DRUMMUTE

Sound computing and Sensor Technology

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Abstract:

This semester project at Aalborg University showcases a new interface for drumming to reduce noise made while playing the drums and to increase mobility of a drum kit. It also describes the process through which important subjects were researched and finally the design and evaluation thereof.
The project investigates how different types of drums work and looks at other current solution that exist. The product is created with a micro-controller and different types of sensors and also shows how to create ones own drum sounds by using sound processing software.
The product attempts to separate itself from the competition by trying to achieve the trifecta of authenticity, low noise level and mobility that none of the other products quite achieve.
The final evaluation, done with drummers of various experience levels, shows that the product fulfills some of the given success criteria, and that most of drummers have a clear interest in the product and its possibilities. The possibilities being the future development on the product, eventually giving it more customizability, and generally making the product more refined.

Contents

Chapter 1

Introduction

This project aims to create a new drumming interface to help reduce the amount of noise created when playing drum kits, both acoustic and electronic, as well as allowing drummers to play much more freely on the go, or with significantly less space

Through the background research chapter we found several existing solution to the problems mentioned above and much information related to drums such as how different types work, including electric drum kits and different sensor technology to help us create our prototype. Interview with a professional drummer gave us a good idea as to what our target group would look for in a product, such as this.

This eventually lead to a final problem statement as follows: *"By using a layout similar to an acoustic drum kit, how can we make an electronic drum kit , that is mobile, easy to set up and reduces the overall noise level?"* This was the question we went into the design phase to investigate and hopefully answer.

During the design phase, which has its own chapter, many different possible designs were explored, but in the end a foldable drum mat was the victor, and this was afterwards tested on real drummers. The project focused a lot on how to create this drum mat through sensor technology and how to create drum-like sounds from scratch using sound processing software.

The evaluation chapter shows the process of the tests with both drummers and just technical tests with the soft- and hardware, and afterwards shows the thoughts and considerations about the results of these tests.

In the final chapter, the project and its success criteria will be concluded upon, in an attempt to actually make a real answer to the question proposed in the final problem statement chapter.

Chapter 2

Initial Problem Description

This chapter is about the initial problem statement, including motivation for the problem as well as important research questions to answer.

2.1 Initial Problem Statement

"How can we create a physical interface to simulate a drum kit that is mobile and eliminates the noise of a drum kit?"

2.2 Motivation

Drum kits are very loud and disruptive and is not something drummers play when being considerate of other people. Electronic drums do exist and can dampen the amount of noise created, but do not completely eliminate it. Another known problem of a drum kit is the inconvenience of carrying it around as they are quite large, heavy and consist of several different parts. You usually need a fair-sized car to carry it around if you plan to practice somewhere, such as band practice or events. Another issue with the drum kit is the time required to take it apart and set it up once again at the destination. The instruments usually also needs to be tuned to make sure it plays as intended. Several other solutions are starting to be introduced to consumers, which are meant to help solve some of these problems without compromising the drummer experience. DrumPants [1], Aerodrums [2] and drum pads look to eliminate some of these problems and provide an instrument that is equivalent to a normal drum kit.

This project aims to create an alternative device, being easier to transport and being quieter, as an adequate replacement for practice aid for drummers.

2.3 Research Questions

Keeping the initial problem statement and motivation in mind, several questions will have to be answered for further work with the project. These are:

- Does a solution currently exist for drummers to practice without using a full drum kit and how does it work?
- How is it possible to simulate the sound of a drum kit?
- Which kind of sensors could be used to simulate the drum kit?
- How can the system output sound?

Chapter 3

Background Research

The following chapter consists of the information found during the background research for the project. It covers several different subjects such as acoustic drums and how they are used, as well as sensor technology and state of the art projects that try to solve the same problems that we do.

3.1 Drumming

Figure 3.1: A picture of a standard 5-drum drum kit. The kit consists of, from left to right, ride cymbal, floor tom, 2 hanging toms above the bass drum, snare drum, crash cymbal and hi-hat. [3]

Drumming has a wide context that consists of many different kinds of percussive instruments. The thing that all modern versions have in common is that the instrument is made out of a hollow cylinder and the top of the cylinder is covered by a tightly stretched membrane. For this project, we decided to focus on a regular drum kit that consists of a 12' and a 13' hanging tom, a snare drum, a bass drum, a floor tom drum, a hi-hat and a crash and ride cymbal[4]. An example of such a drum kit can be seen on figure 3.12.

The bass drum, as seen in figure 3.2 is the foundation of the drum kit. It is used to create the foundation rhythm of the most songs and has to have a constant beat to it. In rock songs for example you might use the 1st and 3rd beat through the song or you can go with every 4th to make the constant base rhythm through the song. With the bass drum you can create the genre of music that you want to play based on how you place your beats. Hitting it results in a very deep boom. The drum is usually stuffed with some type of cloth and the sound can change depending on the drums tuning, as well as how much cloth is stuffed into the drum. Unlike the other drums, the bass is not hit with the drum stick but rather using a pedal.

Figure 3.2: A picture of a bass drum[5]

Figure 3.3: A picture of a snare drum. The snare is attached to the bottom of the drum [6]

The snare drum, as seen in figure 3.3, is a vital part of a drum kit. This drum provides what is called 'back beat' and is a very important part in various drum patterns. The snare drum is a bit special in its construction since it has a rattle at the bottom of the drum. The rattle is a number of wires that look like springs that have been tied together and are stretched across the drum. The sound from the snare drum can vary from a soft sizzle sound to a loud crack depending on how the drum is tuned and how it is hit.

Figure 3.4: A picture of a hanging tom type drum. [7]

The tom tom drums are mainly used to fill in tunes and are used to support the rhythm. These are the most basic of drums. The floor tom is the biggest of the toms and stands on the floor. The other toms are usually situated on top of the bass drum. The floor tom has a deeper sound than the other toms, though not as deep as the bass drum.

Figure 3.5: A picture of a hi-hat cymbal [8]

Figure 3.6: A picture of a regular cymbal[9]

Cymbals and hi-hats are basically the same type of instrument with the hi-hats consisting of two cymbals facing each other where one is inverted and when the pedal is pressed the two will be pulled together. The hi-hat is shown on figure 3.5 with a regular cymbal seen on figure 3.6. The hi-hats can be used as an instrument on their own, but are most often hit by the drummer when they're either open or held closed. This greatly changes the qualities of the sound from the instrument. Hi-hats are mainly used to keep up the beat count and not for the rhythm, but some genres use the hi-hats as a crucial part in their rhythm. The cymbals are usually high-pitched and depending on how they are played can be heard for a long time after hitting them.

Most tom tom, bass and snare drums are made of timber. The most popular types of timber used for drums are poplar, birch, maple, beech and mahogany. The type of timber might not necessarily decide how the drum sounds, but its shape and size does.

3.2 Electronic Drums

While drums have existed for over 8000 years [10], it's newest iteration is quite young. The electronic drum, unlike it's acoustic counterpart, is not made of wood and skin but rather, depending on the cost of the instrument, plastic, iron, rubber or mesh. The very first electronic drum kit was developed in 1971 by drummer Graeme Edge from the band Moody Blues and professor Brian Groves from Sussex University [11]. While the drum kit was not made available commercially it was nonetheless used in a song performed by Moody Blues and it paved the way for different companies to start developing electronic drum kits of their own. Most of the early electrical drum kits used sound samples for the sound they produced. The electrical kits would sound like the acoustic because they were recorded from the latter and many musicians of the time felt that the drum kits sounded quite terrible comparatively. In 1997 Roland introduced a new model, TD-10, which changed the formula by using mathematical models for creating the sound of the drums rather than samples as well as improving the pads the drummers were hitting.

Figure 3.7: A Yamaha DTX760K electric drum kit [12].

A large problem with many of the early electronic drums was their poor use of materials. The drums were often so hard that the drummer could damage their wrist in extensive play sessions and the sound the drums would produce were, in many cases, seen as sub par. Still, the electrical drum kit holds many advantages compared to the acoustic drum. The kit is usually much lighter and easier to transport and in many cases it is much easier to change the nature of the sound produced than when using an acoustic kit. The electronic drums also do not require the same amount of tuning that the acoustic drums do. There is an example of an electronic drum kit in figure 3.7.

3.3 Sensor Technology

Unlike acoustic drum kits, which simply play a sound when hit, electronic drum kits need to have some type of sensor to recognize when the user hits the drums and then play the matching sound. Many different types of technology exist that could, potentially, solve this problem.

3.3.1 Touch Sensor

Touch sensors are a type of sensor used to detect when a surface or similar has been touched. These sensors can work in several ways, the most common of which are described below.

Capacitance switch These kind of touch sensors function using the electric current, led from the surface touching the sensor as a trigger. For example most modern touchscreens function this way, as it uses the finger to lead a current. This is why most touchscreen cannot be operated while wearing gloves. [13]

Resistance touch switch Resistance touch sensors work by using electricity, but not necessarily a finger, unlike the capacitance switch. They work by lowering the resistance between two pieces of metal. [14]

Piezo touch switch Piezo touch switches work by bending a piece of piezo ceramic, often located behind a surface that is actually touched. This allows this type of sensor to work with any object touching the sensor, not just a finger or a stylus.[15]

3.3.2 Gyroscope Sensor

Gyroscopes are a type of sensor used to detect rotation in an object. Depending on the sensor, this can be measured in both the x-, y- and z-axis. There are many different types of gyroscopic sensors, with varying degrees of accuracy and size, however, for the majority of applications at this scale, the most common one is a vibration gyro. It works in the way that some drive arms vibrate in a specific direction. Upon movement, the Coriolis effect makes the vibration go in the vertical direction, which is then picked up by a sensor. [16]

3.3.3 Accelerometer

An accelerometer is used to measure proper acceleration, also known as g-force. In common applications, it is used to detect movement and acceleration. It works by having a mass placed on top of a spring, and as the sensor moves, the object will move slightly, the spring will move along with it. This movement is then detected, and converted to electrical signals. [17]

3.3.4 Piezo Electric Sensor

Piezo electric sensors [18] is a sensor that are mostly used to pressure changes which can be read by the change of the voltage output. Piezo sensors can also measure radiation. The piezo sensor works by having a crystal built inside of it and when a change of pressure happens the ions inside the crystal break the symmetry and a net dipole moment is created within the piezo sensor. The dipole moment makes an electric field across the crystal inside the sensor.

3.4 State of the Art

Having looked at what a drum set consists of and how it is used, the group continued the background research by trying to look at the already created solutions for the problem statement. These are covered here and give descriptions of each of the products main idea and usage.

3.4.1 DrumPants

Figure 3.8: A picture of the bigger set of the DrumPants components available at drumpants.com [1]

DrumPants is a collection of wearable drum pads and footpads to be used as substitute for an actual drum kit [1]. DrumPants work by using six velocity sensitive MIDI/OSC triggers, four of them are in two large straps that is meant to be placed on your thigh while the last two are in one long strip each to be put in your shoes. The strips are used for the bass drum and hi-hat respectively, whilst the last four triggers act as the rest of the drums and the ability to strike them. The DrumPants are made to be wearable and can be worn under or on your clothes. All this is controlled by one device that can be used on the fly to select from more than hundred different samples and musical scales. You can customize which sounds the different pads produce by using an application for your mobile device or your PC. It uses its own in-house program called DrumPants Pro or it can be used by other applications that support it, depending on what kit you purchase. The controller is managed through Bluetooth and the different components are all wired to the controller. It should be noted as well that the DrumPants can be used for other applications that use clickers (such as Google Slideshow or Pandora, a music application) and the samples used when hitting the triggers can be changed to different sounds than the regular drums and cymbals.

3.4.2 Aerodrums

Figure 3.9: A picture of the Aerodrums device [2].

The Aerodrums functions as an alternative to a drum kit by enabling the user to drum in the air using two drumsticks, two foot pedal reflexes and a camera that emits light with an LED ring around it. Using image processing the software is able to give audio that is equivalent to that of a drum to the user, by using a sample library known as Natural Drum Kit. The output of the device supports MIDI notes and can record your drumming straight into a Digital Audio Workstation. The visualization of the use of the device is on a computer screen where your drum set is visible on a flat 2D interface. This interface can be customized to include your own drums, and choose what sound each of them play when hit. [2]

3.4.3 Alphasphere

Figure 3.10: A picture of the AlphaSphere in use [19].

The AlphaSphere is a new music instrument, aimed at being a more open device when it comes to different musical styles and playing techniques compared to a keyboard. The device is made up of several pressure sensitive and ergonomically mapped tactile pads around a sphere with a base at the bottom as seen on figure 3.10. The pads differ in sizes to compensate for the reach of a human hand and the mapping of the buttons are fully customizable. Given that all 48 pads are pressure sensitive it gives a lot more physical depth than a standard MIDI (Musical Instrument Digital Interface) controller. It is also compatible with polyphonic aftertouch so each sound can be modulated individually. Apart from playing notes, the device is also capable of playing samples, sequences or other control data through a custom-made software called AlphaLive. This expands the control from just music and sounds to also control a visual performance since it is a multichannel MIDI instrument. [19]

3.4.4 Portable Digital Drum Kit

There are a large variety of these, with many different levels of quality. Essentially what they are, are medium sized devices with a number of touch sensitive pads that play a sound on impact, usually with a drumstick. The sound that the pads play can for the most part be customized to fit the need of the user. They usually have a built in speaker and an AUX input in order to connect a headset or other speakers.

(a) Digital drum mat [20] **(b)** Digital drum kit [21]

Figure 3.11: Two different types of digital drum kits.

The physical form varies greatly, and ranges from plastic block with a few buttons to plastic-like sheet that can be rolled up for easy storage, both of which can be seen on figure 3.11. The weight for (a) is 840 g and (b) is 7 kg. Higher quality versions usually cost about 1000-1500 dkk. for a new product, but they are also available for somewhere around 300, although these products would mostly be marketed towards children. According to reviews, the sound for the second referenced drum kit is natural, and emulated a real drum quite well. This is an important factor in these products, as this contribute a lot when making it feel like playing an acoustic drum kit. These also lack pedals for bass drum and hi-hat, two important parts of both acoustic and electrical drum set, creating a larger difference between these and normal drum kits.

3.4.5 Drum App

Many different smartphone applications exist for emulating a drum kit. The smartphone application “Real Drum” was chosen for further researcher. This is a free application with between 10- and 50 million downloads, and the developer is “Rodriogo Kolb apps” [22]. It is simply a screen with different drums. There is a large variety of all the different drums, and you can freely choose which drums to have in the drum set, allowing for a large amount of customization. You can also loop the sounds and make recording, again allowing for you to largely customize your drumming, as though you had the modern technology for drumming.

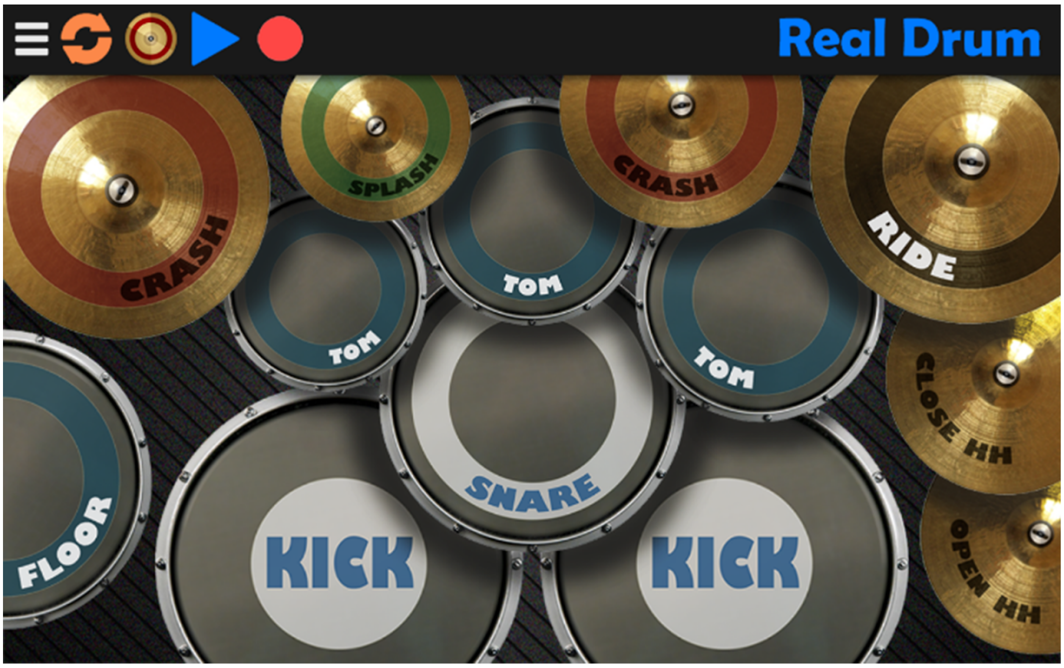

Figure 3.12: A picture of the application "Real Drum" [22].

Figure 3.12 shows the applications main screen . As mentioned, the application is free, but you can pay 10 dkk. to remove ads. The reviews are mostly positive, with an average of 4.3/5, and the really negative ones, are mostly about the application not being responsive, which can most likely be attributed to hardware fault. We tried the application ourselves, and it seemed responsive, and to work properly.

3.4.6 Practice Pad

These are pads made from different materials, usually something rubber-like such as neoprene. They are used for drum practice without being fear of annoying others by being loud, and they are easy to transport, as they are no larger than the surface of a drum. These pads are for the most part emulating snares, and are used to increase the speed of drumming or keeping a rhythm. They can also be used for exercise.

Figure 3.13: A practice pad [23].

Physically, they are usually round and fairly light. The surface material is, as mentioned, some rubber-like material. The price vary greatly and start around 150 dkk. per pad, depending on the quality of the materials. As mentioned, these are mostly similar to snares in size. They are not that useful for drummers with drum kits who wish to practice with the whole kit, but more so for orchestral drummers, who can play the snare exclusively.

3.4.7 Ubiquitous Drum Pants

Ubiquitous Drum Pants are created by Boris Smus and Mark D. Gross from Carnegie Mellon University [24]. The reason for the creation of the Ubiquitous Drum Pants is to work around the problem of regular drums being big so it is hard to bring with one and also that they are loud and can be annoying to ones surroundings. By making a solution to these problems, the Ubiquitous Drum Pant compel rhythm lovers to actually play the drums. An example of the Ubiquitous Drum Pants can be seen in figure 3.14.

Figure 3.14: Boris Smus using the Ubiquitous Drum Pants [25].

The Ubiquitous Drum Pants consists of wired drum pads built of force-sensitive resistors (FSR) and a pull-down resistor circuit, which is programmed to work with an arduino. The pads are taped on the inside of the clothing with electrical tape and a circuit board is concealed in the left jeans pocket.

The wires connect each pad to the circuit board and run through each pant leg also attached using electrical tape. A sweater and the shoes are wired the same way the jeans are and have the same header interface. The header interface for all the articles is a four-pin, to easily plug and unplug the clothes from the system. The wires from the clothes connects to the arduino-based system and when one of the pads is hit, the program detects how much force was behind the hit and transmit that to a computer. The data also includes the pad's string identifier and a value from 0 to 1023. The value represents how hard the FSR was hit. The arduino program also filters out noises that may occur because of foldings in the clothes.

Smus and Gross decided to use a Python program that listens to the serial port for the strings, which represents the drum hits. The system plays the drum tune that corresponds with the string and at a volume that fits the intensity of the hit.

Smus ans Gross did not get to perform a formal evaluation of the Ubiquitous Drum Pants. Although they have gotten positive feedback through the internet because of a video on youtube.com [25] and in person by students at the Carnegie Mellon University in Pittsburgh, Pennsylvania during a demo test. Even though the developers have had a positive response with their informal findings, it is still important to make formal tests. As they say themselves, they would like to learn *On one hand, we want to learn how long non-drummers interact with Ubiquitous Drums. Before losing interest. On the other hand, we want to investigate whether skilled drummers are able to play complex rhythms and get an acceptable response.* [24]

3.5 Competetive Analysis

Having explained the currently existing solutions the competitive analysis looks to find the strengths and weaknesses for the current state of the art. This will greatly help the project by finding and learning from various mistakes others have made.

3.5.1 DrumPants

DrumPants are designed to be lightweight, small and easy to set up making it a very mobile device where even the controller of the components is very small, and is something that can be strapped on your belt or similar. The only noise that is going to be created using this device is the sound of someone slapping their thighs and lightly stepping on the floor. The device is easily installed by strapping the drumpads on your legs and placing the footpads in your shoes or by placing the sensors wherever works for the user and plug it into the controller. The controller is either set up on the spot by dialing through the sound samples put unto the device that was customized back home with the application provided.

3.5.2 Aerodrums

Aerodrums are designed to simulate the use of a drum kit by using the provided drumsticks, the footpad reflects and a camera emitting light to create the virtual drums. The components of the device is easily portable and the only noise produced by using the application is the swaying of drumsticks in the air. But apart from being very mobile the device can be tricky to set up. It uses image processing to detect the position of the reflective ends of the drumsticks and the reflective footpads. The camera has an LED ring around it to emit light onto the components which reflects back the light into the camera. Being dependent on the light from the LED ring, a very illuminated environment can interfere with the cameras ability to find the components. The camera also needs to be plugged in using a USB stick with the software, which means it is required to bring a computer with the components. The camera has to be placed in front of the user, it cannot detect the components otherwise. The fact that it is not a standalone device and that it is dependent on light and camera position is a big downside of this device.

3.5.3 Alphasphere

The Alphasphere is designed as a new instrument and is very mobile compared to a drum kit. It can be carried in a bag and easily placed on a table. The base is not removable but it can be mounted if need be. The device is very lightweight and easy to set up if you have prepared the software part back home, by setting up what the buttons do on the device. The device is tied to a piece of software to customize its buttons. It is unfortunately also tied to the computer using a USB stick as it is powered and configured by the computer as well as using the computer as the one to output signals and sound. But as mentioned this device is designed as a new instrument and not as an alternative to a drum set although it can be set up to play as one.

3.5.4 Digital Drum Kit

Both of these products are easy to transport, although the mat (3.11 (a)) is easier, and both are therefore pretty practical for the purpose of a transportable drum set. Noise-wise, these both have AUX, which means that the drum sounds themselves can mostly be canceled by use of headphones, leaving only the sound of the drumsticks striking the materials. However the portability is also reduced, because of the physical size. The mat needs a fairly large floor area in order to be set up properly, and the ‘box’ requires a similar space, if not slightly less.

As far as realistic physical emulation goes, these are fairly high on the list, as they use drumsticks and also have surfaces similar to drums to hit. You will end up using your arms similar to how you would with a real set of drums, although the spacing of the drums may be off. Both of them also lack pedals, meaning that they will feel much less like normal drum kits and could make a transition between the two difficult, especially for practiced drummers.

3.5.5 Drum App

For a drum substitution, this is very mobile. You will in most cases have your phone with you anyway, so having this application installed is very easy. A web connection is required just to download the application, although this is hardly more difficult than acquiring one of the physical instruments. This said, it is very small, and will not convert the feeling of drums very well due to it’s small size and use of touchscreen, even if it is well developed and features a lot of customization. It is easy to use, easy to take with you, silent, customizable and nice sounding, but not very authentic drum-wise.

3.5.6 Practice Pad

Easy to transport, can fit in basically any bag and does not take a lot of damage from a little bit of rough fitting. While it can definitely be heard when played on, it does not produce a lot of noise compared to an acoustic drum kit. It does have the feel of a drum, but it is only one unless you bring a entire drum kit worth of them, and you will not experience the sound of a real drum from it. As said earlier, it is almost exclusively for technique, as it does not emulate a drum kit very well.

3.5.7 Ubiquitous Drum Pants

The Ubiquitous Drum Pants [24] are a lot like the drum pants by DrumPants Inc [1] but have a few differences. One of the biggest differences is that where DrumPants Inc. have designed the sensors to be put on over the clothes, the Ubiquitous Drum Pants are implemented in the clothing. As Smus and Gross comments themselves, this gives the problem of not being able to wash it. Furthermore the user has to wear the same articles at all times, which could become an annoyance. It will also be hard for the user to easily move the sensors around, to what they believe to be a better location on their body, since the wires and drum pads are attached to the clothing. This could have a negative effect on the user since they will not have an optimal experience with the drums. On the other hand, like the DrumPants from DrumPants Inc, the Ubiquitous Drum Pants is made to be small and easy to bring out as it does not take up much space.

3.6 Related Work

We wanted to know what other scientific papers on this general subject had done with regards to evaluation, therefore this small section goes through two different papers, and specifically their method of evaluation.

3.6.1 "The Drummer: a Collaborative Musical Interface with Mobility"

'The Drummer' [26] is a project presented at NIME 2009, made by Andrea Bianchi and Woon Seung Yeo.

It attempts to create a collaborative multiplayer interface for musical expression through drums, used with a Nintendo DS. It allows multiple performers to play drums simultaneously while also moving around on the stage.

The way this project was evaluated was through tests specifically testing important parts of the project, such as the users' ability to accurately hit the virtual instrument at a relatively high pace, the users perception of usability for the interface and the perceived and actual level of collaboration between the players.

The tests were done on twenty participants all of who had time before the test to familiarize themselves with the system. During the actual experiment, the first thirty seconds of the participants performance were logged and analyzed to obtain records such as their hit/miss ratio and number of taps.

