[MIDI Polyphonic Expression]

[A Bridge Between Acoustic and Electronic Instrument Experience?]

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Abstract

This paper is about MIDI Polyphonic Expression controllers. Since the invention of the synthesizer and computer music instruments a decoupling between performers and sound generators has occurred. Expression has in some ways been lost and the need for performers to physically interact with instruments has not been fulfilled by the proliferation of MIDI keyboards and controllers. Computer music can feel sterile and less expressive than music played with acoustic instruments. The inability of musical controllers to capture expressive gestures makes performing emotionally engaging electronic music difficult for instrumentalists. By looking at the history behind MIDI and MPE and discussing the human need for expression in music, the author gives a framework for an experiment he conducts. By testing several MPE controllers in a systematic way he hopes to answer questions over MIDI Polyphonic Expression's role in restoring tactility and gestural expression to musical instruments.

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Lastly I want to thank Trond Lossius for dragging a way to heavy flight case with a Haken Continuum halfway across the country. Only so a perfect stranger could perform some experiment on it. Very much appreciated.

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1: Introduction

When I was nine years old I went with my family and some of their friends to our cabin for Easter. One of my parents had brought his guitar with him, a cherry red acoustic Takamine. After watching him play it one night I asked if I could try it and he happily obliged. He showed me how to play a couple of chords on it and let me sit and try to figure this out. I struggled for a while, but after a while I managed to awkwardly play one of the chords and strum it, producing an actual musical sound. I found this experience very exciting and it sparked my life long relationship with playing music and especially the guitar. I continued practicing on an old beat up guitar that had belonged to my father, and after a while I got my own guitar. As I continued improving, I begged my parents for an electric guitar, and to my delight for my eleventh birthday I got a Washburn electric guitar with tiny Marshall amplifier. There was no turning back now, I was obsessed.

Around the same time I started playing with an old two row Yamaha electric organ at my grandmothers house. It was a fairly advanced model and had an arpeggiator and a basic onboard drum machine. I would sit at this organ for hours with headphones on, marveling at the sounds it could produce. I had also been into computers ever since we got a computer in our house. And when I was around thirteen I got my first computer program. A friend of mine gave me a copy of a program called Fast Tracker 2. It was a tracker style musical sequencer which afforded me the ability to create my own electronic music compositions. They were very crude and I would most certainly be embarrassed if any of them were to surface, but this was the start of my interest in music technology and electronic music.

Through my teens I continued playing guitar and started playing in metal bands, and at the same time I slowly got more and more into listening to and creating electronic music. I continued using trackers, but also graduated to more sophisticated, modern pieces of sequencer software like Cubase and Logic. In my 20s I started playing a lot of acoustic guitar instead of the electric guitar. And this was the period I started trying to incorporate guitar parts into my electronic music. I always found this process very difficult, because even though the guitar recordings were terrible due to my poor recording skills and equipment, They always seemed to have so much more life to them than the synthesizers and programmed drums I had created.

A few years later I found myself in the Department of Musicology at the University of Oslo, doing a bachelors degree. During this time I took courses in music technology that me realize that there were people building their own instruments with cheap technology and free software. I started learning more about MIDI, a concept I was familiar with from using sequencers, but never really understood the technical aspects or implications of. I realized that you could create a lot of interesting controllers and instruments using this technology. But creating something like an expressive instrument seemed way beyond my capabilities, but I started to think that someone with a better skill set than mine must be doing something like this. Then, in one lecture, someone mentioned the concept of MPE while we were talking, and that maybe that was what I was looking for. I started investigating, and realized that in fact, there were people who had created this type of controller. There were several manufacturers who had their own take on this concept, and I had gone around oblivious to this development for a few years.

When I was deciding on what to write about for my master thesis, I had a couple of topics in mind. I had become very interested in MIDI, I found it fascinating that a group of competing companies had managed to create a non proprietary universal standard that everyone just seemed to adopt into their products. It was also fascinating how it still is the standard protocol for communicating between sound modules and computers, after 30 years. And the protocol is virtually unchanged since its inception. The other thing I was interested in writing about was expression in electronic music. I was interested in why some music even though it is created in a computer, sounds organic, and other music created in a computer sounds like it was made in a computer. After some consideration the solution seemed obvious. I would combine the two topics and write about this exciting advancement in technology and the MIDI protocol, MIDI Polyphonic Expression, MPE.

When I started doing research for the paper I realized that there was not a lot written about MPE, at least not academic work. I wanted to find out how this technology worked, and if it would give the performer the feeling of playing an actual acoustic instrument. That became the focus of the paper. When talking to my counselor he advised me that I could set up an experiment and test MPE controllers myself. The musicology department had several MPE compatible controllers that I could borrow to get some hands on experience. This seemed like a great solution to me. The question I was interested in answering was a subjective one; can an MPE controller give me the feeling of playing an acoustic instrument?

The research questions I ended up formulating were as follows:

- The main question I wanted to answer was: Can MPE mitigate the disjunction between performer and sound source in electronic music instruments?
    - I had two subordinate questions, the first being: Do MPE instruments provide a tactile playing experience?
    - The second subordinate question was: Do MPE instruments provide satisfactory control over pitch and timbre?

Before we move on I would like to clarify some of the terms I used in my research question and some others which will be talked about later in this paper.

- MIDI: An acronym which stands for Music Instrument Digital Interface. It is a digital protocol designed primarily for sending information between different synthesizers and also computers.
- MPE: Another acronym which stands for MIDI Polyphonic Expression. This is a further development of the MIDI protocol which aims to allow players more expressive control over the timbre and pitch of electronic music instruments.
- Electronic music instruments: This refers to any type of sound generator that is not of a traditional acoustic nature. This can be an analogue synthesizer or a virtual emulation of one or a sampler in a computer. For the testing of the controllers I only used sound generators in computers.
- Disjunction: This is a term from a paper by Douglas Keislar called "A Historical View of Computer Music Technology". In this paper he uses the term *disjunction* to refer to a consequence of the development of music technology. He states that with the invention of instruments humans started a process where they partly removed the performer of an instrument further away from the sound source. This will be further discussed in the part "Why MPE for Performers" later in this paper.

So with this basis I chose to set up an experiment with myself as the sole participant. My reasoning for doing this was that I expected the controllers to be technologically sophisticated and require a certain degree of musical proficiency to be able to play any real music with. I also reasoned that since I am an accomplished guitarist, but have very limited abilities when it comes to playing the piano, I would not be too far removed from a beginners perspective to make some assumptions about how it would be to start learning to play on this instrument.

The controllers I tested were:

- Roli Seaboard Grand
- Madrona Labs Soundplane
- Roger Linn Linnstrument
- TouchKeys
- Haken Continuum

The reason that these were the ones I tested were that they were the ones I could borrow. These types of controllers are expensive and are not that easy to come by to borrow from retailers. I had access to all of these except the Haken Continuum through the school. The Haken I got to borrow through Trond Lossius who owned an early model of the controller.

The title of the paper needs a little explanation before we move on. When I use the word bridge it is in one sense a metaphor. But as will be talked about later in the paper, through advancements in musical technology, a decoupling between performers and the sound source has occurred. When playing a piano, a performer plays a key which activates a mechanism that hits a string. We can see this as being a level removed from the sound source as opposed to an instrument where you touch the string, like a violin or a guitar. With electronic music instruments, the sound source is hidden away in a box, and especially with computers, there is no way to physically interact with the sound generator. This creates a gap between performer and sound generator which can't be physically overcome, but my question is, can an MPE controller create a virtual solution to bridge this gap?

In this paper I will start with detailing some background for this topic. I will start with a history of the development of MIDI and its usages in chapter two. I will then move on to talking about how the MIDI protocol works, and some of its limitations. These are both technical and developmental limitations. The next part after that will be an overview of commercial MIDI controllers that have adopted a different playing system than the keyboard. In this section I will also discuss the experimental culture of DIY musical devices. The last part of the background section will give reasons to why MPE is wanted by musicians, and give some insight into how acoustic instruments work and how electronic instruments differ from them.

Then I move on to the project itself in chapter three. I start this part with an introduction where I talk about some previous research that I based this project on. I then move on to detailing how I set up the experiment and which parameters of the controllers I tested. After this I give a detailed account of the testing of each of the controllers, before finally discussing the results and impressions of the experiment in the final section of chapter three.

In chapter four I will summarize the paper and talk about what has been said about the background for the topic, my findings in the experiment and some musings on the future of MPE.

2 Background

2.1: Introduction

To understand the principles of MPE and the reason for musicians and performers wanting these types of controllers, it is helpful to understand some of the background that has led to its development. In this part we will take a look at different angles of the problem to argue a case for how and why MPE came about.

First we will start with detailing why and how MIDI was created, and what advantages it gave to musicians. Next we will take a look at the drawbacks and limitations to the MIDI protocol itself, and how it has stayed nearly unchanged for over 30 years. MIDI is the basic framework of which MPE is founded, so a basic understanding of it will be beneficial for the reader moving forward. After this we will see how the development of MIDI in tangent with other technology has afforded musicians and other music technology interested parties with affordable ways to create their own instruments. And in the final part of the background section I will make a case for why expression is important for musicians, and why the old MIDI standard does not to a satisfactory degree facilitate this.

2.2: History of MIDI and the Benefits

Before MIDI was unveiled at NAMM in 1983, there was no standardized way of having individual pieces of musical equipment communicate and interact with each other. In the late 70s synthesizers had become more accessible and attainable for people, which led to musicians and performers having multiple units which they understandably wanted to be able to control in a practical manner. Before MIDI synthesizers communicated by a method known as Control Voltage/Gate, or CV/Gate (Diduck 2017, 21).

When Robert Moog created his Moog synthesizers, he used CV to control the pitch of the synthesizer. He decided to use a standard of “1 volt per octave” to control the pitch of the synthesizer. In practical terms this means that for every one volt increase that is sent into the synthesizers oscillator, the pitch would increase one octave. So if you divide one volt into twelve parts, you would be able to play all twelve notes in a chromatic scale. When you press a key on a synthesizer, the sound that is produced is continuous, it will play until you press another key. This is where the Gate comes in. It sends a message to a Voltage Controlled Amplifier that the key is either pressed down, or not, on or off. To help sculpt the sound, there is also a component called an Envelope Generator. This controls the attack, decay, sustain and release of the sound. Basically how fast the sound reaches full volume after the key is pressed down and how fast it dies down after the key is released (Pinch and Trocco 2002, 26,27).

These are the basic ingredients of how sound is generated within a synthesizer, and in a self contained system of a single unit it works very well. But the problems occur when trying to have multiple units interact. Most early synthesizers had a CV output and a Gate output. This meant that you could send the voltages from one synthesizer to another. So you could have a master keyboard which could control another keyboard. Since most synthesizers were monophonic, it was desirable to be able to play more than one for an increased timbral output (Pinch and Trocco 2002, 269-271).

Doing this manually was cumbersome, so the ability to be able to connect more than one synthesizer to another and control them from the master increased the performers dexterous freedom. But one of the major problems before the introduction of MIDI was that this system was not standardized. Some of the synthesizer manufacturers used the same "1 volt per octave" implementation as Moog, but not all. This means that if you connect a unit which conforms to Moog's standard, it will turn the notes on and off at the same time, and both will produce a note with the same pitch. When you do this with two units that don't adhere to the same standard, the pitch will be different and the synchronization of two units doesn't work. With this in mind one can see why there was a need for a standard protocol for communication between units (Manning 2004, 265,266).

Before we move on it is pertinent to mention that prior to the MIDI standard systems for digital interfacing between instruments had been developed. Both Yamaha and Sequential

Circuits had made prototypes for digital interfaces. But where two systems that operate with different specifications of the CV/Gate model will be able to produce some kind of sound, if note the intended pitch for instance, two digital systems with different specifications will most likely not be able to communicate at all (Manning 2004, 267). The different versions of CV/Gate speak different dialects while the different versions of digital interfaces speak entirely different languages. So the mentioned prototypes could not communicate at all, and were unusable together. Knowing this we can see some motivation for creating a unified standard.

In 1981 the process for creating MIDI got started. Meetings were held between several of the major manufacturers of synthesizers with the proposal of creating a universal synthesizer interface (Theberge 1997, 85). The initiative for this was originally put forth by Dave Smith who at the time was the president of the company Sequenctial Circuits (Manning 2004, 266). Smith himself says that when Sequential Circuits created the Prophet 5, they created the first synth with a microprocessor. Smith elaborated in an interview and said "...so when everybody started copying it, they used microprocessors. As soon as you have one in an instrument, you realize it's pretty easy for them to talk to each other digitally" (Fortner, 2016). So the adoption of digital microprocessors in synthesizers ignited the idea of creating a communication protocol that would supersede the CV/Gate system.

Further negotiations were held the following year, and resulted in all of the American companies except Sequential Circuits, spearheaded by Dave Smith, dropping out of the negotiations. The crux of the matter was a difference of opinion as to how the standard was to be implemented. There were debates over limiting the technical aspects of the standard. Some of the participants wanted higher specifications for bandwidth and bit rate. But this would have hindered the ability for the manufacturers to implement MIDI at a cost effective level. The intention and vision of many of the participants was to make the standard so affordable to implement that it would make sense to fit this standard into instruments and controllers of all price classes. The prospect of having MIDI implemented only in high end hardware was not appealing to some of the participants. We will talk more about the limitations of MIDI in the next part of the paper. (Theberge 1997, 84-87).

