The Novel MIDI Controller: Designing & Implementing a User–Centred MIDI Controller

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Abstract

Traditionally, MIDI controllers have been designed to cater towards musicians with extensive experience in music theory and ample experience playing musical instruments. However, many people with musical interests can feel intimidated or discouraged to get creative musically with these practices. The non-musicians with a creative urge is a largely overlooked audience in the domain of music composition and music production. In this project, the user-centred design method was employed to design a new touch-free MIDI controller in Processing and Java with the Leap Motion controller sensing user interactions. First, a literature review was performed to prepare enough background knowledge to tackle the project's aims. Then, an initial user-study involving semi-structured interviews and observation studies was carried out to gather user requirements. The findings of this initial study were then used to inform new design ideas from which a new MIDI controller called the 'Novel MIDI Controller' was implemented along with a set of gesture-based interactions. The resulting MIDI controller system was then evaluated via observation studies, semi-structured interviews, and questionnaires with willing participants. Overall, the Novel MIDI controller accomplished what it set out to do, which was to make music composition and music production more accessible towards non-musicians and musicians alike. The gesture-based interaction paradigm was particularly lauded by users for enhancing creativity and accessibility. The project concludes with a summary of objectives achieved and recommendations for future work.

Declaration

I, Joseph Manfredi Cameron, declare that the material submitted for assessment is my own work except where credit is explicitly given to others by citation or acknowledgement. This work was performed during the 2021–2022 academic year except where otherwise stated.

The main text of this dissertation is 14,897 words long.

Ethical considerations for this project and its user research studies were noted and approved by the School of Computer Science Ethics Committee. The ethics approval form can be seen in Appendix B. All participants recruited for studies were made aware of the participant information sheet found in Appendix C and required to sign the consent form found in Appendix D.

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Joseph Manfredi Cameron
(16/08/2022)

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Chapter 1

Introduction

Throughout history and crossing over many cultures, languages, and civilisations, music has played an important and essential role in human society [70]. Every known culture participates in and contributes to music and its performance and/or creation to some degree [13][11]. Thus, music has been classified as a cultural universal [60]. In ancient China [41], ancient Egypt [57], and ancient Greece [107] , music was used for ceremonial and communal entertainment purposes. Today music is a fundamental part of everyday entertainment, is one of the best expressions for human creativity [84], and acts as one of the best communication methods as it transcends all languages and cultures [11]. Music also affects people on an individual level and has been shown to trigger emotional, behavioural, and physiological responses in humans [43]. These insights have led many to state that music is a fundamental part of the human condition [64][94][11].

Naturally, with music sparking so many emotions, there is much interest towards the processes of music creation and music recreation/performance. Musical compositions are primarily created, shared, and played with reference to some sort of musical notation system. Before the advent of computing, composers would create music by writing compositional ideas to paper within the rules of a musical notation system, where they would test their ideas on an instrument of their choice by playing it aloud. Following this process of composition naturally requires a high-level of expertise in music theory and a high proficiency for playing at least one musical instrument. In modern times with the aid of computers, MIDI data, and musically-focused software and hardware such as digital audio workstations (DAWs) and MIDI controllers, composers can still follow a similar composition process while harnessing the power of computers to hold their compositions, and reduce the physical limitations of repeatedly playing instruments and the spatial limitations of only having access to a few instruments/sounds. MIDI, and music production technology in general will be discussed further in Chapter 2.

1.1 Motivation

Creating music has usually only been reserved for highly skilled musicians who are capable of playing one or multiple instruments to a high standard. Most professional composers are at the very least exceptional piano players with years of experience writing and reading classical sheet notation via their chosen instrument. However, it is known that every human on an individual level has at least some musical talent, interest, or awareness [63][61]. For example, it is very common for anyone, musician or non-musician, to sometimes hum an existing or original musical composition throughout everyday life, whether in the shower or while commuting to work, as shown by Taylor et al [98]. Furthermore, there is expressed interest from people with varying musical backgrounds to be able to express their creative musical ideas [22][72]. Unfortunately, many people become intimidated at various stages of progression in music. It's all too common for people with a genuine interest in music to feel discouraged from pursuing it as a hobby due to encountering difficulties in physically playing musical instruments as a child or an adult, feeling intimidation, time restrictions, or for a variety of other reasons. Many more people could exercise their musical creativity and gain joy out of doing so if given the right tools and level of accessibility [53].