After the test, the participants filled out a survey, giving them a chance to judge collaboration potential of the system and their own experience. As a finishing test, the reaction time of the system was evaluated, with two different setups, essentially having the client different distances from the router, and measuring the time it took for the events to happen at the server.

3.6.2 "The Pneumatic Practice Pad"

"The Pneumatic Practice Pad" [27] is a project presented at NIME 2015, made by Eric Sheffield, Sile O'Modhrain, Michael Gould and Brent Gillespie.

This system is a practice pad that, through an electric air pump, emulates the tension of different drums. This was made so that an experienced drummer would not have to have dozens of different practice pads for the purpose of practicing.

This product was measured in two different tests, one to measure rebound, and a playing test with experienced drummers.

The rebound test was performed with an elaborate setup with the pad and a drumstick, using gravity as the downward force in order to make the force consistent.

A video was then taken of the drumstick hitting the pad with a high speed camera and analyzed the rebound with different tensions, where the drumsticks velocity was measured after the first bounce. Comparison tests with a snare drum and a floor tom were also made.

The playing tests were made with seven participants who all had at least eight years of experience with percussion instruments.

Each participant was asked to play about three minutes per trial, which included stick control, measures of rudiments, and a short snare drum solo. These all fall under rudimentary snare drum style, which is why they were chosen. These exercises were repeated eight times at different pressure settings with one trial being the participant's own practice pad. The participants were not given any information about the tension before, and were asked to play with their own technique, and then adjusting the situation.

After each trial the participant was asked to rate the comfort level from 1-5, and were also asked for general comments about the experience.

3.7 Sound Synthezising

As mentioned earlier, most electric drum sets use samples from acoustic drum kits as their own sounds, and most of these do it using PCM, Pulse-Coded Modulation [28]. This works by sampling the amplitude of the stream at uniform intervals and it is standard form of audio in many audio applications and computers. Most electric drum kits have a large amount of different samples to choose from, giving a slightly different sound depending on which type of drum kit has been chosen. A more refined form is used with Roland's superNATURAL technology [29], which uses different mathematical models to alter the sound of the sample to fit how the user is playing. This technology is used in many of Roland's new electronic instruments such as pianos and drums.

While there exists large libraries of different drum sounds on the Internet, most of these are of sub-par quality unless one is willing to buy access to better ones. However, one can try to synthesize sounds from the ground up instead. The program Pure Data [30] is an example of a program which can create different types of sound. It does this by using oscillators with different types of sound waves and the ability to alter these sound waves through various means such as combining different signals or frequency modulation [31]. Another possibility is using Java. Java has packages for MIDI sounds, even being able to synthesize through sampling but also from scratch through the use of different algorithms [32]. That being said, as mentioned earlier from-scratch synthesizing is rarely used professionally when it comes to creating electric instruments. It's usually quite difficult to create sounds that sound like their chosen instruments from scratch and with a good sample there's little difference between the acoustic and electric instrument.

3.8 Drummer Observation

We got in contact with a drummer to observe how he interacts with a drum kit and how many different sounds he creates on the drum kit while playing, along with asking a few questions during an unstructured interview.

Two members of our group went to do the observation, which was conducted at Kulturskolen Nordkraft in Aalborg. The playing of the drums and the interview was recorded on video, so we would be able to look back at the gathered data and information from the interview. The drummer, a 21 year old male, had been drumming on a drum kit for 8 years and been playing on percussion instruments for 12 years.

It took around 15 minutes for both the interview and playing the drums. It all started with the drummer going through the different drums and cymbals, what gives the different drums their unique sound and how to change the sound by, as an example, tuning or changing the material of the drumhead. He did the same for the pedals, first telling a bit about them and then showed how to change the resistance of them. After that, he played a bit and made it possible for us to see how he interacts with the drum kit as seen on figure 3.15. It is prominent to see how he not only uses parts of the drums when using one drum, but uses the whole drum to make a lot of different sounds. The possibility of creating a lot of different sounds from the drum kit was, for the drummer, one of the most important features and something he believed was lacking in the electronic drum kits you can get today. As such, this is a feature we should try to bring into our design.

Figure 3.15: The drummer playing on the drumkit during the observation

The drummer also believed that an electronic drum kit should be as close to a real drum kit as possible, especially if the main purpose of it is to train their techniques on. This means that drumsticks should be part of the design, as they are an important part of a drum kit. The drumstick is an extension of the drummer and they should be able to use the sticks without really thinking about it. Another thing he said was that it was often hard to go from a practice pad over to a real drumkit, which can be seen in figure 3.16. This is because there are more bounce in a practice pad and when the drummer then has to play on the real thing they will not get the same amount of bounce, which makes it harder for the wrist. Therefore he believed that it should be the other way around, by making the rebound of the practice pads lesser than on the actual drumkit. This should also be considered in the design of our prototype.

Figure 3.16: The drummer playing on a practice pad while explaining the difference combared to a drum

The interview and observation of the drummer gave us some ideas of what to do with the design. That we need to have different sounds on the different drums, we should decide if the drummer should be able to tune to make different sounds and if we want to use drumsticks and if so how much bounce the drumpads should have.

3.9 Target Group

The target groups were discussed to be either generally people who would like to learn to play drums, or drummers. It was split between these, because both would be viable target groups for a product that simplifies a drum kit, since it can benefit new players to have a dumbed down version of the drum kit, as it can be easier to learn then, and it can benefit experienced players to have a simplified drum kit in order to better play on the go.
The target group is meant to be drummers that mainly play on an acoustic drum kit. They do not have to be professional or been drumming for many years, but they do need to have a bit of knowledge of how to operate the drums or a least a big interest in the drums. The reason for this is that we want the target group to set our future artifact in perspective to an acoustic drum kit. Because we do not require our target group to have years of experience with a drum kit, we do not have an exact age range in which the target group must fit.

Drummers that either live at home with many people or live in an apartment would benefit most from this new interface, since it would work around the problem of producing a lot of noise. Drummers that would like to be able to take their drum kit with them but is unable to do so because it is too large and they do not have the means to take the drum set with them would also greatly benefit from this new interface. Therefore, we can sum up our target group as follows.

The target group is all drummers who desire a way of practicing, without causing inconvenience for those around them.

3.10 Chapter Conclusion

The different solutions presented in this chapter all have their different merits, but none of them quite meet the trifecta of authenticity, mobility, and low noise level. Many of them are close, with the drum pants being easy to transport and not noisy as long as you have a headset, yet not too authentic. The Digital Drum kits being silent and authentic, but not something you would be able to take out on a whim.

The most prevalent of the problems, would be the authenticity, as it is very difficult to achieve on something several times smaller than what it attempts to imitate. Therefore, even though many of the products do what they do very well, they are not the product that we will attempt to make, as they are not necessarily very authentic.

Chapter 4

Final Problem Statement

The different solutions inspired the group to investigate how to combine the ease of setup with the digital drum kit mat and the overall great functionality of the DrumPants while satisfactorily simulating a drum set for experienced users. Considering the above sentiments, the focus of this project will remain on the interaction and mobility of the solution and not the theory of music. The music and theory behind it should remain a tool to bring forth the process. This does not eliminate the possibilities of creating sound samples similar to that of a drum set. Using an instrument should be about playing it, not complicate it with the calibration, setup, portability.

4.1 Final Problem Statement

"By using a layout similar to an acoustic drum kit, how can we make an electronic drum kit, that is mobile, easy to set up and reduces the overall noise level?"

4.2 Success Criteria

- **Provide a recognizable interface**
  The interface should be similar to that of a drum set and easy to operate.
- **Designed for arm and hand movement**
  The interface should be designed with arm and hand movements in mind for the operation of the device along with the user being able to transfer their skills from drumsticks to arm and hand movement.
- **Mobility and easy to set up**
  The device should be something that can be packed in a backpack and disassembled and assembled with ease.
- **Reduce the noise level**
  The device should be able to produce audio by other means such as a output for a headset or speakers to eliminate the noise created by an original drum kit. It should also reduce the overall noise level when operated.

- **Should be usable in most public spaces**
  The device should be small enough to be playable in most public spaces. This is to give the drummers the opportunity to take the device with them if they want to play outside their home.

Chapter 5

Design

After having gathered much information about drums and settled on a final problem statement, we can move on to creating the actual product solution. The following chapter includes investigations of different possible solutions and showcases the result.

5.1 Design Samples

This chapter is about the different design ideas we had for the drum kit instrument. We wanted to create a drum kit, which would help existing drummers play without having a drum kit, acoustic or electronic, nearby. We thought of ways to try and avoid unnecessary noise along with being easy to pack and move.

5.1.1 Early Design Samples

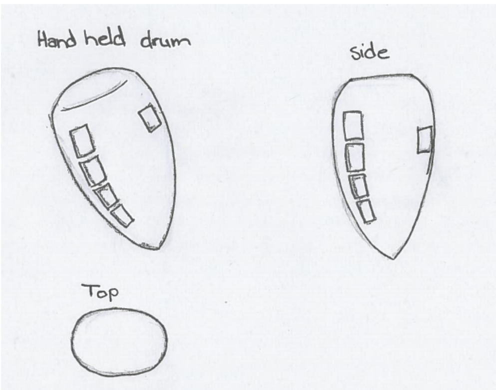

Figure 5.1: The first idea of a hand-held drum

The group's first idea, as seen in figure 5.1 of how the design would look like was hand-held and that all the functions are available within reach of the users fingers. It is a one piece drum, where it would have five buttons, one for each finger, and all of the buttons would have the option to be programmed. Later the group realized that a drummer needs more drum pads that just five, so the group implemented a second piece which was meant to be held in the other hand and would give the drummer more options for more drums. This artefact would be small and be very moveable, which is one of the key features we want for our design. But we thought it would be harder for the drummers, to get the feeling of actually drumming, along with the fact that drumming in the air will give no rebound, as we found in the interview with Marius in section 3.8 would be important for a drummer.

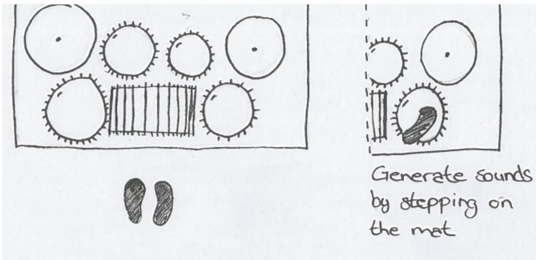

Figure 5.2: A dancing drum mat

The hand-held drum device we designed first was scrapped because the drum feel was non-existent. The design aspect went from a hand-held device to a mat, as seen in figure 5.2, which played drum sounds whenever the user stepped on a drum pad. This concept is similar to arcade games where the player has to dance on the right arrows that are shown on the screen. The mat would be able to be folded and carried around. This still held the possibility to be more mobile than a drum kit, but would be harder to bring around than our first idea as it should be able to have the player step around on it. This also have the problem with not catering to drummers. It would not have the feeling of a drum kit, which we wanted, and was quickly discarded because of it.

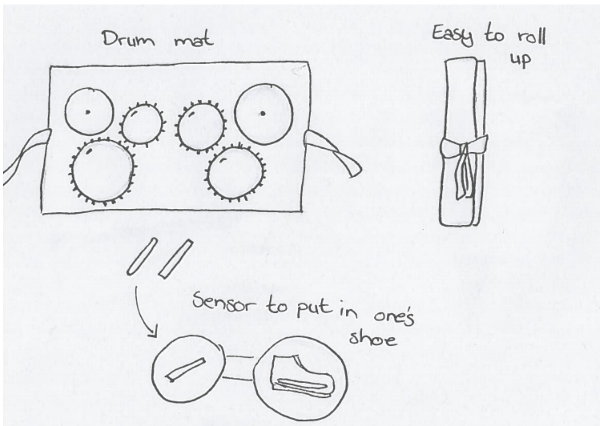

Figure 5.3: A drum mat

The third idea was the one we decided to work further with. We almost used the same layout for this idea, which can be seen in figure 5.3 as the dancing mat from before. The idea still focuses on a mat with the drums seen from the top. The big difference from the second idea to this on is that the hi-hat and the bass drum should be interacted with through sensors in the drummers shoe in the same way the DrumPants and the Ubiquitous Drum Pants does while it feels more like pedals. We also discussed to make the sensors actual pedals, to give the drummers the feeling of playing on a drum kit. The idea is to still keep it as a mat that will be easy to transport by rolling it up and be put in a bag. As it does not have to be stepped on, it does not have to be as big as the dance mat idea would and because of this it will be more mobile. The mat should be made so the drummer can have it on their lap and then start drumming if the drummer wish it. If they, as the interview with Marius in section 3.8 suggested, wish to use drumsticks the mat should be able to work with these as well. We also believe it will be much easier to implement headphones in this idea, which would be beneficial to fulfilling our success criteria.

5.1.2 Design Samples - Drumpad Design

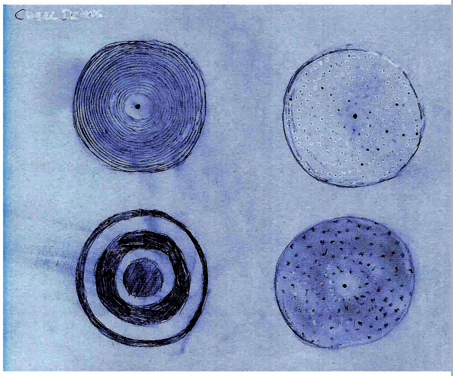

Figure 5.4: Design ideas for illustrating the drums on the mat

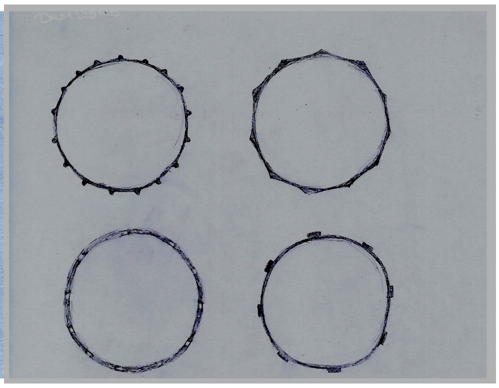

Figure 5.5: Design ideas for illustrating the cymbals on the mat

After we decided on the basic design of our project, we wanted to create illustrations for each one of the drums, so the would be easy recognizable as is one of our success criteria. We thought of a few different designs by looking on different drums on the internet. On figure 5.4 a few of the design concepts for the hanging toms-, floor tom and snare drum. With the design concepts of the regular drums we also made a few cymbals designs as is seen in figure 5.5. We discussed that the drums should have the same illustrations where the cymbals should differentiate a bit. The hi-hat should be different from the other cymbals, this is to hopefully show that it can do something else than the ride- and crash cymbal, which would be through the pedal. We have not chosen a final design for the illustrations because we also wanted to see if it is even necessary.

5.2 Design Overview

The base of the design, is a mat. A lightweight material that can easily be folded, to take up less space, and once folded has a small locking mechanism. This means it basically has two states, folded, and unfolded. The point of this choice is to make the product both lightweight, and easy to transport. Optimally, the folded version would fit right into a backpack, a computer bag, or something similar, so as to make it easily available on the go, and whenever you may choose.

Unfolded, the mat would have one side made to be laid out on your legs or a table, and the other with seven different pads, each representing a different drum set component. A hi-hat, a crash cymbal and a ride cymbal, two hanging tom's and a floor tom, and a snare. These are each slightly different, so that they look enough like their physical counterpart that a slightly experienced drummer would be able to tell which is which. Aside from the look of the drums, the position will also tell the experienced drummer, which of the pads will be which drum, since the position of drums in a drum kit is fairly static.

Along with the mat, follows two pedals. One for the bass drum, and the other to change the sound of the hi-hat. This option was chosen over more pads, because the pedal for the bass is essential to the feel of drumming, and the other one is because changing the hi-hat sound is also very customary when drumming.

5.3 Storyboard

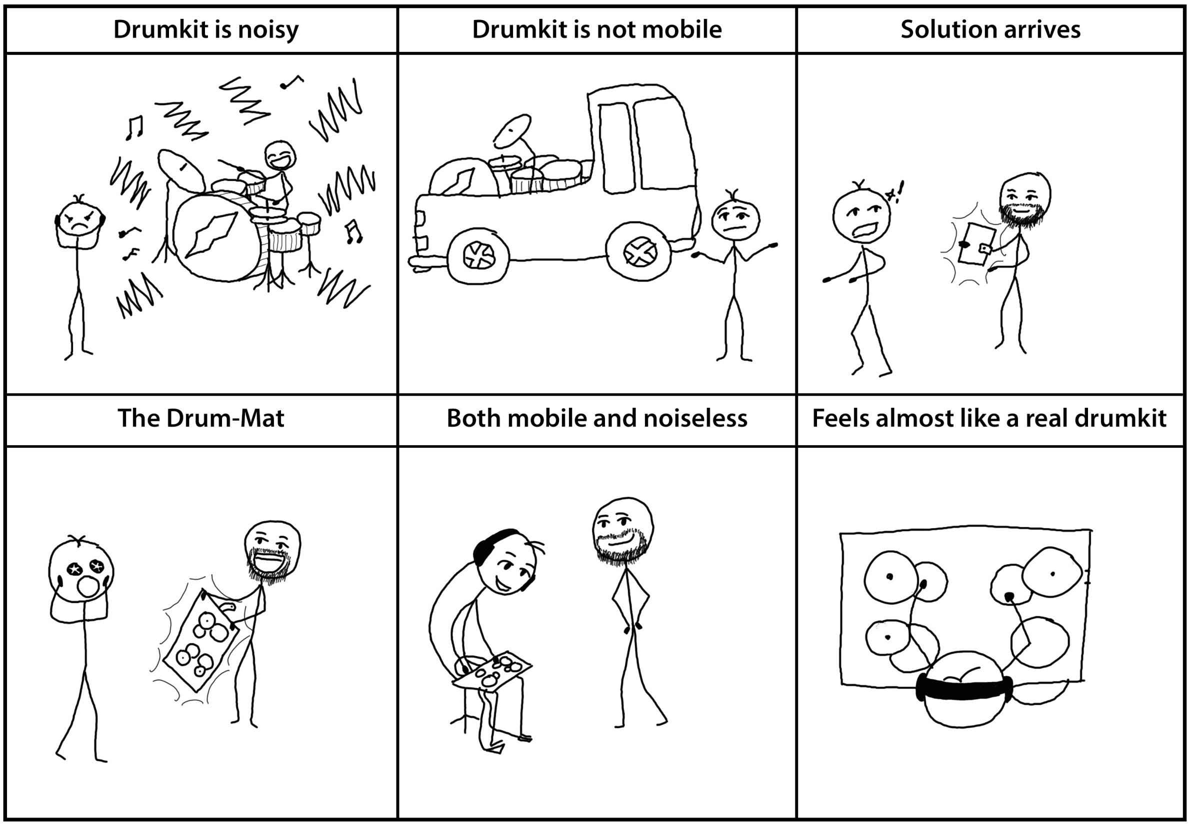

Figure 5.6: The storyboard for Drum-mat giving a short explanation of the problems of the acoustic drum set and how the product can help remove these issues.

The storyboard in figure 5.6 is meant to illustrate the functionality of the product. In the first panel, the main character is dissatisfied with the noise the drum kit makes, when played by someone else. In the second panel, the same guy is slightly dissatisfied with how inefficient it is to transport the entire drum kit. In the third panel, another character arrives, with the folded Drum-mat in his hand. In the fourth panel, the Drum-mat is folded out, to reveal the design. In the fifth panel, the main characters is using the Drum-mat, and enjoying the controlled noise and smaller size. In the last panel, the Drum-mat is illustrated from above, with the main character playing it by hitting the surface.

5.4 Lo-Fi

Figure 5.7: The lofi prototype of the final product showcasing both mat and pedals created for testing.

The lo-fi prototype was created using cardboard and thick paper. The lo-fi prototype shows a good idea of what the final product would look like, with correct placement of drums and cymbals and the ability to be folded over for easier transportation. The prototype also showcases the idea of using a slider for controlling the volume, placement of the power button and using 3 separate entrances for the AUX-jack, hi-hat- and bass drum-pedal. The prototype also uses different colors for the drums and cymbals to showcase which drums would sound similar to users without a good understanding of the different types of drums. It's quite important that as much as possible can be used the first time it's seen and as such the buttons and entrances are explained by the use of conventions: the on/off button is symbolized by the use of a power icon, the volume control with a speaker and AUX port with the image of a pair of headphones. The ports for hi-hat and bass drum are explained with drawings made to look like the hi-hat and bass drum somewhat matching the illustrations found on the pedals.

5.4.1 Procedure

The test was very simple, we asked the participants to try and open the paper prototype and how they would do it. once they have opened the drum-mat, they were asked what the different things meant on the lo-fi without any help from the interviewer. Once they figured out what the different ports were for and what the button and slider did, they were asked how they would start the system, and asked to start playing drums on it. We also asked them how they would use the volume slider to adjust the volume.

5.4.2 Setup

Figure 5.8: The lofi prototype setup.

As seen on the picture above, the setup of the lo-fi test was very simple. The participants were sat in front of the system. In front of them there was the system, earplugs and two cords for the pedals under the table. On the right side of the participant there was an interviewer who asked the questions.

5.4.3 Participants

The participants for the lo-fi test were in the age range from 18-29 and they were all from the 4th semester of Medialogy at Aalborg University. By choosing participants from the university, we could more efficiently get feedback since other students also were in their design phase. However this is not the target group we are designing our prototype for and is not fully representable of our target groups opinion and thoughts.

5.4.4 Lo-fi Results

From the test that we performed we managed to get a lot of positive feedback. Data from all six participants showed us that all of them knew what the subject was about and how to open the product itself. All of the participants knew how to turn the system on and off because they knew what the button was indicating. Some participants had no prior knowledge of how to play drums, but they can see the purpose of the round circles on the piece of paper. Four out of six participants knew that the headphone jack was for headphones, while the remaining were a bit confused but realized quickly after that it was for the headphones. Three out of six participants figured out that the two inputs were for the bass drum and the hi-hat. The two cords for each pedal was also a confusing feature for the participants and could have been optimized for a better result.

5.4.5 Conclusion

From the results we can conclude that the overall design of our drum-set is good, in that it is easy to recognize the different drums, atleast for non-drummers which were our participants for the lo-fi. The small changes that need some re-design are the ports for the pedals and headphones, since some of the participants did not see from the start what it was meant for. Issues that need to be addressed are that the normal drummer might want to use sticks and have a bit more space when they are drumming.

5.5 Design Discussion

This following section discusses the results and how these can be used to improve the design before building the final prototype.

5.5.1 Mat

The core of the design was chosen based on making the system mobile. Several options were discussed here, such as a handheld design and something similar to the drum pants, seen in 3.4.1. These were eventually discarded, as they simply would not convey the feeling of acoustic drums well enough.

After the mat-style design was chosen, we had planned on making the mat so that it could be rolled up. This was the plan for some time, but changed after some consideration of the materials, as it seemed difficult to be able to roll it out and have it rest on your legs without it sinking together due to the flaccid material.

Additionally, it would be difficult within the timeframe to make the pads and the electronics so that they would be soft enough to roll up easily and practically. Therefore the choice was made to make it of two stiffer parts that could fold on top of each other rather than one part that could roll up. The surface area would be bigger this way, but this was deemed to be okay, as it, folded up, essentially would be around the size of a closed laptop, and most bags can accommodate for one of those.

The square shape was never really closely discussed, but seemed obvious from the start, as it should not be too flashy when folded, and the more odd the shape, the more difficult it will be to put practically in to your bag.

In the background research, a somewhat similar mat design was presented, and the main way that this mat separates from this, is that it is made to be more stiff. That mat had to be laid out on a somewhat large area, whereas this mat is designed to be usable while placed upon your lap. Aside from this, there is a pretty essential difference in the size as well, as the mat mentioned in the background research is bigger.

5.5.2 Interface

The drums on the lo-fi interface were chosen, as mentioned, to make them similar to acoustic ones. It was deemed that this would not make much of a difference, as experienced drummers are very likely to recognize the positions of the pads, but it was still chosen, to make the interface look more appealing. In the hi-fi prototype, only the pads are present, but in a finished product, some additional identifying details would also be added. The positioning of the pads were discussed, as it was unclear whether or not the pads were to extend over one another, but in the end it was decided that the overlapping pads made sense, as this was roughly how the drum set would look from above.

The on/off button uses the well-known power icon, and lights up when it is on. This is currently the only thing on the interface that changes, aside from the volume slider, which uses a speaker as its icon to illustrate that it changes the sound.

The inputs were all put in the lower left corner, as it seems the most logical to have them in the same side as the button and slider, because the power source would probably be placed beneath those, and have all the inputs in the same place, even though there are different inputs for the hi-hat and the bass drum.

The inputs also have icons to represent the individual devices, as this seemed like the most simple way of identifying where to plug in what. Another option would be to colour the jacks. The pedals were intended to be as close to the acoustic pedals as possible, but this was deemed difficult, as Rasmus Christensen from 4sound in Aalborg [33] explained that achieving a good feeling for either of the pedals was very difficult, since the hi-hat would sound off if the amount of noise were limited to certain positions, and the bass needed to actually strike something in order to feel right. This meant that we would have to compromise, and it was therefore chosen that the pedals were to be buttons attached to the shoe. This would not achieve the perfect feeling, but, as Rasmus Christensen also said, it was incredibly difficult to achieve a realistic feeling hi-hat pedal, so it would take many resources to achieve something similar to the acoustic pedal.