After Oberheim and the other American manufacturers dropped out, the collaboration was now solely between Sequential Circuits and the Japanese companies, with Roland at the head of operations (Manning 2004, 267). The team that was left made fast progress and by the end of 1982 a draft of the specification was completed, and the acronym MIDI for "Music Instrument Digital Interface" had been decided on (Ibid). Of the naming of the specification, Smith said:

> ...they'd suggested Universal Musical Instrument Interface, pronounced "you-me," as in "we all connect together." I thought it sounded a little corny, but I liked the idea of musical instrument instead of just synthesizer. For some reason "Musical Instrument Digital Interface" popped in my head and I said, "How about MIDI?" Everybody said, "Okay." (Fortner, 2016).

This swift development of the specification led to Sequential Circuits and Roland having produced synthesizers with MIDI interfaces implemented by the end of 1982, and culminated in a demonstration at the National Association of Music Merchants in January 1983 (Manning 2004, 267). At this demonstration Dave Smith and Jim Mothersbaugh connected a Sequential Prophet 600 and a Roland JP-6 together using MIDI interfaces. And it worked (Diduck 2017, 107). It had now been demonstrated that MIDI was a viable interface between synthesizers from different companies, and by the end of the year other manufacturers followed suit and had started incorporating MIDI in their hardware modules. MIDI was here to stay (Manning 2004, 267).

One of the companies that got on board with the MIDI specifications early on were Yamaha. And in the same year as the specifications were ready they released their FM synth DX7 (Diduck, 2017, 81-82). The DX7 was the most selling synthesizer in history. It sold two hundred thousand units in three years. For comparison, the Minimoog sold twelve thousand in its entire production run (Pinch and Trocco 2002, 317). According to Ryan Diduck in his book "Mad Skills"; ..." MIDI was a chief reason for the DX7's mammoth sales (Diduck 2017, 82).

At the NAMM show in 1983 Smith and Mothersbaugh had demonstrated that MIDI would function as a communication tool between different synthesizers. But the use of MIDI was not contained to this domain. MIDI is designed to work with audio, and most applications for it are in some way or other connected to audio. But the information that is sent is pure numerical information (Collins 2010, 46-48). So it can in theory be used to control anything that can decode and utilize the information that is being sent.

First of all, the protocol could be used to send information from computers to synthesizers. Using for instance an Apple Macintosh, composers and musicians could make compositions on the computer and with the help of a MIDI interface they could send the MIDI information of their compositions to synthesizers and the synthesizers would play the music (Yavelow 1986, 11-13). The Atari 520ST even had built in MIDI (Oldcomputers.net, “Atari 5020ST”). But there were other musical uses as well.

Educators started using MIDI to create lessons for school children. Having the possibility of using basic accompaniments, and sharing songs using little bandwidth and storage space was a great resource (Kersten 2004, 44-46). People have also been using MIDI to trigger lighting effects at shows. By converting MIDI signals to a format called DXM you can use a MIDI controller of any kind to trigger lighting. You could even use the information being sent by a MIDI instrument so that the lights on stage will trigger in time with your playing. A recent article by János Kollár discussed the possibilities of using utilizing MIDI in the treatment of stroke patients, coining a concept he calls “Midicine” (Kollár, 2016, 1-2). This illustrates not only the flexibility of MIDI, but also its relevance more than 30 years after its inception.

We have now seen some background on how and why MIDI was created, and also covered some its uses. But MIDI is not without its limitations and problems. In the next part we will see how MIDI works, and cover some of these limitations to the specification.

2.2: Problems and limitations of the MIDI specification

With MIDI in place as a new standard, a lot of possibilities opened up for use with it. Computers could now control synthesizers, you could use on as a master keyboard or controller for other units, and there were beneficial aspects when it came to education.
But the creation of the standard had come at a cost. To make it as accessible and universal as possible, there had to be made concessions when it came to functionality and specifications. A lot of these were to keep the cost down, and some of them have proven to be less than ideal when considering the concept of future proofing. In this next section I will give a brief overview of what MIDI is and what the limitations to the specification are.

MIDI is an acronym that stands for Musical Instrument Digital Interface (Anderton 1986, 1). In essence it is a communication protocol that sends numerical data between compatible devices. The complete specifications of MIDI is a vast and very technical topic, but I will give a short description to describe the essence of how MIDI works. The information that is being generated and subsequently sent when you play a MIDI keyboard is basically four types of information packaged in one message. When you press down the key of a velocity sensitive keyboard, it generates a message stating that the key is "On". Integrated in this message is also information for how fast you pressed the key (this is referred to as velocity in MIDI), a message for the note that is played, and which MIDI channel the information is to be sent via. When you release the key, a message that the key is "Off" is generated, and this message contains the same sub information that the "On" message contains. (Anderton 1986, 33,34). There are several other messages that can be generated and sent within the protocol, but it will be enough for now to understand these general messages.

MIDI works fine for these basic applications, but it also has its technical limitations. One of the limitations refers to resolution. MIDI is primarily limited to 7 bits of information, but some parameters like pitch bend can send 14 bits. But this is also dependent on the controllers being set up to send information with this resolution, and it can impair the throughput of the MIDI signal (Loy 1985, 17-19). There had been skepticism towards limiting the protocol to this low of a resolution when it was being developed, but it was decided that the resolution would be sufficient, and it would keep the costs down. So what is the problem with this, and how is it limiting? A 7 bit resolution means that in practice you only have 128 integers to send as a signal per message, in the case of MIDI it is 0-127. A lot of the parameters you have on a synthesizer works fine with this resolution. For instance, if you have an oscillator type selector where you could select between a sine wave, saw-tooth, square and noise, 128 values are obviously more than sufficient. But other parameters can benefit from a much higher resolution. The best example for illustrating this is the filter of a synthesizer. If we picture a low pass filter that is supposed to sweep from 18 000 Hz to 30 Hz, we quickly realize that the 128 values can not represent each point of the frequency spectrum for this filter sweep.

You can argue that it would not be necessary to represent each frequency, but even so, 128 is too few steps. What happens is that you get a "steppy" effect when you sweep the filter, instead of the desired smooth action. You could imagine the same effect if you think about two dimmer switches which control a light that can represent all the different shades of colours we can perceive with our eyes. One of them has a high resolution and when you turn it from low to max slowly the light seamlessly glides from colour to colour. The other switch is low resolution and when you turn it at the same tempo as the other switch, it just jumps from one colour to the other without the transitions. Fewer colours, less detail. Also, seeing as you can map just about any parameter in a DAW to be controlled by CC messages, there are a myriad of possible parameters that have no relation to a traditional synthesizer that could benefit from a higher resolution. This limitation is obviously relevant to MPE controllers as well. As we will see later in the paper, one of the standard ways an MPE controller is set up is that you use the Y-axis on the key to control the opening and closing of the filter. Depending on the size of the key and the possible travel for the finger this can make the instrument feel less expressive than it would with a higher resolution.

MIDI inherently introduces latency in the signal it sends. This is connected to the fact that the protocol is based on a serial signal path. This means that each event or message that is generated is sent after one another. So if you press down a key on a MIDI keyboard, it sends one message. But if you press down two keys at the same time, they are not transmitted simultaneously, but after one another. This means that the higher the number of keys you press down, the longer it will take for all of them to be transmitted. Some argue that the bandwidth of MIDI is sufficient to capture musical performance and that the delay that is introduced is imperceptible (Loy 1985, 13,17,18) .

There is also a concept called "temporal smearing". This is related to the fact that there is not just delay present in the MIDI signal, but it can also be unpredictable. This can lead to attack times being altered, and this can fundamentally alter the timbre of the sound. All these problems of timing can be a hindrance to what F. Richard Moore calls "Control Intimacy" in his paper "The Dysfunctions of MIDI. (Moore 1988, 22, 23). What he is referring to with this term is the feeling of control a performer has when playing an instrument. Moore states that: "For subtle musical control to be possible, an instrument must respond in consistent ways that are well matched to the psychophysiological capabilities of highly practiced performers." (Moore 1988, 21). The argument that MIDI is not capable of handling real time gestures to a satisfying degree has merit to it, and it is something to consider when realizing that the MPE controllers we will be looking at later have these same technical limitations.

There are alternatives to the MIDI protocol for communication between instruments and computers. An early attempt to create a rival standard was called ZIPI. With ZIPI the creators tried to address some of the limitations of MIDI, but it was never adopted as a standard. (Wright 1993, 86-88) Another alternative to MIDI is called OSC, Open Sound Control. This system addresses many of the technical limitations with MIDI, like bit rate and bandwidth. But while OSC is being used by many practitioners today, it is not in any way the standard that MIDI has become. OSC is something that is used by technologically proficient people to set up their own customized systems, which we will touch on in the next section.

but it has not been adopted by the major manufacturers to any notable degree (Wright et al 2003, 125-130).

We have seen that MIDI is not without its limitations. But it has afforded people with technical know how ways of creating alternative and experimental instruments and devices. In the next section we will look at some MIDI instruments produced by mainstream companies that do not adhere to the standard of a keyboard as an input module Will also have a look at some experimental and DIY based devices.

2.3: Thinking Differently About Controllers

In the previous parts we have seen why there was a need for the development of a protocol like MIDI, and what limitations were inherent in it and still are present. But even though MIDI has its limitations, it has afforded musicians and music technologists expansive possibilities to control sound generators, even design their own sound generators with accompanying controllers. In this next part we will look at some mainstream instrumental MIDI controllers that have adopted other layouts than the keyboard layout. We will also look at some examples of the more underground and experimental scene of musical interface design, and how there are possibilities for people to design their own expressive instruments, but consider the lack in commercial ready built instruments.

Commercial Ventures

When the synthesizer first became a viable instrument for musicians, the two main protagonist in the story, Buchla and Moog had differing opinions on how they should be controlled. Buchla envisioned an innovative way of controlling the new sound generators while Moog, perhaps due to his close collaboration with composer Herb Deutsch, came to favour the keyboard model (Pinch, 7,8, 43, 59-61). The emergence of the synthesizer as a mainly keyboard centric instrument might feel logical in many ways, but it is not without its limitations and problems, much like the instruments it is based around. We will talk in further detail about the limitations that this focus on keyboards brought with it to the implementation of MIDI later.

There have been developments in interfaces for control of electronic instruments for many years. The vast majority of commercially produced controllers are as mentioned based on the keyboard model, but there are some notable exceptions. One of them is the EWI controller which stands for Electronic Wind Instrument. Created by Nyle Steiner in the 1960s, it is a controller that through a mouthpiece detects air pressure, translates that data into digital information which is sent to a synthesizer module (Patcmanmusic.com, “The Nyle Steiner Homepage”). AKAI acquired the product from Steiner and have been refining the design and releasing new models over the years. The EWI gives performers who have wind instruments as their primary instrument a method of controlling different sound generators with an interface that feels more familiar to them than a keyboard.

MIDI has also been implemented in different ways for the guitar. There were ways of controlling synthesizers with guitar before MIDI also, like the Roland GR-500. This was a synthesizer module which was created in tandem with a controller called the GS-500. This concept made it possible for guitarists to play a synthesizer module with their guitar (joess.com “Roland GR-500 Parapahonic Guitar Synthesizer”). Roland further developed this concept of MIDI guitars and in 1986 released the GK-1 and the GM-70. The GK-1 is a hexaphonic pickup that is installed on an electric guitar. The system tracks temporal and pitch information from each string. This information can be sent to any of the compatible Roland guitar synthesizers, or you could send it to the GM-70. The GM-70 is a pitch to MIDI converter. It takes the signal from the GK-1 and converts into MIDI information. When used together the GK-1 and the GM-70 function as a MIDI guitar controller, and the performer can connect to any hardware synthesizer or virtual instrument in their computer that can process MIDI information and play them using their guitar. Roland have refined the concept with smaller pickups and MIDI converters, and improved on the tracking capabilities, but the system remains much the same today (Joess.com “Roland GK-1 Synthesizer Driver”).

One of the interesting aspects of these controllers is that there is nothing that says you have to use it to control for instance a guitar-like sound with the Roland setup. The information that is produced and transmitted are numerical values with no bias towards the sound that will be output from the sound generator. So you could play a violin with your guitar controller, or play a drum beat with the EWI. This leads to some interesting cognitive questions which we will discuss later. But the aspect of MIDI being soundless information opens up a multitude of possibilities for how it can be used. And there are a lot of examples of people being creative about what you can use to create this information and how it is interpreted.

The DIY World of Controllers

In the 1970s, Herbie Hancock worked with an engineer named Bryan Bell. Mister Bell helped Hancock realise a very intricate setup for handling his multitude of instruments. Since there was no standardized protocol for communication between sound generator modules, they had to be create their own setup. This was especially important for Hancocks live show (Diduck 2017, 140-145)

Today performers and technologists can utilise an enormous amount of tools to create and design their own control environments. With protocols like MIDI and OSC, combined with programming environments like MAX/MSP or Pure Data, people can program their own sound generators and control them with self made controllers, or commercially available controllers that might not have been designed for that specific purpose.