With today's advancements in technology and its applications briefly discussed above, it's becoming more possible for people to quickly contextualise a moment of musical inspiration in a computer and share it with others via sheet notation. Nevertheless, even with this technology there are still many issues regarding the accessibility of musical composition tools such as MIDI controllers and MIDI interfaces within DAWs for hobbyist musicians or beginners with a musical interest. Traditionally, MIDI controllers have been designed to enable similar interactions that humans would use with existing musical instruments to recreate music in computers [92]. An example of this would be the popularity of MIDI keyboards which closely mimic the interactions required to play a piano or keyboard [68]. However, given that the

MIDI protocol can allow for composition over multiple instruments/sounds and can permit adjustments for many unique sound effects such as mid-note pitch-bend, it may be advantageous for many people if more intuitive interactions that are decoupled from traditional musical instruments were developed to create MIDI data, and thus enable a different way to create music [68][53]. Furthermore, the new interactions developed would have the goal of allowing people who are not regular players of musical instruments to create their own musical compositions and alter some musical effects through MIDI. There are some examples of gestures being used to control the sound effect parameters of MIDI which can be seen in GECO MIDI [9], AeroMIDI [2], and the gesture-sensing gloves developed by Sama et al [87] and Farella et al [27]. However not much research has been made into evaluating these interactions, and there appears to not be many gesture-based systems that allow for musical composition in MIDI. As a result, one of the main motivations for undertaking this project is to provide a more accessible and intuitive user-centred framework of interactions to play musical instruments and thus play or compose musical notes, chords and sound effects in computers without requiring a comprehensive awareness of music theory or a high–proficiency for playing musical instruments.

Additionally, there are also some issues regarding how music technology software and hardware enable the composition process from a creative standpoint. On most popular DAWs, all tools and options for notes and production effects are available to the user from the start of the process, and they are typically only accessed via traditional mouse and keyboard interactions. While these tools and their immediate exposure successfully perform the function they are designed to cater for, some users can easily become overwhelmed, whether they are beginners or musically experienced. From the standpoint of enabling a better user experience in a creative process such as music composition, that is not going to yield good results [77] [85]. Hence, another motivation for this project is to perform research into and better understand the creative process for musical composition and to develop methods and interactions for providing an improved user experience for encouraging musical creativity rather than solely focusing on satisfying technical requirements.

1.2 Project Objectives

Following on from the motivations outlined in the previous section, this project's objectives are as follows:

Primary Objectives

1. Review past and present related work on the MIDI protocol and ways to interact with/through it.
2. Research methods for using novel interactions with MIDI controllers.
3. Design and implement a software package with a user interface which allows users to create and edit melodies through MIDI with novel and intuitive interactions.
4. Design and implement more accessible interactions that allow musicians and non-musicians to play notes and chords on musical instruments.
5. Design and implement this software and its interface/interactions using the user-centred design methodology.
6. Perform a user study to both understand and gather user requirements for MIDI controller workflows and creative workflows in music.

Secondary Objectives

7. Evaluate the resulting software interface and newly developed interactions with users.
8. Provide some customisable options on the interface for users to suit their preferences.
9. Provide a collection of design recommendations for creating intuitive MIDI controllers and their accompanying user interactions.

Tertiary Objectives

10. Allow musicians and non-musicians to control and operate at least one MIDI sound effect with novel and intuitive interactions.
11. Design and implement an interactive workflow through a MIDI controller that focuses on fostering creativity in music, and then evaluate this user experience with users.

1.3 Project Scope

Musical notation systems are the frameworks that visually and categorically represent and organise the audible characteristics of music. These characteristics include pitch, note length, and time signatures. There are many notation systems from different time periods and different cultures. For the duration of this project, the sole musical notation system that was referred to and referenced was the modern staff notation system.

