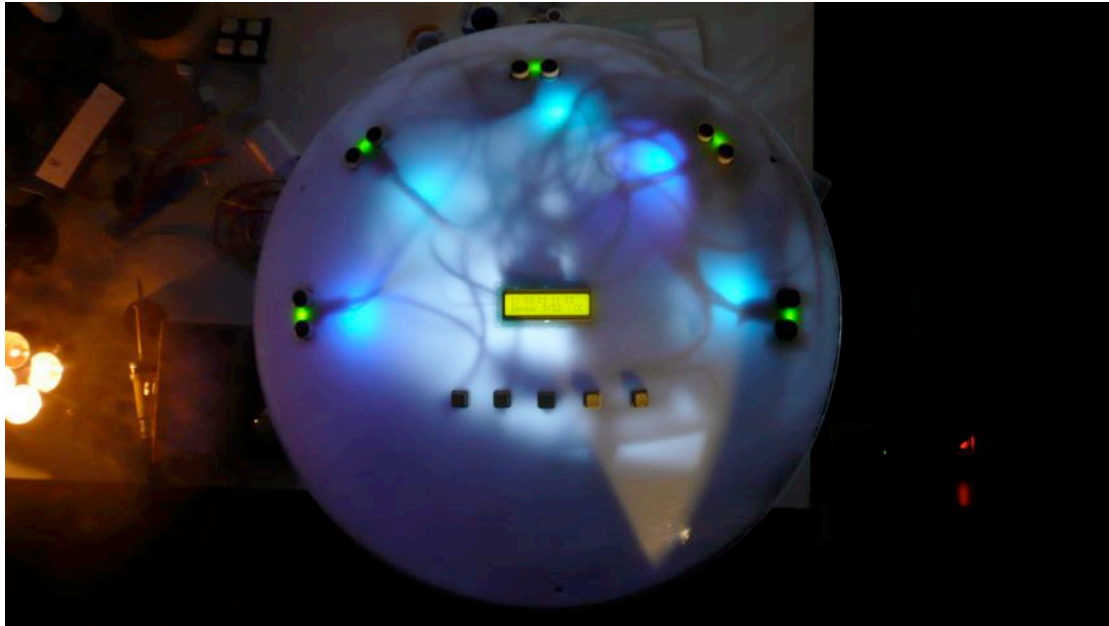


Figure 10. The first UFO Controller prototype

The arched dome also provides some space inside to hide the electronics, wiring and the overall mess of what a prototype usually is (Figure 11). I made a transparent acrylic base plate with a laser cutter to seal the device. The base plate had a small opening for connecting all the necessary external wires (power, USB and MIDI) to the device. The USB can be used to communicate with the Arduino to update the software of the controller. However, the prototype does not currently function as a USB-compliant MIDI controller. The device can be powered via the USB or an external power adapter (9V, 0.6mA).

By the end of the PID course I was not completely finished with the project. It took me around one more week and numerous trial and error iterations of development to finish a fully functional prototype device. The first prototype was inelegantly held in one piece by using hot glue, electrical tape and solder. It had no supporting mechanisms, printed circuit boards or fasteners to keep the wires in place. Nevertheless, I dared to take the prototype on the road with me and, luckily, had no problems at all. The working title of the project was “Wave-o-Matic”, which was changed to “The UFO Controller” later in 2012.

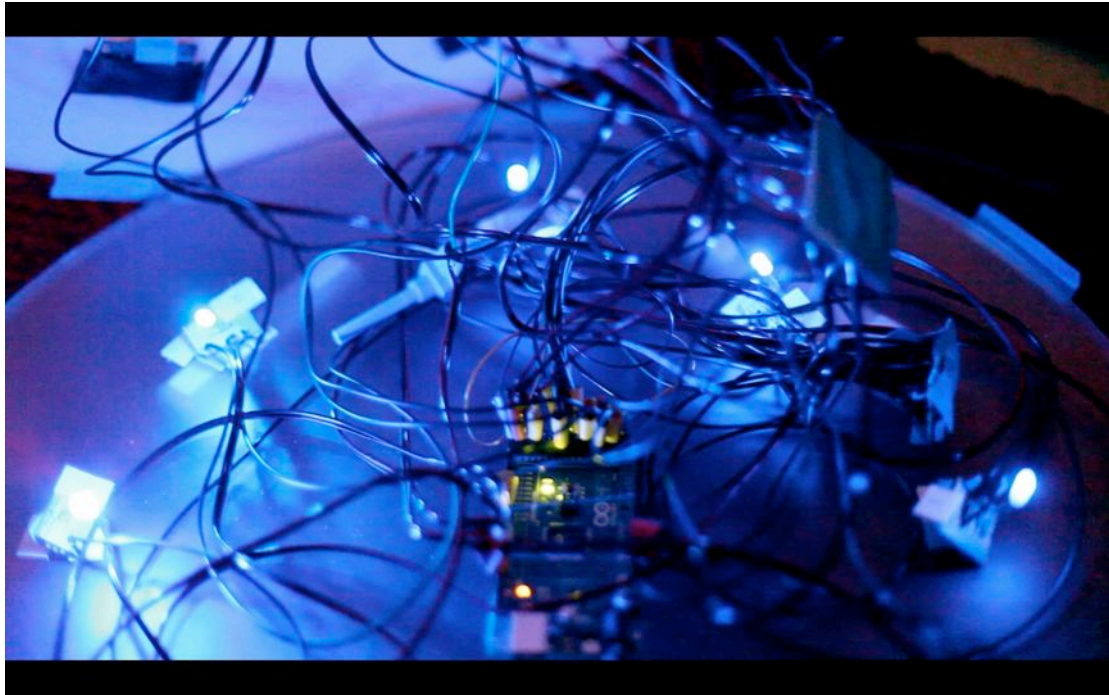


Figure 11. The formidable mess of wires inside the first prototype

## The more robust prototype 2.0

The latest UFO prototype version 2.0 was designed and fabricated in April 2014 and displayed for the first time at the Master's of Aalto exhibition in May – June 2014 (Figure 16). The work started from scratch so a new casing needed to be fabricated. This time it was time to create the prototype with the mentality that it should last long and endure possible future world tours. Here is a list of parts and actions that encompass the prototype 2.0:

### Custom-made shield for Arduino

*I designed blueprints for a printed circuit board (PCB) by using open-source software called Fritzing (2015). The PCB is a shield that can be attached on top of the Arduino Mega 2560 microcontroller. All the critical electronic components and connectors can be soldered and attached to the PCB. The PCB for the UFO was fabricated in the facilities provided by Aalto Fab Lab and Aalto Design Factory.*

*(Figure 14)*

### **Laser-cut parts**

*New UFO parts are stronger plastic acrylic components that were created with a laser cutter at the workshops of Aalto University, School of Arts, Design and Architecture. The technical templates for the laser cutter were created with Adobe Illustrator (Figure 14). The components included many smaller parts for making holder frames for sensors, lights and the LCD screen. All the parts can be connected with metal screws. (Figure 13)*

### **Support for two pedals**

*The new prototype added the feature to use the controller with one or two foot switch pedals. They add layers of extra expressivity to the modes. The pedals can be connected to the UFO with normal ¼ inch plug cables.*

### **MIDI input**

*The UFO now also receives MIDI messages via newly added MIDI IN port. The MIDI input can be used to change settings of the device and control the lights of the device. This feature was used in an exhibition last year to create rhythmical ambient light patterns for the UFO when it was not played.*

### **Stand support**

*The UFO can now be attached to a traditional instrument stand available from most music equipment stores. The connectors are attached to the new base plate of the device.*