In an article called "Principles for Designing Computer Music Controllers " from 2001, Perry Cook talks about several projects he has worked on involving designing controllers (Cook, 2001). By fitting sensors to objects like rhythmic shakers, to the feet of people, and even kitchenware he and his colleagues created controllers that by sending MIDI information could control the performance of different musical loops. They did not actually play any individual notes, but the controllers were intended to guide the music along (Cook

2001, 5-9). Another interesting instrument is called reacTable. The concept of this controller is that you have a table where you place different objects that have markers called fiducials on them. A camera tracks the movement of the objects and converts the positional data of the objects into numbers which can then be sent to a sound generator via MIDI or OSC (Jordà 2003, 96-100). The reacTable was commercially released, but there also exists an open source version of it calle reacTIVision where you can print out the fiducial markers and make your own controller (reactivision.com, "a toolkit for tangible multi-touch surfaces").

A product that has been utilized to perform musical tasks even though it was not designed to do it, is the controller for Nintendo's gaming system, Wii. The controller has positional tracking and an accelerometer built into it. And this sensory information can be transmitted via Bluetooth into a computer and be further converted into MIDI information for use with musical software (Lehrman, 2008).

The electronic music artist Tim Exile has over many years worked on creating his own performative music system. By using a multitude of MIDI controllers and creating his own loopers and instruments in the programming environment Reaktor, he has created a set-up which he has called the flow machine. With this fairly inexpensive set-up he can create whole songs from simply looping short sounds and processing these through the system he has created in his computer (Youtube.com, "Inside Tim Exile's Flow Machine – Gear Guide").

As we have seen there are many exciting possibilities for utilizing MIDI or similar protocols to create controllers that do not adhere to the standard of a keyboard. One can say that there has been a democratization of means when it comes to creating electronic music instruments and controllers.

The feeling of controlling small nuances of the sound of an instrument is something that most accomplished musicians can attest to being of importance to them. In the next part we will look at reasons for why this is, and how the development of music technology, electronic music instruments, computer music and to a degree MIDI has removed the performers from this level of control.

2.4: Why MPE for Performers?

We have now seen how MIDI has afforded musicians and technologists a platform for developing their own instruments and controllers. Now we will see some reasons for why one would want more expressive control over electronic instruments, and how electronic instruments differ from traditional acoustic instruments.

When we think about melodic music we might first think of the human voice. Before musical instruments were constructed, song and the manipulation of the voice were humans only method of producing melodies. But as early as prehistoric times there were built musical instruments, to try and emulate the human voice. This early form of musical technology is a part of a continuous development that is still ongoing. In his article "A Historical View of Computer Music Technology", Douglas Keislar argues that this development can be seen as containing an element of what he calls *disjunction* (2011, 3-9). This means that for each new technological development there happens a separation between one part and another. A few examples will help clarify this concept. The invention of the musical instrument created a disjunction of sound production from the body. The keyboard, a disjunction between the control mechanism and the sound generators. The strings in a piano are not directly plucked by the performer, but are excited by a hammer, which again is actuated by a key on the keyboard, pressed by the performer. The last example I will give is the one of electronic musical instruments. The disjunction here is that the control mechanism is physically uncoupled from the sound generator. The intricate mechanics of the piano forte have been replaced by an on/off switch sending voltages or in the case of MIDI a digital information stream. The actual sound producing elements are impossible to touch or be manipulated physically (Ibid, 6-9).

With this concept of disjunction and decoupling in mind, we can imagine that this is a process with both benefits and drawbacks. The sonic possibilities afforded to musicians and performers by electronic music instruments is immense, and opens up a world of fairly inexpensive exploration of multiple facets of playing and composing music. But with these gains, one could argue that an element of tactility and physical presence have been lost in the process. A need for a *recoupling* of some elements of the sound generator and the mechanism is what we are talking about here. It is hard to imagine physically plucking a "virtual" string, but what can be achieved is the feeling, or illusion of actually touching the electronic instrument. To understand further why one would want to have this more tactile and expressive interaction with controllers, it might help to understand how musicians interact with instruments and how sound is generated from the instruments.

The topic of gestures in music is one that can help us illustrate how important the relationship between the performer and the sound produced can be. There are a number of different movements and interactions that can classified as gestures in a musical context. Some of these are related to direct interaction with the instrument, and others are more subsidiary and can be viewed as less vital to the production of sound, while still being an integral part for a musical performance. In his book "Sound Actions"(Jensenius, 2018), Alexander Refsum Jensenius divides these gestures into four main categories. *Sound-producing actions, sound-facilitating actions, sound-accompanying actions* and *communicative actions*. We are going to concentrate on the first two categories here, but I'll quickly mention the attributes of the other two. Sound-accompanying actions do not have a direct role in the production of sound, but are movements that follow the produced sound, like playing air-guitar. Communicative actions are movements and gestures that again don't directly apply to the sound generation, but could be a gesture between for instance performer and an audience. Exaggerated playing styles on the piano or metal guitarists headbanging are examples of these types of actions (Jensenius 2018, 52-53).

We can divide the sound-producing actions into two subcategories of *excitation* and *modification*. Excitation is the act of engaging the sound producing element. For instance when plucking a string on the guitar, you physically touch the string and make it vibrate (Rossing, 11-14). If we pluck the string and let it vibrate until it dies it out, we can say that the sound produced has a sustained character. If we pluck the string and quickly touch it again, stopping the vibration, the sound has an impulsive character. A common technique on the classical guitar is called *tremolo*. When performing tremolo technique the performer usually utilises three fingers on the right hand. With these three fingers he plays one impulsive sound with each of them in quick succession, and when performed correctly it gives the illusion of continuous sound. This technique is an example of an iterative character of an excitation action. These are the three subdivisions of an excitation action (Ibid, 54-55).

The modification actions affect the sound of an instrument in the sustain portion of the sound.. You have many options on for instance the guitar to modify the sound after the excitation action. If you let the string ring out you can bend the string to create increases in pitch. You can slide up and down between frets to do the same. You can move your hand in a vibrating motion to create vibrato effects. There are a multitude of these options for a performer to affect the sound on most wind and string instruments. To illustrate further some of the decoupling that has happened with the emergence of electronic music, we will discuss another instrument, the piano, in the context of what we now have started to understand about the gestural nature of performance (Ibid, 55-56).

As we have mentioned, the invention of the keyboard created a disjunction between the control mechanism and the sound generators. To excite the string on the piano, the player performs a gesture on the keyboard, which is linked to a mechanical structure with a hammer at the end, which in turns excites the string. The performer's role of sound generation is moved one level away from the sound source. The ability of the performer to modify the sound after the excitation action is also reduced by this mechanical decoupling. Some would argue entirely removed. When the key is pressed there is no way to modify pitch or volume. These decisions have been made by the player the moment the key is struck. Which key is pressed determines the musical pitch of the sound, and how hard it is pressed determines the amplitude of the sound. Even though you can sustain the sound for as long as you hold the key down, or even when letting go if you utilize the sustain pedal, there is no way of changing the role of the sound, other than temporal by letting it exist. And here we can begin to understand some of the problems with controllers for electronic instruments and their dependence on MIDI.

The majority of instrumental MIDI controllers are based around the traditional keyboard. And as we have come to understand this means that like the piano it is based on a fairly static on/off paradigm. The MIDI standard has implemented a few things that are improvements on the piano model. On a standard MIDI keyboard these come in the form of a pitch wheel and a modification wheel. The modification wheel can be assigned to any continuous parameter that can receive MIDI information. So as an example, you could control the amount of cutoff on a low pass filter with the modulation wheel. So you could play a chord, “exciting” the “strings” of the synthesizer, and perform a modification action with the modification wheel, affecting the timbre of the sound. Using the pitch wheel the performer can gradually increase or decrease the pitch of the notes that are being generated. There is also a function in the MIDI standard called “aftertouch” which some controllers implement. When the performer presses down the key, he can further press it down into the keybed to apply pressure on an aftertouch enabled key, and this will modulate the sound according to what parameters the aftertouch is set to affect (Anderton, 34). Combine this with the possibility of having any number of knobs and sliders that can be set up to control and manipulate facets of the sound, MIDI controllers far exceeds the potential for manipulation of the sustain portion when compared with the piano.

But there are limitations to these expressive options. For instance the pitch wheel information is not sent per note triggered, but pitches up all notes that have are currently engaged. This holds true for the modification wheel as well, there is no per note control over these parameters as implemented in standard MIDI keyboards. Another problem is that both the modification wheel and the pitch wheel requires the performer to utilize one of their hands to operate them. So not only is there no per-note expression, but to utilize the expression that is available, the number of notes available to the performer while utilizing these expression possibilities are also limited. One way of getting around this is to program changes into the patch of the synthesizer. By using envelopes, LFOs and other types of modulation, the quality of the sound can be programmed to change over time. But by itself these types of modulations does not give the performer any real time control over the quality of the sound. But these modifications can be linked to for instance the velocity sent by the MIDI keyboard. An example would be to program a patch so that when playing softly on the keyboard, the rate of an LFO sent to the pitch, producing a vibrato effect, would produce a low rate from the LFO, and the harder the performer plays, the faster the rate becomes, producing a faster vibrato. So there are ways to increase the expressive possibilities of a standard MIDI keyboard, even though they might feel too limited for some performers (Ibid).

The problems with electronic musical instruments further decoupling the performer and musicians from the sound source is something that MPE could be a candidate for mitigating. As we will see in the next section, the technical modifications that MPE brings to the MIDI protocol are also intended to give the performer more direct control over the timbral qualities of the sound generator by increasing the number of dimensions that they can manipulate in real time, and also by allowing expressive control per note in real time.

3 MPE Controllers

3.1: Introduction

As I mentioned in the introduction to this paper, I have focused on looking at a few specific MPE compatible controllers. The controllers I have focused on are the Roli Seaboard, Roger Linn Linnstrument, Haken Continuum, Soundplane from Madrona Labs and TouchKeys.
MPE is implemented in different ways in all of these controllers, with some benefits and some drawbacks to each. I had access to all of these controllers to do some testing. The department of musicology has all these controllers and were kind enough to let me use them for a few weeks so I could get some hands on experience with the type of controller I am writing about. I thought that since the main motivation for doing this project was my interest in finding instruments with the same tactile feeling as an acoustic instrument, I would try these different controllers out and see if any of them actually gave a semblance of the immediacy and tactility I think you get with an acoustic instrument.
I created a project to gather some data on the use of these controllers. Some of the data is very subjective and pertains to how I feel the controller works as an instrument and its playability. Some of it is more objective and is geared towards flexibility and ease of use. To get started I modeled the experiment on an article in the NIME Reader called "Towards a Dimension Space for Musical Devices"(Wanderley et al. 2005). The authors state that the goal of the text is to "illustrate an efficient, visually-oriented approach to labeling, discussing, and evaluating a broad range of musical systems"(Ibid, 212). They argue that while there have been earlier attempts of models for discussion and classification, the previous models lack a good visual representation of the devices. They say that there have been created models with a visual component, but argue that there are limitations due to the models employing too few dimensions.

To create their own model of visual representation they utilised a concept called *Dimension space analysis*. This concept was outlined by Graham et al. (214). The concept is that you have a number of axis which each represent a feature or component of the device. The axis spread out from a single point and are finite. Each axis has points marked on it that either relate to a continuous scale or discrete points that works as a score for each component. Lines are then drawn between the point of each axis and create a two dimensional visual representation of the attributes of the device.

In the text the authors state that the *dimension plots* are created "*...from the perspective of a specific entity involved in the interaction"* (Ibid, 214) . This means that it could be one person using the device, or a group. For my experiment i decided to use myself as the *entity*. The motivation behind this entire project is my own desire to find instruments and devices that can bridge my passion for playing acoustic instruments and creating electronic music. I am also an experience instrumentalist with the guitar, but not that comfortable playing with keyboards. I thought that this would give me an ability to act as both an experienced player and more of a novice with these devices.

With their adaptation of the Graham et al. model, the authors decided on a model with seven different axis (Ibid, 214-217). I decided to adopt their approach but make some modifications to it. Some of the components they used for their testing did not seem that pertinent to my own inquiry, so I replaced those axis with others I defined myself. I will first detail the axis I replaced, then give a description of each of the axis as I employed them. The first axis which I found to be unsuitable for my own project was an axis called "Distribution in Space". This axis is intended to represent the total physical are in which interactions take place. Since all the instruments I tested would be interacted with locally, and the output would be local, I saw no need for this axis. The next axis I discarded was called "Inter-actors". This represents the number of people interacting with the device. Seeing since I was the sole participant in the experiment, this axis was not needed and could be replaced with something more appropriate. The last axis I replaced was called "Role of Sound". This axis represents sound roles in electronic media (ibid, 217). It has three discrete points, *artistic/expressive,* *environmental,* and *informational*. Again I did not find this category to be useful for the devices I tested. Instead of these three categories I devised my own and replaced them. The categories I devised where “Plug & Playability”, “Performability”, and “Configuration/Mappings”. I will now detail all of the seven axis that I ended up using, before describing how I set up the experiment.