5.5.3 Materials

The materials chosen for the prototype are not the ones that would be used for a final product. Many different materials were discussed, and we spoke to an employee at a fabric store[34]. In the end, however, felt was chosen as the easiest material to use for a simple proof of concept prototype.

The group discussed whether to make a metallic or acrylic/plexiglass back/spine for the mat, in order to stiffen it up and make it usable on your lap, but this was decided was more of a nice-to-have rather than a must-have feature.

Rubber was decided to be appropriate for the drum pads, as it has a bit of rebound and is easily obtainable and manipulable. This upcoming sections will explain these choices in depth.

Drumpads

The drumpads will need to feel good to strike. As was mentioned in the background research chapter, many drummers prefer practising using the sticks and as such they should be solid enough as to not break when hit. At the same time the product is still mainly created to help drummers practice wherever they might want to and not necessarily with drumsticks. As such the product should also have pads that would be comfortable to strike with your hands. While latex offers a fairly sturdy possibility, latex allergy is a rising problem and seems to be easy to acquire[35]. As such it would be best to either use another material or to shield it from direct touch with the drummer in some way. Many practice pads for drummers tend to be made of rubber. Rubber is a fairly sturdy material and gives plenty of rebound when hit with a drumstick. However, from observing a drummer, we discovered this rebound could be too much, giving the mat a different feel compared to an actual drum kit.

Two members from the group went to 4Sound, a music store in Aalborg that is also the biggest in Denmark[33]. Here we talked with one of the salesmen, Rasmus Christensen, about electric drums, how they sound what materials the pads were made of and the pedals for them. Electric drum-kit pads are normally made from two different materials either rubber or a material called mesh fabric, which is a kind of woven polyester material. A mesh pad give the same feeling as real drum skin with the normal rebounds for the drumstick but does not produce sound on its own as is the purpose of a electronic drum. The differences of the two materials on an electric drum-kit can be seen on figure 5.9 and 5.10 below.

Figure 5.9: Drum-kit's pads made with rubber

Figure 5.10: Drum-kit's pads made with mesh heads

We were also told that the rims surrounding the drum heads were able to have a distinct sound, could be a cowbell, a car horn or something else, depending on what the user wants as they are able to change the sounds. He also showed us different drum-pads used as an addition to either the electric or the acoustic drum-kit were all of these had some kind of rubber as the material to their pads. This means that rubber probably is the best material for our drum-mat as of now, but if we want to make it more like an acoustic drum-kit we should use mesh pads. The pedals to an electronic drum-kit looks like they do to an acoustic one but there are two different types. The first is that the pedals are so close to an acoustic drum-kit that the bass drum still hit a pad, much smaller than normal but still a pad with a sensor in it and the hi-hat pedal is part of the hi-hat pad as normally on an acoustic drum-kit. The second is that the pedals are separated from the hi-hat and from the bass drum-pad so that the sensors are in the pedals alone and plugged to the rest of the drum-kit. As we want a design that is easy to carry around the last set of pedals is the best option for us, as that will give less for the user to pack and take with him, but also give the problem of not feeling like an acoustic drum-kit.

In summary, for the drums we will use rubber for the drum-pads and separate pedals that can be plugged into the mat.

Mat

As the mat has to be folded rather than rolled up, it might be wiser to use a more sturdy material rather than simply using cloth or something similar, seeing as cloth has a tendency to be very flaccid if not stiffened by something. However, we still want the mat to feel at least somewhat nice to touch, to ensure a nice user experience and it will have to be fairly thick to hold all the electronics needed. Due to the electronics inside, it might also be beneficial to make the cover somewhat waterproof, and possibly somewhat insulating as well, seeing as the mat may be transported to places outside an optimal temperature range.

The same two members from the group that went to the 4Sound music shop went down to Stof2000, a store specializing in fabrics[34], and asked one of the saleswomen about the different kinds of fabric, what would be a good material if we wanted it to be stiff but not too thick and that it had to be durable. She suggested different kinds of fabric but the best would probably be durable polyester, which is somewhat stiff on its own but not as much as we would like. Then she told us about a material used to stiffen fabric by ironing it onto it called vlieseline. There are also different kinds of this material and the strongest and thickest would be viledon vlieseline but it is also possible to put more layers of the vlieseline material on top of each other and onto the fabric. Instead of using vlieseline it is also possible to insert felt or foam in the fabric. These materials come in different thickness, where foam is thicker than felt and will probably be too thick.

As of now the best material for our product will be the durable polyester and either the felt or the vlieseline to stiffen it more.

5.6 Minimum Implementation Requirements

In the end, the prototype will not include all of these functions, as the prototype will not be able to play without being connected to a computer. This essentially means that the interface will exclusively have the pads and pedals, because the rest will be done from the computer.

Generally, various things that have been discussed are summarised and categorised here.

Must-have

- Strikable drum pads, which produce synthesised sound upon being struck. This is required in order for the system to be used for practice to get the drummer feel that it is somewhat close to a proper drum kit.
- A way of activating the bass drum and hi-hat using ones feet. Because this is how the bass drum and hi-hat are interacted with in a full drum kit, we feel that it is necessary for our system to have the same form of interaction. For the purpose of minimum implementation, two states are only necessary, for the bass drum, on and off, and for the hi-hat, open and closed.
- A way of outputting the sound produced by the system. For the drummer to be able to listen to what he is playing, sound needs to be outputted in some way.
- The system must be easily portable. Because one of the main problems with existing solutions is lack of portability, this must be a major feature of our solution.
- An interface that is easily recognisable by drummers. In order for drummers to be able to play it easily, the layout should resemble a standard drum kit, or in some other way be easily recognisable.
- The system must be quieter than existing solutions. Another of the major concerns with existing forms of practice for drummers is the noise produced. Therefore the loudness is very important for the solution.

Nice-to-have

- Actual pressure-sensitive pedals for the bass drum and hi-hat. In a full drum kit, especially the hi-hat, the exact position of the pedal is important, and therefore would be nice to have a later iteration of the product.
- Different sounds produced by the drum pads, depending on where and how hard it is struck. Different drums produce different sound, depending on where on the surface they are stuck, and how hard they are struck.
- A self-contained system, including power supply, AUX-output and a micro-controller, to eliminate dependence on a computer. Ideally, the system would not be dependent on a computer. This is mostly due to time constraints, but also due to the price of the individual devices needed to make it function on its own. A power source would be needed, and a processor connected to this, along with additional protection for the internal electronics. We also lack the knowledge to produce several of mentioned devices.

5.7 Chapter Conclusion

In the beginning the design was fluid and had multiple different suggestions which were all considered, such as hand-held controllers or a roll-able mat.

In the end, the design of the prototype became a foldable mat with drumpads, and although the features were compromised on many levels, it still maintained the main feature, which of course is drumming.

The final prototype was made of different fabrics, with rubber pads. No additional stiffening was added to the prototype, but the felt makes it fairly stiff.

During the design phase, the paper prototype was tested. The results were essentially that the perceived affordances were what we expected, and most participants understood the concept and functionality of the drums, with the exception of some of the smaller details, such as the ports for the pedals.

Chapter 6

Implementation

Having created a design for our drum-mat, we continued with building the physical product. This chapter explains how it was built, including materials, and thoughts behind various decisions taken during this process.

6.1 Making the Drum Mat

During the design phase it was decided that the drum-mat would be divided into two: The actual drummat, with hittable pads to act as drums and cymbals, and two pedals for the hi-hat and bass drum.

6.1.1 Physical Mat

To make the drum mat we decided to use polyester as the base, felt to put inside the mat and rubber as the drums. The censors are put inside the mat as well.

In figure 6.1 all the materials we decided to use for making the drum mat is shown. We got the fabric, rubber, fabric glue, felt, buttons and a zipper. We also used cardboard and plastic bottle caps.

Figure 6.1: The materials used for making the mat

As said previously the drum mat was made out of polyester. Polyester is fairly easy to work with and it is a durable material. The mat was sown in hand with the zipper and the strips on buttons to hold the mat together when folded, the finished mat is seen in figure 6.2 and 6.3. The reason why we chose to put a zipper in our prototype was so we would have easy access to the electronics inside.

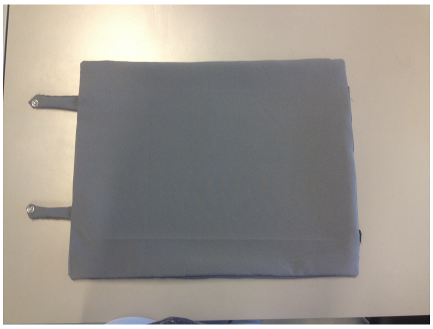

Figure 6.2: The finished sown mat as it looks when it is open

Figure 6.3: The finished sown mat as it looks when it is closed

After the mat was sown we cut two felt mats out as seen in figure 6.4. The felt helps with stiffening the mat a bit along with sheltering the sensors when the mat is hit. The reason we chose two felt mats was that it then would be easier to fold on the middle and the drum mat would be flatter as well if i is being put in a bag.

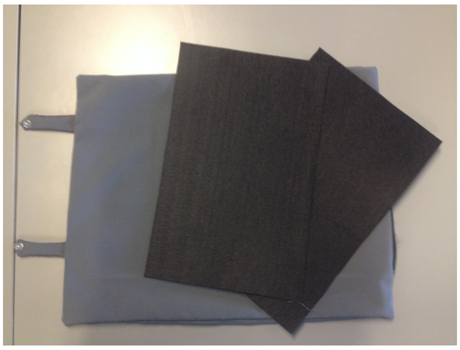

Figure 6.4: The drum mat with the felt on top

We made a template out of paper of the drum pads to make sure they would be the correct size, after that we used this template to cut the pads out of the rubber and glued them to the fabric of the mat. This resulted in the finished mat, though, without the electronics as seen in figure 6.5.

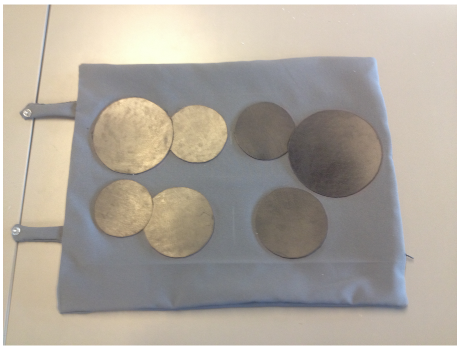

Figure 6.5: The finished drum mat

Lastly we used the cardboard and the bottle caps to make pins for the censors as can be seen on figure 6.6. This was done by cutting the cardboard in the same shape as the rubber pads. Then cut the plastic caps down, so they would not be that high. Some of the smaller pieces of plastic was glued to the surface of the caps to make a triangular shape, making a pin, and the caps was glued to the middle of the cardboards. Lastly, after attaching the sensors loosely to the pin with tape, the cardboards were glued to their respective placed under the rubber pads, on the inside of the mat. One of the cardboard pads is different from the other, which can also be seen on figure 6.6 in the top right corner. The reason this one is different is because there are going to be four censors on this pad, with different sounds for one drum, as this is what we originally wanted for all our pads. This is going to show what our initial idea was.

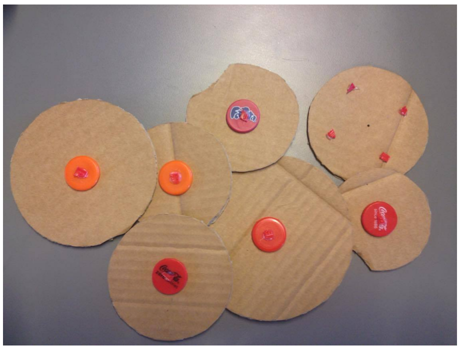

Figure 6.6: The pins the sensors are going to be taped on

6.1.2 Physical Pedals

As we have not been able to make the pedals as actual pedals they are being made of Velcro, to fasten around a persons feet, with a button glued on to a patch of fabric going around the Velcro. The buttons are going to be the bass drum and the hi-hat as normal pedals would have them be.

The Velcro had glue on the backside of it this was used to stick 5 cm of both the hook- and the loop side together. The rest of the Velcro was stuck to the same kind of polyester fabric as the mat is made of. We also made two small tubes of fabric, which was able to go around the Velcro, here we glued the buttons on. The reason for this was so it would be easier to both adjust the Velcro around the drummers feet, for when the person has to strap it on. The finished version can be seen on figure

6.2 Chosen Technology

The technology chosen for this project includes the Arduino, force sensitive resistors, buttons, multiplexer and a PC that can operate Processing and read the serial ports. This section explains how these different electronic objects work.

6.2.1 Force Sensor

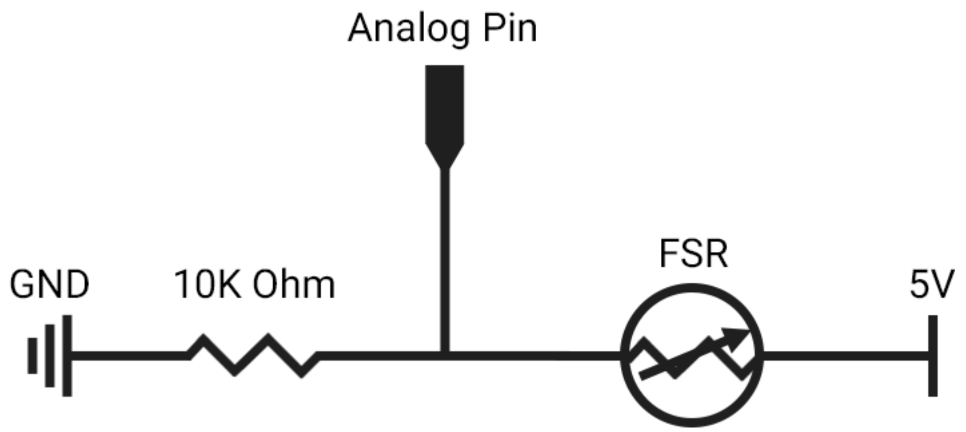

Figure 6.7: A schematic of a FSR attached to an Arduinos analog pin, power rail and ground.

Being able to strike the drum pads (with either hands or sticks) to make a noise, is one of the core abilities of the product. As such the product needs to be able to feel that the drum pads are being struck in some way. To do this, the product will use force sensors beneath the drum pads. The force sensors used are Round Force Sensitive Resistors (Round FSR). These work by lowering the resistance through the resistor when more force is applied.

They are fairly low cost and easy to use, which makes them ideal for a student project like ours. However, they are rarely accurate, and they often vary up to 10% from sensor to sensor. However, they are fine for detecting whether or not weight is applied, just not exactly how much. They are made of plastic, and they are easy to apply to a breadboard or similar. [36]

FSRs were selected as the chosen technology for this project, as they are somewhat cheap, and easy to connect with an Arduino as shown in figure 6.7. While, as stated above, they may not be the most precise, extreme precision is not necessarily needed for the intended use here, and 10% should be well within an acceptable range.

6.2.2 Arduino

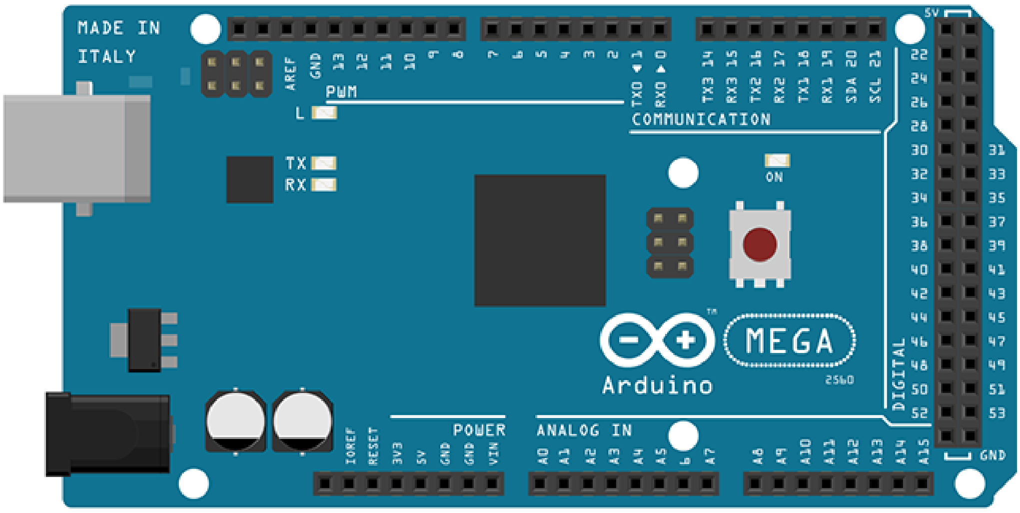

Figure 6.8: A illustration of a Arduino MEGA2560

The Arduino or Genuino outside the US, is a programmable electronic platform designed to be easy-to-use, the hardware used to create it is easily accessible, and the board design is open-source. The Arduino is loaded with a programmable microcontroller to control the parts of the board. It is capable of reading and outputting digital and analog signals. These terminal headers for the digital and analog signals can be used to control and read various different sensors and operate other special made hardware designed to work with the Arduino. Some of these are known as "shields" which can be attached to it to provide the Arduino with more functions of the expense of some digital and analog terminals. The most common ones are for wireless connection via Wi-Fi or Bluetooth and a LED display panel.

The Arduino is going to be used primarily to read sensor values and send these through its serial connection to the computer so it can compute the read values and act accordingly. Another advantage of the Arduino is the price of the device. We are in this project going to take advantage of the Arduino MEGA2560s increased terminals for both digital and analog reads/outputs as we are going to use a good amount of analog terminals to read our force sensitive resistors.

6.2.3 Button

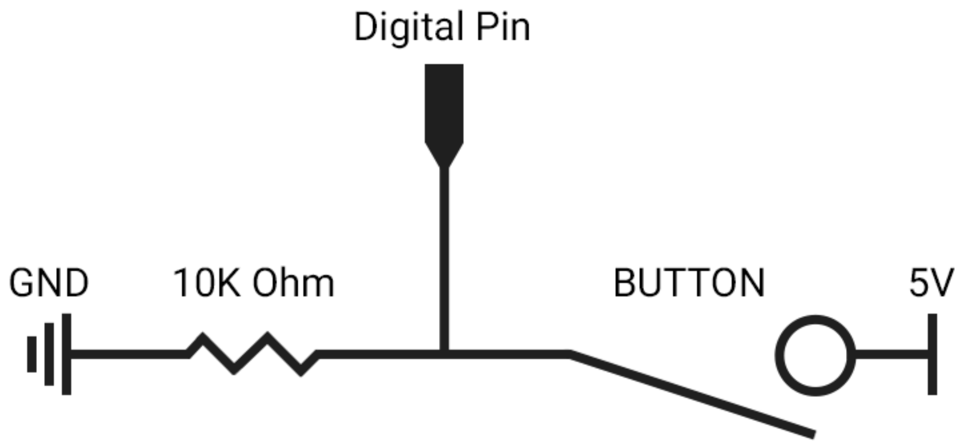

Figure 6.9: A schematic of a button attached to an Arduinos digital pin, power rail and ground.

The button that are going to be used is a simple four-pin button that will only let the current flow through it if hit. This will be connected to a digital input pin and the current is from the 5V power rail in the Arduino. It functions as a separation of the connection unless pressed. The wires can be connected on to whatever pin is desired but the other wire must be connected on the opposite site, not directly across but skewed. An example of a button attached to an Arduino is shown in figure 6.9.

6.2.4 Multiplexer

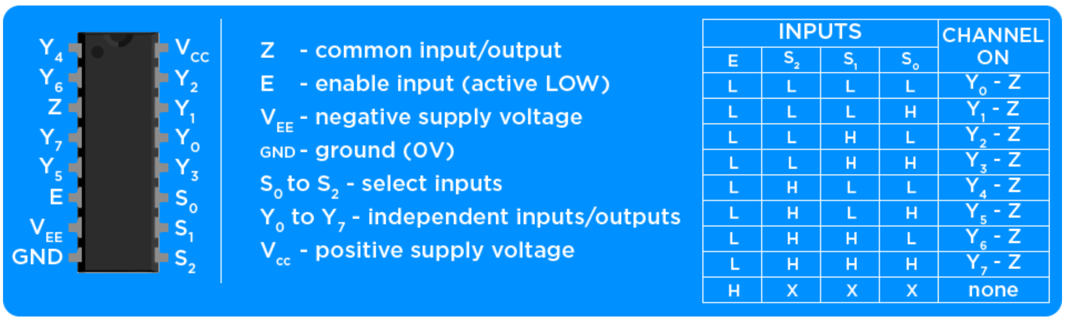

Figure 6.10: A illustration of a 74HC/HCT4051 8-channel analog multiplexer/demultiplexer showing the pin setup and the digital input values to read the different inputs

A multiplexer (or mux) functions as a funnel to take more input signals and reduce that amount of input signals into one pipe line so you can have multiple input signals run through the same pipeline or in our case, the same wire. In this project, the multiplexer are going to work with analog inputs to reduce the amount of analog inputs going into the Arduino as it has a limited amount of analog terminals. The reason why it can reduce the amount connections to one is that is used a digital output signal to determine which data line it lets in.

If we look at the eight way analog input multiplexer that we are using it has as mentioned eight output pins labelled as Y0-7, voltage and ground points and four digital input pins labelled S0-3 and E. According to the provided data sheet that the above figure illustrates, E should always be set to LOW as its digitalWrite value in the program to enable the outputs to be read. If we want to know the value of our sensor connected to Y0, all the digital inputs should receive a LOW signal. However if we were to read Y3, S1 and S0 should receive a LOW signal and S2 should receive a HIGH signal. This can be cycled through the multiplexer very fast but in theory, it is four times slower than attaching each of these sensors directly to the Arduino were you to connect four of them. Even so, this is almost not noticeable as the Arduino is able to operate at a very fast phase.

6.3 Tools Used

This section explains what type of tools were used in creating the product. These include the Arduino software (used to communicate with the arduino), Processing and PureData

6.3.1 Arduino Software

The Arduino software is created by the same people that create the Arduino board[37]. The software is an open-source IDE based on Processing and other open-source software and it is written in the Java programming language. The program runs on Windows, Mac OS X and Linux.

While many other types of software (such as Processing and Pure Data) is able to communicate with the Arduino (either for receiving an input or sending an output to the board), the Arduino software is able uses the serial communication to upload program patches (called sketches) or also known as firmware, to the Arduinos multicontroller.

6.3.2 Processing

Processing is also an open source programming language and integrated development environment built with the purpose of teaching the fundamentals of computer programming by providing visual feedback[**?**]. The language used in Processing is build on the Java language but uses simplified syntax and as mentioned visual feedback. Processing is also able to read the serial ports just like the Arduino software is which makes it able to upload and download firmware to the Arduino. In the case of Processing, it enables it to listen and send information to the Arduino and control its behavior.

6.3.3 Pure Data

Pure Data, also known as PD, is a graphical programming language used for audio and video software [30]. Pure Data is an open source software project with a large user base creating different types of projects. Being a visual programming language, pd can be used without actually writing code. Instead the user can program entirely through the use of different objects created and connected on a “canvas”, called a patch. These objects are simply connected with lines in the patch and each object has various inputs and outputs available to be used by other programs and can be moved and dragged around on the patch. The version used in this project is called Pure Data Extended, which comes with a much larger variety of libraries than the vanilla version of Pure Data, including several which have to do with sound and music. Pure Data Extended, however, is quite dated and has not been updated for several years which means it may not work optimally on newer operating systems.

6.4 Drum Synthesizing

For this project to be of interest to drummers, it is of importance that the drums sounds like they are drums. While it is very much possible to simply sample the sounds from acoustic drum kits, we decided instead to try and synthesize the sounds. We did this to create sounds that would easily be changed or customized depending on where and how the user would hit the drum. Should the drum be hit on the edge of the drum, the sound should be different compared to hitting it in the center. It's also important to make sure the different types of drums have different sounds: the floor tom should sounds deeper than the hanging toms, and the snare should be completely different. We decided to create the sounds using Pure Data Extended as this is a program we have been introduced to that is able to easily synthesize different kinds of sound using oscillators and filtering. This sections explains how each of the different sounds was created using the different functions of Pure Data Extended.