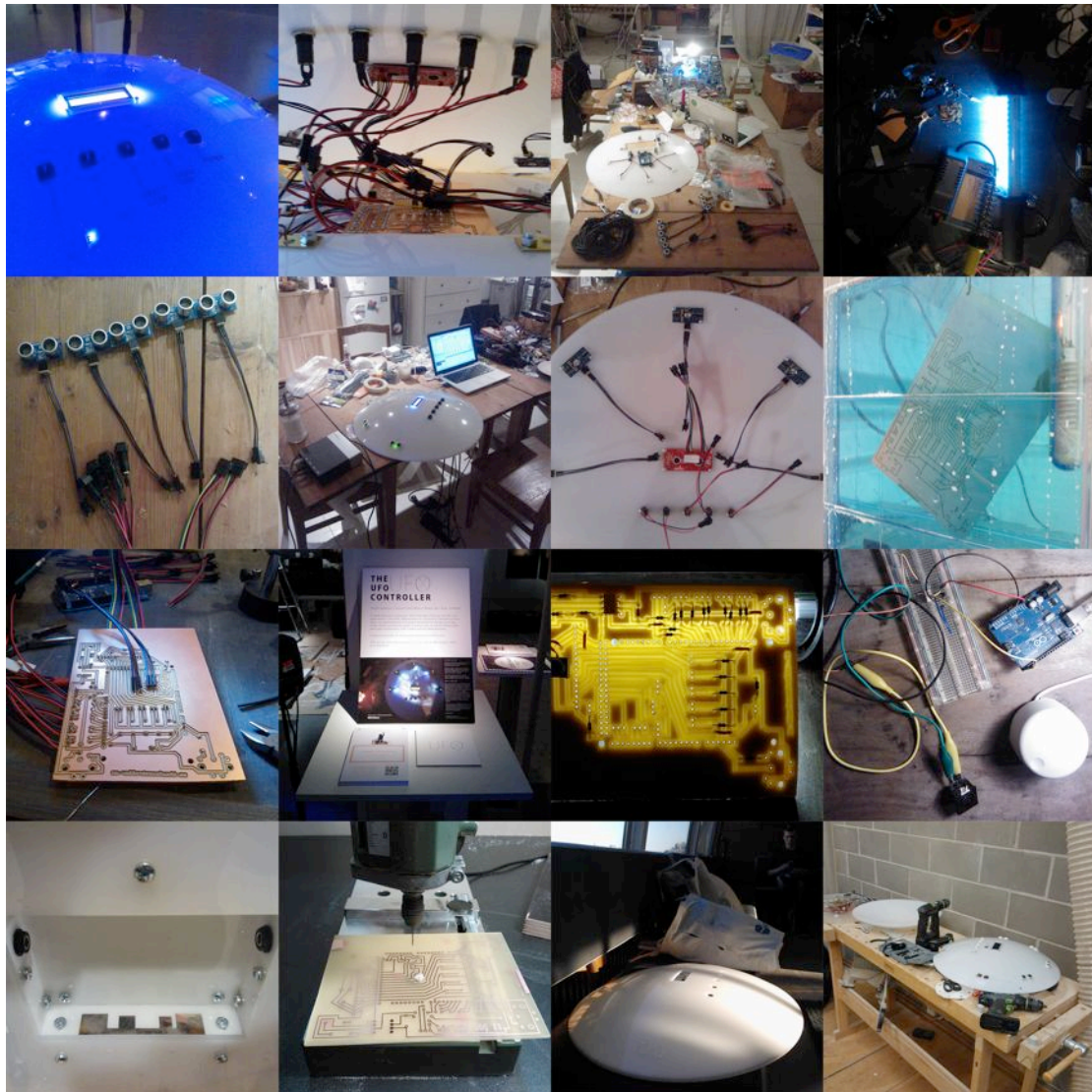


Figure 12. Pictures from various stages of the prototyping process

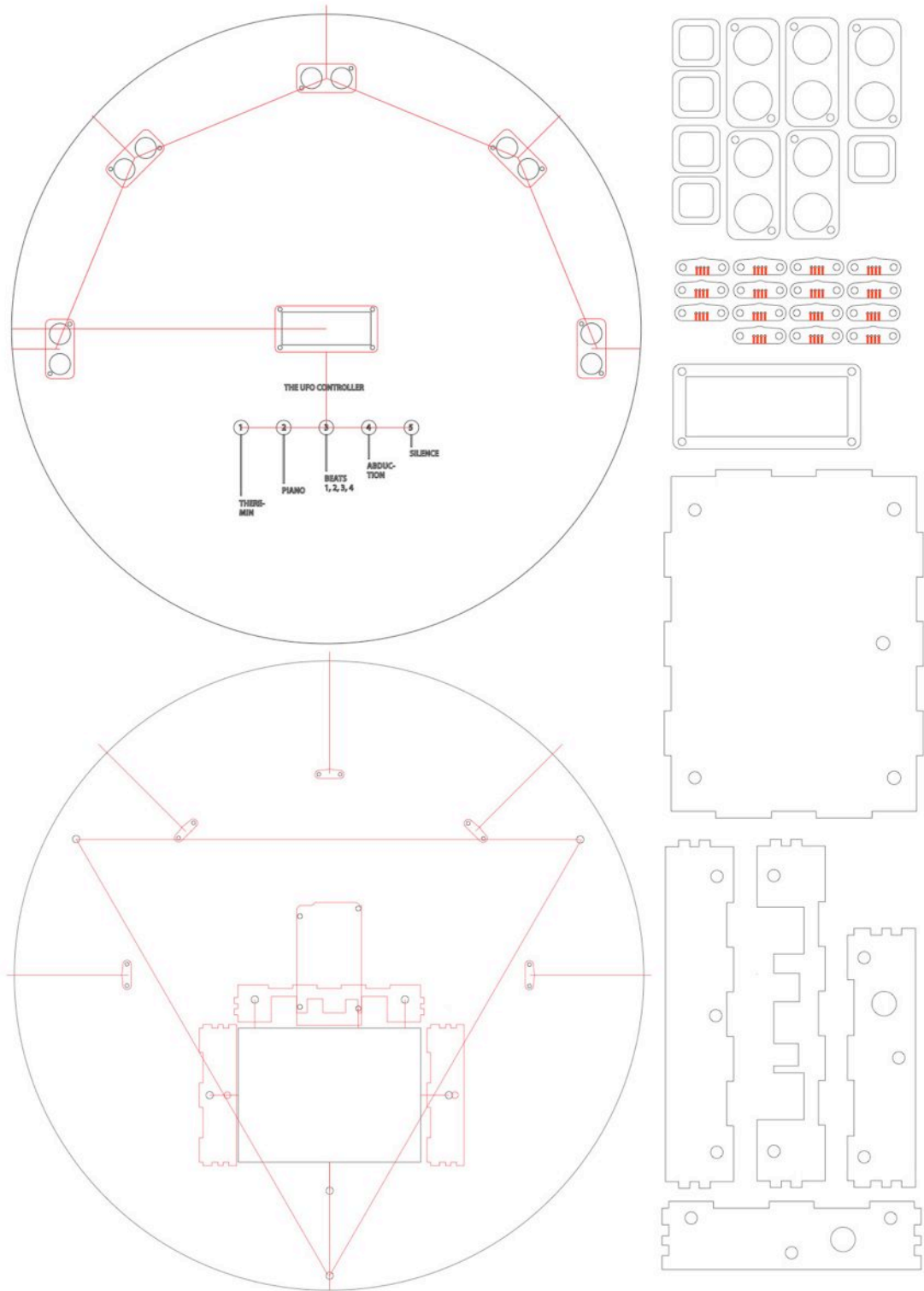


Figure 13. Technical drawings of various parts fabricated with a laser cutter



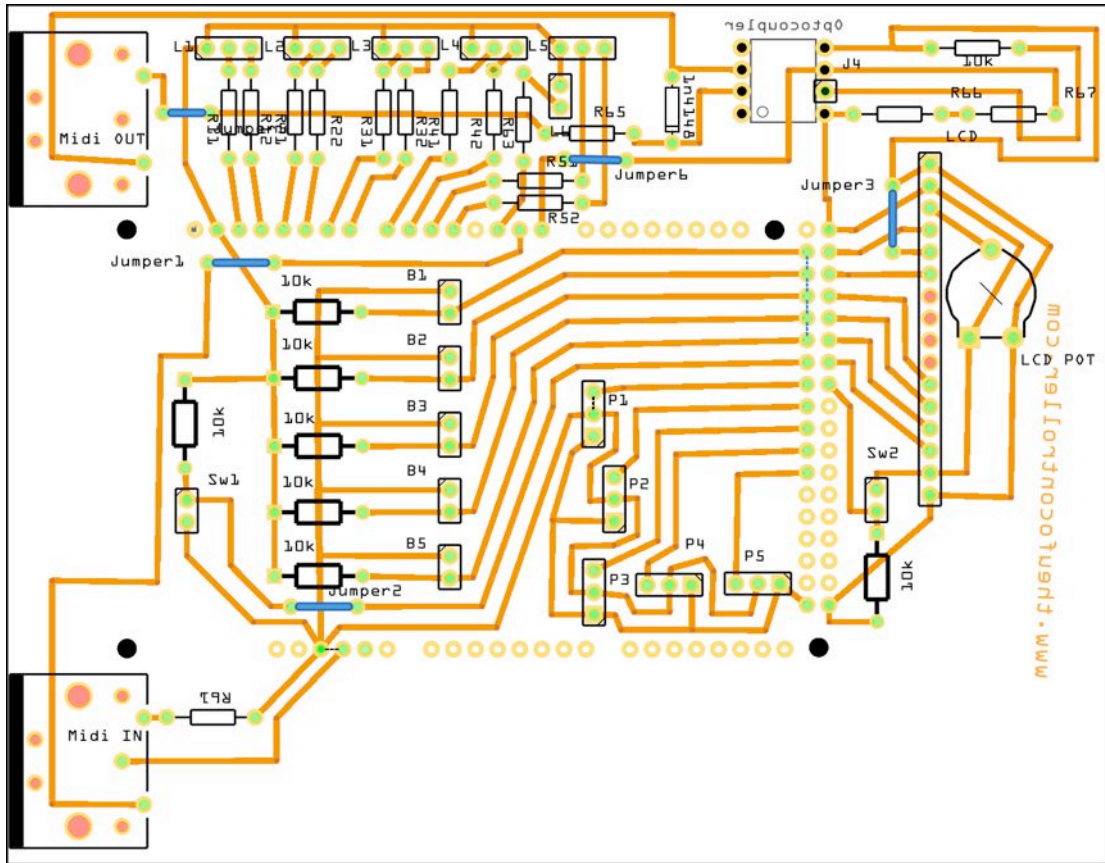


Figure 14. The design of a printed circuit board (PCB) for the UFO

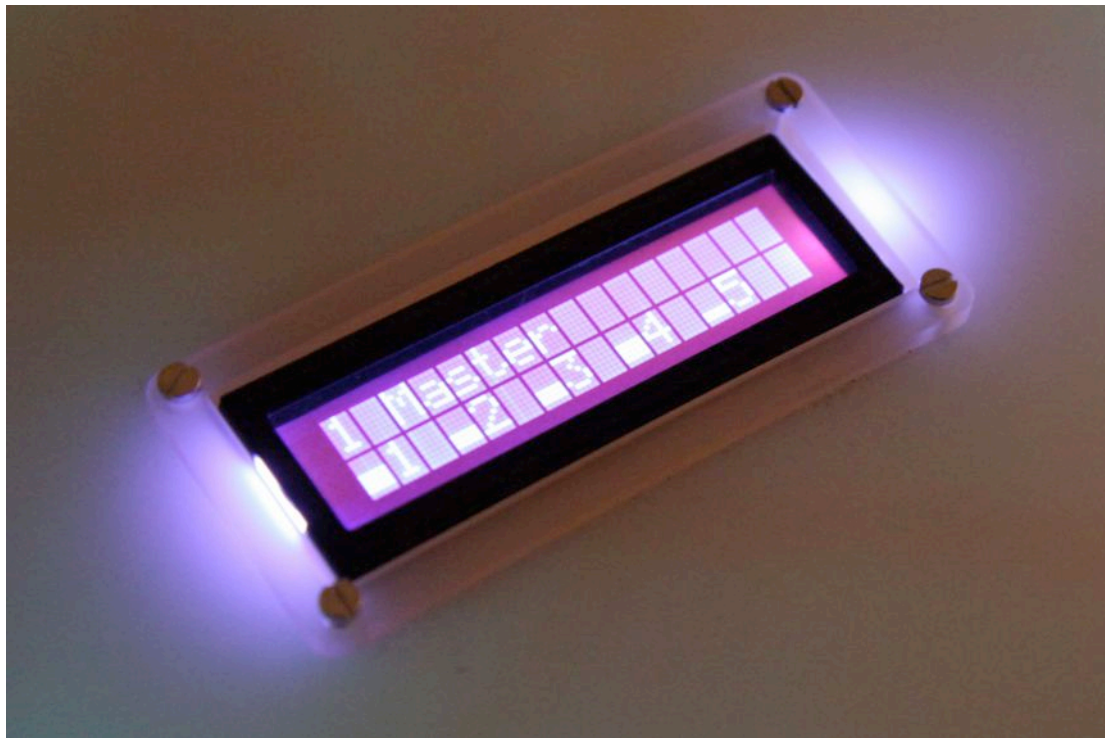


Figure 15. LCD screen showing visual feedback about the controller

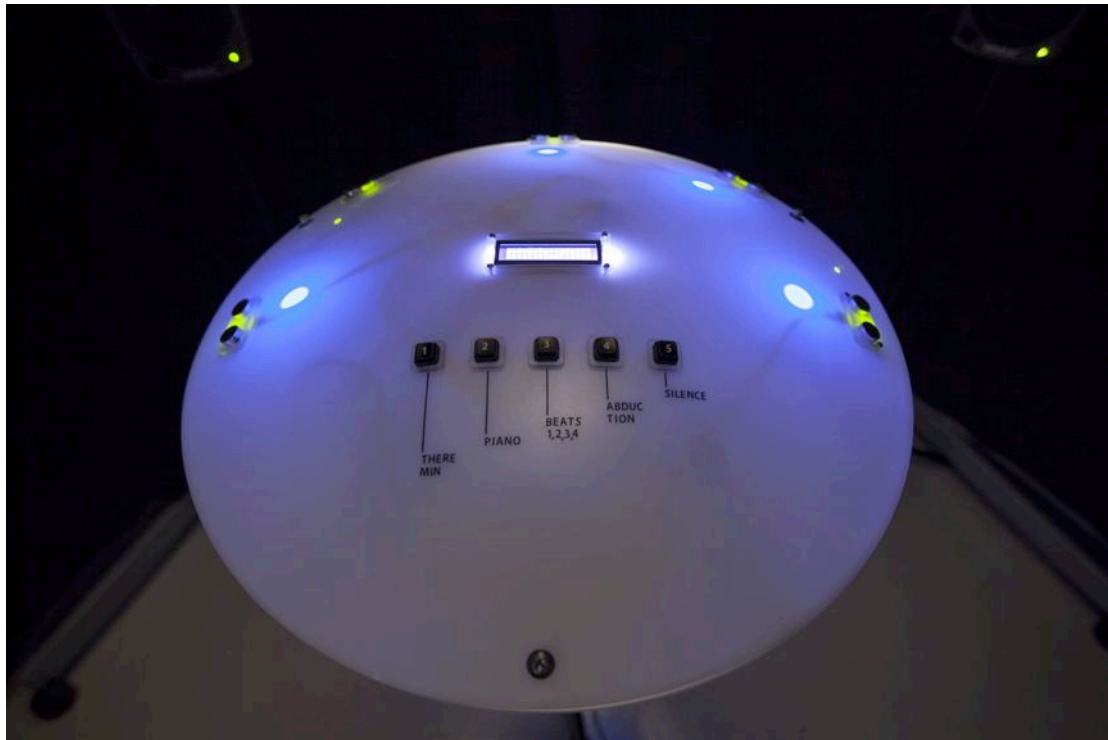


Figure 16. The UFO prototype 2.0 exhibited at Media Lab 20th Anniversary Exhibition (photo by Noora Sandgren)

## The Program

The program running on the UFO is written with Arduino and C languages. It is over 1000 lines of code in size and consists of various functions and methods taking care of different parts of the system. The methods include, for example, `determineNote()` which is used to map the notes of the Airplay mode, `sensorRead(int i)` which provides readings from a sensor (*i*) in distance units (cm) and `updateScreen()` which displays all relevant up-to-date information on the LCD screen. Musical scales for the Airplay mode are held in code tables as well. However, the code and its analysis would be too large of a topic to handle in the scope of this thesis.

## 4 Going gestural with The UFO Controller

*“The question of designing interfaces that address authenticity, that illustrate a link between action and result is therefore of paramount importance.”*

*- Garth Paine (2009: 219)*

This chapter describes the gestures for interaction and functionality of the controller. The following subchapters explain the modes of the UFO: Airplay, Performance and Scenes. By reaching the end of this chapter you will understand how the controller works and in what ways it can be used to aid performance and composition.

## Sensor space and gestures for interaction

The five ultrasonic sensors create a region for gesture interaction on the outer rim of the dome. The sensors have a relatively wide area of detection (beam), which is somewhat the size of an apple. The five beams determine the detection area where you can move your hand to play the controller. As the dome is arched, the beam of each sensor is pointing slightly outwards from the device (Figure 17). The working range of Parallax Ping ultrasonic sensors can be anything from 2 centimeters to 3 meters, but for practical reasons any reading above a set maximum distance (for example, 60 centimeters) is left out. The sensor data is filtered with a software algorithm running on the Arduino.