Figure 1.1: An Example of the Modern Staff Notation System

The modern staff notation system was chosen because it's a common notation system used globally, which allows for more robust transferrable findings for as many people as possible given the time constraints of this project.

Overall, this project was scoped to provide a bridge between a user and a full-featured DAW application, and not to completely replace the DAW. The resulting MIDI controller was orchestrated to provide more accessibility for non-musicians to express their creative ideas, and to enable musicians and non-musicians to better express their musical creativity in composition. It focuses on the composition aspects of music production. A user may later export their compositions to a DAW afterwards for further refinement in other areas if they wish to do so.

1.4 Project Target User Groups/Audience

The target audience for the artefacts designed and created in this project are:

- Adults with no experience in playing musical instruments, musical composition, or MIDI. This group can be considered as the beginner user group. The resulting artefacts of this project should cater for their lack of experience and inspire them to explore further.

- Adults with some experience with either playing musical instruments, composition, or MIDI. These users can be considered as intermediate users, and the resulting artefacts should provide some familiarity for them while also expanding their horizons.

- Adults with vast experience in playing musical instruments or composition, but minimal experience with MIDI and music production software. These users have advanced musical knowledge and the artefacts should still cater for that, but the artefacts should introduce them to the capabilities of MIDI that they may not be aware of and inspire them to discover more.

Chapter 2

Literature Review

This chapter introduces essential concepts that should be acknowledged to understand various aspects of this project. The purpose, significance, and relevance of each concept is discussed.

2.1 The MIDI Specification

The technological standard for controlling and connecting electronic instruments is MIDI. MIDI stands for "Musical Instrument Digital Interface". The origins of the MIDI specification were first introduced by Dave Smith and Chet Wood in the paper "Universal Synthesizer Interface" [92], where the proposed standard had not yet been named MIDI and was instead referred to as the "Universal Synthesizer Interface". The MIDI acronym first appeared in an article authored by Dr Robert Moog in the July 1983 edition of Keyboard magazine [65]. The technical information for MIDI appearing in this section was obtained from both Smith and Wood [92] and the journal article titled "MIDI: Musical Instrument Digital Interface" by Robert Moog [66].

Fundamentally, MIDI on its own does not play any sound. Instead, it instructs other instruments to play sounds at specific times with a specific pitch along with specifying other features such as note velocity. These instructions are achieved via MIDI messages. The advantageous purpose of MIDI is that it allows multiple digital instruments to communicate with a computer and with each other using these specific MIDI messages. This process allows record producers and musicians alike to produce and recreate musical compositions with many sounds originating from various digital/analog instruments with greater efficiency. All of a sudden, it became practical to create music without the limitation of recording equipment and musicians playing physical musical instruments akin to hardware.

In order to allow MIDI to perform optimally as it was designed, multiple different components are required. A fully integrated MIDI system will typically comprise of the following components:

- **MIDI IN**: This component accepts incoming MIDI messages and handles them appropriately.
- **MIDI OUT**: Packages and delivers MIDI messages in an acceptable format to other components.
- **MIDI THRU**: Handles incoming MIDI messages, makes copies of them and sends them back out to other components. It is this that allows single messages to be routed to multiple devices within the system.
- **Synthesiser**: This is the instrument that generates sounds for people to listen to. These synthesisers generate sounds using the techniques mentioned in sections A.1 & A.3.3. The synthesiser can be analog or digital. It is becoming more typical for digital synthesisers to be used as they can be distributed and stored as software packages for use on computers.
- **MIDI Controller**: This is a hardware or software device that creates MIDI messages to be sent out. An example of a MIDI controller would be a MIDI keyboard, where the keyboard would create a MIDI message to indicate a certain key has been pressed when a user presses that certain key.
- **Channels**: A MIDI channel is a single construct of communication that can handle a stream of MIDI messages. There are 16 channels allowed in the current MIDI specification. Channels can be used to differentiate messages coming from different devices.
- **Tracks**: A MIDI track handles a sequence of related MIDI operations, such as notes being turned on or off. MIDI tracks can be used to group related MIDI operations. A good example of this practice would be

using a track to store the MIDI operations of a drummer's performance, and then using another separate MIDI track for keeping the sequence of note on/off MIDI operations for a guitarist's performance.