6.4.1 Procedure

This is a short explanation of how the different patches were created. The different objects are explained more in depth in the later subsections. Sound waves in the real world are sinusoidal waves and as such our patches should include these, created with the osc-object. For getting the right frequencies, using notes given by the University of New South Wales [38], we use line-objects to control the sin wave oscillator and given that a drum sound is not continuous forever, we use another line to control the length of the sound. Since the sound from a drum kit is rarely completely clean, we add a noise object to help add some authenticity to the sound. This is is also controlled to fit different notes and sent through a band-pass filter to make sure it is not overwhelming. Finally,

6.4.2 Bass Drum

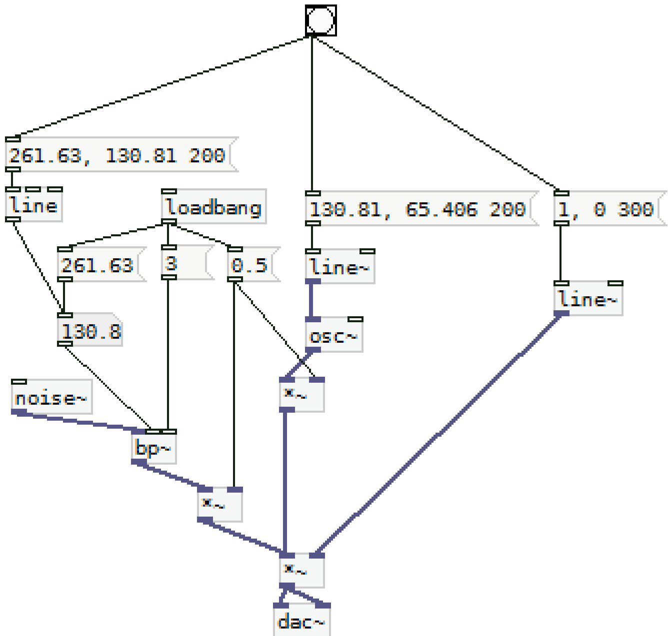

Figure 6.11: The Bass Drum patch used for the program.

As the bass drum is a very vital part of the drum set and this sound was the first created as many of the latter sounds were based off of this. Fig. 6.11 shows a picture of the PD patch used to make this sound. The sound is based on the osc-object, a oscillator which creates a sinusoid ranging from -1 to 1. The object has two inlets, with the left controlling the frequency of the created sinusoid and the right inlet used to control the offset.

Looking at the osc-object, it can be seen that it's input comes from a line object. The line object interpolates values from one value to another over a given time measured in milliseconds. In the case with the line connected to the inlet for the osc, the line is used to make the sound deeper after the initial hit. The two frequencies match specific notes, with the highest being a C3 note while the lower is a C2 note [38].

Let's take a look on the left side of the patch. This also holds a line, although this uses a frequency of a higher note, namely C4. However, this line does not output an audio signal, as seen by the lack of tilde in the object. Instead of outputting a continuous signal it updates it's output at a rate given by the creation argument. Since we don't give it a specific rate, the line uses the default, which means the line gives a new output once every 20 milliseconds. Loadbang is used to make sure all the message boxes are banged when opening the patch. This means that all the messages are sent through their outputs to the receiving objects.

The noise object creates white noise. It creates 44100 random numbers pr. second in the range of -1 to 1. This is send through a bandpass filter which removes the highest and lowest values and sends the rest onwards. This signal, as well as the signal from the oscillator, are multiplied by 0.5 before multiplying them together to make sure that one will not overpower the other. This is coupled with the final Line object on the right. This Line object goes from 1 to 0 and acts as a volume change, making sure that the drums noise dies out as a drum would.

6.4.3 Hanging and Floor Tom

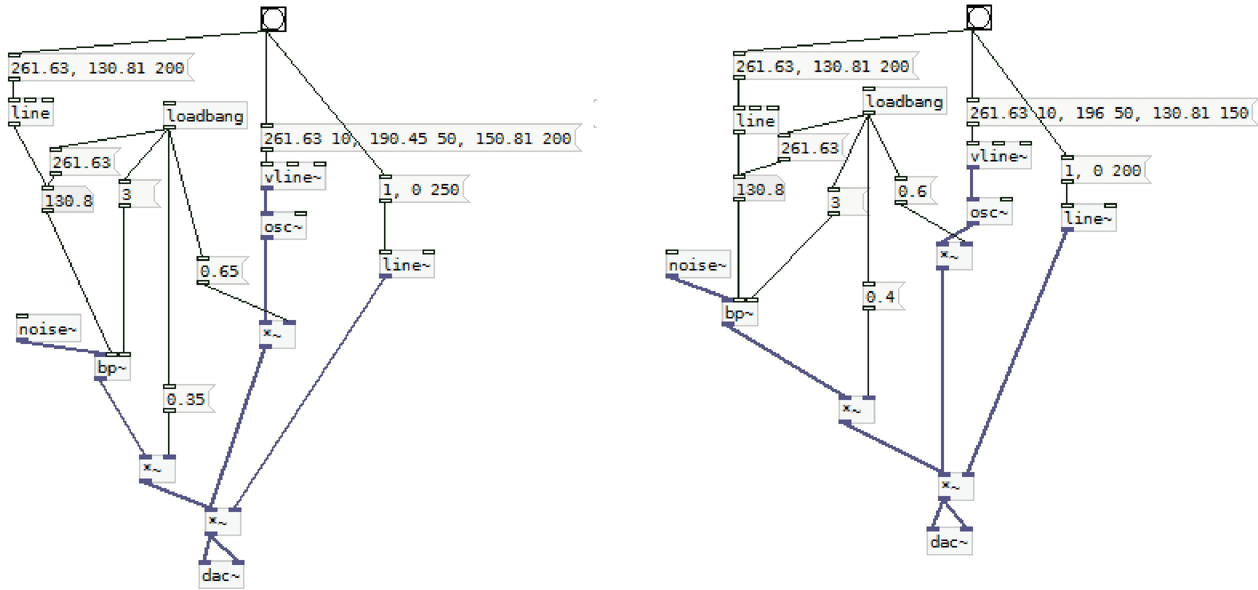

Figure 6.12: The patches for the toms. They are based on the patch used for the bass drum.

The hanging Tom and floor Tom are, as the name implies, the same type of drum. As such, the two use the same patch although with a difference in the given frequency for the oscillator. On fig. 6.12 the floor tom is on the left and the hanging tom on the right. Said patch is based off of the patch used for the Bass Drum from fig. 6.11 although with a few key differences. Rather than using a simple Line object for the oscillator, the toms use a vline object. The vline object is able to switch between three different numbers over a given time for each number, rather than just two. This makes it easy to create an Attack-Decay-Sustain-Release envelop [39], which we are interested in using. As such, our drum can quickly decay from one note to another before we sustain and release the lower note. While both of the toms start with a C4 note, the floor tom quickly decays to a lower frequency than the hanging toms.

The noise of the two drums also differ. To make the sound as close to their respective toms as possible the floor tom's noise has a smaller influence on the sound of the drum, compared to the hanging tom. Finally, the last difference between the two toms is the length of the sound, with the floor toms sound having a longer sound than the hanging toms.

6.4.4 Snare Drum

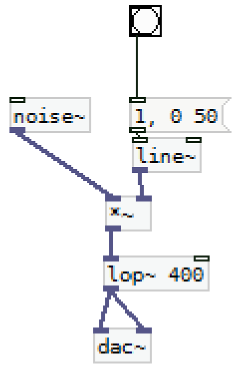

Figure 6.13: The patch used for Snare Drum. It differs from the other patches by not using an oscillator, instead using the noise object.

The snare drum is the final drum on the mat. Unlike the other drums, this does not use the base that was created with the bass drum. As seen in fig. 6.13 the snare drum instead bases it's sound on the noise object. While a snare drum is a normal drum and fully capable of making the standard drum noise we created in the previous patches, for example fig. 6.12, we are not interested in this part of the instrument. As such, we are only interested in the snare part of the drum, which we recreate using the noise object. As mentioned earlier, the noise object creates sounds between -1 and 1 and, as with the other patches, we use a line object to decay this noise quickly. Finally, we send it through a low pass filter with a frequency of 400. This way we only get low sounds to pass through our drum.

In all of these cases our patches create a type of "click" whenever we hit the bang that starts the entire program. Since the amplitude of our volume immediately goes to 1, we create this "clicking" noise whenever the sound is played. This is intentional, as the click works rather for creating the sound of a drumstick hitting the skin of the drums.

All of the sounds were exported as .wav file-types, due to the way the rest of the program was created.

6.5 Hardware

The hardware for this prototype consist of an Arduino, breadboard and FSRs to read the pressure of the hits on the drums. This chapter explains how the hardware is made, how it works and why some of the decisions were made.

6.5.1 Pre Implementation Schematic

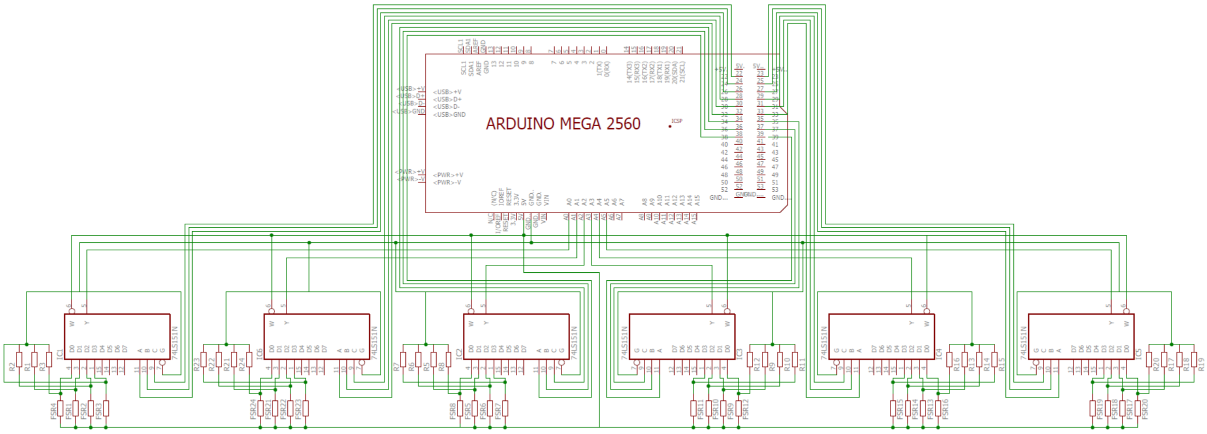

Figure 6.14: A schematic of the first prototype build.

When we started working on the prototype a schematic was made with the visions we had with the prototype. This first schematic seen in figure 6.14 shows several multiplexers and force sensitive resistors (FSR). The reason behind the great amount of multiplexers and FSRs is because we initially wanted to make all the drums able to figure out where they are hit to produce a different kind of sound. However this was deemed not possible due to the amount of available FSRs and the cost required to get more of them. So instead of having all of the drums detect the hit position, we decided to keep one drum with a multiplexer and four FSRs to show the concept of said drum. It was later decided it would be the snare drum that would get the hit position detection. The reason why we needed multiplexers as well were because of the lack of multiple analog pins on the Arduino Mega. Using the multiplexers we could reduce the amount of pins needed from twenty-eight to seven by connecting four FSRs per multiplexer. The multiplexer is explained in more detail at page 44.

6.5.2 Current Implementation

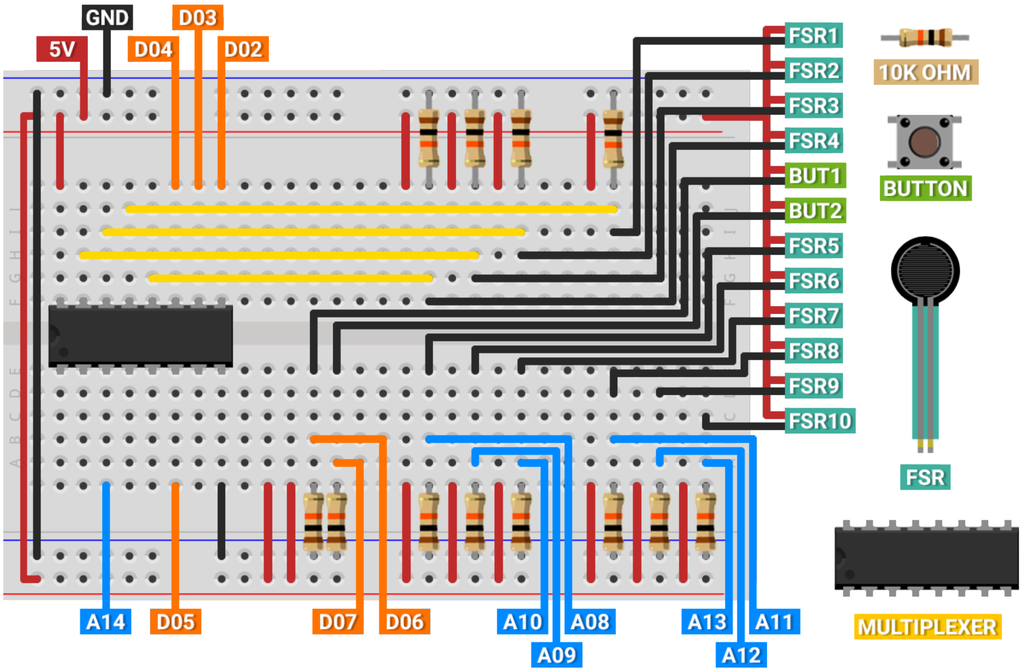

Figure 6.15: A simplified illustration of our current implementation.

Figure 6.15 shows a sketch of our current implementation. It consist of ten force sensitive resistors, two buttons, twelve 10k ohm resistors, one multiplexer, one breadboard and a good amount of coloured wires to easily understand which wire connects to what. The first four FSRs are connected to the multiplexer which are controlled by the Arduino using the digital ports to write HIGH and LOW voltage. The multiplexer outputs one analog signal to the Arduino. The rest of the six FSRs are connected individually to the Arduino's analog pins. Each connection to the Arduino is wired with a 10k ohm resistor. The reason behind the 10k ohm resistors were after testing a few kind of resistors and see what worked best. Turned out that the 10k ohm were to be the best choice for our prototype. Later on we calculated the best resistor for our range that would never reach its max resistance on the FSR but be quite close to. When no one is pressing or hitting the drum it reaches an average of 100k ohm resistance. If you hold it down with full force it reaches an average resistance of around 1k ohm. The equation for the best possible range is;

$$R_1 = \sqrt{R_{min} \times R_{max}} \tag{6.1}$$

We take our 1k ohm as the minimum resistance of the FSR and the 100k ohm as the maximum resistance and gets our result;

$$R_1 = \sqrt{1000 \times 100000} = 10KOhm \tag{6.2}$$

Now we have the resistor required for the most optimal range for our prototype. The buttons used in the prototype is just digital buttons and is connected to the digital pins that is set to read if a connection flows through. Each of them carry 5v from the power rail and emits that voltage once pressed which gives reads as 1, otherwise it will remain 0. The yellow wires on the board indicates the connections to the readings of FSRs connected to the multiplexer.

The blue ones are the direct analog reads. The orange are the digital wires. And black is for ground and red for the power rail at 5v.

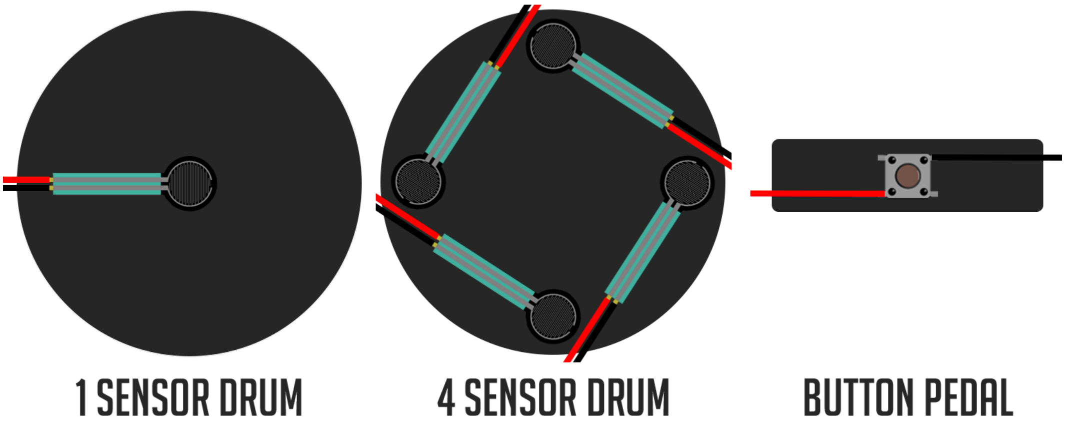

Figure 6.16: A visualization of the sensor usage.

In figure 6.16 it is visualized how the sensors are placed on the prototype. Each single sensor drum has the FSR placed in the middle. The drum with four sensors have the FSRs placed in a square on the circle close to the edge to better find the edge hits and still be able to read if the center is hit. The last one is the pedal with buttons placed on the bands that are to be strapped to the food or shoe of the user. The bottom with the button will be placed towards the ground to function like a pedal on a traditional drum kit. There are several reasons why buttons are used instead of FSRs on the pedals. First off there would need to be something placed in front of the FSR to ensure pressure is applied to it and not the rest of the shoe. Secondly it needs to be calibrated depending on how hard people stump which can vary greatly and could be hard to know when the hihat should be closed according to the applied pressure. And lastly we did not want to break the FSRs in the process by being stumped on under the food without much protection as that will make the pedal larger and possibly harder to put on.

6.6 Software

The software for this prototype makes up of three different programs. One firmware that is used for the Arduino, one for the computer to process and receive the data from the Arduino called Processing and one to control the sounds and play them by receiving the data from Processing through OSC into the program called Pure Data. This chapter aims to explain how each of the programs have been utilized and go through step by step how the programs work by explaining the code.

Figure 6.17: An illustration of how the programs work together.

To give a quick example of how these programs operate together , take a look at figure 6.17. The Arduino will feed Processing with data every time it is requested by Processing over the serial connection (also refereed to as UART or USART). At boot the Arduino will repeatedly ask for permission from Processing to start sending data by requesting a confirmation of connection also refereed to as a handshake. Once done, Processing will ask for data and process it. Once processed it will send the data through OSC (Open Sound Control) to Pure Data which sorts the data received according to the attached label. It will then use this data to figure out when each drum is hit according to how much pressure is applied to the FSR. If the pressure exceeds a certain point, the appropriate sound will play and the volume is controlled as to how hard it is hit.

6.6.1 Arduino

The Arduino serves as a communicator and data gatherer for the Processing program. Its job is to establish a connection with Processing, record the data from the sensors, convert the data and send it to Processing through the serial connection. We are using seven analog pins to read the ten FSRs (Force Sensitive Resistors) and six digital pins to read the two buttons and control the multiplexer.

```
int dS1 = 0;
int dS2 = 0;
int dS3 = 0;
int dS4 = 0;
int dS5 = 0;
int dS6 = 0;
int mS1 = 0;
int mS2 = 0;
int mS3 = 0;
int mS4 = 0;
int pS1 = 0;
int pS2 = 0;
int cS = 250;
int inByte = 0;
```

Figure 6.18: First part of the Arduino code that initializes.

First, we initialize all the values that we are going to use globally through the code seen in figure 6.18. dS# is for the drum sensors which is six of the FSRs. mS# is for the drum with four sensors, short for multi sensors. pS# is for the two pedals, short for pedal sensor. cS is our debugging signal for Processing to check if things are in order to proceed. inByte is for the bytes that the Arduino are going to receive from Processing.

```
void setup() {
  Serial.begin(115200);
  while(!Serial) {;}
  pinMode(2, OUTPUT);
  pinMode(3, OUTPUT);
  pinMode(4, OUTPUT);
  pinMode(5, OUTPUT);
  pinMode(6, INPUT);
  pinMode(7, INPUT);
  pinMode(13, OUTPUT);
  digitalWrite(2, LOW);
  digitalWrite(5, LOW);
  establishConnection();
}
```

Figure 6.19: An example of the setup() part in the Arduino.

When the Arduino boots, it will run the void setup() after initializing as seen in figure 6.19. It will set the serial send and receive rate for the connection between the Arduino and

Processing. When the connection is made we set the pin modes of our digital pins to read or output a signal. The first four is used to maintain and control the multiplexer on the board and the last two reads the buttons for the pedals. Since both pin 2 and 5 will always remain the same, we set them to be LOW right away. Now we run the function called establishConnection().

```
void establishConnection() {
  while(Serial.available() <= 0) {
    Serial.print('A');
    delay(300);
  }
}
```

Figure 6.20: The part of the code that is responsible of making first contact with Processing.

Figure 6.20 shows the part that is responsible for making first contact with Processing called establishConnection(). While(Serial.available() <= 0) will only run as long as the Processing program does not send anything to the Arduino. The while loop sends an ‘A’ over the serial connection every 300ms. Processing uses this ‘A’ to verify the connection between the two and will respond with an ‘A’ when it has received it. This is referred to as a handshake. This while loop will only run once as it is part of the setup() function. Serial.available() will remain 0 until the Arduino receives something and will change to 1 and finish the while loop.

```
void loop() {
  if(Serial.available() > 0) {
    inByte = Serial.read();
    dS1 = analogRead(8) / 4;
    delay(2);
    dS2 = analogRead(9) / 4;
    delay(2);
    dS3 = analogRead(10) / 4;
    delay(2);
    dS4 = analogRead(11) / 4;
    delay(2);
    dS5 = analogRead(12) / 4;
    delay(2);
    dS6 = analogRead(13) / 4;
    delay(2);
    digitalWrite(3, LOW);
    digitalWrite(4, LOW);
    mS1 = analogRead(14) / 4;
    delay(2);
    digitalWrite(3, LOW);
    digitalWrite(4, HIGH);
    mS2 = analogRead(14) / 4;
    delay(2);
    digitalWrite(3, HIGH);
    digitalWrite(4, LOW);
    mS3 = analogRead(14) / 4;
    delay(2);
    digitalWrite(3, HIGH);
    digitalWrite(4, HIGH);
    mS4 = analogRead(14) / 4;
    delay(2);
    pS1 = map(digitalRead(6), 0, 1, 0, 255);
    pS2 = map(digitalRead(7), 0, 1, 0, 255);
```

Figure 6.21: An example of the loop() that reads values from our pins.

Now that Processing has received the connection and responded with a message, Serial.available() will now be 1. This will run the code that allows reading of the individual analog and digital pins and save it in the initialized integers at the start seen in figure 6.21. The multiplexer will also change its output as we change around the values of the digital pins connected to it. It will output four different analog readings every cycle. Since we are sending bytes over the serial connection, we divide the analog values with four to reduce their range from 0-1020 to 0-255. We also map the digital values from 0-1 to 0-255.

```
    Serial.write(dS1);
    Serial.write(dS2);
    Serial.write(dS3);
    Serial.write(dS4);
    Serial.write(dS5);
    Serial.write(dS6);
    Serial.write(mS1);
    Serial.write(mS2);
    Serial.write(mS3);
    Serial.write(mS4);
    Serial.write(pS1);
    Serial.write(pS2);
    Serial.write(cS);
  }
}
```

Figure 6.22: The part of the loop() that sends the read values to Processing.

Now that all of the readings are done, we send it over the serial connection towards the Processing program as seen in figure 6.22. It will now await for a response from Processing to read and send data once again. This will be the ongoing loop until Processing seizes to ask for more data.

6.6.2 Processing

This program is responsible for receiving and reading the data from the Arduino, drawing a visualization of the live drum pads for debug purposes, estimating the position of the hit on the four sensor drum and sending the read and calculated data over OSC. The OSC is short for Open Sound Control and we use this to communicate with our Pure Data patch.

```
import processing.serial.*;
import netP5.*;
import oscP5.*;

OscP5 osc;
NetAddress pd;
Serial myPort;
int[] byteArray = new int[13];
int byteCount = 0;
int dS1 = 0;
int dS2 = 0;
int dS3 = 0;
int dS4 = 0;
int dS5 = 0;
int dS6 = 0;
int mS1 = 0;
int mS2 = 0;
int mS3 = 0;
int mS4 = 0;
int pS1 = 0;
int pS2 = 0;
int cS = 20;
boolean connectionEstablished = false;
boolean centerHit = false;
boolean edgeHit = false;
```

Figure 6.23: First part of the code in Processing.

We initialize our values first as shown in figure 6.23 following the same name scheme found on the Arduino in figure 6.18 at page 53. We import some additional libraries to enable Processing to work with serial connection and OSC.

```
void setup() {
  size(500, 350);
  osc = new OscP5(this, 12000);
  pd = new NetAddress("127.0.0.1", 12001);
  myPort = new Serial(this, Serial.list()[0], 115200);
  osc.plug(this,"data","/test");
}

void draw() {
  rectMode(CORNER);
  background(225);
  drumIllustrator();
  drumPressure();
  drumSignal();
  drumPlay();
}
```

Figure 6.24: Our setup() and draw() function.

In figure 6.24 we run our setup() and draw() functions. The setup() is only run once and sets the size of our UI window, applies the OSC port to be 12000-12001 as well as giving an IP address for the data to be sent which is the local IP of the computer. We also define the port for our serial connection with the Arduino which is usually port 3 but defined as 0 in Processing. We set the serial rate to the same as the Arduino seen in figure 6.19 at page 53. The draw() function sets the background and runs our four functions that is responsible for drawing on the window and estimating the position of the hit on the four sensor drum.

```
void serialEvent(Serial myPort) {
  int inByte = myPort.read();
  if(connectionEstablished == false) {
    if(inByte == 'A') {
      myPort.clear();
      connectionEstablished = true;
      myPort.write('A');
    }
  }
  else {
    byteArray[byteCount] = inByte;
    byteCount++;
    if(byteCount > 12) {
      dS1 = byteArray[2];
      dS2 = byteArray[3];
      dS3 = byteArray[4];
      dS4 = byteArray[5];
      dS5 = byteArray[1];
      dS6 = byteArray[0];
      mS1 = byteArray[6];
      mS2 = byteArray[7];
      mS3 = byteArray[8];
      mS4 = byteArray[9];
      pS1 = byteArray[10];
      pS2 = byteArray[11];
      cS = byteArray[12];
```

Figure 6.25: The serialEvent() that only starts if a message is recieved.