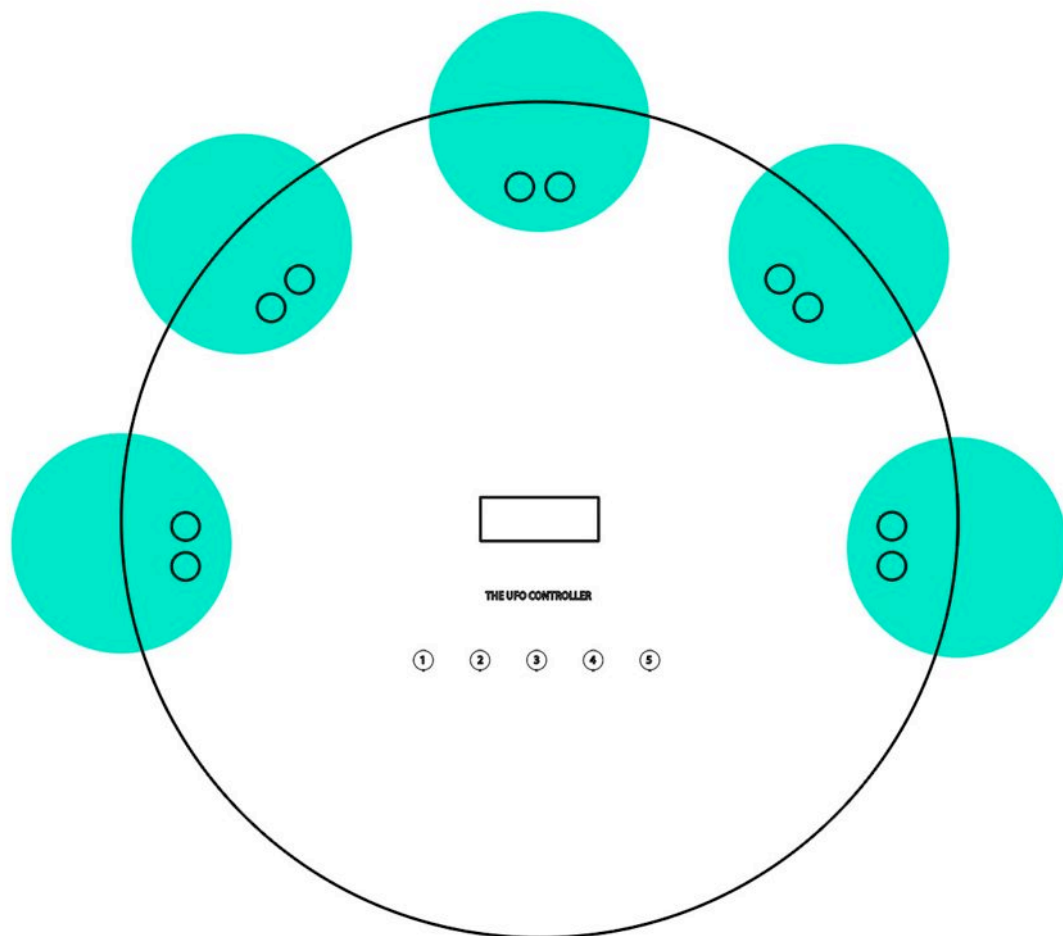


Figure 17. The rangefinder sensor space of the controller

The position of the performer is in the front of the controller when the UFO is standing on a table or a stand. It is recommended to keep the device slightly inclined towards you so the sensor space is more accessible. The position should be such that the performer will have access to all of the buttons on the device, has clear visibility to the screen and can reach all of the sensors with his or her hand. The dimension of the device can currently make it hard for smaller or shorter people to reach out to all of the sensors (especially sensor 3 in the middle), as the performer may have to reach out all the way over the device (with the diameter of 50 cm).

Koray Tahiroğlu (2008: 134) claimed that in his Experimental Musical Instruments (EMI) project the attributes of the sensors conditioned the gestures for interaction. User interface designers explain a gesture as a physical motion (e.g. moving eyes, waving a hand or tapping a surface) perceived by a system providing an immediate response to the user (Saffer, 2009). In the case of the UFO the gestures are quite simple to define, because the system is using rangefinder sensors to measure distance. As the sensor beam is narrow and points directly upward from the sensor, the performer can simply **move his or her hand in the area of the beam** to interact. While the hand is in the beam of the sensor, simple gesture to **move the hand upwards or downwards** alters the distance value being detected by the sensor. To stop the interaction with the sensor the performer can **pull the hand out of the beam**. (Figure 18)

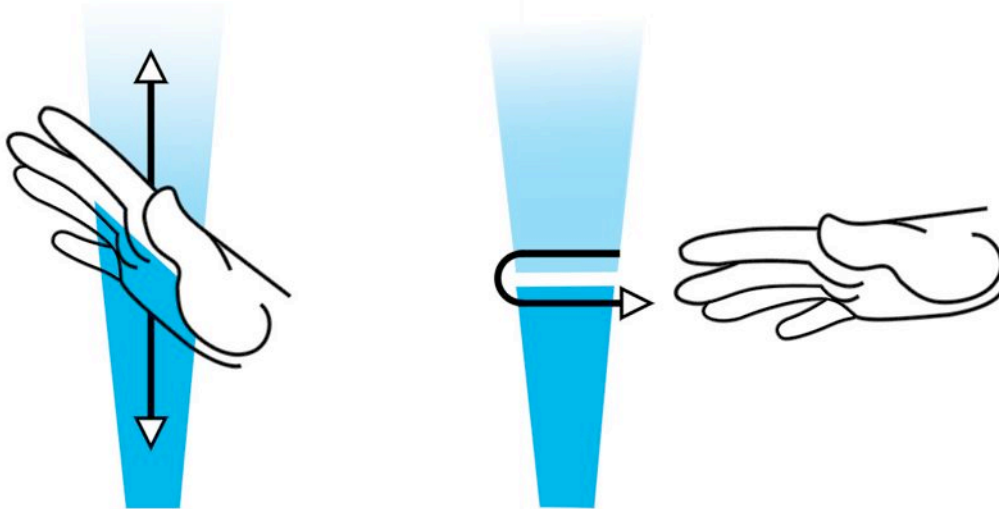


Figure 18. Basic types of gesture interaction

The most natural way of interacting with the UFO is with **two hands** (Figure 19). For example, in the Airplay mode you can play the UFO like an air-piano by using your left hand to control bass notes (from sensors 1-2) and your right hand to play treble notes (from sensors 3-5). In addition, you can connect two switch pedals to the UFO for extra expressivity and rapid switching between the modes. For example, you can use **your foot to press a tactile switch pedal** to add sustain to the notes played. Furthermore, you can change sensor-specific modes by **pressing any of the tactile buttons** below the LCD screen. The buttons change the modes in following order: Airplay, Performance and Silent.

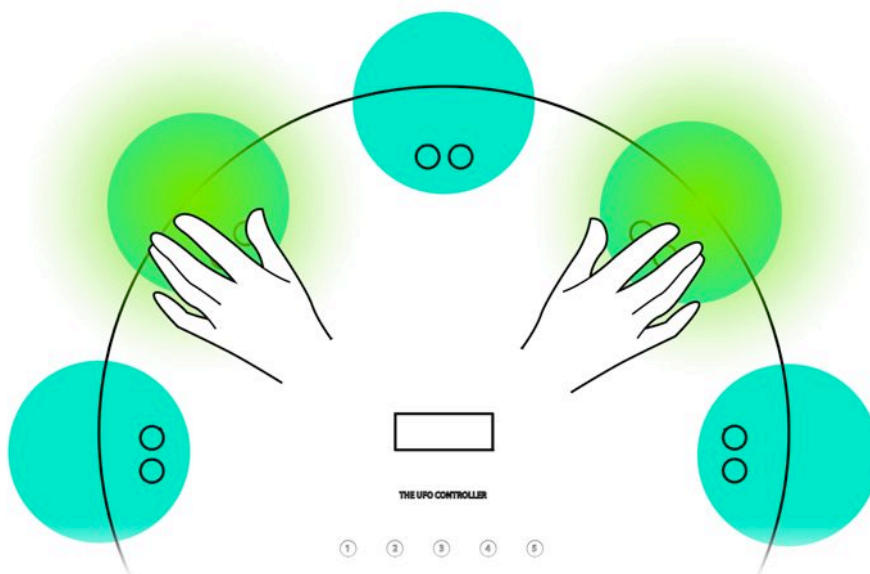


Figure 19. Playing the UFO with two hands

The device gives you visual feedback with an array of LED lights under the sensors and on the LCD screen on top of the device. LED lights are constantly visible and their colors indicate the modes of the sensors. The modes are indicated with following colors: Airplay mode is indicated with green color and Performance mode is displayed with blue color. If a sensor is in the Silent mode (toggled off) there is no visible color light. When you interact with a sensor the light underneath it becomes stronger and indicates the interaction. The LCD screen is displaying numerical and graphical information about the controller: Mode of each sensor, which sensors are active and what values are being outputted.

## Airplay mode

First of the controller modes is called “Airplay”. The mode is selected when the color of the LED light under a sensor is green. In this particular mode The UFO Controller functions similarly as a regular MIDI keyboard but without touching any keys, and it can be considered as the equivalent of playing an invisible keyboard by moving your hands in the air. In this mode each of the sensors have their own unique distribution of musical notes. The distribution of the notes for each sensor is affected by following factors:

- Sensor number (1, 2, 3, 4 or 5)
- Root key (C, C#, D, D#, E, and so on)
- Musical scale (Major, Minor, Ionian, Lydian, Phrygian, and so on)
- The maximum detection distance (for example 63 cm)
- The threshold distance for changing a note (for example 9 cm)

The algorithm running on the Arduino microcontroller software will take all of the preceding factors in account when it creates MIDI notes out of hand gestures. The algorithm will start from the root key of the scale in the lowest octave and continues to place subsequent notes from the scale in the ‘invisible grid of notes’.

Figure 20 shows how the note distribution works for a major scale in C with maximum distance detection set to 63 cm and threshold for changing notes set to 7 cm. The example above has uneven distribution: Every sensor has a certain offset from the distribution and none of the sensors start from the same key. The uneven distribution is great for experimenting with melodies and chords as a single horizontal hand wave gesture can create quite unique note combinations.

63 cm					
56 cm	D2	F3	A4	C6	E7
49 cm	C2	E3	G4	B5	D7
42 cm	B1	D3	F4	A5	C7
35 cm	A1	C3	E4	G5	B6
28 cm	G1	B2	D4	F5	A6
21 cm	F1	A2	C4	E5	G6
14 cm	E1	G2	B3	D5	F6
7 cm	D1	F2	A3	C5	E6
0 cm	C1	E2	G3	B4	D6
	<b>S1</b>	<b>S2</b>	<b>S3</b>	<b>S4</b>	<b>S5</b>

Figure 20. Distribution of notes for the sensors (S1-S5) in major scale in C with the maximum distance for detection at 63 cm and the threshold for changing a note set to 7 cm.

When your hand is above any of the sensors it will play a note according to the distribution of the notes. The note will be sustained (as a legato note) until your hand is pulled out or moved up or down. Pulling your hand out ends the note, moving your hand up by the amount of threshold distance ends the note and plays the next note in the selected musical scale, and moving your hand down the same distance ends the note and plays the previous note. For example, striking



through all of the sensors from left to right at the height of 28 to 35 centimeters would play a sequence of notes G1, B2, D4, F5 and B6 (Figure 21).

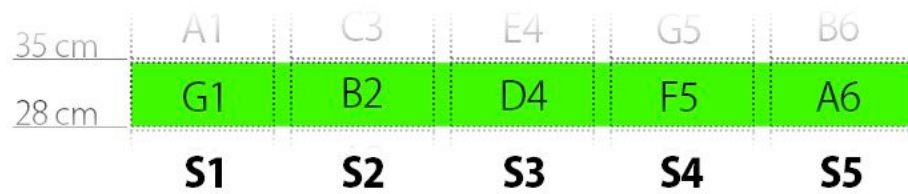


Figure 21. Playing notes from the height of 28 to 35 cm

The Airplay mode is intended for improvising melodies and chords, but it can be challenging to play written melodies precisely (e.g., any existing pop song or classical music melodies). For improvisation, there are some techniques that provide more control and nuances. First of all, the notes are played as short staccato notes if the hand movement passes rapidly through the sensors. Secondly, the notes can be played as legato notes with a slower motion over the sensor space. Finally, the notes can be played as sustained notes with a sustain pedal; If the pedal is pressed and held down and notes are played, they will be sustained until the pedal is released. Playing with both hands is advantageous, as you can, for example, use the left hand to control bass notes and the right hand to control mid or high frequency notes (Figure 22).

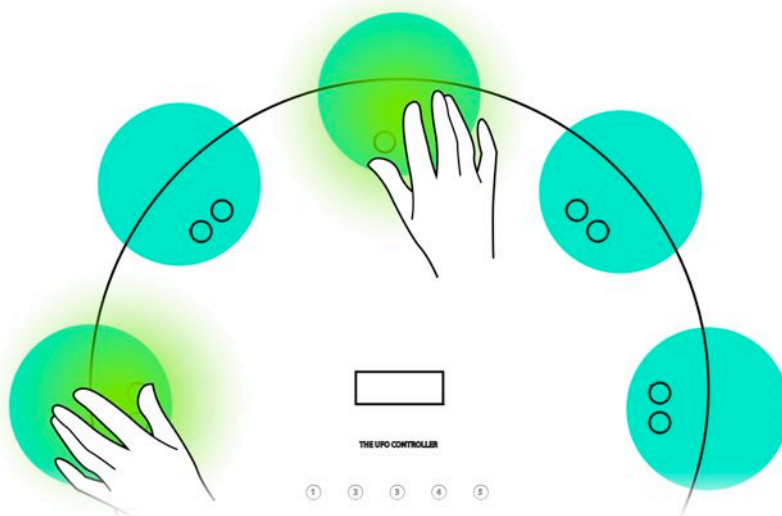


Figure 22. Using two hands to play low and mid frequency notes simultaneously

Normally you can play up to five simultaneous notes at once (as there are five sensor channels) if you extend your arms over all of the sensors. However, playing while holding the sustain pedal can build the polyphony up to 16 notes. In addition to the pitch (key), MIDI note also contains data about the velocity of the sound (a value between 0 and 127). These velocity values are currently generated randomly with a configurable amount of variation. Normal variation for MIDI velocity values when playing the UFO is spread from 50 to 100.