- *Plug & Playability*: This axis represents how quickly I was up and running with the controller as an MPE instrument. Some of these are fast to get up and running, others require a higher degree of technical ability on the users part. To test this out I used the same computer, same software and just plugged the controller in and saw how long it took me to get it up and running. As we see in Fig. 1. the line is divided into four points based on the performance.
- *Required Expertise*: This axis represents how easy or hard it could be for a user to play this as an instrument. All the controllers have strengths and weaknesses, and to test those i tried playing a fixed set of scales, melodies and chords on the controllers. I gave them marks for each task and they get a total rating from zero to eight on the axis, eight representing a representing the highest degree of expertise to play the instrument.
- *Performability*: This is the most subjective of all the categories. After testing the expertise section, I gave myself two hours to freely experiment with the controllers. The test is to see how comfortable I would feel performing with the different instruments after the set amount of time. I divided the axis into three different parts, *frightened, uneasy* and *confident.* I felt these three divisions would adequately describe the levels of how comfortable I would feel performing with the controllers.
- *Degrees of Freedom*: This axis describes how many modes of input the controllers have. They all have at least five, because this is in a way the definition of an MPE controller, but some have more. I have divided the axis into sixteen possible points where the controllers get one point per mode of input.

- *Configuration/Mappings*: This axis represents the flexibility of configuration for each controller. This category could be hard to detail and keep control of, because they are all somewhat configurable as pure MIDI devices. So I only looked at what different modes of configuration you could achieve using it only in its standard setting. I used three categories to represent this on the figure; *rigid, flexible* and *very flexible*. In addition to the types of alternate configurations I considered if you could change the configurations on the controller itself, or if a layer of software was necessary.

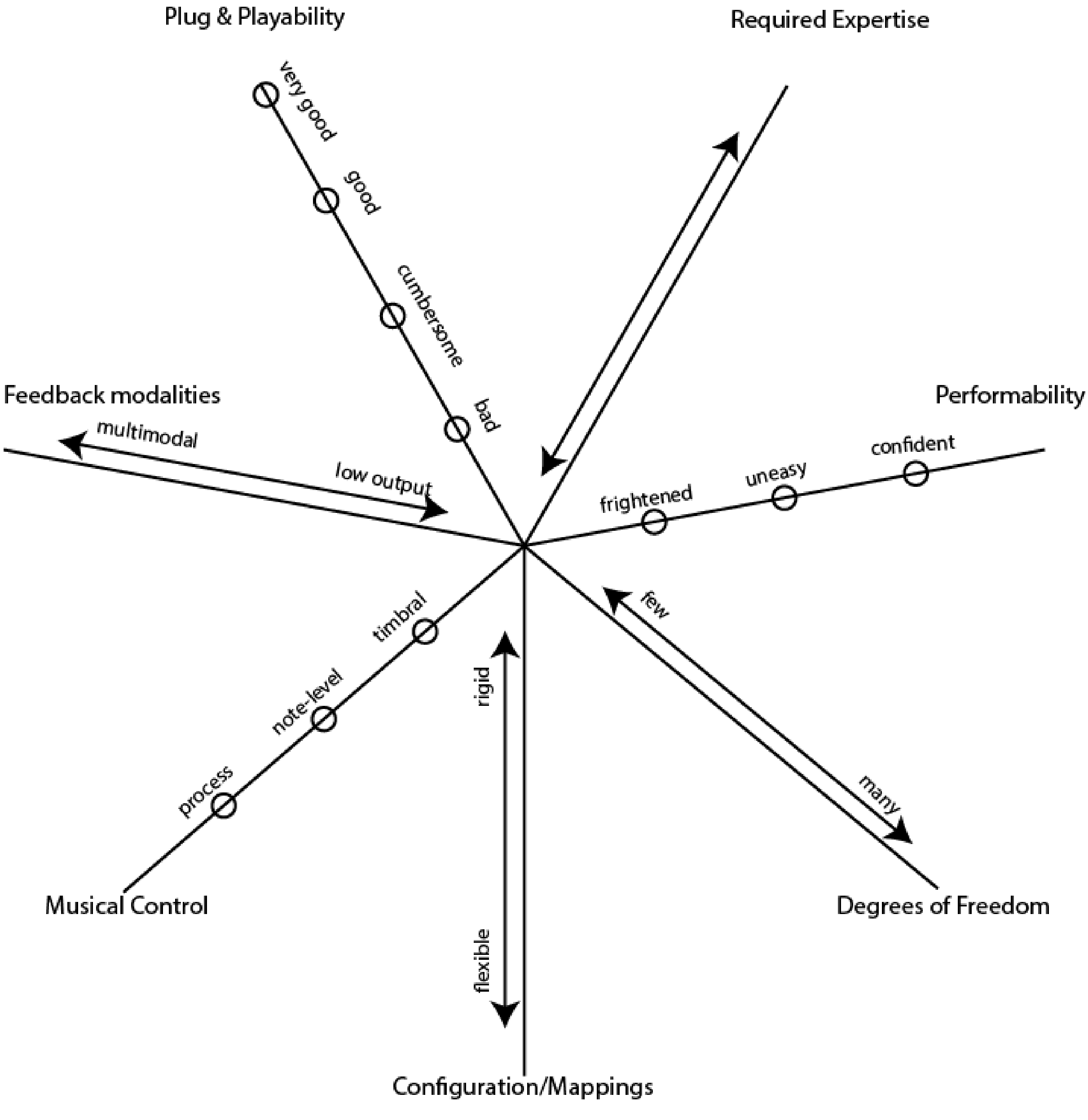

Figure 1: My modified version of the seven axis model

- *Musical Control*: This axis represents to what degree you can control the sound of the instrument. This category is taken directly from the article and have three fixed points. *Process, note-level,* and *timbral*. My assumption before even starting the experiment was that all the controllers tested would meet the timbral requirement because that is what is sought after in an MPE controller.
- *Feedback Modalities*: This axis represents the number of output modes that each controller sends. This is on a continuous scale from *low output* on the low end, and *multi modal* on the high end.

In fig. 1 we can see a model of the seven axis. We see that the the distribution varies between continuous and discrete. It also moves clockwise from “Plug & Playability” based on how interactive the test of the axis is, as well as the order I tested each axis in. Some of the axis were tested by actually playing or experimenting with the controller itself. Others are more metrics and evaluation of attributes. I will now detail how I went about setting up the experiment.

3.2: Setting Up The Experiment

All the controllers were tested in the same manner. Even though some of these points rely on subjective experience, I wanted to make sure that the testing conditions were as equal as possible for all of the controllers. The three axis which were the primary ones tested for playing and hands on use of the controller were the Plug & Playability-axis, the Required Expertise-axis and the Performability-axis.

I started testing the Plug & Playability-axis first with each controller. The object of this test was to find out how long it would take to produce MPE playing from a VST, on a computer that was not set up with the controllers in any way beforehand. Here follows a detailed list of the equipment I used:

- The computer I used was my own Macbook Pro Late 2011.
- I installed a DAW on it named Bitwig. This would have worked with any DAW, but Bitwig has integrated MPE support, so I thought it was a good choice.
- The synthesizer VSTi I used was Synthmaster 2. I chose this plugin because it is MPE compatible and uses relatively few system resources. I just needed a virtual instrument that would unpack the MPE information and let me know by auditory feedback if the controllers were generating this information. Quality of sound was not a consideration.

The criteria for testing this axis was how long from plugging in the device to the computer it would take me to generate this result. Before plugging it in, I had opened Bitwig and an instance of Synthmaster 2, with an MPE compatible patch in the VSTi, so that this would not have an impact on the total time. I then started a stopwatch as I plugged in the device to keep track of the time it took. The intent was not just to see how long it would take the computer to recognize the device, but how long it would take me without any prior knowledge of the setup process to get MPE information from the controller to the VSTi. So the time would include all the time it took to gather manuals, if needed, work out technical problems on the computer and so on. The ideal being a controller that you just plug in and it is ready to be used. I divided the axis into four discrete points, based on the amount of time it took to finish this part of the experiment. The possible scores were as follows.

- 0-5 minutes = “Very good”.
- 5-15 minutes = ”Good”.
- 15-30 minutes = “Cumbersome”.
- 30+ minutes = “Bad”.

- The next part in the experiment was to test the required expertise. To test this I had a fixed set of musical examples I would try and play on the controller. I had learned how to play all of the examples on both piano and guitar before playing them on the controllers.

The first part was simply playing scales on the controller. I chose very basic diatonic scales.

- C Major
- C Minor
- Eb Major
- Eb Minor

The reason I chose these are that I wanted one scale that contained all the white keys from a piano, and some that contained a few flats.

The next part that would be tested was playing chords on the controllers. I composed two very simple chord progressions in the major key for this. One that contained some inversions, and one where the chords move around in first inversion. The reasoning behind this was that I suspected that controllers that have a tuning layout based on for instance guitar instead of piano might prove more difficult to play certain chord structures on. I played these progressions in both C Major and Eb Major.

Lastly I wanted to test some music that required slide and vibrato techniques. This is one of the most exciting aspects of the MPE controllers. The ability to be able to glide between notes without having to press the key or pad again, and applying vibrato on each note. I chose two short musical pieces for this.

- The first one was the guitar solo part in Weezer's "Say it Ain't So". I chose this because I know the part well, and it contains both string bends, slides and vibrato playing.
- The second piece was a part of the theme from the movie "Schindler's" list. I wanted to have something that was written for the violin, and I chose this again because I know the piece and have played it on guitar and piano, and also

because there is a lot of vibrato and glides in the melody. I gave marks to the controllers for each of the tests and summed them together for a total score between zero and eight.

When testing these axis I used another computer which i borrowed. This computer had a copy of a virtual synthesizer called “Equator”. It is produced by Roli, which also are the creators of one of the controllers I tested. You can use it with any controller you want, but I chose to use that because it is specifically designed for use with MPE controllers. I used the same sounds for the same examples for all the controllers.

Next I wanted to test the axis which I called Performability. The object here was simply to see how comfortable I would feel performing with the controller in front of an audience after a set amount of time. I suspected that some of the controllers would lend themselves more to a studio environment than as performative instruments, so I wanted to try this out. The test was simple. I used Equator again and set a countdown clock for two hours. I wanted to give each instrument enough time to reveal whatever shortcomings they might have. And at the same time give them enough time so that I could get a bit comfortable with them. The thought was that I would pretend that I had a gig to play that night, and I had two hours to practice on this instrument I was unfamiliar with. I divided the axis up into three discrete points. Since this was a subjective test, I chose subjective words, and I named the points from good to bad:

- “Confident”.
- “Uneasy”
- “Frightened”

These axis were the ones that required physical testing of the actual controller. The other axis were more to do with metrics and required me to study the controllers, their output and their respective manuals.

With the Degrees of Freedom axis, I read what the manual stated the dimensions for input per note were. In addition I tallied up the number alternative inputs, like pedals, pitch wheels touch strips and so on. I then gave a point for each dimension of input and each controller a score between zero and sixteen. I made it a maximum of sixteen because I did not anticipate any of the controllers to exceed this number. For the Configuration/Mappings axis I read in the manual about what other modes besides the standard "instrument" mode you could use the controllers as. Since the controllers all send MIDI, you can map them to anything that receives MIDI, but I was more interested in whether or not there were any extra built in functionality.

The Musical Control-axis was the easiest to test, and I anticipated that all of the controllers would fall in the category "Timbral level".

Feedback Modalities were again tested by researching how many modes of feedback the output of each controller produced.

Now that we have seen how I set up the experiment, I will give a detailed description of how each controller fared in the experiment, before presenting the visual results and discussing the results and their implications.

3.3: Roli Seaboard Grand

Figure 2: Roli Seaboard Grand, top view. Image from Roli.com

Specifications

The Roli Seaboard Grand is an 88-note controller designed around the concept of a piano claviature. It is made of type of rubber which enables a type of faux haptic feedback. In addition to the keys it has a touch strip in the same rubber material, situated underneath the keys. It also has a dial to select different presets and switch octaves. The controller has three inputs for pedals on the back. It also has two balanced TRS ¼" audio outputs, a volume fader, a headphone output, two USB ports, a power input and a power switch, all situated on the back of the instrument. The first commercial release of the instrument was in 2013. The version I tested is a beta version of the Seaboard, but it has been updated to have the full feature set of the commercial release.

Figure 3: Roli Seaboard Grand, back view. Image from Roli.com

Practical testing

I started with testing the Plug & Playability of the instrument. The Seaboard has an onboard version of Equator, the sound generation VST I used to test all the controllers. But I tested it the same way as the others, with Bitwig and Synthmaster 2, to get an equal result. It connects to the computer via a standard USB connection. I connected the instrument to the Macbook and it was immediately recognized. As soon as I started playing, I got sound from the speakers and it worked with MPE functionality. The whole process took 40 seconds from I connected the controller to the computer. That is as fast as you can expect from any controller and I gave it the top mark of "Very good". One thing to note about the Seaboard is that to configure it you need to go through a software editor. This in itself is not a major issue, but to access the editor you need to register an account which is connected to a serial number you get with the instrument. This is understandable when one thinks about theft protection, but makes it a bit hard to just loan the instrument to someone who wants to perform with it for a night.

The next axis I tested was the Required Expertise Axis.