The serialEvent() function works as a trigger when it receives a message over the serial connection that will run completely independent of the draw() function. As shown in figure 6.25 it consist of an if and else statement. The if statement checks if there has been made a first contact with the Arduino. If not and it receives an 'A' from the Arduino, it will clear the buffered data and acknowledge a first time contact and send an 'A' back to the Arduino to trigger the Serial.available() on the Arduino to be 1 and start reading and sending data as earlier explained in figure 6.21 at page 54. Once the connectionEstablished is set to true, the else part of the function will run. This makes sure to fill the array up with the sent data from the Arduino until it is filled. Once filled, it will distribute that data and place it in its appropriate place.

```
        OscMessage data7 = new OscMessage("/top");
        data7.add((int)mS1);
        osc.send(data7, pd);

        OscMessage data8 = new OscMessage("/right");
        data8.add((int)mS2);
        osc.send(data8, pd);

        OscMessage data9 = new OscMessage("/left");
        data9.add((int)mS3);
        osc.send(data9, pd);

        OscMessage data10 = new OscMessage("/bottom");
        data10.add((int)mS4);
        osc.send(data10, pd);

        OscMessage data11 = new OscMessage("/rightPedal");
        data11.add((int)pS1);
        osc.send(data11, pd);

        OscMessage data12 = new OscMessage("/leftPedal");
        data12.add((int)pS2);
        osc.send(data12, pd);

        OscMessage data13 = new OscMessage("/debug");
        data13.add((int)20);
        osc.send(data13, pd);

        myPort.write('A');
        byteCount = 0;
      }
    }
  }
```

Figure 6.26: The end of the serialEvent() function that sends the data to Pure Data and asks for more data.

In figure 6.26 we take the data gathered from figure 6.25 and send it to Pure Data using OSC. We label the message for Pure Data to filter, apply an integer to the message and sends it to the defined port in setup(). Once the whole serialEvent() function is done we reset the byteCount to 0 to restart the insertion of data and send an 'A' to the Arduino saying it is ready to receive another package.

```
void drumIllustrator() {
  int multiColor = ((mS1 + mS2 + mS3 + mS4)/4);
  stroke(225);
  strokeWeight(3);
  fill(0, 0, dS1);
  ellipse(170, 110, 100, 100);
  fill(0, 0, dS2);
  ellipse(80, 80, 120, 120);
  fill(0, 0, multiColor);
  ellipse(160, 230, 120, 120);
  fill(0, 0, dS4);
  ellipse(70, 200, 100, 100);
  fill(0, 0, dS5);
  ellipse(330, 240, 100, 100);
  fill(0, 0, dS6);
  ellipse(290, 120, 100, 100);
  fill(0, 0, dS3);
  ellipse(380, 160, 120, 120);
  strokeWeight(0);
  fill(0, 0, pS2);
  rect(150, 320, 50, 30);
  fill(0, 0, pS1);
  rect(300, 320, 50, 30);
}

void drumPressure() {
  fill(255);
  textSize(18);
  textAlign(CENTER);
  text(dS1, 170, 115);
  text(dS2, 80, 85);
  text(dS3, 380, 165);
  text(dS4, 73, 210);
  text(dS5, 330, 247);
  text(dS6, 290, 126);
  textSize(15);
  text(mS1, 160, 200);
  text(mS2, 190, 235);
  text(mS3, 130, 235);
  text(mS4, 160, 270);
  fill(0);
}
```

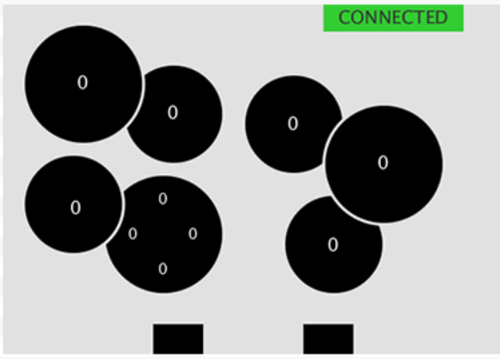

Figure 6.27: The drumIllustrator() and drumPressure() functions that draws the drums and displays the pressure and an example of the live UI.

The drumIllustrator() and drumPressure() functions seen in figure 6.27 is responsible for drawing the drum pads as illustrated. This is done by drawing a good amount of ellipses located properly and fill them according to the pressure. The more pressure there are the more blue they appear. The two squares in the bottom are the two pedals, they will also illuminate blue when pressed. The text is done by the drumPressure() function that draws the gathered data on the appropriate drum.

```
void drumSignal() {
  textSize(18);
  textAlign(CENTER);
  if(cS == 20) {
    fill(90, 90, 90);
    rect(310, 0, 160, 28);
    fill(225);
    text("CONNECTING...", 390, 20);
  }
  if(cS >= 21 && cS < 250) {
    rectMode(CENTER);
    fill(255, 69, 0);
    rect(250, 185, 350, 110);
    textSize(40);
    fill(20);
    text("RECONNECTING", 250, 175);
    textSize(15);
    text("One moment as everything turns", 250, 200);
    text("back to normal...", 250, 220);
  }
  if(cS == 250) {
    fill(50, 205, 50);
    rect(320, 0, 140, 28);
    fill(50);
    text("CONNECTED", 390, 20);
  }
  if(cS == 0 || cS >= 251) {
    rectMode(CENTER);
    fill(255, 0, 0);
    rect(250, 185, 350, 110);
    textSize(40);
    fill(20);
    text("RESET ARDUINO", 250, 175);
    textSize(15);
    text("Press the red button on the Arduino with", 250, 200);
    text("the label 'RESET' and wait 3 seconds", 250, 220);
  }
}
```

Figure 6.28: An example of our error check to figure out if Processing is recieving the data in the right order which is displayed in the UI window.

The part of the code shown in figure 6.28 is responsible for displaying errors in the reading of the data the Arduino has sent. First off it tells us when the program has not established a connection and will display the grey "CONNECTING..." box. Next up is the "RECONNECTING" box that will be displayed if the values are similar to what is displayed when the Arduino is resetting. The program will display the "CONNECTED" green box once everything is in order by receiving the value of 250 from the Arduino. If things are not in order it will display the red "RESET ARDUINO" box asking the user to reset the Arduino by pressing the red reset button on the board. Once done it will take a few seconds before it resets and reconnects. It should now receive the data in the correct order.

```
void drumPlay() {
  if(mS1 > 40 && mS2 < 40 && mS3 < 40 && mS4 < 40 && centerHit == false) {
    OscMessage data14 = new OscMessage("/playSnareEdge"); //1 0 0 0
    data14.add((int)1);
    osc.send(data14, pd);
    edgeHit = true;
  }
  if(mS1 < 30 && mS2 > 30 && mS3 > 30 && mS4 > 30 && edgeHit == false) {
    OscMessage data23 = new OscMessage("/playSnareCenter"); //0 1 1 1
    data23.add((int)1);
    osc.send(data23, pd);
    centerHit = true;
  }
  if(mS1 > 30 && mS2 < 30 && mS3 > 30 && mS4 > 30 && edgeHit == false) {
    OscMessage data24 = new OscMessage("/playSnareCenter"); //1 0 1 1
    data24.add((int)1);
    osc.send(data24, pd);
    centerHit = true;
  }
  if(mS1 < 30 && mS2 < 30 && mS3 < 30 && mS4 < 30 && (edgeHit == true || centerHit == true)) {
    OscMessage data27 = new OscMessage("/playSnareEdge"); //0 0 0 0
    data27.add((int)0);
    osc.send(data27, pd);
    OscMessage data28 = new OscMessage("/playSnareCenter"); //0 0 0 0
    data28.add((int)0);
    osc.send(data28, pd);
    centerHit = false;
    edgeHit = false;
  }
}
```

Figure 6.29: An example of the code responsible for the estimation of the position of the hit on the four sensor drum.

In figure 6.29 is a cut-out of the code that calculates the position of the hit on the drum that has four FSRs under it. This is done using several if statements to figure out which of the sensors are pressed and send a 1 to Pure Data to work with under the label playSnareEdge or playSnareCenter based on what is detected. Only one of them can be send every time the pad is struck as there is two booleans that triggers once one is activated. The if statements can't run if one of them is true. There is another if statement that runs if everything is below 30 and thus sends a 0 back towards Pure Data on both labels and resets the hit detection.

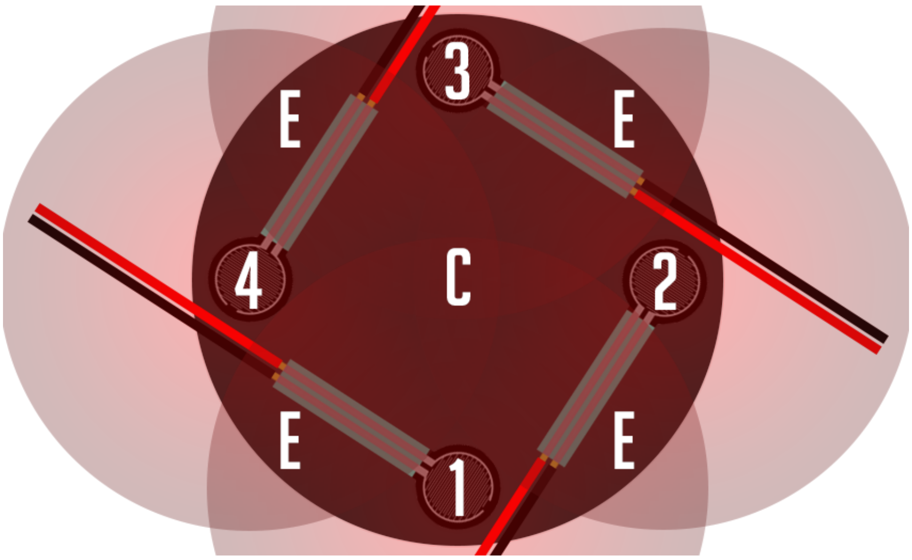

Figure 6.30: Illustration of how the hit detection works in Processing using the four FSRs. E stands for edge and C stands for center.

Shown in figure 6.30 is an illustration of how the estimation of the hit on the drum with four sensors work. As mentioned we use if statements to tell Pure Data if the edge is hit or the center. This is done by counting how many of the sensors goes beyond a certain value. In this case the edges triggers above 40 and the center triggers above 30. The reason why the edge requires a higher value is to ensure that the center will be calculated before the edge does. The center requires three to four sensors to be above 30 while the edge only requires one or two to be above 40. If the pad is struck at one of the Es on figure 6.30 it will count as an edge as it will only find two that goes beyond 40. If you hit sensor 2 it will also count as an edge hit as it will be the only one to go beyond 40. If you however are to hit the C or close to it, it will either detect all four of them to be above 30 or at least three of them. This will send a center to Pure Data and it will play the appropriate sound.

6.6.3 Pure Data

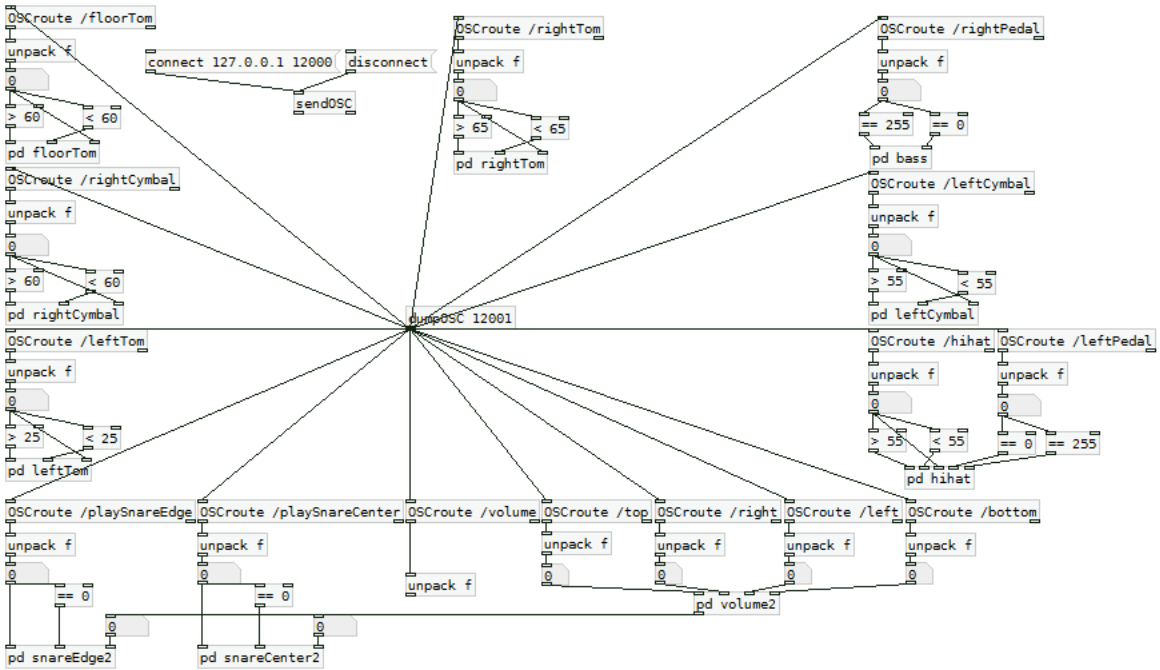

Figure 6.31: The overall Pure Data patch that controls the small individual patches.

The program we use to play the sounds and calculate the volume of each sound based on how hard the drum is hit is Pure Data. We made a patch for it seen in figure 6.31. In the middle of the figure, you can see a function called dumpOSC 12001. This is the outlet of all the data that is send through OSC over the port 12001 from Processing. This is then filtered based on the given label from Processing such as playSnareCenter or floorTom. Once filtered into the correct path, we unpack the message and get the integer we send and now have a number that Pure Data can use to figure out when a sensor is hit or not. The drum sounds are played based on a few more factors. First of all the pressure from the drum needs to exceed beyond a certain point. This varies depending on the drum as some of the pads weigh more than others as they are larger in size. The weight affects the FSRs as they will read an initial force on-top of it. Most of the pads will not rest at zero when turned on because of this. Once it exceeds the given number it will trigger a 1 from its if statement. It will also send a 1 through a different path once it is under the same value. They will output a 0 if their requirement is not fulfilled. These values are then send into a separate patch which starts with 'pd'. These patches are responsible for playing the sound when needed and control the volume based on how hard it is hit.

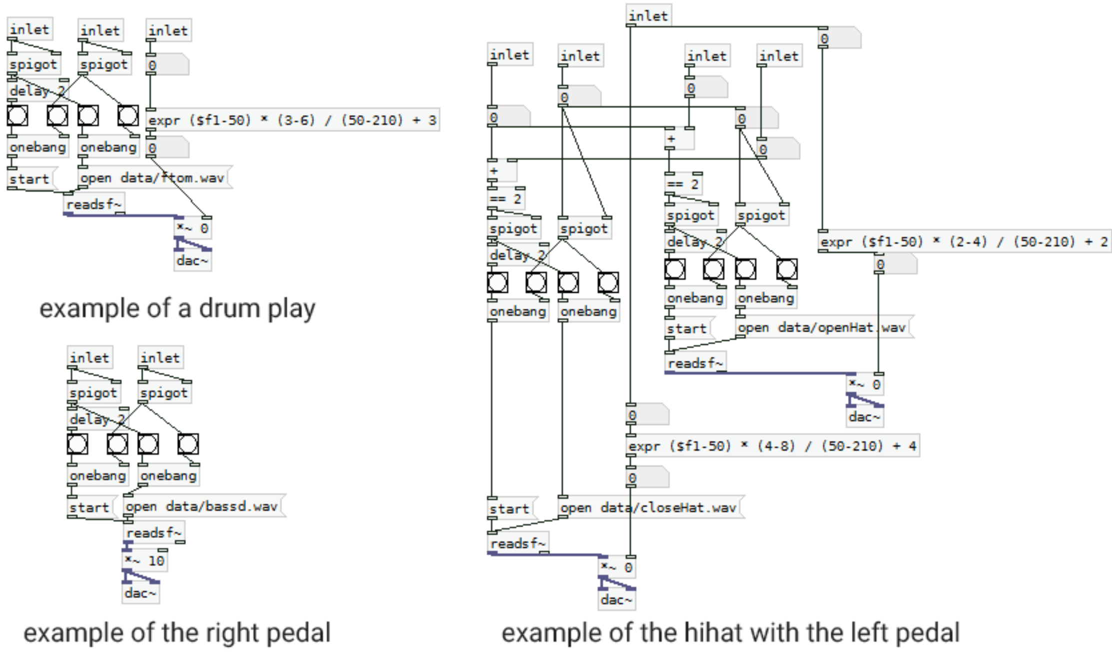

Figure 6.32: Examples of some of the patches found in the main patch.

In figure 6.32 there is several examples of how the patches included in the main patch found in figure 6.31 at page 61 looks. The first example of a drum play works with three pieces of information sent into it. A inlet from the if statement that checks whether or not the pressure has exceeded a certain point. If above the given point, it will be 1, otherwise 0. The second inlet will give a 1 if it is below the given point and a 0 if it is over. The third inlet is the raw read from the FSR varying from 0-255, we use this for the volume calculation. The first two inlets goes into a spigot. The spigot functions as a gate for information. The first input on the top left of the object gets the information that is to be delivered and the input on the top right takes a 0 or 1. If it is 0 it will not let any data through, if it is 1 it will open the gate and let the data flow through the outlet. This data is then send into a bng object. It sends a bang once a 1 is received and this bang will go into a onebang object. The object functions similar to spigot but this time it can only run once. The input on the top left inlet will receive the bang request and the top right inlet has to received a bang before it will allow a bang flow through the outlet after being triggered from the first inlet. This ensures only one bang goes through when it is hit and when released. When hit it will initiate the start message attached to the readsfw̃hich reads the sound file that is opened when the drum is not hit. This is then put into the *˜ object which multiplies the volume of the waves. This is calculated using the data gathered from the third inlet with the raw data from the FSR. This is put into the expr object that maps the data 50-210 to 3-5. The 3-5 is then applied as the multiplication to the volume control and is in the end set to output the audio through both the right and left channel. The reason why the range is 50-210 is to ensure that the lowest volume will be applied when struck and maximum volume is reachable. Usually when the pad is struck hard it close to never exceeds 200. 3 is the minimum volume to make sure that this specific drum sound is about as loud as the rest of the drum sounds. 5 is an acceptable amount louder than 3 as the maximum volume for this sound. If struck lightly it will be less loud and if struck hard it will be louder. This example are used in most of the smaller patches to play the sound but under a different name.

The next example of the right pedal is a bit simpler but uses the exact same method as the drum play. The only thing the pedal does not do is calculate the volume as it is a digital read that is either 0 or 255. If 0, the second inlet will output a 1 and if 255, the first inlet will output a 1. If the requirements is not fulfilled the inlets will emit 0.

The example of the hihat including the left pedal uses the same method as drum play. However there is two different sounds that needs to be played depending of the state of the left pedal. This is also a digital value that is either 0 or 255. If the pedal is pressed and the hihat is hit, it will play the closeHat.wav file. If the pedal is not pressed and the drum is hit, it will play the openHat.wav file. If neither is pressed or hit it will open the openHat.wav file and if the pedal is pressed but not hit, it will open the closeHat.wav file. The volume is based on the hihat hit pressure and not the pedal. As for why wav files were chosen is because we use sound samples to play the sounds during the evaluation and as we are only synthesizing the volume of each drum sound we chose to also export the individual sound patches made in Pure Data as wav files as well.

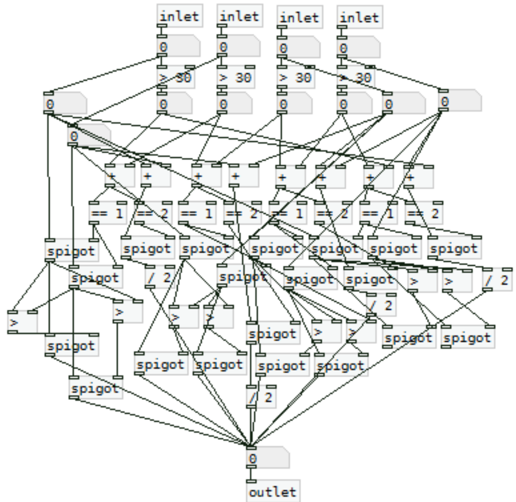

Figure 6.33: An example of the volume control used for the drum with four sensors.

The example shown in figure 6.33 is the volume control for the drum with the four sensors. It takes four inlets which represents one sensor each. If their value exceed 30 it will output a 1. If the additive of two inlets are 2, it will take the two raw FSR readings and divide them by two and send this data through the outlet. If the additive of the two are 1, it will take the pressure value that are the highest of those two and send that data to the outlet. This is done for all the four inlets. The data sent through the outlet then goes to a patch similar to the example of the drum play which will calculate the final volume for the sound played.

6.6.4 Flowchart

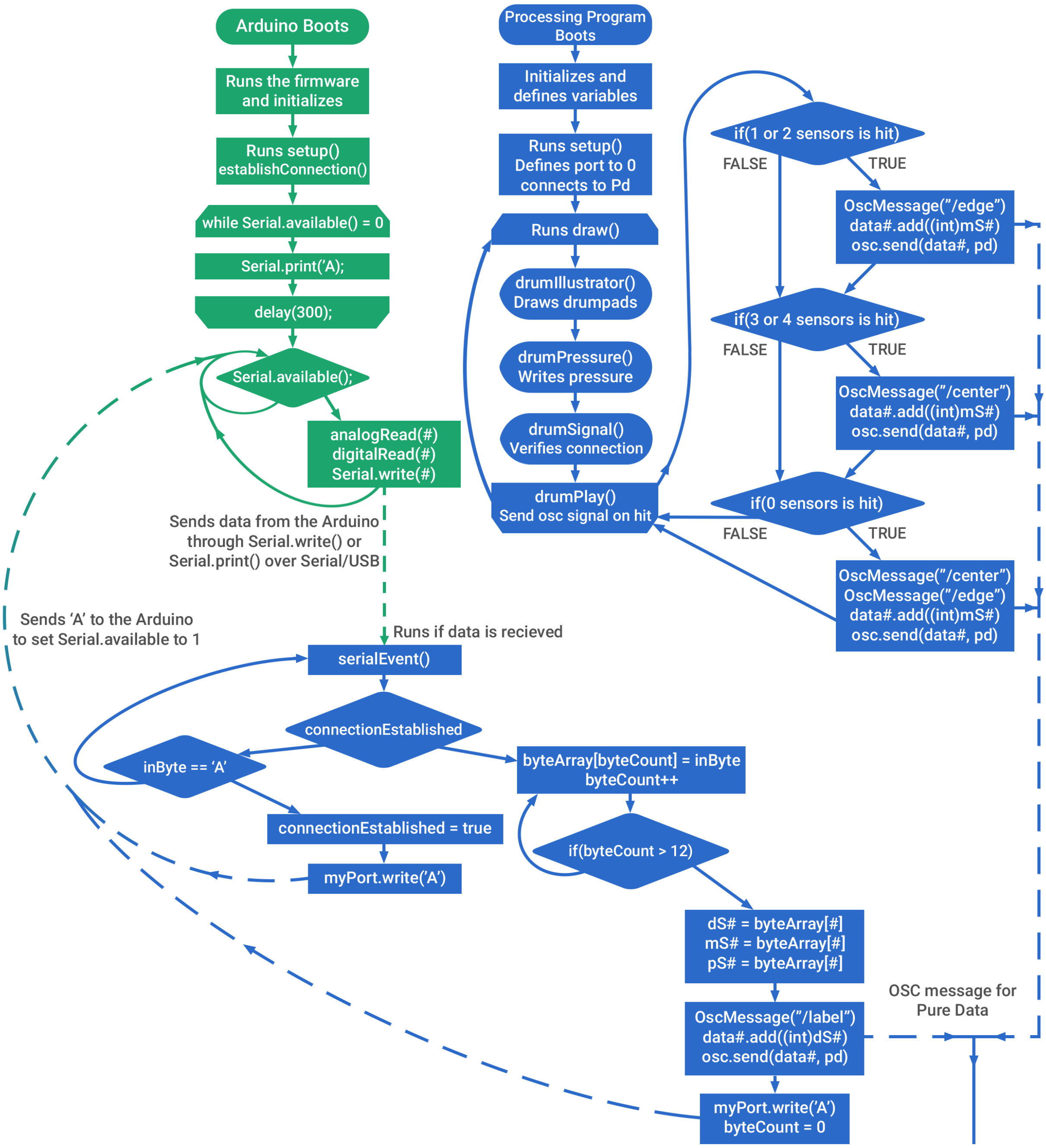

Figure 6.34: Flowchart of the Arduino firmware (top left) and the Processing program (top right and bottom).

The flowchart shown in figure 6.34 explains how the Arduino and Processing software works together. It shows how each of them are dependent on each other to be able to read and send anything. The Arduino will keep calling for the Processing for a response until one is received. The Processing code will receive that message and reply once, making first contact. Once that data is received, the Arduino will start to read and send the data every time Processing has received it and asks for more. This data is then send through OSC to Pure Data and it also calculates when the edge or center is hit on the snare drum in the function drumPlay() that runs in the draw() function. The draw() and serialEvent() function are working out of order, the draw() will always keep cycling through while the serialEvent() will only run once data is received.