During the performance you can change the root key and musical scale at any time. The root key can be changed from a menu that opens by holding the leftmost button for two seconds. Furthermore, the scale can be changed from another menu that is accessed by holding the rightmost button for two seconds. While the menu is open you can use the leftmost and rightmost sensors to select the key or the scale, and the selection is shown on the unit display.

## Performance mode

Second of the controller modes is called “Performance”, which allows the sensors to send continuous controller (CC) MIDI messages. Performance mode is selected when the color of the LED light under a sensor is blue. The CC messages are commonly used to alter parametrical (numerical) values in software and synthesizers. A single CC message consists of a controller number (0-127) and a value for that (0-127), and the controller numbers can be customized for each sensor. Therefore, every sensor in Performance mode sends a value between 0 and 127 with a specific controller number when their beam is blocked from any point below the maximum detection distance (which is same as it is for Airplay mode, usually around 60cm). The UFO remembers the last CC value played with a sensor and stores that for the sensor. This means that if you pull your hand out from the beam the value will stay in the last measured distance. The value is shown graphically on the LCD screen.

CC messages are normally used to control synthesizer parameters such as pitch modulation, volume or effect depth. The MIDI standard allows these messages to be mapped to any parameter in a DAW application running on a computer. This mode is the most used in my own performances. It can be regarded as the same kind of action as turning a knob in your MIDI controller, but doing it in the air instead.

## Scenes mode

Third of the controller modes is called “Scenes”. It was originally used to create an instrument-like exhibition version of the UFO and was first presented at the Masters of Aalto (MOA) exhibition in 2014. It adds features to connect with an Ableton Live patch that has a preset library of four unique instruments I created for the UFO. It is an additional code branch that was uploaded to the Arduino before the exhibition. The mode differs from the aforementioned modes in following ways:

- Each button triggers a unique scene and modes for the sensors (Figure 23)
- In each scene, the sensors can arbitrarily be in Airplay, Performance or silent modes
- The scenes are connected with virtual Ableton Live instrument patches
- Fifth button triggers a scene called “Silence” which stops all audio

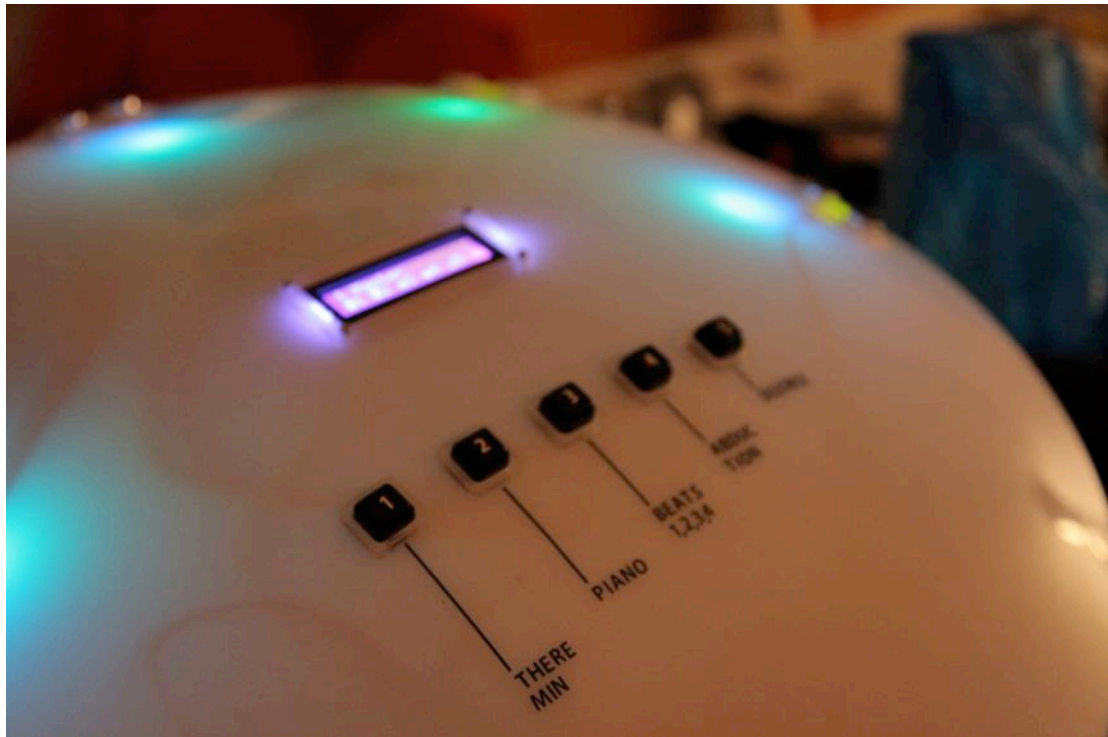


Figure 23. In the Scenes mode buttons are used to switch between various virtual instruments

The five available presets for the MOA exhibition were:

1. Theremin
2. Piano
3. Beats (1,2,3 and 4)
4. Ambient
5. Silence

Each preset had a special sound design for the corresponding virtual instrument. Piano sounded like what you could expect it to sound and so on. The computer running Ableton Live was hidden in the exhibition, and most of the visitors thought that the UFO was an actual instrument creating all of the sounds. Even though it was an illusion in a way, it was the first time the UFO was prototyped as a stand-alone instrument, which is a possibility for future development.

## Potential usability problems and resolutions

Playing with a new controller prototype is fundamentally an experimental trial-and-error process, in which you constantly try new things with the controller and learn from the results. Tahiroğlu (2008: 136) explains that control difficulties, badly designed interaction and usability problems can disrupt the communication between a musician and the instrument. In worst case, they can even stop the evolution of the instrument (Tahiroğlu, 2008: 136).

The expectations for new controllers using digital technology are naturally very high as a result of the tradition and articulative depth of acoustic instruments (Tanaka, 2009: 254). The history of most traditional instruments spans over two centuries and it has allowed the instrument makers to refine them to the highest level of standards. This should be kept in mind, especially, when a new prototype has been in development for a noticeably shorter amount of time. **First thing that the UFO lacks in comparison to traditional instruments is tactile feedback.** This can lead to problems especially in terms of control when you are inexperienced in playing the controller. Siegel (2009: 198) claims that instruments without physical resistance can be difficult in learning to play. The Theremin has exactly the same problem, and the playing of the instrument was extremely hard to learn (yet it still remains relatively popular). The UFO, on the other hand, is aided by modes such as Airplay and performance to make your performance easier. Therefore, the musicians playing the controller could think it in a way that they are controlling or conducting the performance instead of playing an instrument.

Performing with the UFO is intended to be easy, fun and straightforward experience for professional musicians, and with assistance of pre-defined instrument patches it should be accessible for users who have no previous knowledge of playing any musical instrument. **The mapping of the MIDI control data to a device capable of creating sounds requires some prior knowledge in electronic music instruments.** However, when everything is set, the modes (such

as Airplay) make musical improvisation easy and allow users to play a broad range of musical melodies, even without having any knowledge of music performance or theory.

**Velocity changes in the Airplay mode are currently randomized and this reduces the amount of musical expressivity of the performer.** Velocity control could be resolved by calculating the distance and time your hand travels in a sensor beam before stopping. The distance and time could be used to calculate a velocity vector but by calculating the velocity this way the attack of the sound would not be instantaneous and could be expected to be audible only when your hand stops. This is a known problem with gestural analysis. It takes time to interpret gestures, since the gesture must be finished before it is possible to analyze the expressive content (Siegel, 2009: 201). This causes the system to always 'be "one step" behind' (Siegel, 2009: 201). However, with more sophisticated gesture analysis and artificial intelligence, the gestures could be predicted with even higher precision. Alternative solution would be use to the initial height of the gesture to determine the velocity. Nevertheless, this issue needs further investigation and prototyping.

**"Ghost echoes" can disturb the sensors and cause the controller to behave unusually in small or narrow spaces.** This problem persists with the current Parallax Ping ultrasonic rangefinder sensors as a result of their range (3 meters) and shared frequency. If the UFO is played in a very small room, the ultrasonic sound of a sensor can travel across the room and be picked up by another sensor. Usually it helps to remove any obstacles or objects from the direct vicinity of the sensors. This problem can be addressed by trying to change the sensors to more suitable ones (shorter range and differentiated ultrasonic frequencies).

**The prototype units are quite fragile and they would need a reinforced long-lasting casing, which can be designed with the help of an industrial designer.** Additionally, **the ultrasonic sensors are not protected from dust or fluid spills** during the performances as the sensors are attached to the UFO dome. This can be

addressed by researching alternative rangefinder sensors that could be placed underneath a protective material (e.g., foam, transparent acrylic, metal grill). In this case, ultrasonic sensors are likely out of the list because they should not be blocked with any absorbing material. This would most likely lead me to investigating optical sensors (IR) and using a transparent non-refractive material to protect it.

## 5 Gestural free-space instruments

*“All musical instruments are tools that map human motoric input on an acoustic output.”*

*– Godfried-Willem Raes (2007)*

This chapter discloses some of the already existing instruments and music controllers that are based on the free-space gestural interaction. Waving your hands in the air to interact with user interfaces is not a recent innovation like you could easily imagine. It has been popularized in sci-fi movies like *Minority Report* but free-space gestures were already used in electronic music almost 100 years ago. In chronological order this chapter explains the characteristics of each instrument and controller, when they were invented, how their interaction works and how they differ from the UFO.



## Theremin

The most notable invention in this field is the Theremin (1919, initially known as Termenvox) by Russian inventor Léon Theremin (1896-1993). The instrument is often mentioned in the history of electronic music as the first instrument that can be played without touching it. Léon Theremin rejected the traditional piano keyboard and fingerboard based interfaces and created a device that could be played with free-space hand gestures. The Theremin looks like a wooden box (usually sitting on a stand)



Figure 24. Léon Theremin and his eponymous novelty instrument Theremin

with two antennas pointing out of it (Figure 24). The Theremin is controlled by not touching the device but by adjusting the distance of your hands to the two antennas. One of the antennas is controlling the pitch of the sound, and the other one is modulating the volume. (Glinsky 2000, Collins 2007)

The basic operation principles are based on electromagnetic interference. Léon Theremin, working in his laboratory in St. Petersburg, initially noticed that by moving his body around an electromagnetic field created by an oscillator of the device changed the emitting frequency of it. He observed that his human body could hold some of the electric charge created by the electromagnetic field (effect known as natural capacitance in physics). He amplified the signal to create an audible effect out of this phenomenon and added one oscillating circuit for volume control and two antennas to control the electromagnetic capacitances. The antennas are functioning as plates of capacitors that can be used to measure variances in the electromagnetic field. This fluctuation of electromagnetic fields is

used to affect the radio frequency oscillating circuits (controlling volume and pitch). (Glinsky, 2000; Grimes, 2015)

The Theremin is well known for being a very challenging instrument to master due to the fact that the pitch and the volume controls are not controlled in steps like with normal keyboard or fingerboard instruments. The performance requires a tremendous amount of practice because of the analogous free-space control. The performer needs to be able to hear and distinguish note frequencies, as it is possible to play all the pitches outside the Western tuning. Not only is the playing technique uncommon but also the sound of the Theremin is unique due to the elementary vacuum-tube oscillator technology. It makes a simple and sweeping electronic tone that is often characterized as mysterious, eerie and original. This description also had greatly to do with the fact that the Theremin concerts were experienced as highly theatrical and bizarre performances. There were not too many performers who could master the instrument but one of them, Clara Rockmore (1911-1998), amazed her audiences with her virtuoso Theremin playing skills and helped to establish the legendary status of the instrument (Figure 25). (Byrne 2012, Glinsky 2000, Théberge 1997)



Figure 25. Clara Rockmore was the most known Theremin virtuoso

The instrument received most attention in 40s and 50s when it was used in numerous Hollywood movie soundtracks (mostly in science fiction and psycho-dramatic films such as *Spellbound* in 1945 and *The Day the Earth Stood Still* in 1951). The popularity of the Theremin continued with the best-selling song *Good Vibrations* by Beach Boys in 1966. The popularity of it diminished over the

decades due to various reasons, such as the difficulty level of playing the instrument and the fact of not being properly able to alter the timbre of the sound being played. The Theremin, now being an instrument with a cult status, still

remains a curiosity on the concert stages. However, the crowds, who have seen the Theremin being played live, concur to the fact that it is an impressive and powerful live performance instrument. The remarkability comes from the unordinary free-space gestural control, the unique sound and the appearance of the instrument. The positive effect of the Theremin in the domains of electronic music, popular culture and the innovation of electronic music instruments is indisputable. It has opened up the world of free-space control for new generations of inventors and artists. Furthermore, Theremin instruments are still being produced and manufactured by Moog Music in the USA. (Glinsky, 2000; Collins, 2007; Byrne, 2012; Théberge, 1997)

The UFO Controller has quite similar method of playing as the Theremin, as both instruments are played with free-space hand gestures. Even though there are similarities in the gestural control, I regard the UFO as a new kind of interface for musical expression. It is a unique device with original features and MIDI capabilities, but it also introduces completely new sensors and gestural actions for playing the instrument. The technology underneath is very different in the two, and it should be noted that the UFO is not capable of producing any sound synthesis on its own.