- **Sequencer**: This is a standalone component that controls the sequence of multiple MIDI operations delivered by MIDI messages from multiple tracks and channels. When MIDI was first introduced, sequencers were hardware components. Sequencers allow users to record and edit MIDI operations, and thus their musical compositions. This ability to record and edit compositions indefinitely reduces the limitations imposed by having to re-record full sections of live performances by musicians. Today, sequencers are typically built into all audio-related software applications that are designed to handle MIDI information.

MIDI messages are sent between these components to achieve certain actions and operations. MIDI messages can be categorised into two main types:

- **Channel Messages**: These messages communicate information that is relevant to an individual MIDI channel. Channel messages include a channel label, musical performance operations (such as triggering a note of a certain pitch to play), and settings for a specific MIDI channel (these settings may include sound related parameters or not).

- **System Messages**: These messages are intended to be acknowledged by all components/devices in the whole system. These messages do not carry channel labels. System messages typically control timing of operations in sequencers.

For this project, there is a focus on channel messages, as they are the most relevant types of MIDI messages for musical composition and performance.

MIDI channel messages are categorised into the following two categories:

- **Channel Voice Messages**: These messages carry musical performance and composition information. Hence, these are typically the most common messages to occur in a MIDI system. Channel voice messages include note on/off events, polyphonic key pressure messages, control change messages (MIDI CC messages), and pitch bend change messages.

- **Channel Mode Messages**: These messages specify the operating modes of a MIDI channel. A typical example of a channel mode message would be turning all notes off, which effectively mutes an entire channel by switching it off.

For this project, there is a focus on enabling musical composition, live performance, and sound alteration via effects such as pitch-bend alteration. Therefore, channel voice messages will be used. The most relevant channel voice messages for this project are detailed below.

2.1.1 Note On/Note Off Event Messages

A note–on event message indicates when a certain note should start playing. A note–off event message indicates when a certain note should stop playing. Using a piano as an example, when a player presses down on a key, this would be equivalent to triggering a note–on event. When that player then lifts up from the piano key and the key is released, this would be equivalent to triggering a note–off event.

Note–on and note–off messages both consist of 3 bytes. The first byte is a status byte, and the two following bytes are data bytes. Figure 2.1 shows the structure of note–on and note–off MIDI messages.

Message	Status Byte	Data Byte(s)	
Note-Off Event	1000bbbb	0kkkkkkk	0vvvvvvv
Note-On Event	1001bbbb	0kkkkkkk	0vvvvvvv

Figure 2.1: Structure on Note–On & Note–Off Event MIDI Messages [66]

The leading bit of the status byte is always 1. The second, third, and fourth bits of the status byte indicate whether the message corresponds to a note–on or note–off event. 000 means a note–off event, while 001 equals a note–on event. The last four bits of the status byte determine the MIDI channel, for example 0001 means channel 1.

The leading bit of the first data byte is always 0. The remaining seven bits equal the key being turned on/off. A value of 0111100 would equal key 60. This key corresponds to the pitch of the note that is being turned on/off.

From MIDI, key 60 translates to the note of C4 [71], which would generate a sound of frequency 261.63Hz (Table A.1) .

Again, the leading bit of the second data byte is always 0. This time, the remaining seven bits equal the velocity value of the note being turned on. The velocity value for a note being played mimics the strength with which a key would have been pressed by a pianist on a real piano. For many synthesisers, this is mapped to alter the volume of the note being played. The velocity value can be any value between 0 and 127, with 0 being the least powerful/quietest velocity, and 127 being the most powerful/loudest velocity. For note–off event messages, the velocity given in the second data byte can be zero.

Here is an example of the MIDI messages that would be sent for a C4 note that is pressed with reasonably high power on a MIDI keyboard and then released soon after.

$$Note\ On\ Message = 10010001\ 00111100\ 01111000$$

$$Note\ Off\ Message = 10000001\ 00111100\ 01111000$$

The first message is a note–on event that says trigger a note–on event on channel 1, where key 60 is turned on with a velocity value of 120. The second message is a note–off event that says trigger a note–off event on channel 1, where key 60 is turned off.