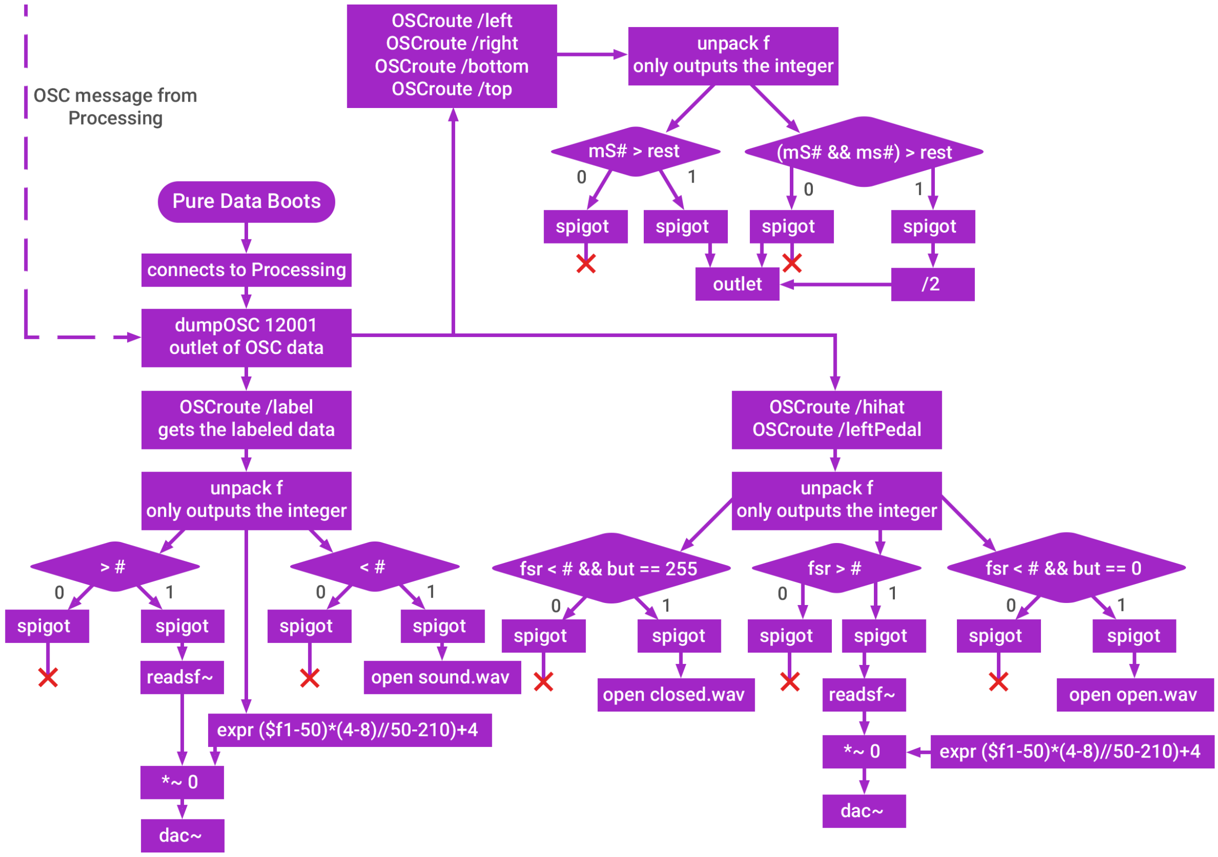

Figure 6.35: Flowchart of the Pure Data patch and how it uses the received data.

The last part of the flowchart from figure 6.34 seen in figure 6.35 is the Pure Data part of the prototype. This part receives the sent data from Processing and uses the raw drum reads and calculated data to figure out when to play a sound and at what volume.

Chapter 7

Evaluation

In the previous chapter, we explained how we created Drummute. With this, we were ready to run evaluation on our target group to check our product against our success criteria. This chapter explains the evaluation procedure of the created product as well as the results from these evaluations.

7.1 Hypotheses

Based on the success criteria, several hypotheses were made to as the objectives. The hypotheses were the following

The system detects hits on the pad with 100% response, regardless of which part of the pad is hit.
This will be tested with a mechanical test, where we will hit the different pads 200 times and check how many of them are detected. We want a 100% hit detection rate, in order to ensure the best possible user experience.

When struck, the system produces less noise than an acoustic drum set.
This will have to be tested with noise measurement equipment, preferably in a sound proof environment to get more precise results.

When struck, the system produces less noise than an electronic drum set.
The procedure for testing this hypothesis is the same as the hypothesis above.

An experienced drummer will be able to recognize the layout of the drums on the drum kit.
This will be part of the research during the user tests. The users will be asked to identify which drums each of the pads represent. They will have to write their answers on a separate piece of paper that shows the layout of the Drumplication.

The system is equally usable both with and without drumsticks.
This will also be investigated during the user tests. The users will be asked to try drumming both with hands and with drumsticks. This will then be measured by asking the tester to rate the feeling, through either an open question, or a series of more direct questions.

There is no difference in the comfort level when playing on the drum mat on the

lap compared to on the table.
This, as the two previous hypotheses, will be tested on the users. While they alternate between playing with their hands and drumsticks, they will also be asked to alternate between having the mat on their lap and on the table. We will get results both from watching their interaction with the mat and also by asking questions during the interview.

Playing the system will be no more or less difficult for left handed people than for right handed ones.
This is tested by asking participants which is their dominant hand. Afterwards, they will be asked to rate difficulty, and we might be able to see whether there is a correlation.

7.2 Technical Tests

The hypotheses are tested in different ways depending on their focus. This section explains the technical tests that do not need response from the target group.

7.2.1 Hit Detection

First of all, the accuracy had to be tested, in order to check whether the system really was 100% accurate. This was done through a simple test. Two hundred strikes on each pad, with no particular strength or position, to add randomness to the test, so it was not just one point of the pad that was tested. Every detection was counted using the program using a simple counter that counted every successful detection. It was not measured how much striking one pad affected the other pads.

Pad	Number of strikes	Number of detections	Percent rate
Crash cymbal	200	150	75,0%
Ride cymbal	200	168	84,0%
Hanging tom 1	200	144	72,0%
Hanging tom 2	200	165	82,5%
Floor tom	200	150	75,0%
Snare	200	159	79,5%
Hi-hat	200	159	79,5%
Average	200	156	78,0%

Figure 7.1: The results from the hit detection test

The table seen in figure 7.1 shows the results for the tests. As visible, the results are not 100%. The highest success rate is for the second hanging tom, with 82,5%, which still is not close to the goal of faultless detection.

7.2.2 Impact Delay Test

This test was done to see how much delay there is within our system as the measured hits have to travel through a lot of stopping points and the huge amount of input would likely to be bottlenecked.

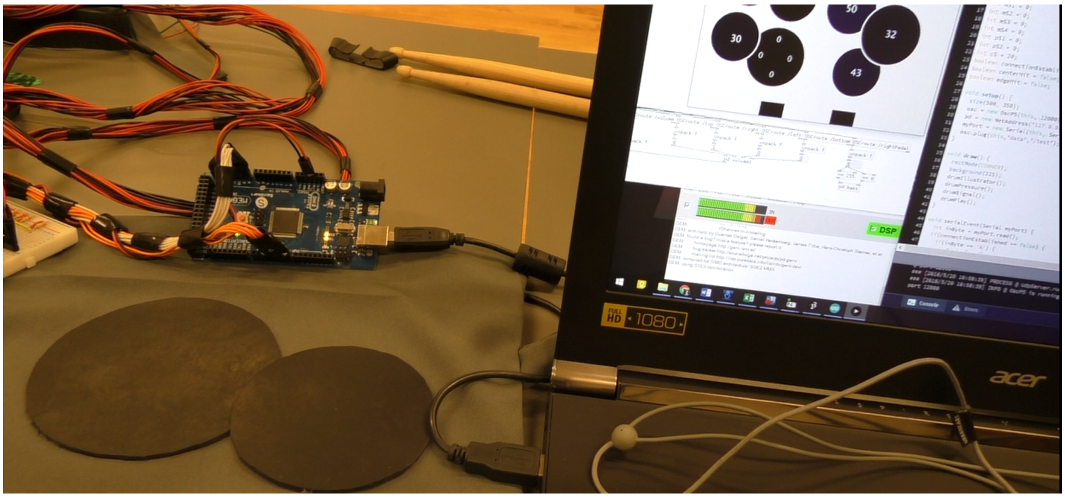

Figure 7.2: The setup of the delay test

We tested this by having a camera record at 100 frames per second to convert the numbers we get to millisecond delay. We recorded 10 taps on one of the pads and implemented that a light on the Arduino would light up every time there was contact with the pad. Within the frame of the camera we also had the program running where it detects the pressure that has been loaded onto the sensor as you can see in figure 7.2. Once we were done filming we set the video clip in editing software to determine how many frames the delay is. This was done by moving frame by frame once the light on the Arduino was lit and then the amount of frames was counted until a number showed up on the program.

Tap #	Frames before triggering	
1	7	
2	8	
3	8	
4	8	
5	7	
6	8	
7	7	
8	8	
9	11	
10	6	
Avg.	7,8	
Delay	78	Ms

Figure 7.3: Results of the delay test

In figure 7.3 we can see the results from each individual tap that was made and for each tap there is the amount of frames that was delay for that particular tap on the pad. From the test we can see that the average amount of delay was 7,8 frames when viewing the video in 100 frames per second. To convert this delay to milliseconds we had to multiply the average by 10 ms/frame, as there is 1000 milliseconds in 1 second, and we got the number 78 ms which is the delay of the system from when you press on the pad until the program notices the pressure made on the pad.

7.2.3 Noise Level Test

This test was made to see the difference in noise between electronic drum kit and our system. The setup for this test used a microphone, electronic drums, our system and Audacity [?] to record the sound and see the amount of noise generated by the drums measured in dB within Audacity. The microphone was placed 0,5 m above the electric drum kit, the same was done with the drum mat. We tested both hands and sticks for the Drummute, but only sticks for the electric drums as it is not made for playing with hands. We used the same strength for all of the samples.

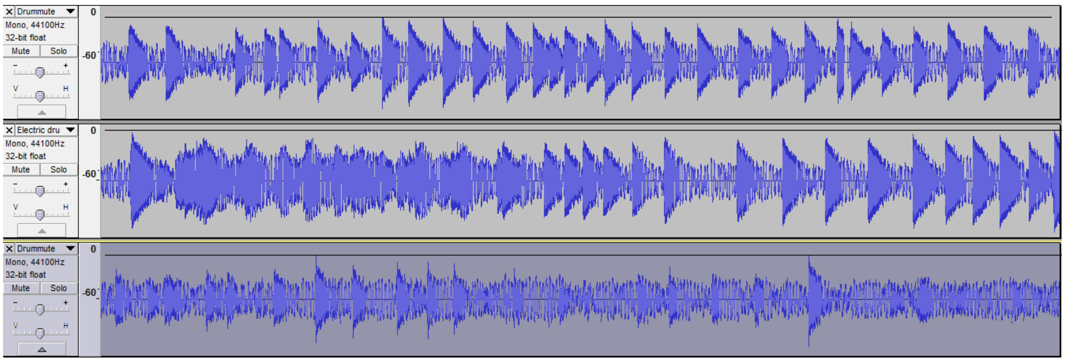

Figure 7.4: Three test levels in Audacity, the upper track is Drummute with drumsticks, the middle track is the electric drum-kit and the lower one is the Drummute with hands

Figure 7.4 shows how the three sound levels are compared to each other after the test was done. Comparing the amplitude of the three waveforms it is clear that the electronic drum kit is more noisy than both the other tracks done with the Drummute.

Sadly, we did not have access to an acoustic drum set to record and compare to with our results. however since our results show that our product was less noisy than an electronic drum kit, and electronic drum kits are less noisy than an acoustic version, we can argue that our drum mat is less noisy than an acoustic drum kit.

7.3 Technical Results

The amount of different possible technical tests were limited, as the system did not have many different technical things to test. The time and prototype limited the technical tests to hit detection, delay and noise level.

7.3.1 Hit Detection

As mentioned earlier, the hit detection was as low as 78% on average, with a fairly large sample size. This is entirely too low, and would generally leads to a less than optimal experience with the drums.

The tests were performed by one group member striking the pad in question 200 times in a row, with no particular strength or position. The strikes were pseudo random, and could be from a wrong angle, or some strikes might be too weak, this is not an optimal method of doing this. Optimally, you would be able to replicate the same positions and strength a number of times, to see which specific types of strikes or strengths the pads respond the most or least to. This might have yielded significantly different results, which could really swing either way. It might prove that the drums are more responsive than expected, but might also prove that they are less responsive. No tests with drumsticks were made, which could be seen as an oversight, but since the drumsticks were acquired late in the development phase, the development had not been focused on playing with them. It was apparent, that when playing with the drumsticks the system was significantly less responsive.

If these results were to get better, the materials of the prototype, and the build of the construction that holds the sensors, would have to be changed to steady the sensors more. Underneath the pads there would have to be slightly truncated cones with the top on the sensors, possibly a tougher material underneath the sensors so it does not absorb as much of the striking power.

7.3.2 Delay On Impact Test

From the evaluation we experienced that the delay in the drum mat was distracting to play with as they would not be able to play their rhythm that fast because of the delay. We would like to remove as much delay as possible. To do that we need to remove the computer as the data has to go from the mat to the arduino, then to the operating computer which runs processing and then to PureData. If we made an independent system without computer, the delay would probably be lower as the data has to travel through less.

The sounds that we used, for the evaluation as mentioned before, might be creating a delay for the drummers as there might be a small window of silence in the sound sample.

7.4 User Test Procedure

Following the technical tests, the hypotheses regarding usability and the target group had to be tested as well. In this section the test procedure for testing with the users is covered.

7.4.1 Test Procedure

In order to conduct our user tests, we needed to establish a test procedure, so that all the areas we wanted to find answers to, both in the test itself and also the following interview, were covered. This was done the following way.

The participant was asked to start off with one of the 4 positions, decided by the group pseudo-randomly, as we did not want a participant to start with the same position as the previous participant. As such, it simply had to be one of the other 3 positions. The 4 positions are as follows.

- Mat on lap, with drumsticks.
- Mat on lap, with no drumsticks.
- Mat on table, with drumsticks.
- Mat on table, with no drumsticks.

Throughout the test duration, after a non-specific amount of time in a specific position, the test participant was asked to switch position, again to one of other untried positions which was chosen by us. The amount of time spend on each position varied quite a lot, but the average was one and a half minutes. This was repeated until all 4 positions had been covered for an adequate amount of time. The test participant was then asked to proceed to an interview.

It is also important to note that we did not use our own synthesized drum sounds. The reason for this is that the sounds was not finished at the time the test took place. We instead used samples from an actual drum kit found on github [40].

7.4.2 Evaluation Setup

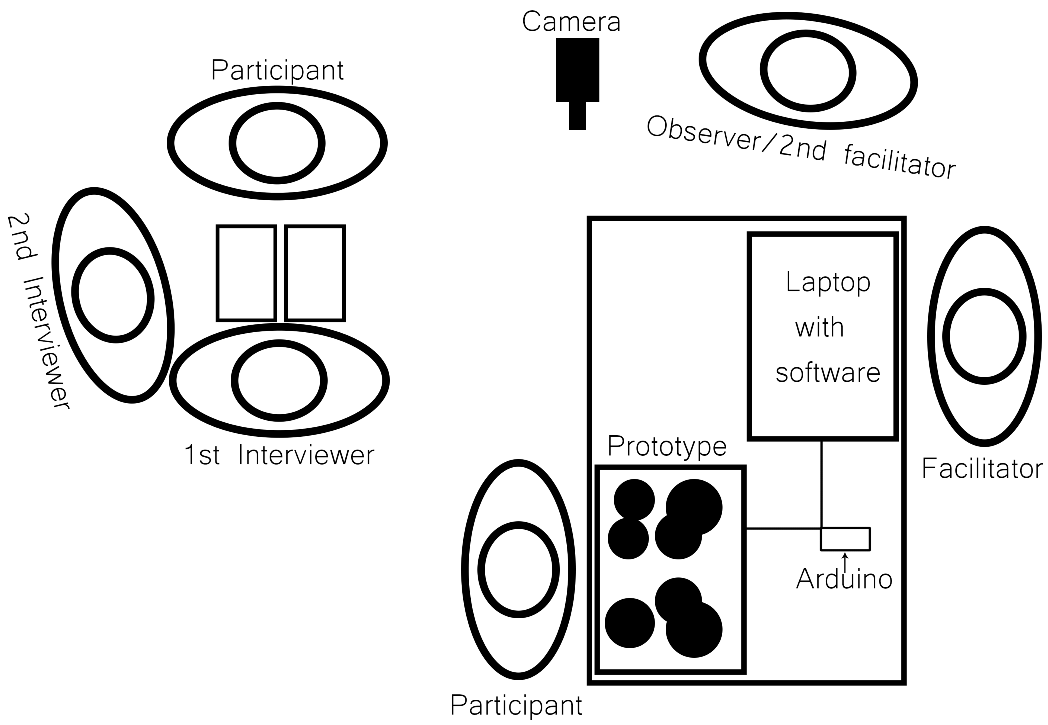

Figure 7.5: A figure that show the setup of the evaluation

Figure 7.5 represents the setup for the evaluation. For the evaluation we used four group members for the course of the evaluation. We had one facilitator that kept the software and hardware working throughout the evaluation, using a laptop that was connected to the drum-mat. The second person acted as an observer and took notes during the evaluation and controlled the camera that filmed the evaluation and introduced the participant to the project. The last two group members that attended the evaluation ran the interviews, one interviewing the participant while the other used the dictaphone to record what the participants were saying and was needed to have if the interviewer could not write down all the things that the participant said at the evaluation. This way we had an opportunity to go back and hear the interview once again, if needed.

7.4.3 Interview

Before the test began we needed them to sign a consent form informing them of what the test would consist of and that we were allowed to used the gathered data. The consent form can be seen in appendix B.

The user tests required that we inquired the participants about a few select things, and this section will go through those.

Pre-test Interview

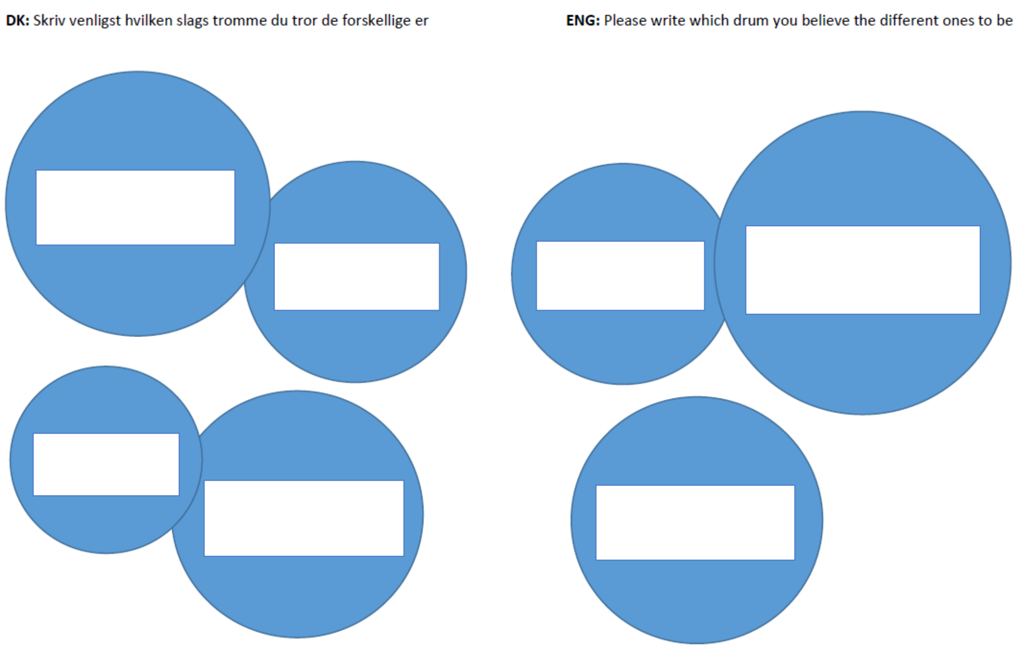

Figure 7.6: The picture used for illustrating the drum layout.

Before the participants were asked to play the drums, they were asked to illustrate which drums they thought were which, and to do this, they were given a piece of paper with the drum layout as shown in figure 7.6. They were then asked to fill in the blanks of the picture, with the name they recognized the drum as. The initial plan was to print out snippets of paper with the names of drums on them for the participants to put on the drum, but this was changed in order to let the participants call the drums, by the names they know them as. Another reason we changed this procedure, was to avoid the users being able to tell the placement of the drums through the process of elimination.

Post-test Interview

A list of questions were created for the facilitators to ask the participants once they had played the drums. These were based on a combination of the success criteria and the hypotheses, in order to test both of these. The interview questions can be seen in appendix A.

Firstly, the participants were asked their age, their dominant hand, and for how long they had played drums. These are simply questions that may or may not have some significance, were the sample size larger. After this they were asked if they preferred playing with or without drumsticks on the prototype, and why, which is just a simple engaging question that starts the interview and asks a fairly important question regarding the system.

After this are four questions, all in similar fashion asking the participant to rate the difficulty of using the mat on a scale from one to five, depending on whether it was on their lap or on the table, and depending on whether or not they used drumsticks. These combinations then makes for four different ones. These are to get some numbers so that some statistics regarding the matter can be made, since this is a very important part of the product.

After this the participant was asked how they felt using the pedal substitutes, which is to judge whether the substitution is really usable.

Then another scale of one to five, where the participant is asked to judge how accurate compared to a real drum the system feels.

In the last part, we asked a few questions about their personal opinion, such as if they had to change something about the drums, what would they change, and if they liked using the system in general, and whether they would use the system while travelling or such, were it more developed.

7.5 User Test Results

The user tests gave many different results and these are covered in the following section.

Addressing the hypotheses

Unfortunately, we have a very small sample size due to unexpected issues with acquiring test participants. Therefore, the statistical analysis possible will be lacking and inaccurate, however, we will attempt to look at the results, and describe how more could be done if a larger sample size was acquired. Specific details about the results can be found in Appendix D, but an overview of the results can be seen in figure 7.7.

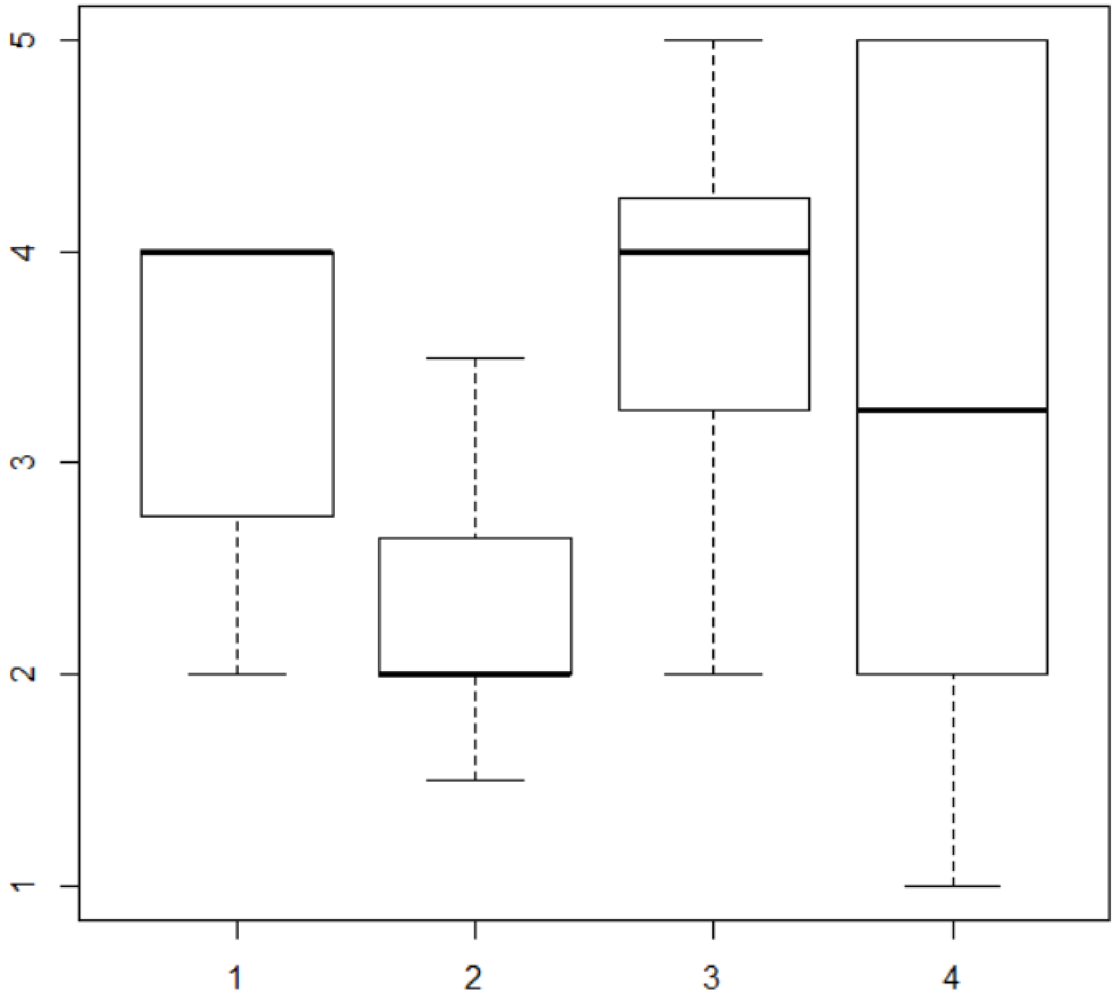

Figure 7.7: A boxplot diagram showing the distribution of data from our interview. The Y-axis is the score given, and 1 is lap without sticks, 2 is table without sticks, 3 is lap with sticks and 4 is table with sticks.