- I started out testing playing scales on it. Seeing that the instrument is based on a piano structure the placement of the fingers is fairly easy if one has ever played a bit on a standard piano or keyboard. But to play scales cleanly requires a good amount of skill and practice from the performer. The controller has triggers for the black keys in between the white keys. This opens up possibilities for more expression, but it takes some getting used to if you are used to playing on a piano.
- Playing chords on the Seaboard has much of the same feel to it. The finger placement is easy, but intonation is an issue here as well.
- When i next tested playing the guitar solo part and the theme from Schindler's list, I used the touch strip below the keys instead of the keys themselves. The touch strip works really great for this type of playing. It responds in a satisfying way to pressure and I really got the sense that I was playing an actual instrument rather than just pressing on/off on a controller. One thing that makes it a bit more difficult than some of the other controllers is that the touch strip does not have any markings on it, so you have to look at the keyboard to get a reference point for intonation. This means that to get good intonation you might have to practice a bit more than on some of the other controllers where you actually glide from key to key.
- The Seaboard ended up getting a total score of seven on the Required Expertise-axis. It is not an easy instrument to start playing if you are a

beginner, but it is very rewarding and has a great scope for increasing expertise for performers.

The next axis I tested was the Performability-axis. As mentioned in the description of each axis, I used the Equator synthesizer and played around with the controller for two hours. The Roli Seaboard is immediately rewarding and exciting to play around with. After a short while one gets comfortable enough with the intonation to where it does not feel as intimidating as it might feel when one first tries the controller.

There is also a consistent feel to the controller when playing. There were no surprising results or false triggerings that I encountered. There is a definite technical challenge to playing the instrument but the natural feel of the controller more than weighs up for that. Therefore I placed it in the "confident" category on the axis.

Inputs and outputs

The next axis was the Degrees of Freedom-axis. The Seaboard has the five dimensions of input we expect from an MPE controller. In addition to that it has the touch strip, which can be played simultaneously with playing on the keys themselves. It also has three inputs for pedals which further increases the dimensions for expression. In total it has nine inputs, which gives a lot of control for expression.

In the standard mode the Seaboard has no extra options for configuring it to act in other ways than as an instrument controller. There are no alternative modes of operation and so I put it in the "rigid" category on the axis of Configuration/Mappings.

On the Musical Control-axis it falls into the category of "Timbral level". That is the highest level on the axis.

The Seaboard is a bit hard to place on the Feedback Modalities-axis. In a strict sense it only gives you auditory feedback, so it only receives a score of one and is towards the "Low-output" point on the axis. What makes it a bit hard to place is that a case could be made for it having another feedback modality, which is the feedback you get from the rubber surface when playing. But it is not really any haptic feedback in the true sense, so I could not give it another point for that, but I felt it worth mentioning.

3.4: Madrona Labs Soundplane

Figure 4: Soundplane, top view. Image from madronalabs.com

Specifications

The Soundplane is an MPE enabled controller made by Madrona Labs. It was first released in late 2011 with an initial production run of thirty units. The controller has one hundred and fifty pads that respond to velocity, pressure and x and y axis movements per pad. The playing surface is fashioned entirely out of walnut which is intended to give the user a feeling more akin to playing a real acoustic instrument than traditional MIDI controllers.
It is a relatively small and light controller weighing 2.1 kg with a total physical measure of 74 x 20 x 3 cm, so it is a very portable instrument. The Soundplane has no inputs or outputs on it expect for a USB-port. It is USB-powered so there is no need for an external power supply.

Madrona Labs is a fairly small company and the instrument is produced in batches of thirty one or two times a year. (Madronalabs).

Figure 5: Soundplane, back view. Image from madronalabs.com

Practical testing

I tested the Soundplane in the same way as the others, starting with The Plug & Playability-axis. This was not the strongest point of the Soundplane. After connecting it to the Macbook with the USB cable it took twenty five minutes to get any sound from the Synthmaster plugin in Bitwig. To get it working you have to set it up to send MIDI via the IAC MIDI driver in OSX. This process is in itself complicated and might be too complicated for people with lesser computer knowledge. And this is much more straightforward in OSX, with Windows it is even more complicated. To set it up you also have to download a software editor. The editor itself was not easy to find on the website of Soundplane. After finding the editor and setting up the IAC connection, I still could not get any sound to play. I read through the manual a few times and could not figure it out. After a while I noticed there was a toggle named "active". After toggling it on, I got sound out of the plugin, and it also worked with MPE immediately. One could say that I should have noticed the option sooner, but after reading through the manual thoroughly I could not find any mention of the option in the manual. The manual was not very informative, and I would counter with saying that in my opinion the option should have been toggled on by default. Either way, the amount of time from connecting the controller to the computer before I had MPE enabled triggering of Synthmaster put the controller in the “cumbersome” category.

Next I tested the Required Expertise-axis.

- The fingering positions for playing scales on the controller feels natural, and as long as you hit the correct pad intonation is not a big problem on this instrument. But the keys are relatively small and you need to be very precise. I also noticed at this stage of the testing that the triggering of notes did not seem to be as consistent as one would like. When pushing the pads I did not get the expected result all the time, but at this stage I thought it might be attributed to my inexperience with the instrument.
- Chords were much more difficult to play on the controller. There are a few problems that contribute to a technically challenging experience playing chords on the soundplane. The fact that it is set up like a guitar makes the finger positions for some chords much harder than on a controller based on a piano setup. This is exacerbated by the small keys. When your hand is in an uncomfortable playing position, it makes it harder by having such a small striking surface. The problem with uneven triggering was also a factor here.
- When testing the guitar solo and violin part the Soundplane fared much better. It was really intuitive to glide between the pads for sliding parts, and intonation is not that difficult on it since there is a pad designating where to stop. Not like on the Seaboard where there is the touch strip. I played both the guitar solo and the violin melody without fault after just a few tries, and without fault many more times when i got them coded in my muscle memory. The problems with triggering are not present when you glide between notes. The part that lets the controller down a bit is that the pressure is not as sensitive as one might like. I had to press very hard to get notes to ring out after gliding to them, and it was

hard to get a satisfactory volume increase when actually pressing hard. This made it harder to get really expressive with held notes.

- The Soundplane got a total score of six with the ability to play gliding melodies making up for the shortcomings it has in playability of chords.

As with all the other instruments I played around with the Soundplane for two hours to test the axis of Performability. This further confirmed the impression I got from the initial testing. Playing solo violin sounds and guitar sounds with only one finger was very rewarding and gave predictable results. The pressure dimension is a bit uneven and does not produce a dynamic range I ideally want, but it can be worked around. On the other hand, I did not get any more comfortable playing chords during the two hours of testing. It is really hard to produce consistent results since you have to be really precise on a small surface, and you have to apply a good amount of pressure to produce notes. Getting consistent volume between different notes in a chord seemed almost impossible to me. And melodic lines with more legato or staccato playing still produced unexpected results and false triggering. I would be able to perform using the controller, but I would use it as more of pedal steel emulator, only playing sliding melodies. I would never dare try to play a chord in front of an audience. I therefore put the controller in the category “uneasy”.

Inputs and Outputs

When it comes to the Degrees of Freedom-axis, the Soundplane has four dimensions of input according to its own specifications. It sends out MIDI information for velocity, x and y axis and pressure. It has no inputs for any form of sustain of expression pedals which is a drawback.

The controller does not have any alternative configuration modes in its standard setup and therefore categorized as “Rigid” on the Configuration/Mappings-axis. As expected it falls into the category of “Timbral level” on the axis of Musical Control.

On the Feedback Modalities-axis, the Soundplane is problematic to place in the same way as the Seaboard. The walnut keys bend to your touch and gives a feeling of having a feedback mechanism reminiscent of a real acoustic instrument. But since there is no real haptic feedback, I find that giving it one point for the auditory feedback gives it the correct score.

3.3: Roger Linn Linnstrument 128

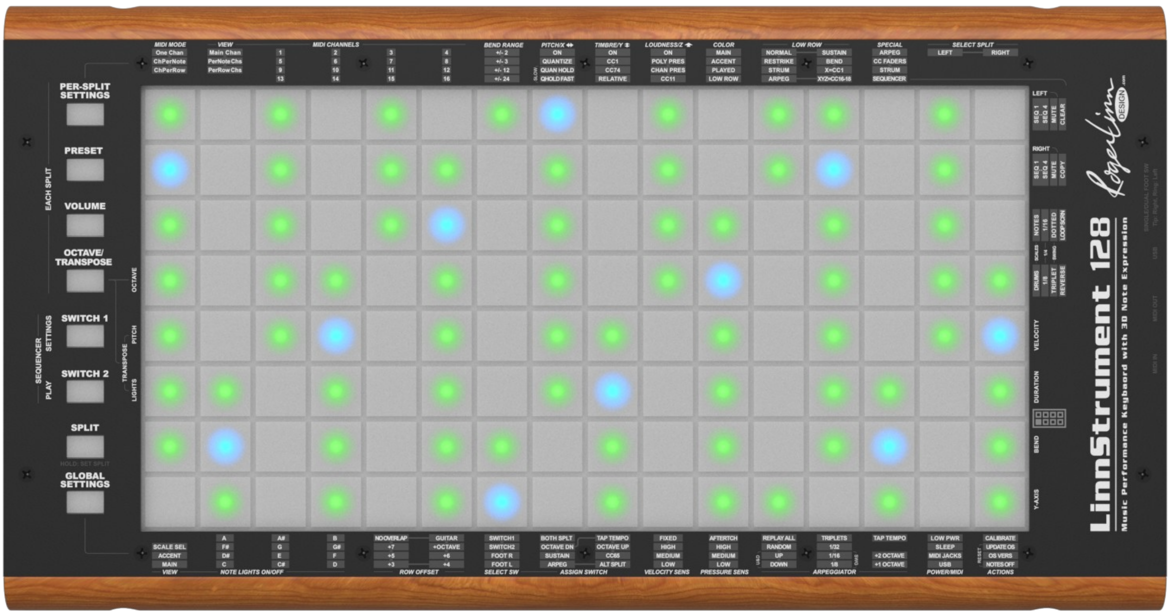

Figure 6: Roger Linn Linnstrument, top view. Image from rogerlinn.com

Specifications

The Linnstrument 128 is an MPE compatible controller with 128 RGB backlit pads. The pads respond to velocity, pressure, x and y axis as well as release velocity. The controller connects to the computer via USB and is bus powered. It also has connections for MIDI in and out, as well as a ¼ inch jack input for a footswitch. The pads are made of rubber and can be used for playing as well as switching settings directly on the controller (Rogerlinn.com). The controller was first released in 2016 (Sethi, “Roger Linn Releases Linnstrument 128”)

Figure 7: Roger Linn Linnstrument, back view. Image from rogerlinndesign.com

When testing the Plug & Playability-axis I ran into some minor problems. The Linnstrument was immediately recognized by OSX and I got it to play sounds from the Synthmaster plugin immediately as well. But I did not get it to work as an MPE controller right away. I needed to read a bit in the manual, and after a while I figured out that MPE was not turned on by default. The unit needed to be switched from "One Channel" MIDI mode to "Channel Per note". When I switched on this option it worked perfectly and the controller sent MIDI information to an individual MIDI channel for each note pressed. The whole process took ten minutes. Getting it to play sound only took fifteen seconds, but since the point of the experiment was to see how fast one could get it up and running as an MPE controller, it falls into the category "Good" instead of "Very Good".

The next part I tested was the Required Expertise-axis.

- Playing scales on the Linnstrument was easy and intuitive. The pads felt precise and there were no accidental triggering. Intonation was not an issue because you have to apply a bit of motion to activate pitch bend, and the quantization between notes worked smoothly. The layout of the controller also made it easy to orientate where you should put your fingers. It is set up in the style of a guitar, so each row up vertically is an interval of a fourth up. There are also lights on the pads, with a blue light indicating the set root note at any given time.

- Playing chords was a more frustrating experience. The pads are quite small so you have to be precise. Whereas this did not feel like a problem when playing scales, the guitar layout made some chord shapes awkward. I did not feel confident that I would get an even volume distribution between the notes or even manage to hit the right key. This is something that will improve if the performer practices a bit, but the pads are on the smaller side and a guitar setup is not the most appropriate for playing chords. You can change the tuning on the Linnstrument, but the point with this test was to see how easy the instruments are to play in their standard configuration.
- I then moved on to testing how it was to play the guitar solo and violin melody on the controller. The Linnstrument excelled at these tasks. The clear layout of the notes made it straightforwardly to figure out where the notes were. And gliding my finger between the pads produced accurate slide and pitch bend effects. The pressure sensitivity worked intuitively to produce increases and decreases in volume, and the whole playing experience felt very dynamic and natural. The pads felt a little stiff, but the response in sound when applying pressure was as expected. I did not really have to think when playing these parts, it just flowed out naturally and felt like I was playing a real instrument.
- The Linnstrument is a very enjoyable and easily playable instrument. The downside of the controller is that chords can be hard to play correctly. It received a total score of five on the axis.

After playing around with the Linnstrument for two hours I had no hesitation with placing it in the “Confident” category on the Performability-axis. It was a very enjoyable experience to play around with different sounds from the Equator instrument. The triggering was faultless and I never felt that wrong notes or sounds were down to anything other than my own lack of technical proficiency with the instrument. After a while I got more confident with playing chords as wheel. A controller like this is not likely to be as easy to play chords on with as a controller based on a piano setup. But I quickly found methods for mitigating the problems I encountered when first playing on it. I found the Linnstrument to have the feel of an instrument, which produced consistent results, and I would have no hesitation performing with it in front of an audience.