## Radio Baton and Conductor

Radio Baton (also known as Radiodrum) is a free-space musical instrument that can be played by waving two mallet sticks in a three-dimensional space. The instrument fundamentally works in similar fashion as the Theremin but uses radio frequencies to measure capacitance. The mallets (that look like drum sticks) function as radio wave transmitters and are connected with wires to a table-like surface that contains an array of receiving antennas (Figure 26). The surface can be used to measure precise three-dimensional positions (x, y and z coordinates) of the mallets sending the radio signal. Unlike the Theremin, Radio Baton makes no



Figure 26. Max Mathews playing the Radio Baton

sound but functions as a controller for another devices (e.g. a synthesizer or a computer) that create sounds. (Mathews, 1991; Schloss, 2015)

The Radio Baton was initially designed to function as a three-dimensional computer mouse by Bob Boie working at Bell Labs in the mid 1980s. Thanks to Max Mathews, a computer and electronic music pioneer also working at Bell Labs at that time, the Radio Baton found new use cases for electronic music performance in his hands. (It should be noted

that Bell Labs is regarded as one of the largest sources of innovation contributing to the electronic music technology used in studio environments today. In the 60s and the 70s, devices such as harmonizer, pitch shifter, digital delay and vocoder were invented in the experiments carried out in the laboratories.) In the late 1980s, Mathews created a computer program called Conductor that can be used to perform sequences of pre-programmed songs by using the Radio Baton mallet sticks. The main idea is to wave your hands with the mallet sticks like a conductor of an orchestra. The nuances of your hand gestures trigger new notes or melody passages from the predetermined sequence being played. The gestures also affect various sonic parameters and tempo of the sequence. The Conductor sends MIDI notes and CC values to an external synthesizer or computer that handles the playback and synthesis of the music. (Mathews, 1991; Byrne, 2012)

Mathews (1991) argued that traditional instruments took a tremendous time to learn and that was a prerequisite to expressive performance. Additionally, he claimed that the inability to master an instrument or to play note sequences correctly was one of the main reasons why amateur musicians discontinued playing the instrument. Furthermore, Mathews believed that computer aided music (with program such as the Conductor) can make music easier to perform

and help musicians to pay more attention to expression than just technique (e.g., memorizing notes for songs, practicing muscle memory and making very demanding muscle movements during the performance). Little did he know back then that the computer aided music programs and instruments permanently changed the whole domain of electronic music production and performance. The features of the Conductor and the gestures used to play the Radio Baton were an inspiration for the gestural mapping and sound design of my live sets with the UFO.

## Laser Harp

French lightning designer, visual artist and composer, Bernard Szajner, had no classical background in music and could not play any traditional instrument properly, but got into music after a history of creating laser and light shows for numerous



Figure 27. Bernard Szajner playing his version of Laser Harp in 1980

European bands. In 1979, he started composing electronic avant garde

music with classic synthesizers of the time. For his live shows, he created a device called the Laser Harp (1980) that was connected to an array of synthesizers through a digital sequencer device called the Polysequencer MDB. It was unable to produce any sound on its own but it was one of the first custom-made electronic music controllers of the time. (Nice, 2009; Szajner, 2015)

Szajner built his first Laser Harp into an upside-down triangular cardboard frame with a wall of laser beams pointing up from the bottom tip of the triangle (Figure 27) (Nice, 2009). The controller was played by blocking any of the laser beams from any point in their path (Tanaka, 2009: 240). The device contained optical sensors that could detect if any of the laser beams were interrupted. In most Laser Harp

adaptations, each of the beams is assigned with a unique note that is played when the beam is interrupted.

In early 1980s, the Laser Harp was a monumental controller that the concert crowds had not previously experienced. It complemented the performer with exceptional novelty and showmanship value. It is no wonder that the invention caught the attention of another French artist, Jean Michel Jarre. He asked Szajner to build a Laser Harp for his tour in China in 1981 (Nice, 2009). Szajner agreed and the rest is history. Jarre continues to use the instrument even today, and it has endured the strains of time and remains a signature highlight of his concerts. Ever since, Szajner has refrained from using the instrument himself.

The UFO can be regarded as quite similar controller to the Laser Harp. The methods of interaction are strikingly similar: moving your hand into a beam causes a musical effect and pulling the hand out stops the effect. With both devices, the effect is accompanied by visual feedback: The UFO illuminates the LED light whereas the laser beam of the Laser Harp is cut out. The difference between the two is that the Laser Harp is not measuring distance and is not capable of detecting up-and-down movement (distance). Some modern adaptations of the Laser Harp have rangefinder sensors next to each laser beam, which can be used for additional expressivity.

## D-Beam



Figure 28. Roland MC-505 with D-Beam technology

Roland introduced a new hand-gesture interface called the D-Beam for the Roland MC-505 (groovebox) in 1998 (Figure 28). The D-Beam utilizes a simple infrared sensor (facing upwards, embedded in the device panel) that can detect the distance of your hand from the sensor spot in close proximities (i.e., up to 30-40cm range)

(Wikia, 2015; Wikipedia, 2015). It can send continuous control (CC) MIDI data, which can be used to control assignable effects of the device (Tanaka, 2009: 240). Roland has incorporated the D-Beam in some of their more modern synthesizers with two separate sensors (beams). D-Beam is used mainly for expression, modulating different effects and parameters of the device, instead of playing notes or pitches. The most common mappings for the D-Beam are to use the sensor to control pitchbend, filter frequency cutoff or resonance. D-Beam is very similar to a single sensor in the UFO, but what differentiates the UFO from the D-Beam is the fact that the UFO can support longer distances, it works with ultrasonic sensors and has multiple sensor spots. Tanaka (2009: 240) claims that similar kind of 'sound-beam system' is being used as a 'dedicated controller for music therapy applications'.

## Moog Theremini

Theremin is not a new instrument any more, but it would certainly attract more players if it would be easier to play. Moog Music realized this and the rising demand for novelty electronic music instruments. They released a modern version of the Theremin called Theremini in 2014 to fill in a potential gap in the marketplace, and the Theremini addressed the most known shortcoming of the Theremin: it was too hard for most people to play and learn properly. The Theremini has a feature that automatically tunes the frequencies of the output signal to the notes in the Western music (Fortner, 2015). Additionally, you can set the automated tuning to follow a certain root key and a scale (from a comprehensive list of known musical



Figure 29. Moog Theremini

scales) (Fortner, 2015). The Airplay mode in the UFO works in a similar fashion, but without the sound synthesis. The tuning feature, the modern synthesis engine, the editor software (that allows you to design your custom presets) and the well-known Moog brand have made the Theremini accessible to a larger consumer group than ever before. I have not played with a Theremini yet, but it certainly sounds promising as it lowers the notorious threshold of difficulty to start playing the Theremin. The Theremini can be a great instrument but it certainly lacks the scale and versatility of a comprehensive MIDI controller with multiple sensors. It should be also noted that Bob Moog (founder of Moog Music) actually started his career in electronic music instruments by building and selling his own Theremin units in the 1960s (Glinsky, 2000).

## Microsoft Kinect

Motion sensing has taken gigantic leaps since the introduction of the Theremin. One of the most recent innovations in the field is a motion control device developed by Microsoft for the Xbox game consoles and Windows PCs, called the Kinect (Microsoft, 2015). It is a natural user interface device that allows the users to interact with the host device (e.g., Xbox) by using their body gestures and spoken language (recognized by the voice recognition algorithm). Kinect is a proprietary device and includes a normal RGB camera, a depth sensor and a cluster of microphones. The depth sensor uses an infrared laser projector to capture 3D video data in any lighting conditions, which enables the Kinect to work even with the lights off. The most advanced feature of the Kinect is the ability to track up to six people by using the depth sensor and microphones. Furthermore, while it tracks people, it extracts their features (e.g., facial recognition, position and movement of the physical body and joints) and motion (i.e., velocity of joints in their bodies) for the Kinect applications to use.

After the initial launch of the Kinect for Xbox 360 in November 2010, the device was hacked within a week and the release of open source drivers followed. Since





Figure 30. The original Kinect for Xbox 360

then, the original Xbox 360 Kinect has become one of the favorite gadgets of all media artists. It is inexpensive and reliable solution for heavy-duty motion capturing and

there are hundreds of online tutorials and hacks available for it. The Kinect has also been used to create various gestural interfaces for making music, such as Kinectar Performance Platform and NI mate (Jean, 2012: 94; Delicode, 2015a). The Kinectar is an application that allows you to easily map relevant body gesture information to MIDI data and send it to your music software or synthesizer (Jean, 2012: 98). The NI mate, primarily a tool for motion capturing, does the same thing as the Kinectar but also introduces virtual triggers that you can activate with your gestures (Delicode, 2015a). Fundamentally, they are invisible triggers in the physical space around you that can be used, for example, to trigger samples and toggle effects in Ableton Live (Figure 31).



Figure 31. NI mate and triggers working in Ableton Live

As these Kinect applications provide vast quantities of real-time data from your body position and motion, a question arises: How to use this data in your music

performance? This so-called mapping problem has been faced in countless contemporary music, dance and theater performances that have utilized the Kinect for free-space gesture interaction, and yet there is no standardized solution for it. The optimum solution for mapping is probably discovered with an iterative trial-and-error process and with a lot of patience. I personally found the Kinect to be suitable for occasional experimenting in the studio, but not convenient enough to become my plug-and-play go-to tool in the music production and performance. Nevertheless, I have thought about the following question: Could the Kinect replace my UFO? A Kinect application could basically detect my hand gestures in a similar way as the UFO does, but there are few issues in the gesture recognition of the Kinect that have negative impact on usability:

1. Kinect applications pose a latency of approximately 200 milliseconds that is unacceptable for time-critical music performance
2. The resolution of the original Kinect is really coarse (i.e., causes imprecise values) and can cause rounding issues for body gestures. The new Kinect for Xbox One has significantly higher resolution and (probably) does not have similar issues.
3. The Kinect can act unreliably when played in sunlight or in a smoky club due to the infrared sensor technology

Latency is actually one of the most harmful factors when music performances are considered, and one-fifth of a second (i.e., latency of 200 milliseconds) can be really disruptive for a performer who is used to receiving immediate feedback from his or her gestures. I have felt this kind of latency as a disconnecting aspect in a live performance that has even prevented me from performing. Fortunately, the UFO is not producing similar latency issues for performance.

Lack of visual feedback (except what you can see on the laptop screen) in the Kinect performances has also been confusing for me, both as a performer and a member of the audience. Without a screen or informative visual projections, there is no

clear visual indicator that you are successfully interacting with the system. On the other hand, a physical object on stage would give a performer a visual reference point and allow the performer and the audience to realize when the interaction is taking place. The UFO as a physical device with a system for visual feedback helps to communicate information to both the performer and the audience.

## 6 Preparing the UFO

*“The main technical challenges concern the design and build of the controller itself and how it maps its information onto sound. The musical success of the controller will often hinge upon these two elements.”*

*– Andrew Hugill (2008: 153)*

The UFO Controller originates from the idea of a performer being able to do effective and energetic live music performances by using hand gestures. This chapter begins with examining the importance of body gestures in music performances and continues by explaining the importance of mapping and sound design of a free-space gestural controller. Furthermore, it opens up two mapping examples for the UFO and the popular music applications Ableton Live and Reason.

## Importance of body gestures in music performance

Studies reveal that audiences are able to detect highly detailed pieces of information about the musical language (pitch, timing and variations of the dynamics) and emotions from body movements of a performer (Davidson and Correia, 2002: 242). The embodied experience of a musician playing an instrument is 'both perceptually available and comprehensible to audiences' (Davidson and Correia, 2002: 242). In contrast, if you imagine a scenario of a musician performing with a laptop and compare it to a scenario of a musician playing a cello it is easy to realize what kind of information will be missing from the laptop performance.

'The purpose of the gestures is to create music' in live performances and according to Siegel (2009: 192-193) a gesture can be divided into musical and visual components. The visual movements of a performer form an effective communicative channel of expression to the audience, occasionally even having a stronger significance than the acoustic information (Goebel, W., Dixon, S., Poli, G., Friberg, A., Bresin, R. and Widmer G., 2008: 211). Furthermore, Siegel (2009: 193) even questions which one of the gestural components (i.e., musical or visual) can be considered as the primary element these days, as many performers of popular music use them to, for example, emphasize emotional states or interact with audiences. These performance movements of self-projection, moreover, play an important role in communicating expressive intentions to the audiences (Davidson and Correia, 2002: 244). However, these "extramusical gestures" are usually not related to playing an instrument, but they can be related to the roles or cultural models attached to instruments and different genres of music. For example, a rock guitarist will more likely express gestures of self-projection due to the manners related to rock music and playing guitar. My belief is that these gestures express the showmanship and add excitement and tension to the performances. Moreover, Paine (2009:219-220) claims that new musical instruments should be designed to facilitate and support this kind of expressive showmanship. He argues that it can be achieved by allowing performers to play new instruments with same amount of

nuanced and subtle expressions as with traditional instruments. I would argue that we are not there yet, due to issues such as latency, technical unpredictability, imprecise sensor readings and so forth. Nevertheless, it sounds like an ultimate design goal for any digital instrument.