From looking at the boxplot in figure 7.7, we can see that the general trend is that the scenario where the participants are using the system on a table without sticks is generally considered easier, due to the lower score given. The rest of the boxplots yield fairly inconclusively results, due to a large spread, especially in scenario 3 and 4.

If we start out by looking at the specific hypotheses addressed in 7.1. Only two of these hypotheses can be addressed through the interview data, and those are:

- The system is equally usable both with and without drumsticks.
- Playing the system will be no more or less difficult for left handed people than for right handed ones.
- There is no difference in the comfort level when playing on the drum mat on ones lap and on the table.

Participant	Lap no stick	Table no stick	Lap with stick	Table with stick
1	4	n/a	4	5
2	4	2	5	2
3	4	2	4	3
4	4	2	3	1
5	3	1-2	4-5	3-4
6	4	3	2	2
7	2	2	4	5
8	2-3	3-4	3-4	5
Average	**3.44**	**2.29**	**3.75**	**3,31**

Table 7.1: Table showing averages of various categories

Unfortunately, the middle of the three is impossible to draw any conclusions for, due to the lack of sample size, and the fact that all of our test participants have been right handed, except one but he still played as if he were. This makes it impossible to conduct any form of two sample test, seeing as we do not have a second sample. However, if a sufficient sample size of left handed people were had, then some analysis could be done as to whether or not the left handed people considered the system more or less difficult to use than right handed people, by using the data gathered from the interview, and the questions asking the participants to rate the difficulty of using the system, using a response variable of a number on a scale 1 to 5, with 1 being easy and 5 being hard.

The first and last of the three hypotheses can be addressed through the data gathered in the interviews. Looking at whether or not the system favours drumsticks or other methods of drumming, can also be looked at by using the questions asking users to rate the difficulty on a scale. First, we want to find an average of the given ratings, as seen in table 7.1.

In calculations, all scores that are between two numbers will be set to the middle, so a score of 3-4 will be set to 3.5 in calculations. The score that is listed as n/a is listed as such because this test participant did not try using the system in a table without sticks, due to external circumstances.

By looking at these averages, we can conclude that on average, the situation in which the test participants play with the system on a table with no drumsticks, is the preferred method. However, in order to address our hypothesis in a proper statistical manner, we need to perform a non-parametric one-way test, due to the two factors, the drumstick or not, and whether or not the participant was playing with the system on a table or on his lap. However, in order to address the two hypotheses separately, we split the data into two groups, as shown in table 7.2 and table 7.3.

Once again, values between two scores are assigned the middle value. For convenience, the single score that is n/a is assigned the value 2.9 and 2.84, respectively during calculation, to minimise influencing the calculations.

For this, we decided to use a Friedman test. The principle of a Friedman test involves ranking each block together, in this case the results given by each participant, and then considering the values of the ranks by the columns, which contain the various scenarios, created from the two factors. In order to perform a Friedman test, the equations shown in figure 7.8 must be used.

No sticks	With sticks
4	4
4	5
4	4
4	3
3	4-5
4	2
2	4
2-3	3-4
n/a	5
2	2
2	3
2	1
1-2	3-4
3	2
2	5
3-4	5
2.9	**3.53**

Table 7.2: A table describing averages of scores given with and without drumsticks.

Lap	Table
4	n/a
4	2
4	2
4	2
3	1-2
4	3
2	2
2-3	3-4
4	5
5	2
4	3
3	1
4-5	3-4
2	2
4	5
3-4	5
3.6	**2.84**

Table 7.3: A table describing averages of scores given with the system on the participants lap and the table.

$$\bar{r}_{\cdot j} = \frac{1}{n}\sum_{i=1}^{n} r_{ij}$$

$$\bar{r} = \frac{1}{nk}\sum_{i=1}^{n}\sum_{j=1}^{k} r_{ij}$$

$$SS_t = n\sum_{j=1}^{k}(\bar{r}_{\cdot j} - \bar{r})^2,$$

$$SS_e = \frac{1}{n(k-1)}\sum_{i=1}^{n}\sum_{j=1}^{k}(r_{ij} - \bar{r})^2$$

$$Q = \frac{SS_t}{SS_e}.$$

$$\mathbf{P}(\chi^2_{k-1} \geq Q).$$

Figure 7.8: Screenshots of the formulas used in a Friedman test.

First, we addressed the hypothesis regarding whether or not there was significant difference in difficulty between playing with or without drumsticks, using data from table 7.2. Using the software R [41] we calculated the relevant results, which yielded a P-value of 0.1655. We then performed Bonferroni correction on our test results, which provided us with a P-value of 0.083. This means that there is no significant difference in difficulty between playing with or without drumsticks, assuming $\alpha = 0.05$.

Next, we performed the same test with reorganised data, from table 7.3, in order to address the hypothesis regarding whether or not it is more difficult to use the system on your lap or on a table. Once again, using R to perform the calculations to minimise human error, we get a P-value of 0.1088. Using Bonferroni correction, this results in a P-value of 0.036. This means, assuming $\alpha = 0.05$, that we can reject the null hypothesis that there is no difference in difficulty between using the system on ones lap and on a table, and therefore accept an alternate hypothesis that there is a significant difference.

Addressing the individual feedback

Through the interviews, we gathered a lot of individual, subjective feedback from our test participants. Generally speaking, most of our test participants really enjoyed the concept of our system, however, in actual terms, the flaws and lacks of our system did heavily reduce the enjoyment of the experience, so naturally, a massively increased hit detection, especially with drumsticks.

The ease of setup and portability was one of the most commended features of our system. Many of our participants would definitely utilize the portability to bring the mat along with them, although there were also a few who said they would probably be too shy to use it in public.

Many of our participants agreed that good way of making the drums more identifiable, would be to colour-code the drums. For example, the cymbals could have a yellow ring around the, the toms could be green, the hi-hat could be red, etc. One participant also suggested a simple label on each, so that the system would be more accessible to new drummers, although it is currently targeted towards people with at least some experience in drumming.

In terms of general feedback aside from the general categories listed above, there was quite a bit. Some participants suggested making the mat more rigid, but still having it foldable to in the middle, because the soft fabric made it hard to do several hits in quick succession. Almost everyone also commented on the fact that they felt the system was too small. This is perfectly valid feedback, however, if they also want to retain the same portability, this might be rather hard to achieve in reality, seeing as it is currently designed to fit in a standard 15" laptop bag.

With regards to the sounds, it was brought to our attention that the 2 hanging toms, nor the 2 cymbals, should have the same sounds, as they currently do in our system. This was a fact that had escaped our attention during the background research, so in a future version of the system, this will naturally have to be amended. We also need to consider redesigning the hi-hat so that it makes a sound upon being pressed down, and not just alter the sound when the hi-hat is struck.

Another suggestion suggested to us was to make the layout customizable. While the current layout is a very common "cookie-cutter" layout, some drummers do move their drum kits around in order to achieve a layout that they prefer. With the current way the system is set up, this is not possible, so that is something to look into in future development. Along with this, one of the major complaints about the system was that fact that it was flat. A full drum kit has the drums at different heights, which allows more freedom of movement, and prevents ones hands from getting in the way of one another. This is an issue in our system, and while it is one that might be slightly unrealistic to implement, it could be something to look into and look into what possibilities there are of implementing it.

7.6 Not Tested

Given the final prototype, neither the portability, nor the ease of setup could be tested. The prototype simply did not allow for it, as it was connected to many cables, and was not fully reinforced. Therefore, these parts can only be discussed and pondered.

7.6.1 Portability

The portability seems to be a simple matter in this scenario. The mat can be folded in half, and when it is, it does not take up much space. Given a regular backpack has room for a laptop, it is fair to assume that it would also have room for our mat. This is if the mat replaces the laptop, but if the mat instead laid besides a laptop, the space may be significantly more limited in the average bag, which could lead to some obvious problems, such as lack of space for other things.

This could be problematic in scenarios such as going to school, where you would need to bring your books and other equipment, or if you were going through an airport, it might limit space for hygiene tools for instance.

This is however speculation, as we do not know accurate measures for bag volumes nor laptop sizes. Overall, it can be said that this mat would easily fit into a backpack, or practically any other bag made to accommodate a laptop.

The discussion above is when we consider the product's current form, which means no battery or aux inputs, or proper pedals, which puts a whole other dimension to fitting in it into a bag. Depending on how long you would want the battery life of the product, you would put

somewhere between two AA batteries and four AAA batteries.
This would not take up a lot of space, but with a small processor also being on there it might take up more space. It also has to be considered that the current prototype does not have a reinforced spine, which means it cannot properly be laid on your lap and hold its form. This spine might be a thin layer of acrylic glass, or a minimalistic metal spine. What they all have in common, is that they would make the product heavier, less flexible, and take up more space. It is impossible to know for sure before the entire product has been made, but it is safe to assume that it would not be as easy to fit into a bag, unless the mat was further downsized.

7.6.2 Ease of Setup

The ease of setup could not be tested either. That is to say, it could, but would not yield any particularly valuable information for the fact the prototype is not fully developed. The reason is the current setup is created with cables connected to the laptop, which is not part of the final design. Therefore, making participants go through the setup procedure, such as plugging in the right cables and starting the program, would simply be unhelpful.

In the final prototype, the hope is that it would be as simple as unfolding the mat and clicking the on/off button, plugging in the pedals and putting them on the ground, plugging in a headset or speaker system, and then playing. This could easily be tested by putting all of the components in front of a participant and asking them to set everything up, which, with the right indications on the equipment, should be no insurmountable task.

7.6.3 Pressure Detection

Since the system was made to emulate a drum kit and it therefore had different volumes depending on your striking power, this would be nice to have tested.

It did end up being problematic to test, as we had no proper way to measure the striking power accurately enough to draw any conclusions from it. Otherwise, we would have to use a machine of sorts that could strike with multiple different pressures multiple times in a row. Then, count all the times the system successfully played a loud sound and a less loud sound, similar to the accuracy test.

Given the results of the hit detection tests, it does seem unlikely that the pressure test would be more successful than 50-60%, since the hit detection test was 78% and it is fair to assume that, even if all the hits were successfully detected, not all of the pressure detection tests will be right either.

With this taken into account, the value for when the sound changes can be changed to be whatever seems fitting for the environment, so it might not be terribly relevant under any circumstances.

7.7 Subconclusion

During all the tests and interviews it was found that the mat would work and our target group would like to use it. This however is if the problems with the responds time for the sound is optimized as well as actually be produced every time the user strikes the pads.

There were also some wishes for the design of the mat. Even though all of the participants during the test found it easy to understand the layout of the drums and cymbals, they would like some colour codes or icons to present the drums and cymbals. Here we could use our illustration ideas, which can be seen in the design chapter. There were also a wish of making the pads bigger so it would be easier to hit them. And we should also consider changing something with the material with the mat so it will not slide down the legs of the users if they were to play with it in their lap. They also expressed that it was a bit odd to have all the drums and cymbals to be the same high but could not see themselves how it could be changed.

The pedals were working as we wanted and mostly as the participants thought it would. The only thing was that participant 1 and 2 would commented that they wanted the hi-hat to make a clap sound when you press the pedal fast, as it would do on an acoustic drum kit. Other than that no one had critic to the pedals.

Most of the participants could see themselves using the drum mat one way or another, some would use it in their freetime if they was sitting in the train, most would use it in some kind of practice situation.

Chapter 8

Conclusion

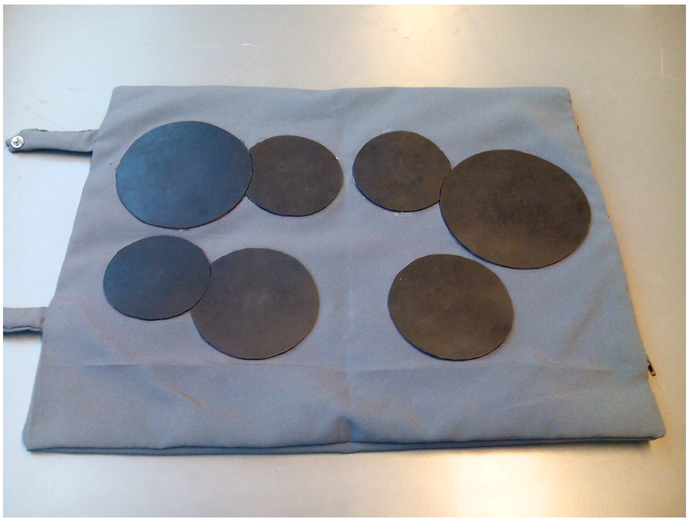

Figure 8.1: An image of the final design solution.

In conclusion, the background research chapter illuminated the problems with the existing solutions, which was, in a lot of cases, a lack of authenticity, and lead us to some conclusions about how the design should be made. This was carved in stone with the final problem statement, and afterwards designed around in the design chapter.
The product was implemented in as a watered down prototype with less features, while still maintaining the main ones.
Finally, the product was tested on real drummers, and the results were evaluated, through analysis and discussion.

In the end, most of the success criteria were tested, and some were fulfilled, while others were not.

The interface was recognizable to the drummers, as they were all able to identify which drums were which purely based on the placement of the pads. This can definitely be chalked up as a success.

The arm and hand movement had not received as much attention as it could have, however the drummers generally seemed to be okay with the layout, although they seemed to not be opposed to make it bigger.

The mobility and ease of setup were all in all not fulfilled, as the prototype was never developed to this point, notwithstanding we believe this is achievable by developing further on the already planned design.

The noise level is conclusively lower than an electrical drum kit as was measured, and thus also an acoustic one.

It was also concluded, through a Friedman test and Bonferroni correction, that there was no significant difference in difficulty between playing the mat using drumsticks or without, assuming that $\alpha = 0.05$. However, when looking at the difference in difficulty between using the system on a lap and on a table, once again assuming that $\alpha = 0.05$, there is a significant difference in difficulty.

Whether or not the product is usable in public spaces is not entirely conclusive, but it seems at least some of the drummers would be interested in using the while traveling or similar, but this could most definitely be tested in further depth. Two of these are definitely and conclusively fulfilled success criteria, while two of them are arguable, and one can be considered unsuccessful. Regarding the problem statement,
"By using a layout similar to an acoustic drum kit, how can we make an electronic drum kit , that is mobile, easy to set up and reduces the overall noise level?",
we would argue that it is answered. Our prototype reduces the noise level and is using familiar controls, and through the design and evaluation phases we have shown that it would be possible to design the product in such a way that it would be both mobile and easy to set up.

It does not seem unfair, given the feedback from the drummers, to say that the product has potential. To achieve this potential, additional work would have to be done, and even then, there is no saying if the product will stand out between similar products. The feedback does seem to imply that the regular drummer would have at least some sort of interest in a product of this sort, and with further development, a commercial product could be produced. Our final iteration of the product can be seen in figure 8.1.

8.1 Quality of Solution

The quality of this solution to the problem could be higher. With that said, with the time used, the prototype does express the idea very well.
The final solution is not on exactly on par with the current state of the art solutions, as they have much more specifically made materials, and presumably also had significantly more development time.
For these reasons, we would argue that the quality is fairly high. Could be higher with more development time and different priorities, but it is high. With only slight explanation, an experienced drummer will be able to understand, and have a good perspective on what a completely developed product would be, and therefore this could qualify this solution to having high quality.

Chapter 9

Future Work

This section ponders on the idea of further developing the project. Which improvements can be made, and what it might be used for.

9.1 Improvements

The first and most important thing that would need to be implemented in any future version of the system would be improved hit detection, especially with drumsticks. This could be done by revisiting the setup that ensures the transfer of pressure onto the sensor. An easy solution would be to simply lower the threshold for triggering the sound; however, the side effect to this would be that when striking, one drum pad, the spread of the impact could trigger some of the surrounding sensors as well. This could be countered by surrounding each pad with a ring of shock absorbing material, for example a thin layer of sponge, such as the kind found in blackboard sponges. Another solution could be to replace the rubber pads with a thinner layer, as it is currently rather thick, and this may affect the amount of pressure transferred to the sensor. A third solution would be to place a stuff material directly beneath the sensors, to ensure that the sensor makes contact with something when pressed down, and therefore triggers properly.

Based on the commonness of it being mentioned by the test participants, the second most important thing to change would be to make the drum pads larger. This in itself is a rather simple fix; however, this would come at a cost, in the form of portability. The mat is currently designed to be able to fit in the same space as a 15" laptop, making it easy to transport. Making the pads larger, would also make the mat larger, and thus reduce the ease of transport.

Another commonly mentioned feature would be to in some way create the mat so that the pads can be in differing levels of height. This might be quite hard to implement, given the way the mat is set up. However, after some consideration, we came up with a possibility that might be to, in some way, have some telescopic stick hidden in the mat, which could be pulled out and locked, to ensure things like the cymbals were higher up. The obvious downside to this is the fact that, depending on how this might be designed, is that it would add an element of fragility to the system, as these stick might break if a user struck the cymbal sufficiently hard.

Through our tests, we discovered that the participants not being able to recognize the drums wasn't really a concern. However, if we were to market the system to new drummers, some way of discerning the drums from one another, some way of colour-coding, as suggested by several of our test participants, might be a good solution.

Another potential development would be to make the system stand-alone. As it stands currently, the mat is dependent on a computer to function. However, the initial goal was to make it a standalone system, with all processing happening on the Arduino. This would also be beneficial with regards to the delay, seeing as the delay currently present in the system is because there is a speed cap on data transmission from the Arduino to the computer. Having all this locally would minimize causes for delay. This is however not a small task, and there are also other things to consider, including, but not limited to, audio jacks, power buttons, a power source, likely a battery for easy of transport, and also some sort of protection, to ensure that the Arduino, or other internal electronics, do not break during transport or use.

9.2 Potential Uses

As it stands now, the potential uses for our system are limited, if not entirely non-existent. However, with some of the improvement listed above, the potential uses are certainly there.

One of such uses is simply for personal use by drummers. This is also the problem we have operated with throughout the project, designing it for drummers who desired some way of practicing their instrument quietly and more easily. With further development, most importantly improved hit detection, and making it a standalone product, this product could be marketed towards personal use for drummers, to ensure practice without disturbing neighbours or family members, or practice while on the go.

More potential uses could be in education. If the various drum pads were colour coded, the system could be used to help teaching new drummers how to play. But again, wider context like this would probably require a majority of the above improvement to be implemented, in order to be viable.

Bibliography

[1] D. Inc., “Drumpants,” Webpage, 2016. [Online]. Available: http://www.drumpants.com/

[2] Y. M. Richard Lee, “Aerodrums,” Internet page, store, 2016. [Online]. Available: http://aerodrums.com/aerodrums-product-page/

[3] D. S. Glasgow, “Pearl vision vbl birch 22" fusion piece kit (black ice),” Store Page, 2016. [Online]. Available: http://drumshopglasgowonline.co.uk/images/PearlVBLBlackIce.JPG

[4] D. Zone, “How does drums work,” Webpage, 2016. [Online]. Available: http://drumzone.com.au/the_drum_kit_10.html

[5] D. for Beginner, “Right way to use the bass drum pedal,” Webpage, 2016. [Online]. Available: http://drumforbeginner.com/lets-begin-drumming/bass-drum-techniques/the-right-way-to-use-the-bass-drum-pedal

[6] Thomann, “Snare wires,” Webpage, 2016. [Online]. Available: https://www.thomann.de/dk/onlineexpert_page_snare_drums_snare_wires.html

[7] D. Superstore, “Mapex saturn iv mh exotic 8x7 rack tom drum cherry mist rosewood burl,” Web store, 2016. [Online]. Available: http://www.drummersuperstore.com/Mapex_Saturn_IV_MH_Exotic_8x7_Rack_Tom_Drum_p/snmt807brle.htm

[8] D. M. Center, “Tama iron cobra hi hat stand hh905,” Web Store - Dural Music Centre, 2016. [Online]. Available: http://www.duralmusic.com.au/tama-iron-cobra-hi-hat-stand-hh905-1076.html

[9] RockemMusic, “Cymbal,” Webpage, May 2016. [Online]. Available: http://www.rockemmusic.com/product/paiste-14-101-crash-cymbal-tornado-boom-cymbal-stand

[10] O. W. Encyclopedia, “drum,” Webpage, 2016. [Online]. Available: //www.oxfordreference.com/view/10.1093/acref/9780199546091.001.0001/acref-9780199546091-e-3486

[11] M. Dean, *The Drums: A History.* Scarecrow Press, 2012.

[12] Yamaha, “Dtx760k,” Store page- Yamaha, 2016. [Online]. Available: http://usa.yamaha.com/products/musical-instruments/drums/el-drumkit/dtx700_series/dtx760k/

[13] U. H. Werner Kaps, “Capacitive touch switch,” Webpage, June 2007. [Online]. Available: https://www.google.com/patents/US7232973

[14] A. D. Lewis, “Touch switch,” 1978. [Online]. Available: https://www.google.com/patents/US4123631

[15] D. W. Caldwell, “Touch switch with integral control circuit,” 2001. [Online]. Available: https://www.google.com/patents/US6320282

[16] Epson, “Gyro sensor - how they work and what’s ahead,” Webpage, 2016. [Online]. Available: http://www5.epsondevice.com/en/information/technical_info/gyro/

[17] Sparkfun, “Accelerometer basics,” Webpage, May 2016. [Online]. Available: https://learn.sparkfun.com/tutorials/accelerometer-basics

[18] J. Karki, “Signal conditioning piezoelectric sensors,” Texas Instruments, Application report, september 2010. [Online]. Available: http://www.ti.com/lit/an/sloa033a/sloa033a.pdf

[19] A. Place, “Alphasphere,” Internet Webpage, 2016. [Online]. Available: http://www.alphasphere.com/

[20] Amazon, “Pme w758 portable 9 pad drum roll-up drum kit high quality material color white,” Store Page, 2016. [Online]. Available: http://www.amazon.com/PME-Portable-Roll-up-Quality-Material/dp/B00EK5UO1Q

[21] S. Creation, “Yamaha dd-65,” Store Page - Sound Creation, 2013. [Online]. Available: http://www.soundcreation.ro/tobe-electronice-tip-pad-drum-pad-uri-cid286_2063/yamaha-dd-65-id10061.html

[22] R. K. Apps, “Real drum,” Smartphone Application, 2016, drum. [Online]. Available: https://play.google.com/store/apps/details?id=br.com.rodrigokolb.realdrum

[23] M. Friend, “Hq percussion realfeel 2-sided speed and workout drum pad,” Store Page - Musician’s Friend, 2013. [Online]. Available: http://www.musiciansfriend.com/drums-percussion/hq-percussion-realfeel-2-sided-speed-and-workout-drum-pad

[24] B. Smus and M. D. Gross, “Ubiquitous drums: A tangible, wearable musical interface,” in *CHI ’10 Extended Abstracts on Human Factors in Computing Systems*, ser. CHI EA ’10. New York, NY, USA: Carnegie Mellon University, Pittsburgh, PA, USA, 2010, pp. 4009–4014. [Online]. Available: http://doi.acm.org/10.1145/1753846.1754094

[25] B. Smus, “Ubiquitous drums,” Youtube, 2009. [Online]. Available: https://youtu.be/HjWx9fp-8oU

[26] A. Bianchi and W. S. Yeo, “The drummer : a collaborative musical interface with mobility,” in *Proceedings of the International Conference on New Interfaces for Musical Expression*, Pittsburgh, PA, United States, 2009, pp. 316–319. [Online]. Available: http://www.nime.org/proceedings/2009/nime2009_316.pdf

[27] E. Sheffield, S. O’Modhrain, M. Gould, and B. Gillespie, “The pneumatic practice pad,” in *Proceedings of the International Conference on New Interfaces for Musical Expression*, E. Berdahl and J. Allison, Eds. Baton Rouge, Louisiana, USA: Louisiana State University, May 31 – June 3 2015, pp. 231–234. [Online]. Available: http://www.nime.org/proceedings/2015/nime2015_286.pdf

[28] Joe, “How do electronic drums work?” Online Article, 2016. [Online]. Available: http://www.dawsons.co.uk/blog/how-do-electronic-drums-work

[29] R. US, “What is supernatural technology?” Website Article, June 2013. [Online]. Available: http://www.rolandus.com/blog/2013/06/04/what-is-supernatural/

[30] PD, “Pure data,” Webpage, 2016. [Online]. Available: https://puredata.info/

[31] F. Manuals, “Oscillators,” Webpage, 2016. [Online]. Available: http://en.flossmanuals.net/pure-data/ch018_oscillators/

[32] Oracle, “Synthesizing sound,” Documentation, Oracle, 2015. [Online]. Available: https://docs.oracle.com/javase/tutorial/sound/MIDI-synth.html

[33] R. Christensen, “4sound aalborg,” Personal communication, April 27th 2016. [Online]. Available: http://www.4sound.dk/aalborg

[34] Stof2000, “Stof2000 aalborg centrum,” Personal communication, April 2016. [Online]. Available: http://stof2000.dk/

[35] S. P. H. W. A. H. Z. D. M. M. P. B. Ruëff F, Kienitz A, “Frequency of natural rubber latex allergy in adults is increased after multiple operative procedures,” *PubMed.gov*, 2001. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/11551255

[36] Adafruit, “Round force-sensitive resistor (fsr) - interlink 402,” Webpage, 2016. [Online]. Available: https://www.adafruit.com/products/166

[37] Arduino, “Arduino software,” Official Internet Webpage, 2016. [Online]. Available: https://www.arduino.cc/en/Main/Software

[38] T. U. N. S. Wales, “Note names, midi numbers and frequencies,” Internet Page, June 2005. [Online]. Available: http://phys.unsw.edu.au/jw/notes.html

[39] F. Manuals, “The envelop generator,” Webpage, 2016. [Online]. Available: http://en.flossmanuals.net/pure-data/ch028_envelope-generator/

[40] Croge32, “arudinostuff,” Github Repository, May 2014. [Online]. Available: https://github.com/Croge32/arduinostuff

[41] R. Foundation, “The r project for statistical computing,” R Foundation. [Online]. Available: https://www.r-project.org/

[42] ActiVition, “Guitar hero,” Webpage, 2016. [Online]. Available: https://www.guitarhero.com/

Appendix A

Consent Form

Vi er gruppe mta16443 fra 4. semester Medialogy på Aalborg Universitet. Vi har i dette semester arbejdet med at udvikle en form for elektriske trommer i form af en måtte.