Inputs and Outputs

The Linnstrument operates with five dimensions of input on the controller itself. With the addition of the ¼” jack for a pedal it gets a total score of six on the Degrees of Freedom-axis

As fun as the Linnstrument is to play as an instrument, it really stands out from the other controllers when it comes to the Configuration/Mappings-axis. Firstly you can change the tuning of the pads, meaning you can have different intervals between rows than the standard of a perfect fourth. You can also split the layout vertically so you can play one instrument with the left side and another on the right side. There are also modes for a built in arpeggiator and there is a separate mode for using the pads to control CC messages. There is also a mode called “Strum”, where you can have for instance a note layout on the left hand side of the controller, and a row of pads on the right which you can strum, much like a guitar. All of these modes can be set up using different kind of splits so you can utilize the standard configuration simultaneously with these alternate modes. There is also a built in step sequencer on the Linnstrument. These alternate modes can all be accessed and configured from the unit itself, there is no software layer which makes it very accessible and straightforward. So the Linnstrument falls into the category “Very Flexible” on this axis.

On the Musical Control-axis, the Linnstrument also falls into the category of “Timbral Level”.

On the axis for Feedback Modalities I gave the Linnstrument a score of two. Unlike some of the others, it does not give any sort of tactile feedback. But in addition to auditory feedback it also has the feedback of the lights on the pads which light up when touched.

3.5: Haken Continuum

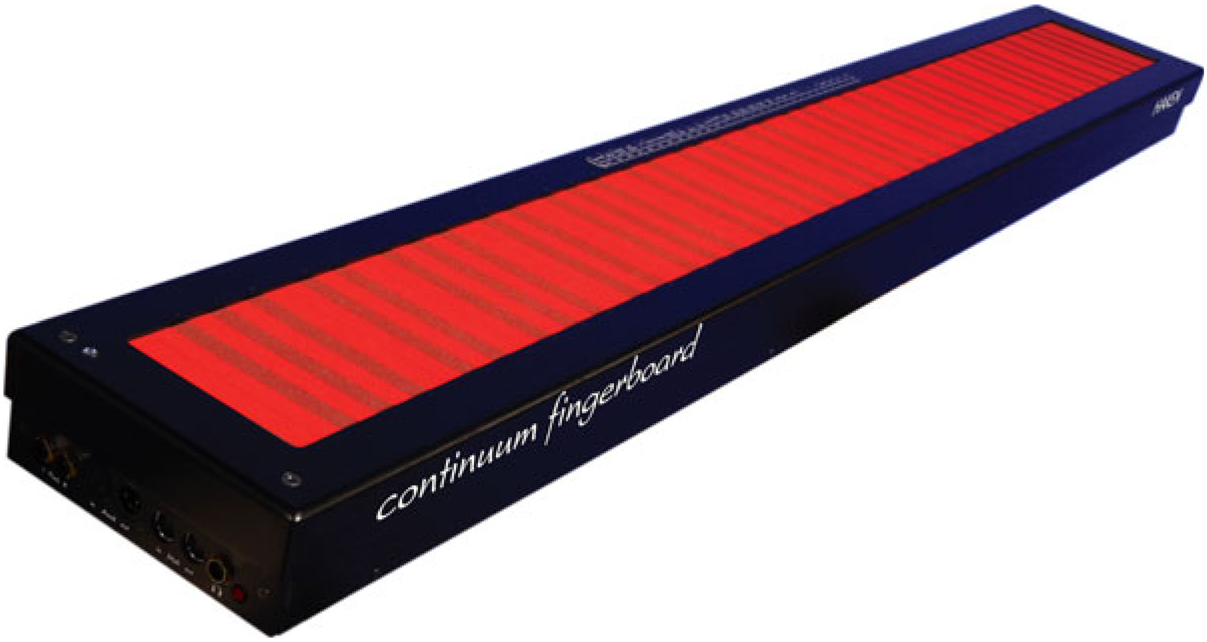

Figure 8: Continuum, top view. Image from hakenaudio.com

Specifications

The Haken Continuum is an MPE compatible controller produced by Haken Audio. It has a flat playing surface with markings for white and black keys. It has a register of almost eight octaves. It connects to the computer via a MIDI DIN connection. The controller also has three ¼ jack inputs for sustain and expression pedals. The version I tested was an older version of the Continuum. The major difference is that the new versions have a built-in synthesizer. There have been upgrades to the hardware, but with the updated firmware the version I tested is comparable to the newer versions when it comes to testing the playability of the controller with MPE, but the reader should be aware that there has been development of the controller since the iteration I tested. (hakenaudio.com, “Continuum Fingerboard User’s Guide”).

Practical Testing

The testing of the Plug & Playability axis worked well with the Continuum. After I connected the MIDI cable from the Continuum to the MIDI to USB interface it took two minutes to get MPE sound playing in Synthmaster. The only setup required was actually setting up a generic

MIDI controller in Bitwig so that the signal from the MIDI to USB interface would be routed into Bitwig. This controller got the highest score possible in the test of “Very Good” for plug & playability.

The next part to test was the Required Expertise-axis.

- Playing scales on the controller was easy in some ways and hard in others. This controller features a keyboard style layout, but there are no raised keys or real difference between black and white keys, other than the visual aspect and the pitch they produce. It is a totally even surface. So the fingering for the scales was very natural and maneuvering on the surface felt familiar and natural. The hard part was getting the intonation right. There is pitch bend on each note, so you have to place the finger precisely and try and avoid to much movement after placing the finger or you might easily increase or decrease the pitch as far as a semitone.
- Chord progressions were more difficult to perform than scales. There is not that much space for each finger. And the problems with intonation I experienced when playing scales became much more frustrating when playing chords. Again, the layout of the playing surface makes it easy to figure out where to place your fingers, but playing a chord without it accidentally going out of tune will require a great deal of practice from the performer. And I would imagine people with larger hands than me would struggle to get consistent results.
- When playing the guitar solo and the violin theme the continuum excelled. The layout makes it very easy to visualize where you need to slide your finger to hit the next note when performing glides. It feels very accurate and consistent. The spongy playing surface also gives a sense of feedback when applying pressure and the amplitude response from the pressure dimension feels intuitive and natural. The pitch bend on each note makes much more sense when playing the

instrument like this than with especially chords, and applying vibrato felt very satisfying and expressive.

- The Continuum has its drawbacks when trying to play it as a traditional instrument, but the implementation of playing monophonic melodic lines so easily really increases its playability and accessibility. It received a total score of five on the Required Expertise-axis.

The next step in the testing of the Continuum was the Performability-axis. As with the other instruments I set a countdown for two hours and played around with the controller using the Equator synthesizer. After the two hours had gone I was a bit unsure as to how to categorize it on the axis. It is immensely fun to play around with the continuum. As mentioned, it is not a controller which lends itself to be played like a traditional keyboard instrument. I never got comfortable playing chords, and legato or staccato melody lines are not that easy to perform on it. But it is really good for playing gliding melody lines, and with that I felt immediately comfortable. What the continuum is best at though, is for experimenting with sounds and making expressive soundscapes. When used with certain patches in Equator, just putting ten fingers on the surface and pressing down and moving them around created very exciting and fun results. But it is not something that is predictable and would be hard to use in a performance. Of course, if the performance was of unstructured improvised soundscapes it would be perfect. But performing with it as a traditional instrument would not be something I would be very confident of doing. It works best as a studio tool for experimentation. If I was to play the imaginary concert after the two hours of practice, I would not play a single chord, and ask to be kept low in the mix. I ended up placing the Continuum in the category of "Uneasy" on the axis.

Inputs and Outputs

The Continuum responds to five dimensions of input on the keys. In addition it has three pedal inputs for expression and sustain. This gives it a total score of eight on the Degrees of Freedom-axis.

The Continuum has some options on the instrument itself for setting up split layers and modes of playing. It also has numerous other options that are available through a software editor. The fact that these options are not readily available on the controller itself made me place it in the “Flexible” category of the Configuration/Mappings-axis. But I feel the need to note that I considered moving it up to the highest point.

On the Musical Control-axis the Continuum ended up in the category of “Timbral Level”.

The Continuum only receive a score of one on the Feedback Modalities axis, this being auditory.

3.6: TouchKeys

Figure 9: Doepfer LMK2+ with TouchKeys fitted. Image from touchkeys.co.uk

Specifications

TouchKeys are a sensor overlay product which enables MPE playing on any standard sized keyboard. The product consists of a thin tape-like film that contain sensors which track finger movement. The sensors record movement on an x and y axis affording the player two dimensions of expression in addition to the velocity information from the keys they are attached to. It connects to the computer via a Micro USB port, and in addition you have to connect the keyboard they have been fitted to (touchkeys.co.uk). They also sell keyboards which have already had the TouchKeys installed, one of them being a Doepfer LMK2+ . This version they call TouchKeys 88 and is the version I tested(Touchkeys, "Touchkeys 88 – Doepfer LMK2+).

Practical testing

I had big problems when testing the Plug & Playability-axis for the TouchKeys. You need to connect it using both a USB cable for the TouchKeys themselves, and a MIDI connection or a USB connection for the MIDI Keyboard they are installed on. In this case, as mentioned, it was the Doepfer model with the TouchKeys pre-installed. This is all a bit fiddly. The TouchKeys do not interact directly with the computer, but have to be set up in a software layer. I had some problems actually locating the manual and the software, but it did not take too long. After I found it I realised that I had to set up an IAC bus in OSX. I could not figure out for a while how I was supposed to get MPE functionality to play through the Synthmaster, and only got the signal from the Doepfer to play. After a while I figured out what I was doing wrong and got the TouchKeys signal into Synthmaster and I had MPE functionality. This whole process of connecting, searching out the manual and software and then setting up all the different options in OSX and the software itself took a total time of 35 minutes. That puts the TouchKeys in the category of "Bad" for Plug & Playability.

I then tested the Required Expertise-axis.

- I started with playing the scales, and this worked perfectly. The main reason for this is that the TouchKeys actually operate as a standard MIDI keyboard in many ways. If you play scales as you would play them on a piano, it will play like a piano. You have to apply a fair bit of pressure on the keys to engage the x and y axis, so playing scales is a one to one experience compared to a piano or other keyboard.

- Playing chords works in the same way as playing scales. The controller feels and responds exactly like a piano when playing chords. You can apply a little bit of vibrato to the chord if you apply enough pressure, but you can easily choose whether or not to engage this with how you play.
- Testing the guitar solo part and the violin theme was a different experience. There is no way to actually glide between notes on the TouchKeys. It is easy enough to play both the guitar solo and the violin theme if you just play it as a standard piano. And you can add some vibrato to the melody by using the x axis. But actually playing the parts with gliding notes was nearly impossible. The y axis manipulation is situated on the key itself, so performing them requires a tremendous amount of skill and precision. You can set the amount of pitch so that you can actually glide an entire octave on one key, but this is not a practical solution. The most expressive way I found to play these parts was to have each key be set to pitch up or down a whole tone, and then you could at least play some bends on the keys.
- The ease of playing scales and chords weighed up for the difficulty in playing the violin and guitar parts. TouchKeys got a total score of four on the axis.

Inputs and Outputs

TouchKeys only create input data for the x and y axis itself. There is no pressure data being recorded, or release pressure. The velocity dimension is not provided by the TouchKeys themselves, but I counted that as a dimension since it was a part of the TouchKeys 88 that I tested. It also has a sustain pedal input which I also counted seeing as it was available on the model I tested. That gives TouchKeys a total score of four on the Degrees of Freedom-axis.

There are no options for alternative configurations on the instrument itself, so I placed it in the category of “Rigid” on the Configuration/Mappings-axis.

As all the other controllers, TouchKeys was placed in the “Timbral level” category on the Musical Control-axis.

The controller only provides auditory feedback so it got a total score of one on the Feedback Modalities-axis.

After testing all the controllers and giving them marks for each axis, I created figures for each of them. In figure 10 we can see the results from the experiment visually represented side by side. More full sized versions of each model can be found in Appendix A of this paper. Now we will move on to discussing the results of the experiment

3.7: Results and Discussion

As mentioned, In Figure 10 we can see the results of the experiment represented by the models. If one studies the shape of these figures for a little bit one can learn to judge the merits of a certain controller with a quick glance. People could use this model to test other or future MPE controllers, and one could imagine building a database of the results. Even if one looks at the figures without any previous knowledge of the models, the naming is clear enough to make sense of for an overview of the merits of a certain controller. I find this way of representing musical instruments and controllers very appealing, and I would love to see reviewers of instruments implement something like this. It could be really helpful to sort through the myriad of new releases that are coming to the market. Next I will talk a little more in detail about my experience with the controllers, and the specific and general benefits and problems i found.