Räisänen (2011: 77) argues that the development of our music culture towards computer-based music creation has weakened the relevance of musical instruments and challenged their importance as tangible objects. This claim can be justified as most of the electronic sounds are nowadays played with a computer both in studios and on stages. Nevertheless, I argue that physical instruments or controllers are largely relevant, especially, in live performances to develop movement, energy and connections between gestures and sounds. As electronic music live performances are audiovisual experiences, physical and tangible instruments add an additional layer of visual components to the performance. My experiences with the UFO have also proven that audiences can also link the role of the performer to the instrument or controller being played (e.g., the UFO player, the piano player, the singer). Paine (2009: 218) claims that the authenticity of the actions of a performer will be questioned if the audience is incapable of realizing what the role of the performer is in the music being produced on stage. My experiences with live performance and seeing numerous live concerts from the audience have given me the insight to validate this argument. Suspicion about the authenticity of a live performance can disconnect the members of the audience from an otherwise enjoyable concert experience they were having.

These notions of body gestures and live performance of music can be subject to change as the music culture evolves. The current perception of playing music live was established by the acoustic tradition. It is dependent on the gesture on an instrument that results in its sonification (Paine, 2009: 219). Now that electronic music is more popular than ever, who knows if the computerized music will change the perception of live music for the future generations?

## Effective mapping strategies

A mapping indicates a one-to-one communication channel between a sound and a motion (Siegel, 2009: 199). It is the function that pairs the gestural input with a source of sound. With the UFO in the Performance mode, this could mean for example mapping of the gesture from the sensor 1 to a low-pass filter cutoff frequency of a software sampler. In result, a simple gesture of moving a hand up and down on top of the sensor 1, it would also move the cutoff frequency value up and down in the software. In addition, one can add as many layers to the mapping of the sensors as one wants. For example, the sensor 1 could also control the amount of reverb and delay being added to the mix. In the Airplay mode, sensors can be mapped to control a single or various virtual instruments in the software. The MIDI data from the UFO is mapped in the receiving software used in the live performance.

Multi-layered mappings can lead towards more interesting sonic results but they also add an additional level of complexity to the performance. These ‘complicated schemes’ for ‘translating movement into sound’ can actually weaken the apparent relationship between gesture and sound (Siegel, 2009: 199). However, the audiences instantly understand simple mappings but their trivial nature does not ‘necessarily induce perceptible links between motion and sound’ (Siegel, 2009: 199). Mappings that are well established allow a performer to translate gestural actions into sounds without anyone questioning the authenticity of the performance. Tanaka (2009: 254) indicates ‘**responsiveness, resolution, and finesse of a technology**’ as the key factors that can ‘translate to the often-elusive musical “feel” that is central to the successful deployment of an instrument in a performative context’. I would argue that one of the key factors in the evolution of a new musical interface is the considerate design of connections between the physical gestures of a performer and the parameters of the sounds produced. The design of these relationships should take the nature of the controller, gestures, aesthetics and sound design into account.

For the audience it is crucial to comprehend the relationship between gestures of a performing musician and the resulting sounds. Siegel (2009: 200) claims that in performances of traditional music, this understanding is usually taken for granted. However, if there is a suspicion that a performer is not actually producing the music on stage (e.g., a singer is not actually singing) this “pact” between audience and performer can be broken (Siegel, 2009: 200). Performing with the UFO has given me the first-hand experience on this relationship. When we started performing live with Phantom, some of my mapping settings were quite ambiguous and weak as I was still learning to play with the controller. I realized after the shows, that some of the audience members had difficulties in believing that the parts performed with the UFO were played live. They indicated that the relationship between my gestures and the resulting changes in the sounds was not “clear” enough. Hence, the “pact” between the audience and the performer was disrupted. I think this issue should not be addressed by explaining the fundamental working principles of the controller on stage. The concert should not be an event for demonstrating technology. Instead, this problem can be addressed with a skillful mapping of gestures to appropriate sounds within a respectable artistic context.

The laptop as an “instrument” supplies you with a seemingly infinite amount of possibilities for real-time synthesis and sound manipulation (Paine, 2009: 216). The real challenge is to master the art of setting constraints and limits to the process mapping. The optimum solution would be to constrain the performance in a way that would be delivered as ‘a virtuosic performance of a recognizable musical work’ (Paine, 2009: 216).



## Mapping example 1: Conducting sound levels

In this mapping example, a hand gesture starting from the surface of the UFO and moving up from there can be used to control dynamics of the musical elements. For example, a sweeping gesture going upwards can be used to increase volume levels of harmonic layers to enrich the composition. Conversely, by lowering the hand from the top to the surface of the UFO will dampen these sounds and leave an echo of the sounds playing in the background. For this mapping to be effective, the sounds should have a direct relationship to the musical content of the song and morph with the existing harmonies. The controlled musical elements can be predetermined or improvisational, depending on the song and its context. This kind of mapping technique is suitable especially for timbral and textural compositions. It can be implemented for all of the sensors and each of them can control a unique layer of sound. The mapping is simple, yet effective, and relies heavily on sound design.

*Caution: DAW jargon ahead!*

### How to map it in Ableton Live

The conductor like mapping can be implemented in Ableton Live, for example, by creating a separate audio track A for the sounds and assigning sensor 1 to control it. Like in the example shown in Figure 32, add an Auto Filter effect on the track to control the level of the sound. The cutoff frequency of the Auto Filter can be mapped to the sensor 1 along with the three sends to the return tracks (B, C and D). The return tracks (B, C and D) contain three unique effect chains that alter the incoming sounds with effects such as delay, reverb and chorus. These return tracks pass only 100% wet signals. Only with these four MIDI mappings you can create a dramatic effect on the sounds played on the track A. Furthermore, this method can be repeated for all of the five sensors to create a more compelling performance.

## How does it work with the mapped sensor?

When your hand is down on the sensor 1, the filter cutoff frequency of the track A is down as well. As a result, the sound signal will be inaudible. When your hand is moved up, the filter cutoff frequency of the track A goes up as well and allows the sounds to pass through with all the frequencies. Meanwhile, the sends have gone up with the same gesture and the sound is now sent to the return channels (B, C and D). Now the sound is ultimately bright and will stay that way until your hand is moved down on the sensor 1 to lower the cutoff frequency of the filter on the track A. Once your hand is moved all the way down, the sound will be inaudible on track A but the delay, reverb and chorus effects leave an echoing tail of sound playing in the return channels (B, C and D).



Figure 32. Mapping example “Conducting sound levels” in Ableton Live 9

## Mapping example 2: Theremin

In this mapping example we have a virtual Theremin instrument that you can play with the UFO. Sensors 1 and 2 are set to the Performance (blue) modes while sensors 3, 4 and 5 are set to the Airplay (green) modes (Figure 33). The sensor 1 is mapped to control the amplitude of the instrument: Keeping your hand down on the sensor means that the sound is inaudible and by moving your hand up on the sensors it adds volume. To add some more expressivity, the sensor 2 is mapped to control the vibrato of the sound. Most importantly, sensors 3, 4 and 5 are triggering the MIDI notes that are sent to the instrument. Additionally, a sustain pedal can be used to sustain the notes that are being played. The root key and scale for the notes can be selected from the menus that can be accessed by holding down the leftmost or the rightmost button.

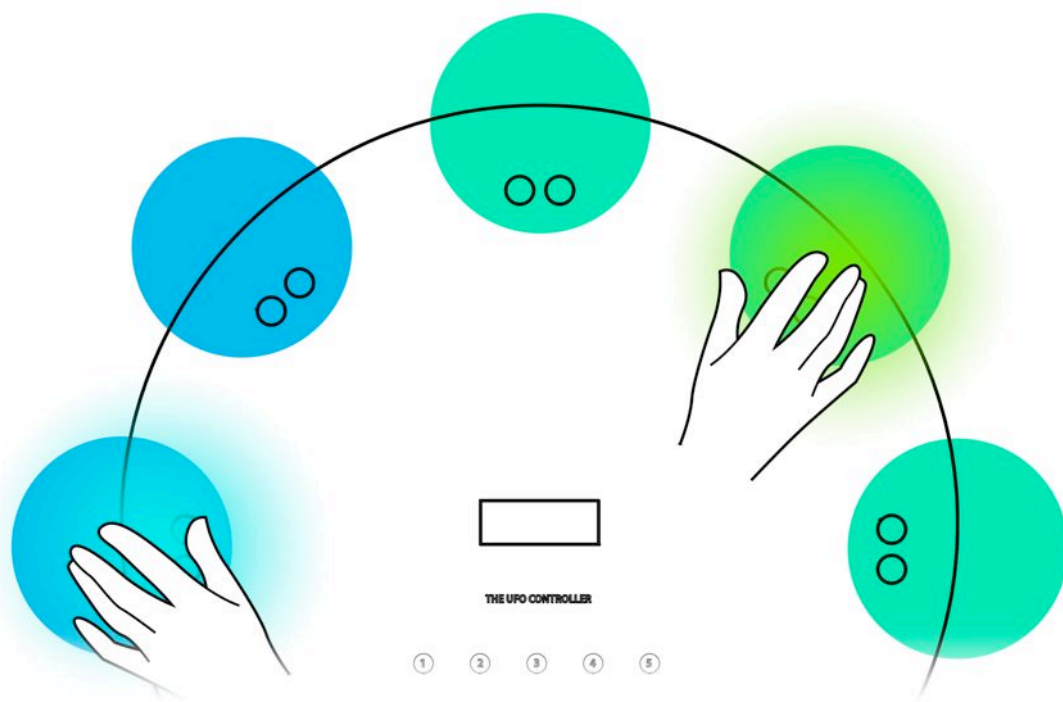


Figure 33. The sensor modes for the Theremin mapping. The Airplay mode is indicated with green color and the Performance mode with blue color.

## How to map it in Propellerhead Reason

Theremin mapping example could be implemented in almost any DAW, but this time we map the MIDI controls in Propellerhead Reason (Figure 34). First, create an instance of a Thor synthesizer and design a simple sine-wave oscillator patch for it. Remember to keep it monophonic and set the portamento to 50% in the patch. Use the modulation matrix of the Thor to connect the modulation wheel to the pitch of the oscillator. Now map the sensor 2 of the UFO to control the modulation wheel. Next, connect the Thor to a Scream 4 distortion effect unit and apply a mild amount of distortion to the sound. Map the sensor 1 to the master volume of the Scream 4. Furthermore, connect the signal from Scream 4 to an Echo delay unit. It will add some natural delay and warmth to the sound. Now, send the incoming MIDI from the UFO to the Thor synthesizer and you are ready to go.



Figure 34. Simple Theremin patch in Propellerheads Reason. Yellow color highlights the parameters mapped to sensors 1 and 2.

## 6 Performing with the UFO

*"Koskinen's gear included a very cool theremin-type device that looked like it was salvaged from a Starship Enterprise model. The device added a nice touch to the live feel of the show, which was nice as there is only so much visible effort you can put into twiddling knobs when working with primarily pre-recorded backing tracks."*

*– David de Young (2013), HowWasTheShow*

This chapter unfolds the story of my band Phantom, how it came to perform with the UFO, and analyzes the feedback from my live performances with the controller.

## The story of Phantom

Phantom is a band that was formed by singer & songwriter Hanna Toivonen and me in January 2012. We first met in the Summer 2011 and started working on some music for Hanna's jazz project. However, we were too busy at the time to properly finish any songs. In January 2012, the story continued when I received a phone call from Hanna. She asked me if I would like to play a few shows with her at SXSW 2012 in Austin, Texas. I said YES. We ended up taking this gig opportunity even though, at that time, we had no songs at all. With a mild panic attack around the corner, we started writing and producing songs in the studio day and night. We started to see some results and realized where the project might be heading: sonically it started to blend Hanna's jazzy vibes to the electronic sounds and field recordings resulting in eerie and vocal-driven downtempo and electronica. By the end of February, we had an EP with four songs ready to be released. The EP was named *Scars* after our first single track.

Next, we needed to figure out how we would play our music live. It needed to be compact, just the two of us, as we could not afford to bring a band with us to Austin. I had shown the first UFO prototype to Hanna at the studio and she thought it would be perfect for the live set. Few days before we were set to board the plane to Texas, we started creating and rehearsing the first Phantom live set. It was programmed with Ableton Live and controlled with the UFO along with two other MIDI controllers. Furthermore, the setup was so compact that it would fit into our suitcases and cause no extra luggage costs. We got safely to SXSW, played three shows in Austin that week and had a fantastic time performing with the new band and the controller. The songs we played live were not perfect, but they definitely were "good enough" to win over the audiences. The UFO and the band were received with immediate curiosity and

wonder. The excitement levels were high also because of our newly released music video *Scars*. It was shot in Finland a week before we started the trip. It used the first prototype version of Z Vector, which is an application by Delicode for generating immersive visuals with the Kinect camera (Delicode, 2015b). The resulting video was a strikingly unique piece of audiovisual content and seemed to resonate extremely well with our newly found fans and random viewers (Figure 35). However, it did not catch that much fire in the beginning, as we did not have a PR or marketing plan in place.