Denne test vil fokuserer på at teste brugervenligheden på forskellige måder, ved at spille et bestemt stykke musik på måtten ved et bord, på skødet og med og uden trommestikker. Testen vil først bestå af denne gennemgang af måtten og deltageren vil derefter blive guidet over til et interview omkring oplevelsen. Både testen og interviewet vil være individuelt.

Der vil være to personer fra gruppen under testen af trommerne, en som vil guide deltageren og en til at observere og notere. Der vil være to andre fra gruppen som vil interviewe og deltageren vil blive henvist til den ene af disse personer.

[ ] Jeg bekræfter hermed at jeg er frivillig deltager af denne test udført af 4. semesters medialogi gruppe mta16443, ved Aalborg universitet.

[ ] Jeg forstår at min deltagelse i testen er frivillig og jeg bekræfter min forståelse for at jeg på et hvilket som helst tidspunkt i løbet af testen har ret til at afbryde testen af hvilken som helst grund.

[ ] Jeg giver tilladelse til at blive filmet på video og lyd gennem testen og interviewet og må bruges til videnskabeligt brug eller undervisning.

[ ] Jeg giver hermed tilladelse til at alt information under testen kan bruges anonymt i projektarbejde. Alt lyd og video bliver opbevaret sikkert til projektets afslutning, hvorefter det bliver destrueret, med mindre jeg giver min tilladelse til andet.

Fulde navn (i blokbogstaver)

____

Dato

____

Underskrift

____

Appendix B

Interview Questions

- Age:
- Gender:
- Dominate hand:

1. How long have you been playing on a drum kit?
2. Did you prefer to play with or without drumsticks??
3. Why?
4. On a scale from 1-5, where 1 is easy and 5 is hard, how difficult was it to use the mat on your lap without drumsticks?På en skala
5. fra 1-5 hvor 1 er let og 5 er svært, hvordan var det så at bruge måtten på skødet uden trommestikker?
6. On a scale from 1-5, where 1 is easy and 5 is hard, how difficult was it to use the mat on the table without drumsticks?
7. On a scale from 1 to 5, where 1 is easy and 5 is hard, how diffuclt was it to use the mat on your lap with drumsticks?
8. On a scale from 1 to 5, where 1 is easy and 5 is hard, how difficult was it to use the mat on the table with drumsticks?
9. How did it feel to use the "pedals"?
10. On a scale from 1 to 5, where 1 is not and 5 is almost the same, how much did it feel like you were playing a normal drumset when
11. you hit the pads? Why (Not)?
12. If you had to make the drums more recogniseable, what would you have done?
13. DId you like using the mat? Why, why not? Good/bad things?
14. Could you see yourself using this on the go? On a busride? When waiting in the airport? Etc.

Appendix C

Drum Recognition Data Sheet

	Left Cymbal	Right Cymbal	Left Tom	Right Tom	Floor Tom	Hihat	Snare
Participant 1	x	x	x	x	x	x	x
Participant 2	x	x	x	x	x	x	x
Participant 3	x	x	x	x	x	x	x
Participant 4	x	x	x	x	x	x	x
Participant 5	x	x	x	x	x	x	x
Participant 6	x	x	x	x	x	x	x
Participant 7	x	x	x	x	x	x	x
Participant 8	x	x	x	x	x	x	x

Figure C.1: A table showing if the different participants chose the correct drum placement.

Appendix D

Test Observation and Interview Data

After each participant had tested the mat, they were asked some questions. The results of each are shown below. In each subsection, is also a table containing the result of the quetsions involving a scale. In the first 4 columns, 1 means very easy to use, and 5 means very hard to use, and in the last one, 1 means very inaccurate, and 5 means very accurate.

Participant 1

Our very first participant, who had 17 years of drumming experience and was right-handed, really liked our concept. He preferred playing on the mat with his hands, but if the sound was consistent, he would prefer playing with the sticks. He commented that there was a lack of sound upon pressing the hi-hat pedal, and that he felt that the delay between hitting the drum and the sound being played was too great. He felt that the absorption of the energy was greater on the mat than an acoustic drum kit, resulting in an unrealistic feel. He did however think that the tom-tom's were very true to life and saying that the 2 tom's should have different sounds, they are not identical, unlike what the program was set to. Same applies to the cymbals, they should have different sounds. He also thought that the sensitivity should be increased, so that less pressure was needed to activate the sound.

He also suggested making the layout customisable, and not just having a standard cookie-cutter layout. He was however very open to the idea of bringing it along if he was to go on a long train ride or similar. Results from the score-giving questions are shown in table D.1

Lap no stick	Table no stick	Lap with stick	Table with stick	Feel
4	n/a	4	5	2

Table D.1: Results from Participant 1's interview.

Participant 2

Our second participant, right-handed, who had 37 years of drumming experience was of the opinion that the general concept of what we had developed was quite good. However, there were several things that he thought needed to be developed. For example, he preferred to use his hands to play. However, if the sound was consistently being played when struck with the sticks, he would prefer that. He also commented that the hi-hat should make a sound when the pedal is pressed down, and not only when it is hit. Additional comments were that the layout was very good, however it seemed very small, so size could be increased.

Generally he thought that the portability and ease of setting up would see more use as an alternative for a practice room, rather than taking it along on a train ride or similar. Results from the score-giving questions are shown in table D.2

Lap no stick	Table no stick	Lap with stick	Table with stick	Feel
4	2	5	2	3

Table D.2: Results from Participant 2's interview.

Participant 3

Our third participant had somewhat less experience with drumming than our first two, having only played for around half a year, but was still successfully able to give some qualified feedback. He was right-handed. His immediate comment was that it felt very small, and that his hands got in the way of each other a lot. He did however feel that it felt very intuitive, and was easy to get into. He did however feel that the sound was too low, which was easily fixed by turning up the volume. He also felt that the accuracy of detecting hits was too low if it were to be a real product. He suggested a multi-level setup, as a full drumkit, as now the drums are all at the same level and flat, which also contributed to the drummers hands getting in the way of each other. He did however feel that the cable work was unsightly, and the pedals were weird. He probably would not bring it along on a trip however, and he also suggested that more distance was put between the pads, as well as making them larger. Results from the score-giving questions are shown in table D.3

Lap no stick	Table no stick	Lap with stick	Table with stick	Feel
4	2	4	3	2

Table D.3: Results from Participant 3's interview.

Participant 4

Our fourth test participant was also a fairly new drummer, and also right-handed, having only playing for between a half and a whole year. He preferred to play on the may with the drum sticks, but the flat mat was a problem for him, seeing as a full drum kit has different levels. He did however really like the pedals. He felt that the mat was significantly more useful on the table than on the lap, as it constantly slid off the lap, and whenever you wanted to use the bass drum or the hi-hat, the mat moved, making it difficult to accurately hit it. He did however think that the mat might be optimized by having fewer drums. For example, one could make do with only 1 tom drum, and smaller crash cymbal. He did however like the sounds when they worked, although the delay was an issue.

Generally he liked the idea for having a portable drum kit, but would probably more use it for practice at home. He also suggested having colour coding for the various drums, for ease of identification if you were not an experienced drummer. He compared it to a video game like Guitar Hero if this was done [42]. Results from the score-giving questions are shown in table D.4

Lap no stick	Table no stick	Lap with stick	Table with stick	Feel
4	2	3	1	3-4

Table D.4: Results from Participant 4's interview.

Participant 5

Our fifth participant was also an experienced drummer, having 13 years of experience. He preferred to play on the mat with his hands, because of the lack of rebound in the mat, plus the fact that crossing hands was very difficult. He was also right-handed. He quite liked the pedals. His main concern with the mat was the fact that the sound, or lack thereof distracted him from keeping his rhythm. He also, like some previous testers, commented on the delay from impact to sound being played.

He also saw potential in using it for practicing while on the move, or even just practicing fairly noiselessly at home. He also suggested colour coding the drums, for easier identification. Results from the score-giving questions are shown in table D.5

Lap no stick	Table no stick	Lap with stick	Table with stick	Feel
3	1-2	4-5	3-4	1-2

Table D.5: Results from Participant 5's interview.

Participant 6

Our sixth participant, also right-handed, had 4 to 5 years of experience with drumming. He preferred drumming without sticks, because of the small size of the mat, and also the distance to the mat. He liked the pedals, but did however comment that it was difficult to make beats in rapid succession. He thought that the feel was quite accurate on the tom and snare, but not at all on the cymbals. He was however a fan of the layout, but also suggested colour coding the drums. He liked the concept of the mat, and preferred playing with his hands, while the mat was on his lap. He would however not bring it in public, however he said that this was mainly due to him being shy, and such a mat would bring unwanted attention. His final comment was that he thought that the drumming surfaces should be larger, and more spread out. Results from the score-giving questions are shown in table D.6

Lap no stick	Table no stick	Lap with stick	Table with stick	Feel
4	3	2	2	3

Table D.6: Results from Participant 6's interview.

Participant 7

Our seventh participant had around 6 months of drumming experience, and was also right-handed. He generally preferred drumming with drumsticks, as this was the feeling he was used to. He did however think that despite this, drumming on the mat with sticks was very hard, because it did not feel similar to a full acoustic drumset. He did however really like the pedals, and thought they had good reactions to being activated. He did however comment that the tom's should not be identical. He did however like the layout, but commented on the lack of multi-levels. He would however not use it for transport, but would think about using it to practice in his apartment, to avoid disturbing his neighbours. Results from the score-giving questions are shown in table D.7

Lap no stick	Table no stick	Lap with stick	Table with stick	Feel
2	2	4	5	4

Table D.7: Results from Participant 7's interview.

Participant 8

Our eighth and last test participant was also an experienced drummer, having 13-14 years of experience. He was left-handed, but played drums in the same way as a right-handed person, seeing as this was what he had been taught. He vastly preferred drumming without the drumsticks, as he felt more "in contact" with the system, as the drumsticks made him feel disconnected, unlike a proper drumkit. He didn't feel like the system felt like a proper full acoustic drumkit, due to the slight delay from contact to the sound being played, he felt disconnected from the system. In order to easily identity the drums, he suggested using colours or even labels on each different drum.

He really liked the fact that the system could be taken off the table and placed on the lap, as himself and other drummers often played on any available surface regardless, so therefore he would probably use the mat to play on subconsciously while, for example, while watching a movie.

He did however have some extra comments on the system in general. For example, he commented that the mat might be too soft, which makes rapid hits in succession very difficult. He suggested making it more rigid, but still bendable on the middle. He did however like the fact that the casing was fabric, as it was fairly durable, instead of for example hard plastic, that might break if hit too hard.

Results from the score-giving questions are shown in table D.8

Lap no stick	Table no stick	Lap with stick	Table with stick	Feel
2-3	3-4	3-4	5	1-2

Table D.8: Results from Participant 8's interview.

Summary

All in all, we got a got of feedback, most of which will be discussed in section **??**. However, for a quick overview of the results, here are the averages scores given by our test participants, in table D.9.

Lap no stick	Table no stick	Lap with stick	Table with stick
4	n/a	4	5
4	2	5	2
4	2	4	3
4	2	3	1
3	1-2	4-5	3-4
4	3	2	2
2	2	4	5
2-3	3-4	3-4	5
3.44	**2.29**	**3.75**	**3,31**

Table D.9: Table of averages from the interview.

For scores that were given between two values, the number used in calculations was set to the middle value, etc. 3.5, 4.5.

During the test we found that many of the participants used the drum mat in the same ways as the other participant, how they preferred to play, what they felt did not work and what they thought of the layout. A table of the layout results can be seen in appendix C.

Participant 1

The first participant is studying a master in music and was quick to identify the drums and cymbals on the mat, he found no problem with the set-up and when he began playing he commented that the drums sounded as he expected.

Our first participant started with playing the mat on the table with his hands. During the first few seconds he crossed his hands as he would do if he was playing on an acoustic drum kit with drumsticks. He also commented that it felt a bit odd as he was used to only playing with drumsticks. When he played with his hands he used the tips of his fingers to hit the pads.

After the first part he played the drum mat on the table with drumsticks. He was more enthusiastic to be allowed drumsticks but was soon disappointed because the sound did not respond well to the sticks and he had a hard time actually getting drum sounds from the system. This also resulted in him putting his drumsticks down and try with his hands again.

After this he played with the mat on his lap with his hands. He felt that the mat had an annoying slant and the mat would slide down his legs. Because of this the participant kept pulling the mat up a bit every time he stroke with his hands, which made him drum a bit slower than he normally would.

Lastly he played on his lap with drumsticks. As he was disappointed from earlier he was not very enthusiastic this time. It did not help that he felt awkward holding the drumsticks so close to his body resulting in him feeling he can not move his arms probably. Another thing with this set-up is that he could not pull up the mat, which then sled further down before he had to stop playing and pull it up.

During the tests he showed no signs of having trouble with the pedals, he did however look like he wanted there to be a sound when he stepped on the button for the hi-hat to make it say the same sound as it does on an acoustic- and electric drum kit. In the middle of the test he also commented that he would like this feature instead of just changing the state of the hi-hat.

Participant 2

The second participant is a teacher at Aalborg's music conservatory and he used a bit more time trying our product, to give feedback, than some of the other participants. He had no problem distinguishing between the drums and cymbals either and also called them by their proper names. He also said during writing the names for the drums that it looks like a standard drum kit.

This participant started playing the drum mat on the table with drumsticks. He tried the drums out to hear the different sounds, but the computer has a bit of trouble keeping up to the fast pace of the drumsticks so the sound does not always register. He started by just using one drumstick on the ride cymbal where he used two on it after. He then moved around the mat doing the same with all drums and cymbals. He had a problem hearing the difference of the sounds on the snare drum and suggested using two much more different sounds than the ones we are currently using.

He then played on the mat with his hands and it on the table. This went a lot better than with the drumsticks partially because the sounds actually being played. It had a few problems playing sounds when he hit the pads repeatedly and quickly. He crossed his arms when playing. A problem with some drums playing even though it was not intended by the participant showed itself. When he played with his hands he used his tree middle fingers to strike the pads. After playing with his hands he went back to play a bit with his drumsticks to try and get a rhythm going, but got the same results as the first time he tried.

After playing on the table he tried the mat on his lap with his hands. He still crossed his hands and did not have any additional problems compared to when he played on the table, except that the mat slid down his legs a bit as he was playing.

Lastly he played on the mat with drumsticks while it still rested on his lap. Here he had the same problems with the drumsticks being too close to his body and having to move his arms far back. He did not like playing this way.

He had no problem with the pedals, they worked as they should and how he thought they would, which is everything we want.

Participant 3

The third participant was fairly new to drum kits, he had 6 months experience, only playing as a hobby and knew the basic, which is what is required for our participants. Even though he has not played for years like the two former participants he had no trouble identifying the drums and cymbals, also calling them by their official names. Even though he had no problems he still took a bit of time writing the names, probably because he wanted to write the correct therms and still knew which were drums and which were cymbals.

This participant started with playing the drum mat on his lap with his hands. He played a bit slow and does not use his body the same way as the two previous participants did. This could be because he has not played just as long as the others, along with them doing it professionally. When he played the drum mat he used his fingertips to hit the pads. One thing that is different from the two previous participants is that the mat did not slide down when on his lap. This could have something to do with his more relaxed posture. Where the other sat up straight and used their whole upper body, this participant sat back in the chair only using arm and hand movement. His legs where also in a 90 degree angle, which made the mat even and not tipping downward.

After this he still had the mat on his lap but this time, playing with drumsticks. Playing the drum went slowly and the mat started to slide, which was an annoyance to the participant. Here there the problem with the sound also appeared.

Then the mat was put on the table and the participant had to play with drumsticks. This time he crossed his arms, which resulted in the drumsticks colliding together and disrupting the drummer. The drummer was also a bit faster in his play than when it was on his lap. Other than that there were no difference in the experience or new information of the third participant compared the former participants.

Lastly he had to play with his hands while the drum-mat lied on the table. This looked to be the easiest for the participant. He was quick to get a rhythm going and the sounds were mostly going through when he wanted them to. He also crossed his arms here and when playing he used his fingertips. This is also where he really began playing with the pedals using the bass drum more and trying to change the state of the hi-hat. He was successful and this time there were no problems with the pedals either.

Participant 4

The fourth participant was also a beginner but have a bit more experience than participant three because he played drum kit between a half and a whole year. He took a bit more time than the others to name the drums, but named them without problems and recognizing if they were cymbals or drums, which indicates that the reason it took time was just to remember the specific names of the different components.

This participant started with using drumsticks to play on the drum mat while it lay on the table. He was very careful and did not hit the pads with much power. He crossed his arms and the sticks smacking together. He had trouble getting any sound out of the prototype.

After this he had to play with his hands, still with the mat on the table. He still hit the pads softly and uses mostly one hand but still tries to find a rhythm. He was told that he could hit the pads a bit harder if he wanted to, as they were not going to break. This looked like it helped him get more into playing. When playing he used his tree middle fingers.

Then he had to play while the mat was resting in his lap, with his hands. He said that he felt awkward as the mat got so close to his body. He changed the way he used his hands from the table to the lap. On the table he used his tree middle fingers to strike the pads with as mentioned above, but on his lap he sometimes used his fist to hit the pads along with hitting with an open palm. The mat did not slide away from him.

Lastly he played with drumsticks with the mat in his lap. He still felt that the mat is to close to his body. He was faster while playing with drumsticks than he was playing with his hands. When he crossed the drumsticks they hit each other. The participants tried to hit the center of the pads as much as possible, but a few times he hit the edges of the pads on purpose too. He had a hard time getting sound out of the mat with the drumsticks.

He had no trouble using the pedals and they worked as they should.

Participant 5

The fifth participant, like the others, thought the setup of the drums was easy to recognize and was quick to write the names of the drum kit parts down on the paper. Unlike the last two participants, the fifth had years of experience in drumming and still plays.

This participant start with playing the mat with his hands while it is set on the table. As the others he crossed his hands as well when striking the pads on the left side of the mat. He tried to get a rhythm going. When he used the pedal for the bass drum he lifted his whole foot instead of just the tip. Could have something to do with the chair being too high for him.

When he had to use drumsticks on the mat, still laying on the table, he was seriously disappointed because the sound did not play and because of that he was quick to put the drumsticks down.

Then he played the mat while it was on his lap using his hands. Here he got a new chair, which was smaller, which meant that his feet could touch the floor and he did not lift his whole foot when using the bass drum. The pad slides and the participant has to pull it up sometimes so it will not fall. When using his hands he used his fingertips on his tree middle fingers.

Lastly he played with drumsticks, still with the mat in his lap. As we have seen before the sticks hit each other when the participant crosses them to strike the pads. But this time the mat actually stays in place and does not slide anywhere. He does still get the problem of not always getting sound feedback when the pads are hit.

Participant 6

The sixth participant have around 5 years of experience in drum kits but have not been playing for the last 4 years. He still has the experience and basis knowledge of drumming with again is the most important factor for us. As seems to be a pattern he did not have problems distinguish between the drums and cymbals.

He started with playing with drumsticks while the mat lay on the table. He also crosses the sticks like the other participants. He also has trouble getting feedback from the mat in the form of drumsounds. He is quick to find that the hi-hat changes state from open to closed.

Then the participant had to use his hands instead of the drumsticks, with the drum mat still laying on the table. As soon as he starts he likes the sound better, on the reason that it actually produces sound almost at every strike. He changes between using his tree middle fingers and his fingertips to strike the pads.

After this the participant had to have the mat in his lap and play with his hands. Here the chair is too tall for this participant as well, and as we at this time did not have a shorter chair he decided to not use the bass drum or changing the state of the hi-hat. He still crosses his arms and this time he only plays with his fingertips.

Lastly he uses the drumsticks. As his arms come to close to his body it is hard for him to use the drumsticks and he holds much higher on the stick, than a drummer normally would, to shorten the distance between the stick ends and the pads. This time he gets next to no sound from the mat.

Participant 7

The seventh participant is a beginner as well but knows the basic. He was not sure of the names of all the drums and cymbals but he knew which were which. Other than not remembering the names he was quit quick to write down what was drums and what was cymbals.

In the beginning this participant played with his hands while the mat lay on the table. He crosses his hands as the others did but seems to find it a bit more problematic. He produce sound from the snare drum when he just tries to play on the hi-hat and discovers that he brushes the snare with his arm. He is a bit slow while playing, looking like he is trying to figure out the sounds and gets confused when it either gives more sounds than he thought it would or does not play at all. He begins with just playing with one hand and uses two after a little while. He also alternates between using his whole hand and just his fingertips to strike the pads with.

After this he is given drumsticks to play with, the mat is still on the table. He finds it even harder to produce sounds with the sticks but other than that his reaction is mostly the same as to when he played with his hands. The only other change is that he is a bit faster while playing.

The the participant has to have the mat in his lap while still playing with drumsticks. As is also seen earlier in the other test this participant feels that his arms get to close to his body and does not feel he has enough space to move his arms to play comfortably. He actually asked if he were allowed to move it out from his body and half of the mat rest on the table while the other half was on his knees. We told him that it would unfortunately not be allowed during the test. To get a bit more arm movement the participant holds higher up on the drumsticks. Other than that the test went as the former ones, with it being hard for the participant to produce sound.

Lastly he had to play using his hands while the mat still was in his lap. He looked to use his arms a little, as he feels he gets a bit more freedom to move them around without the additional length. This time he only strike the pads with his fingertips or just a single finger and not with his whole hand, as he did when it were on the table. He still crosses his arms. He also hits additional pads with his arms and has to lift them a bit higher to try and not do this.

He had no problems with the pedals either.

Participant 8

The eighth and final participant was the same drummer we got to interview during section 3.6 "Drummer Observation". As stated in that section as well he has 12 years of experience with drums. He was also quick to write the drums down along with the proper term for each of them.

This participant begins with the mat on the table and with drumsticks. As has been discovered in the former tests there is a problem with the sound and so he uses a lot of time hitting each drum and cymbal repeatedly to hear what the sound is before trying a beat.

After this he has to use his hands to strike the pads, while the mat still lays on the table. Here he gets much more feedback and starts a rhythm much faster. In the beginning he uses his whole hand but this changes to be two of his fingers and in the end just his fingertips.

He seems more into the mat at this point.

Then the participant has to have the mat in his lab and still use his hands to play. He is actually very enthusiastic about playing and keeps a beat. He reacts in the same way as when it lay on the table.

At last he uses drumsticks again, still with the mat on his lap. He sits further back in his chair this time to widen the distance from his body to the mat. Again he gets the problem with not getting sound feedback but he still tries keeping a rhythm.

He has no problems with the pedal and likes the feeling that it does not interfere or keeps playing even if the button is pressed down.

Summary

To sum the information gathered trough the test the participants did not like how the mat reacted on the drumsticks. They found it easier to keep a rhythm while playing with there hands on the fact that the almost created sound when they stroke the pads. They had no problems with the pedals at all and felt they where easy to work with. Most felt that the mat got to close to their bodies when having it in their lap and liked it on the table better. While some liked that they could get the feeling that they could take the mat with them anywhere and play, as long as they used hands to play. In the end they liked the concept of the drum mat but it needs more work to be usable and even though we wanted to test usability they were more interested in producing music. Also non of the participants had any problem with the layout and felt it intuitive to play on.