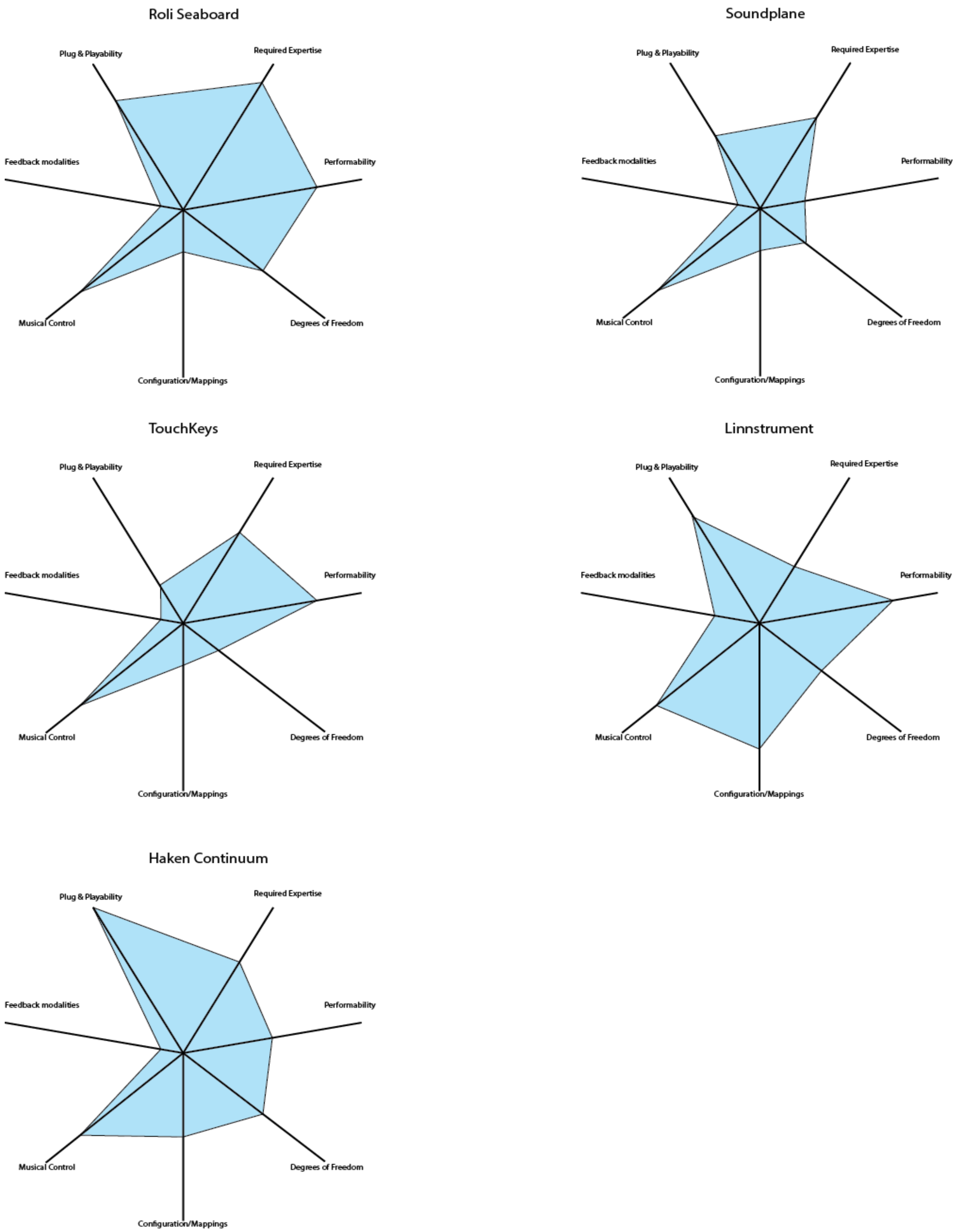

Figure 10: The resulting models of all the controllers from the experiment

When we look at these models we can see that there are some areas the controllers are pretty much constant at. The feedback modalities and the musical control are the two main areas where there is little deviation between them. With musical control they all score at the top level, you can control the sound on a timbral level with all these controllers. This means you can change the character of the sound, not just harmonies or melodies. And you can control the timbral character of the sound on a per note level. With the standard implementation of MIDI, and especially with a standard MIDI keyboard, you could for instance control the cutoff of a filter with the modulation wheel, but it only controls that parameter for all the notes you are triggering.

The more interesting part is that looking at this, one could postulate that a higher degree of feedback would be very beneficial to MPE controllers. My thoughts about the subject is that some form of tactile, haptic feedback would increase the feeling of playing a real acoustic instrument. When you touch a string on an instrument directly, there is a feedback mechanism between the finger, the string, the instrument and the sound it produces. This feeling is more present in some of these instruments than a traditional MIDI controller, but as an experienced instrumentalist there is still a gap between touching the keys or pads on an MPE controller, and the production of the sound.

But with this in mind there were definitely controllers that gave a better feeling of playing a real instrument than others. The springy texture of the Seaboard was very inspiring to play. It gave a sense of being in control of the sound and responding to my gestures and intentions in a manner very reminiscent of an acoustic instrument. The same can to a certain extent be said for the Soundplane. The walnut pads are certainly an interesting and exciting choice, but it falls short of the mark due to the difficulty of consistent triggering. The Seaboard is especially a marked step forward when it comes to a tactile sensation in musical controllers, but I still had the feeling that it was more of a virtual feedback than actually touching something physical.

If we look at the Required Expertise-axis we can draw some conclusions on how these controllers are to play when it comes to difficulty. They all have a relatively high degree of require expertise. And this is to be expected. They are not intended to be musical toys, but actual instruments which require time and skill to master. But with some of them, technical abilities from other instruments are less transferable. The Haken Continuum was the controller which was the hardest to play even though I have some experience with playing piano. The layout of the instrument is similar, but the level of precision needed to play chords and melodies was much higher than on the other controllers. Of all these controllers I would say that the Continuum is the one that is the most like a new instrument. Even though it has the keyboard layout, you have to approach it from a different angle than any instrument you might have previously played.

The Seaboard might have been the instrument that merged the tactile feeling and playability the best. But the most comfortable controller for me personally was the Linnstrument. Even though it did not have the same level of tactility as some of the others, I felt that the pressure I applied to it gave the auditory feedback I expected. And the controller was so easy and intuitive to use. I felt an instant sense of recognition for how it could be played and it just responded as expected to everything I tried to play. I would say that the Seaboard might be the best controller for experienced pianists and people who want the best combination of tactility and playability, while the Linnstrument might be the best for people who want an easier playing experience but at the same time have a lot of expression possibilities.

Another point where there are deviations is with the axis I named "Configurations/Mappings". All of the controllers that I used in this experiment are in some way or another building upon known instruments and expanding them or in the case of the TouchKeys, just implementing MPE on top of existing instruments. The only controller in this experiment with a great implementation of flexibility is the Linnstrument. It is done with for instance modes for splitting the keyboard, and using it as a standard midi controller with CC messages implemented directly from the hardware. This method of flexibility integrated into the controller itself works great because it works as a playable instrument in the standard configuration mode. As mentioned earlier in this paper, an issue with the development of new controllers is the mediation of customization versus immediacy. Roger Linn has managed to mediate these potentially conflicting aspects into a cohesive unit. But at the same time, there is not a great need for a lot of customization with these controllers. I think the want for a feeling of a self contained instrument trumps the need for individual preferences, at least at this stage of development in MPE. That being said, the fact that so many options are available on the actual controller of the Linnstrument really makes it more accessible and a very welcome addition.

When testing these controllers I realized that they actually give a much higher degree of expression than a standard MIDI keyboard. The ability to apply vibrato and effects to each note brings so much life into the sounds that you play. Being able to glide between notes like on a violin opens up a whole other world of expressive possibilities. All of these aspects of MPE controllers really imbue them with a sense of life where other controllers might have felt sterile and lifeless. But do they bridge the gap between acoustic and electronic instruments? We now move on to the conclusion of the paper where I will recap what we have read in this paper and answer the research questions I stipulated in the introduction.

4: Conclusion

This paper has been about MPE controllers and the gap that exists for performers between the experience of playing acoustic instruments and electronic music instruments.

When synthesizers became an accessible commodity in the late 70s there arose a need for developing ways of communicating between these synthesizers and other modules. The solution turned out to be a collaborative endeavor between some of the biggest synthesizers manufacturers in the world. Together they created a universal specification that they named MIDI. This protocol has been integrated into most synthesizers and controllers that have been produced since. It also has provided educators with instructional tools, and musicians and artists with affordable, accessible tools to realize their own musical setups and instruments. Performers and technologically minded people have used the MIDI protocol to create exciting experimental instruments and controllers, and the threshold for creating these things have never been lower.

But at the same time, the MIDI specification is not without its drawbacks. Limitations to the bandwidth and bit rate makes control intimacy a hard thing to achieve, and is a hindrance to capturing real time expressive gestures in performance. The disjunction between musicians and sound generators has been a phenomenon since the invention of the first instrument removed the sound generator from our own body. With the introduction of electronic music instruments and finally computer music instruments, the sound source has been locked away in a box where it is impossible for musicians to physically touch. This need for physical control over the sound source is a very human thing.

One of the main goals of MPE controllers is to create a semblance of physical interaction with these locked away sound generators. By providing per note timbral and pitch manipulation it hopes to mitigate some of the disjunction that has occurred with the development of electronic and computer music instruments.

To find out if and to what degree this has been a successful endeavor, I tested several MPE controllers in an experiment. The results of these tests were illustrated in a seven axis model, one for each part of the test. The MPE controllers proved to have strengths and weaknesses across the board. And while all of them provided some type of MPE functionality, the implementation was not equal in quality.

Now I would like to reiterate the main research question and the subordinate questions that I posed in the introduction to this paper before I will discuss what answers I fond to these questions.

- Can MPE mitigate the disjunction between performer and sound source in electronic music instruments?
    - Do MPE instruments provide a tactile playing experience?
    - Do MPE instruments provide satisfactory control over pitch and timbre?

To start with, let us discuss the first subordinate question regarding whether or not MPE instruments provide a tactile playing experience. After conducting my experiment I could not give a definitive answer to this question. Some of the controllers have tactile qualities to them, but as I mentioned in the discussion of my findings, there is no real feedback in them. If there was some form of haptic feedback integrated into something like the Seaboard I would be able to say yes to this question. But as it stands my answer will have to be; “to a certain degree”. Some of these controllers do not even provide a semblance of a tactile playing experience, while some are made of materials which at least give the performer some feeling of manipulating something real and physical. I feel that MPE does not give the tactile feeling I personally was hoping for, but I expect that newer iterations of this type of controller will advance the feeling of touching a real object.

I found the next question that pertains to whether or not MPE instruments provide a satisfactory control over pitch and timbre a bit easier to be definite about. I would say, yes, it does. Let us keep in mind that “satisfactory” is a relative and subjective term. And as the subject for the experiment I have had to try and view this from more than one angle. My own experience with testing these controllers gave me a satisfied feeling when playing glides, adding vibrato and affecting timbral elements to the sound with gestures. That is to say, satisfactory playing the best of the controllers that were available. Some of them have not implemented these aspects in a good way. The problems with the Soundplane triggering and the feeling of inconsistency that some of these controllers give is very detrimental to this experience. But playing with the two controllers that I liked the best, Seaboard and Linnstrument, this was not an issue. And the amount of control over pitch and timbre felt very satisfactory. The other angle that I have to try and view it from, is that of people with higher demands or expectations than myself. There is no doubt that there will be people who feel that the resolution of the pitch bend is not as good as it should be. For instance, the touch strip on the Seaboard is not a one to one experience to gliding on a physical fretless string. But it gives a good enough semblance of the real thing to call it satisfactory and view it as a good starting point for further development.

Finally to the main question posed at the start of this paper. Can MPE mitigate the disjunction between performer and sound source in electronic music instruments? To this question I can wholeheartedly answer “Yes”. If the question posed had been the same as the title of the paper, if it could “bridge” the gap I would be more hesitant to give this answer. There are certainly limitations to these types of controllers, and they do not remove you from thinking that you are not touching an actual acoustic instrument. But they do mitigate the disjunction and push the performer further towards feeling like he is interacting directly with the sound source. Being able to control so many dimensions of expression per note is such a different experience from playing on a traditional MIDI keyboard that one can not help but be appreciative towards the innovators who have pushed this development forward.

In conclusion, I find that MPE controllers give enough of a semblance of tactility and control over pitch and timbre to clearly say that they are a great step forward in the quest for bridging the gap between acoustic and electronic music instruments. Looking forward I am excited by the adoption of MPE into the mainstream and look forward to seeing what this development can mean for the future of expressive music interfaces. I tend to think that there might be a need for a major update to the MIDI protocol to capture gestural information to a degree that feels wholly realistic. The limitations of the MIDI protocol might be such that a true emulation of the physical world can never be achieved as long as instruments depend on building their framework around it. But while it is not a perfect solution, or a very stable bridge between acoustic and electronic instruments, MPE provide a real big step towards fully realizing the dream of merging the physical world of instruments and the virtual.