Then out of nowhere, The xx (a hugely popular indie pop band from UK) posted the *Scars* music video on their blog and social media channels. Suddenly, the millions of followers of The xx were made aware of Phantom and our single *Scars*. This caused a peak of momentum for Phantom that resulted in reaching out to more fans, getting e-mails from all sorts of music industry professionals, receiving invitations to perform at various events and festivals around the Europe and so on. It was naturally a turning point for Phantom. We realized that our musical act had a lot of international potential. It was the beginning of a time that would allow us to play our music to international crowds and also get more experienced as music producers and live performers. The UFO was naturally a big part of this development and it got a noticeable amount of attention in the media as well: TechCrunch, Create Digital Music, Synthtopia, Helsingin Sanomat, Ilta-Sanomat and more (Cutler, 2012; Kirn, 2012; Pöppönen, 2014; Ruokanen, 2014; Synthtopia, 2012).

*"Phantom's downtempo electro is filled with some catchy and bittersweet melodies, and it has been compared to Massive Attack, Portishead and The xx. Seeing Phantom play live with a MIDI theremin in the shape of a UFO is an experience everyone should have." - Music Finland (2013)*

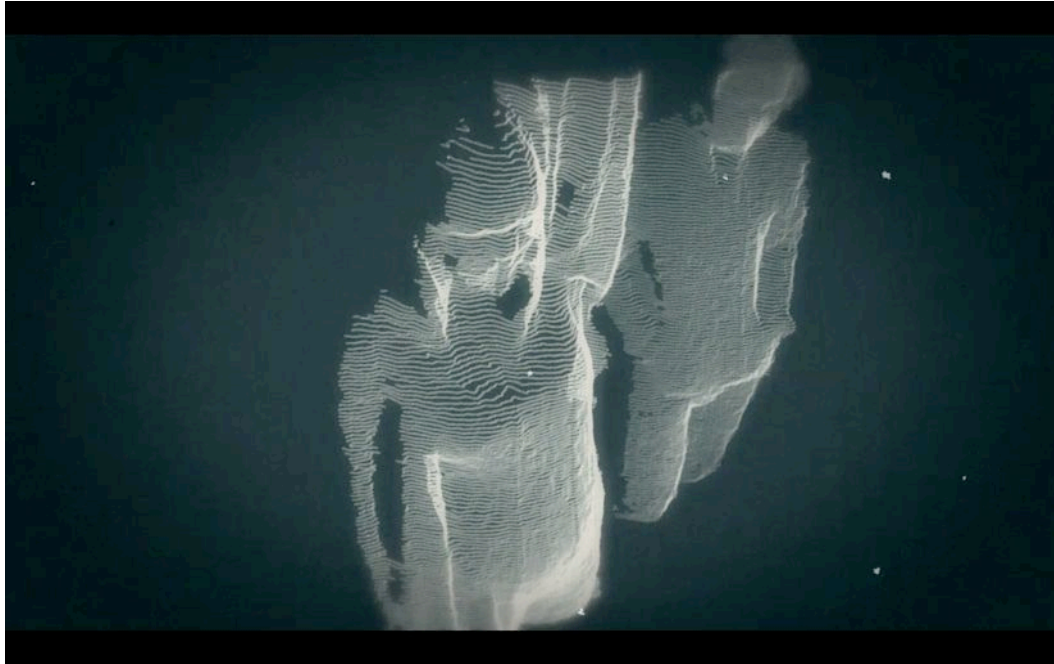


Figure 35. Screenshot from the music video "Scars" by Phantom



## Feedback from the performances

*“Phantom’s UFO Theremin is the best handmade instrument we’ve seen. There’s making your own instrument and then there’s making a Theremin that looks like a UFO. Finnish duo Phantom have succeeded in doing just that, adding spacey sounds to their songs (think Alpines and The xx) and a cool talking piece to their set.”*

*- Rhian Daly (2013), NME*

To this day, the UFO has seen almost 100 shows all around the world. Most of these have been shows with Phantom played at concert venues, clubs and festivals but there have been shows in museums, art galleries and conferences as well. The first live show with the controller was played at **Tromsø International Film Festival (TIFF)** in January 2012. I performed my own electronic music as **Kitkaliitto** and wanted to test how a real audience would perceive the UFO. To my surprise, it almost stole the whole show, and many of the audience members came to ask about my peculiar controller after the show. I remember that during the show a young boy pointed to me and said to his father: **“Look daddy! He’s a magician!”**.

The role of a magician or a wizard has been one of the most common reference points, and people have actually used that to describe my part in the UFO performances. It might be largely due to the resemblance of the hand gestures, lights and sounds to actions that we connect to conjuring (i.e., casting spells) in the fantasy movies and our popular culture.

The second most used comment about the UFO refers to the original Theremin. Most of the audience members who have come to talk to me after the shows have had previous knowledge of the Theremin and asked **if my controller is actually a new version of the Theremin**. The journalists have also seemed to be making comparisons to the Theremin in their articles about the UFO or Phantom. I think it is a good sign when people have a cultural reference point in the history of musical instruments. It helps them to understand the functionality of the controller better and also observe things more critically.

Some of the people who have seen Phantom concerts have said to me that **the gestural control with the UFO has made my role more interesting in the performances and allowed me to become more “visible”**. I have noticed that with most electronic duo bands, in which one of the members is the lead singer (or rapper) and the other one is handling the so called “DJ duties”, the attention of the crowd usually focuses more on the lead singer. This happens naturally as the role of the DJ is not contributing that much in terms of interesting visual or aural information. The performance of this DJ figure often takes place behind the laptop and by using controllers that are not clearly visible to the audience. Nevertheless, the feedback I got about my “visibility” means that **performing with the UFO might be equally interesting for the audience to observe**. Moreover, the feedback has indicated that Phantom has discovered a “sweet spot” for dividing the attention of the audience between the singer, the UFO performer and the visual projections.

The feedback provided by **the audience members and the journalists really prove that the free-space gestural control has brought additional value to the performances**. They claim it brings more energy, interest, action, coolness and juxtaposition to the Phantom shows. The notion of juxtaposition can be described with the collision of two totally different worlds: the jazzy singing by Hanna is fused with alien-like sounds and performance. I think the notion of coolness comes from the gestural interaction and the fact that **the device actually looks like a flying**

saucer from outer space. The science fiction appearance has received a lot of positive comments from the people and some of them even suggested that the UFO should look even more alien-like.

The feedback also points out that **they have enjoyed watching me “lose myself” with the UFO.** The proximity of the controller and the instant reactivity with the gestural free-space interaction make the UFO an instantly accessible controller for me. It extends my expressivity and creativity on stage as it **enables me to get “carried away” in the moment of performance.** Furthermore, it is an excellent sign, if it is not only me (the inventor and the performer), who is enjoying the performances with the UFO.

The fact that Phantom has a custom-made controller in the live setup has raised a lot of interest and respect towards the band. The reactions of the crowds and the journalists have indicated that **it is admirable when bands create their own instruments** and bring some “outside-the-box” thinking to their music. The **criticism that I have faced with the UFO has been more or less related to the mapping issues** that have resulted in disbelief about the authenticity of the instrument and the performance. Wrong decisions made regarding the mapping can cause weak connections between the gestures and the resulting sounds. I have realized that more obvious connections between the gesture and the sound result in a better audience reception. In the beginning, I overdid the UFO parts and emphasized the controller too much. With some more experience, I learned to use the UFO more sparingly (i.e., only in specific parts in some of the songs) and that has made a big difference. Less has been more in the case of Phantom.

## Media quotes

“Finnish duo Tommi Koskinen and Hanna Toivonen left the world of tech start-ups behind to make fantastic spooky glacial slo-mo pop which has the likes of The xx going “yes” about them. They haven’t quite left the tech world behind – we were very taken with the onstage musical gadget Koskinen used, which was activated by motion sensors.”

- Jim Carroll (2013), *The Irish Times*

“It’s an endlessly tweakable effects unit (apparently made out of an old lampshade) that reacts to movement above its various sensors, creating an effect not unlike a multi-tasking Theremin. It’s impressive to watch, even in a shop.”

- Charlie Ivens (2013), *The Line Of Best Fit*

“I am charmed by a random instrument or two, and the prize at Eurosonic in this category goes to Finland, and Phantom’s own UFO-shaped theramin. You can witness it (and the band) in action yourself here, when the pop duo played in the pop-up show at H&M (organised by Music Finland).”

- Carmel McNamara (2013), *Nordic Vibes*

“Koskinen provides the instrumental part with a laptop and a controller. This little and innovative live setup is completed with a real UFO. The UFO is built by Koskinen himself out of an inverted lampshade. Like a magician over his crystal ball, he moves his hands over the UFO to manipulate the sound. There is room for improvisation with beats and the UFO, where Koskinen makes good use of the controller.”

- Anne Bouma (2013), *3voor12*

“The female vocals fit perfectly with the spooky electronic sounds of Tommi Koskinen. The eye-catcher on the stage is his little UFO-shaped Theremin. In his own words, he built it himself out of a ceiling lamp into a kind of mini Theremin. He stood as a kind of magician conjuring up sound from his Evoluon in table format. It was an imposing appearance from an intriguing act.”

- Oscar Smit (2013), Gonzo Circus

“Next up is Phantom, who takes us from folk to electronic. Having formed their duo no later than in January this year, Tommi Koskinen and Hanna Toivonen start off their set by introducing the UFO – a handmade instrument that well, looks like a big white UFO with blinking green lights. With stunning Kinect visuals showcased in the back, Hanna is losing herself in the vocals while Tommi is doing magic with the UFO. He surely looks like a wizard onstage (said in the best possible way), provoking and controlling what turns into beautiful tunes from the handmade UFO.”

- Silje Strømmen (2013), Ja Ja Ja Music

## 7 Future & conclusions

*“The ‘amplification’ of human gesture made possible with the new interfaces may create distorted giants of unreal proportions – but we may recognize them at least “*

*- Simon Emmerson (2000: 212)*

## The bright future of new music controllers

The last decade has been highly prolific for the digital music technology, as the research has been highly driven by the demand for new kinds of instruments, controllers and tools (Leman et al., 2008: 29). According to Emmerson (2000: 209) the studies on human-computer interfaces for musicians and performers was developing as the most significant new field of music research by the end of 20<sup>th</sup> century. Koray Tahiroğlu (2008:151) claims that the design of new digital music instruments has largely focused on matters of usability, interaction, engineering and technology. Furthermore, Tahiroğlu (2008: 192) argues that the future research focuses more on discovering novelty interaction possibilities and dynamics control structures for experimental music instruments. In its entirety, music emerges to be a driving force for innovation due to its wide scope of domains from sound to sense to social interaction (Leman et al., 2008: 36). Therefore, it is no wonder that there is constant innovation in the area of new musical interfaces. At the same time, popularity of electronic music is growing and we are witnessing a transformation what Collins (2009: 349-350) describes as ‘mass pursuit’ for electronic music as all the tools become more accessible and affordable.

In 1990s the Internet has enabled musicians and inventors to share knowledge and resources online, and this has eventually led to the formation of a group known as NIME (i.e., New Interfaces for Musical Expression). Their aim is to innovate and develop new sensor-based instruments and control interfaces (Singer 2008: 204). The group started their annual conferences in Seattle, Washington in 2001 and have continued to collaborate on musical innovations ever since. Arguably, the biggest innovation is not happening in the commercial market, but as MIDI is a nonproprietary standard it has allowed the D.I.Y. (Do It Yourself) inventors, musicians and makers to create remarkable amateur creations (and some of them have even been successfully turned into commercial products). These hacking musicians have been known for having the exceptional ‘ability to appropriate and

repurpose machinery and technology for expressive musical ends' (Tanaka, 2009: 254). Meanwhile, the interaction possibilities created by the inexpensive digital media technology are constantly growing. Modern sensor components, which are rather inexpensive and largely available, enables, for example, the use of almost any physical or virtual action to control instruments, music applications and even whole performances. Siegel (2009: 212) points out that 'a standardized interface device or system' for the sensors and interaction has yet to be developed, implying that 'the field is still in an experimental phase'.

The importance of gestures is predicted to increase tremendously as we have entered a new age of interaction design (Saffer, 2009). The tactile gesture interaction has become commonplace within the last decade, and the free-space gestural interaction is expected to follow. A recent example of this is the popularity of the game console systems (such as Nintendo Wii and Microsoft Xbox Kinect) that have introduced the free-space gestural interaction in their games (Nintendo Co., 2015; Microsoft Ltd., 2015). Furthermore, Paine (2009: 229) indicates that these interfaces have been adopted to electronic music performances so swiftly that it is a 'clear indication that gestural control is seen as important to both musicians and audiences alike and remains one of the most intricate and complex areas of development in laptop music performance tools'.