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Appendix A

MPE Controllers Models

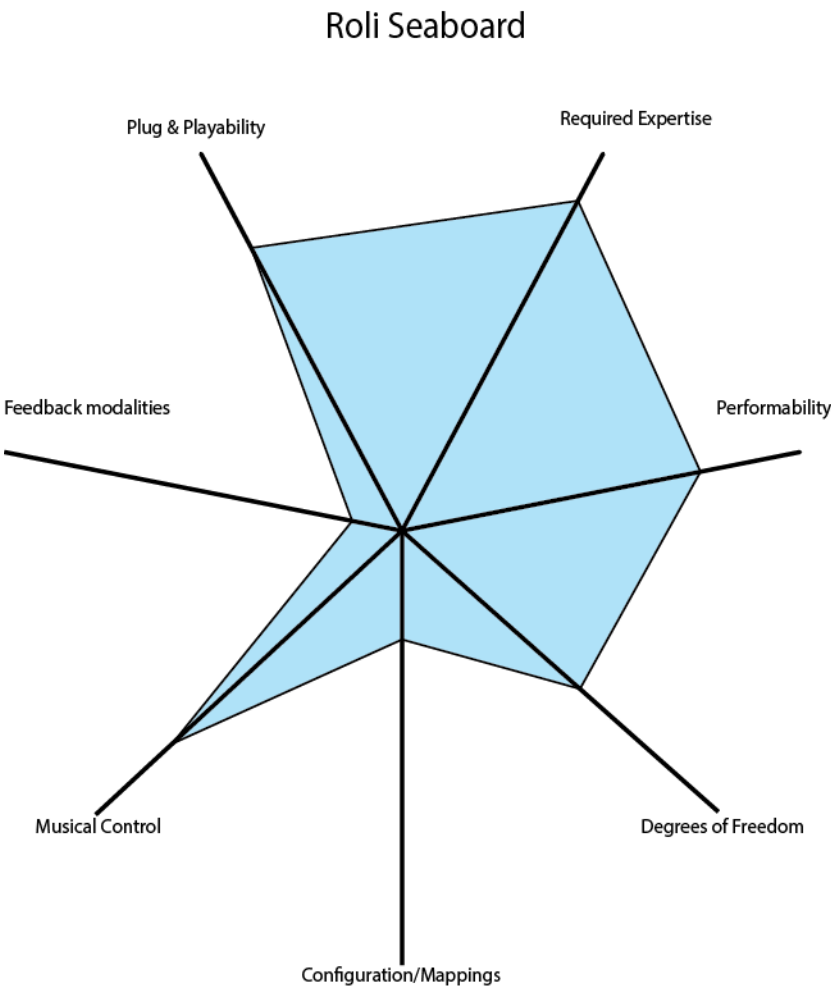

Figure 11: Seven axis model of the Roli Seaboard

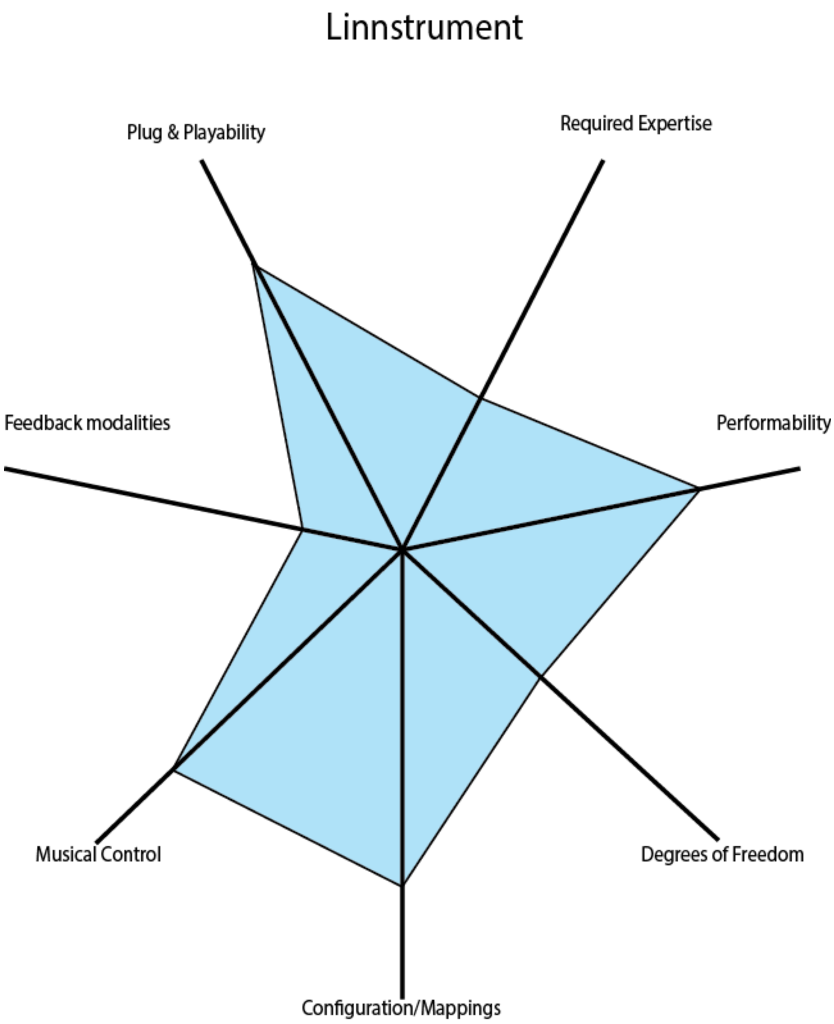

Figure 12: Seven axis model of the Linnstrument

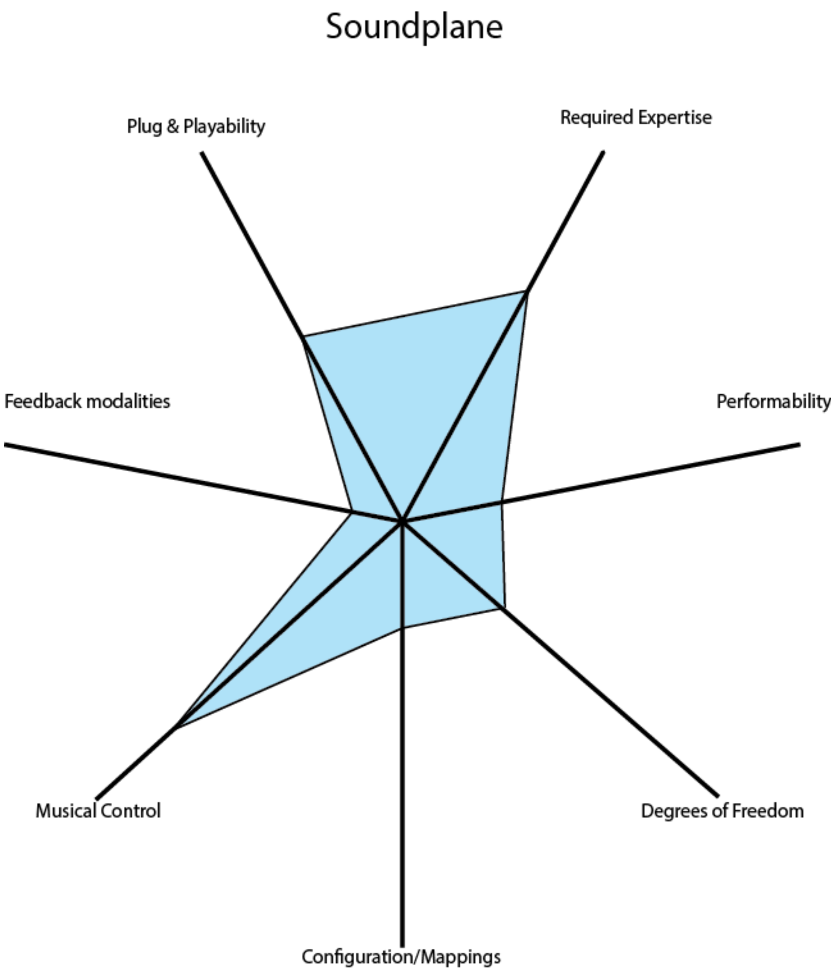

Figure 13: Seven axis model of the Soundplaned

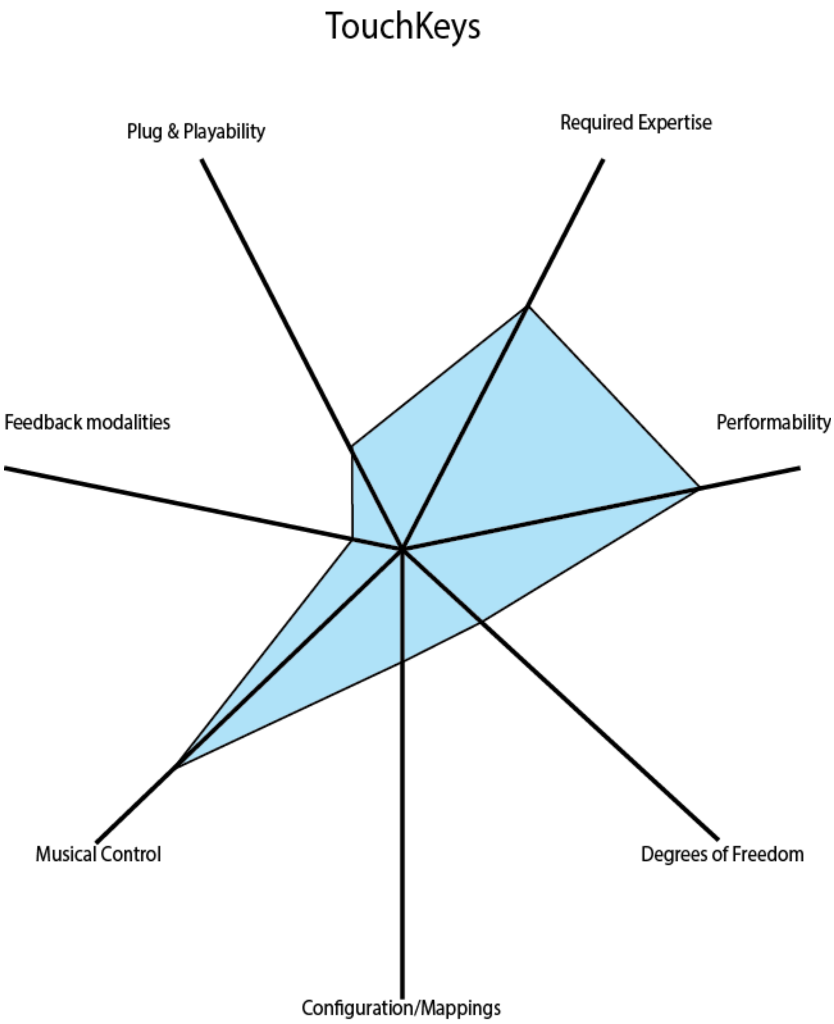

Figure 14: Seven axis model of TouchKeys

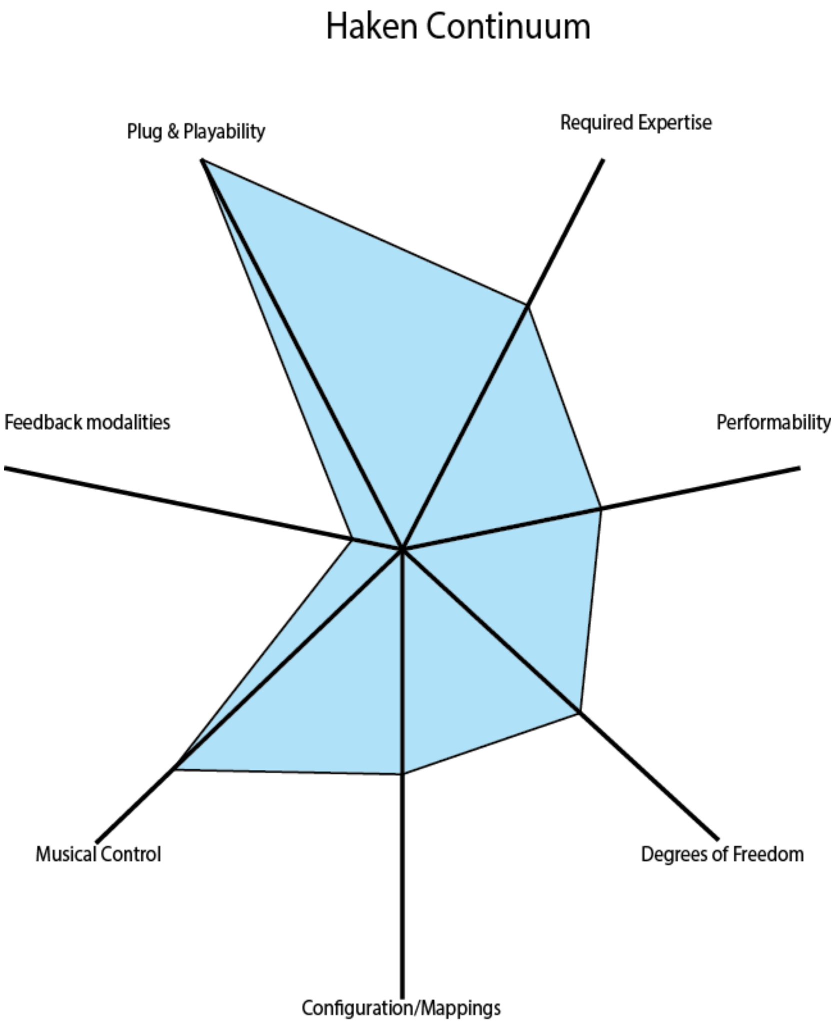

Figure 15: Seven axis model of Haken Continuum