This rise of experimental music interfaces, inexpensive technology and D.I.Y. attitude will lead the performance of future music to a more personalized and customized space. After all, custom-made instruments or controllers are just the very beginning of what the future bands can do. I can envision them having fully customized stage setups with their own tailored instruments, musical robots, interactive lightning rigs, motion tracking systems and so on. Furthermore, it will not only be about being a multi-sensor band playing music on stage, but the participation of the audience in the musical performance, that I would assume will become an even larger part of the live shows. The attitude and the accessibility of technology are not the only factors leading to this development. The financial



realities of modern music business and the vast abundance of music producers are making the competition even tighter. It is about standing out and doing everything one can to start building gradual peaks of attention momentum that can lead to a differentiating factor, more fans and eventually income.

My prediction about major future trends is that augmented (AR) and virtual reality (VR) instruments along with free-space gestural interaction will be among the next “big things”. We have finally practical VR headsets (e.g., Oculus Rift, Morpheus) and various technologies that allow functional, fluent and low-latency free-space gestural interaction (e.g., Kinect, Leap Motion). The developers (early adopters) are rushing to the market to be the first ones to make a killer app for the new platforms. Presumably soon, the detection algorithms (with the help of artificial intelligence) can start predicting the gestures more precisely and learn to know how their users move and behave. In only few years, we have seen dozens of more capable sensor units, AR/VR platforms and applications that have paved the way for a new set of expectations and standards for digital applications in a world where augmented virtual reality and free-space gestural interaction are commonplace. Music applications will naturally be in the forefront of this technology as music and live performance set high requirements for the new technologies. I would assume that, first we will experience mass-market entertainment products (such as Guitar Hero and Rock Band). After this, we will start seeing innovative applications for producing and performing music in a whole new set of tools, quality standards and environments that merge the physical and virtual like we have never seen before.

## Next destination for the UFO

In the immediate near future the development of the UFO continues by integrating it even more effectively to the new Phantom live show. We are experimenting with new gestural mapping techniques and figuring out new kind of

arrangements for the live set. In addition, the new live show will also use a custom-made Max 4 Live patch that allows me to wirelessly control Z Vector visuals running on another computer with my UFO (Figure 36). This coupling of motion, audio and projected visuals will increase the role of gestures in the performance. For that matter, I can say that my band is the most fruitful platform to test new technological ideas for performances, whether they are about the UFO or something else. Hopefully the future takes us on the road more often and gives us the possibility to try out new ideas for live performance.

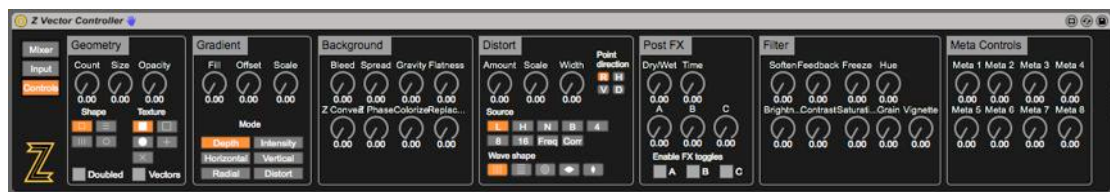


Figure 36. Z Vector Controller Max 4 Live patch

Future iterations of the UFO can bring a lot of new features. First of all, it would get more character and personality if it had its own sound engine and unique sound patches. I argue that having a unique sonic identity could make it a truly memorable instrument like no other. Arduino microcontrollers, however, lack the computing power to create proper sound synthesis for the UFO, but the sound engine could be implemented, for example, with an additional Raspberry PI microcomputer. It would have enough processing power to run a Pure Data or a SuperCollider patch to generate the sounds. The user experience could be further enhanced with a built-in speaker to amplify the sounds created with the UFO. This would certainly make it more accessible and fun while adding some ease of use. However, my intention is not to create a toy-like instrument with these features, but to begin developing the UFO from a controller to an actual instrument. From the day one of the project, my objective has been to create a stand-alone device that would not require a computer to function. In addition, another prototype version of the UFO is currently under development. It is a smaller unit based on Teensy 2.0++ microcontroller with three rangefinder sensors and transparent casing

(Figure 37). It will be a USB-compliant MIDI device that does not require old-fashioned MIDI cables to work.



Figure 37. The casing for the smaller controller prototype

The future of the UFO holds also the idea of making a commercial product out of it one day. The current prototype can be considered a minimum viable product (MVP) for the music controller market, but there are issues with the current design (please see the end of Chapter 4) that need to be addressed before it could be ready to be adopted by “the real users”. My intention is to, first, put my efforts into resolving those issues and, then, start investigating the possibilities to make UFO units available commercially. Furthermore, there should be a clear focus on the target user group of the UFO. The envisioned end product has always been a sophisticated performance instrument for the music professionals, but the question has emerged, whether that is the best commercial market for it. Taking it to the commercial level is not a trivial challenge and it comes with largely financial risks. An alternative approach would be to make DIY units on demand, provide open source code and instructions online and not to think about “making it big” commercially. At this moment, I prefer the latter option. Nevertheless,

crowdfunding the project on Kickstarter could be an effective way of getting initial funding for developing UFO units. Recently, there have been many successfully crowdfunded experimental instrument projects on Kickstarter such as the multi-touch gesture controller INSTRUMENT 1 (Artiphon, 2015).

## Final conclusive thoughts

*“Contemporary electronic music is, in a way, moving away from laptop controllers“*

*- Koray Tahiroğlu (2008: 154)*

Throughout the UFO project I have found some comfort in the fact that my background is not in the category of “classically trained musician”. My inability to play traditional instruments is not bothering me as much as it was when I started this project. In fact, it led me to discover an alternative path in music that looked more like me. We could assume that technical expertise of traditional instruments (or novelty controllers) would make you a better musician or a performer. It can most certainly be a beneficial asset in your music career, but in the end it is more about you as an artist expressing your own persona. Altenmüller and Schneider (2009: 342) state it perfectly: ‘the best trained musicians with the best working sensorimotor networks will not move their listeners if imagination, colour, fantasy and emotion are not a part of their artistic expression’.

I have been fortunate with my band (Phantom) that we have been able to merge artistry, music and technology in a seamless package that seems to touch audiences without regarding their musical preferences or backgrounds. The crossover of different fields (technology, music and art), genres (electronic, jazz, pop) and our personas has created a band with a wide appeal and strong identity. There have

been many elements right from the very beginning and I can easily say that UFO is one of those. It has elevated the live sets to a new level, become an integral part of the band and obtained its own character, while it has aided me in the process of composing music. The result has been more than tangible during the Phantom shows, as The UFO has caused a noticeable amount of “Wow” effects in the audiences with the free-space gestural control. In 1920s, playing an instrument without touching it was a subject of wonder when the Theremin was introduced to the public (Glinsky, 2000). One could think that we have seen it all by now, but the gestural control of the Theremin astonishes even today. In the right setting, a novelty gestural controller interface like the UFO can make a big difference. It probably will not work for all projects and circumstances, but it has worked perfectly for Phantom and also been one of the major factors that have given the band a genuine reputation for creativity.

The concert feedback and its analysis have proven that the UFO has added exceptional excitement and interest for the music performance. Furthermore, the observations from the live shows, the survey of “MIDI controllers and electronic music performance” and the literature review has validated that bodily gestures are highly relevant in the performance of electronic music. Now, we have reached a point in the history of electronic music where the performers and the audiences start demanding more than just laptop performances. Even if the music is virtually inside your computer, it makes no sense for it to be disembodied in the context of the live performance. It is time for the laptops to move under the table and make space for the most unimaginable instruments and controllers to come.

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Follow the projects at [www.theufocontroller.com](http://www.theufocontroller.com) and [www.wearephantom.com](http://www.wearephantom.com)

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Figure 1. Koskinen, T. (2015) *MIDI clip in Ableton Live 9*, [Screenshot]

Figure 2. (2006) *Potentiometer*, [Photograph], Available: <https://en.wikipedia.org/wiki/Potentiometer#/media/File:Potentiometer.jpg> [23 Jul 2015]

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Figure 7. Koskinen, T. (2011) *Early mock-up image of the controller*, [Image]

Figure 8a. *Arduino Mega 2560 microcontroller*, [Photograph], Available: <https://store.arduino.cc/product/A000067> [23 Jul 2015]

Figure 8b. *PING))) Ultrasonic Distance Sensor*, [Photograph], Available: <https://www.parallax.com/product/28015> [23 Jul 2015]

Figure 9. Koskinen, T. (2015) *Distribution of sensors*, [Image]

Figure 10. Koskinen, T. (2012) *The first UFO Controller prototype*, [Photograph]

Figure 11. Koskinen, T. (2012) *The mess of wires*, [Photograph]

Figure 12. Koskinen, T. (2014) *Prototyping*, [Photograph]

Figure 13. Koskinen, T. (2014) *Technical drawings*, [Image]

Figure 14. Koskinen, T. (2014) *The design of a PCB*, [Image]

Figure 15. Koskinen, T. (2014) *LCD screen*, [Photograph]

Figure 16. Sandgren, N. (2014) *The UFO at Media Lab 20<sup>th</sup>*, [Photograph], Available: [https://www.flickr.com/photos/media\\_lab\\_helsinki/15832505215/in/album-72157649369551501/](https://www.flickr.com/photos/media_lab_helsinki/15832505215/in/album-72157649369551501/) [10 Aug 2015]

Figure 17. Koskinen, T. (2015) *The rangefinder sensor space*, [Image]

Figure 18. Koskinen, T. (2015) *Basic types of gesture interaction*, [Image]

Figure 19. Koskinen, T. (2015) *Playing with two hands*, [Image]

Figure 20. Koskinen, T. (2015) *Distribution of notes*, [Diagram]

Figure 21. Koskinen, T. (2015) *Playing notes*, [Diagram]

Figure 22. Koskinen, T. (2015) *Using two hands to play*, [Image]

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Figure 32. Koskinen, T. (2015) *Mapping example in Ableton Live 9*, [Screenshot]

Figure 33. Koskinen, T. (2015) *Modes for the Theremin mapping*, [Screenshot]

Figure 34. Koskinen, T. (2015) *Theremin patch in Reason*, [Screenshot]

Figure 35. Delicode (2012) *Phantom – Scars (music video)*, [Screenshot], Available: <https://www.youtube.com/watch?v=HFpou6izBQg> [25 Aug 2015]

Figure 36. Koskinen, T. (2015) *Z Vector Controller M4L patch*, [Screenshot]

Figure 37. Koskinen, T. (2014) *The casing for the smaller controller prototype*, [Photograph]

Figure 38. Taake, A. (2015) *Phantom in Heidelberg 2/2*, [Photograph]

Figure 39. Taake, A. (2015) *Phantom in Heidelberg 1/2*, [Photograph]

Figure 40. Ahanen, E. (2015) *Phantom at Tavastia*, [Photograph]

Figure 41. Shemeikka, M. (2014) *Phantom at Flow 2014*, [Photograph]

Figure 42. Shemeikka, M. (2013) *Phantom at The Great Escape in Brighton in May 2013*, [Photograph]



Figure 40. Phantom at Tavastia in February 2013 (Photo: Eetu Ahanen)



Figure 39. Phantom in Heidelberg 1/2  
(Photo by Annemone Taake)



Figure 38. Phantom in Heidelberg 2/2  
(Photo by Annemone Taake)



Figure 41. Phantom at Flow 2014 (Photo by Mira Shemeikka)



Figure 42. Phantom at The Great Escape in Brighton in May 2013 (Photo: Mira Shemeikka)

## GLOSSARY

Ableton Live is a popular digital audio workstation for Windows and OS X. It is designed for live performances.

Arduino is an open source electronics prototyping platform with a family of digital microcontrollers and a software editor IDE (Integrated Development Environment). It allows artists and designers, who have fairly little or no prior experience with coding and electronics, to start creating their hardware projects.

Clock synchronization is a CV signal that can be used to synchronize the tempo of analog synthesizers, drum machines and sequencers. There are also devices that convert Clock CV to MIDI and vice versa.

Control voltage (CV) is an analog method of using voltage changes to control synthesizers, drum machines and sequencers. For example, older Moog synthesizers use voltage between 0 and 5 volts to control parameters.

Modular Synthesizer is a synthesizer that can be fully customized and constructed from specialized modules. These modules can be, for example, different kinds of oscillators, envelope generators and effect processors.

Oscillator is an electric circuit designed to produce an oscillating signal waveforms (e.g., sine-wave, triangle or square wave). Audio oscillators create these waveforms in audible frequency ranges i.e., 16 Hz to 20 kHz)

Pitch modulation is a CV signal used to modulate the pitch of a synthesizer oscillator over time.

Gate input is a CV signal that is used to trigger the sound of a synthesizer over time.

Propellerhead Reason is a digital audio workstation for Windows and OS X. It contains a virtual studio rack of hardware synthesizers, samplers and effects units.

The MIDI Standard is a communication protocol that connects all of your MIDI-compatible digital studio equipment together. MIDI can be used, for example, to send data from your computer to a synthesizer and back.

Z Vector is an application (developed by Delicode) for generating immersive real-time visuals with depth cameras. Phantom is using the Z Vector to create visuals for their live sets.

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