In this project, it will be common for users to trigger the creation of these note–on/note–off event messages when interacting with the MIDI controller to create melodic compositions.

2.1.2 Pitch Bend Messages

Pitch bend messages are MIDI messages that finely alter the pitch of MIDI notes in a given channel. Figure 2.2 shows the structure of a pitch bend MIDI message.

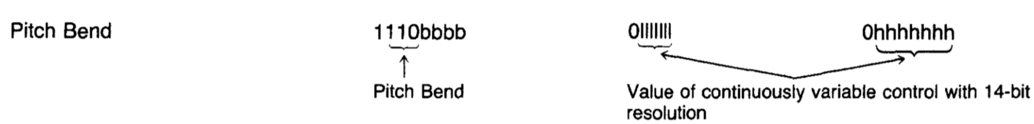


Figure 2.2: Structure of a Pitch Bend MIDI Message [66]

Again, the first byte is a status byte, and the last two bytes are data bytes.

The first four bits of the status byte are always 1110 to indicate that the MIDI message is a pitch bend message. The remaining four bits in the status byte again equal the MIDI channel in question.

For the remaining two data bytes, the leading bits are always 0, and the remaining 7 bits in each byte equal the new pitch value. This means that pitch bend change messages can carry any one of 16384 values from 14 bits, which allows for fine tuning pitch changes to the scale of individual cents between notes [25]. Technically, pitch can also be changed with MIDI CC messages, however MIDI CC messages only allow 7 bits for specifying a new value. The 14 bits available in this tailored pitch bend message makes this type of message far more appealing for delicately altering the pitch of notes.

In this project, pitch bend MIDI messages will be used to allow users to alter pitch of musical notes.

2.2 Existing MIDI Controllers

2.2.1 MIDI Keyboards

The vast majority of existing MIDI controllers are MIDI keyboards. MIDI keyboards use the keyboard-style mode of interaction for users to trigger MIDI events.

Figure 2.3: A Novation Impulse 25 MIDI Keyboard [100]

Pressing a key triggers and sends a note–on event MIDI message for that key (see section 2.1.1). Releasing a key triggers and sends a note–off event MIDI message for that key (see section 2.1.1).

An interesting interactive feature of most MIDI keyboards is the pitch-bend wheel.

(a) A User Using the Pitch Wheel

(b) A Pitch Wheel in its Neutral Position

Figure 2.4: The Pitch Bend Wheel

Users can scroll this wheel up or down to trigger and send pitch bend MIDI messages (see section 2.1.2) that correspond to the wheel's position. This action alters pitch within a specified range. It is common for these wheels to snap back to their neutral position when a user releases the wheel.

2.2.2 MIDI Pad Controllers

MIDI pad controllers allow users to compose MIDI notes in the same way as MIDI keyboards except users press buttons instead of keys. They are primarily designed to trigger audio samples, such as drum samples. The Novation Launchpad X [80] is a good example of a pad controller, with its colourful buttons arranged in a grid.

Figure 2.5: The Novation Launchpad X [80]

2.2.3 GECO MIDI & AeroMIDI

GECO MIDI [9] and AeroMIDI [2] are both software applications that use the Leap Motion Controller [50] to sense a user's hand gestures and positions to manipulate sound effects via MIDI events. Although they both offer lots of scope for sound-effect manipulation, there have no extensive features for triggering MIDI note events or for editing any musical compositions.

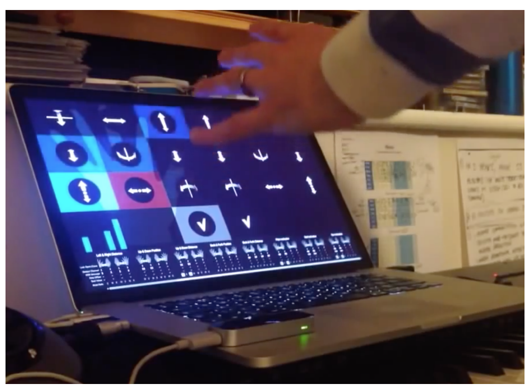


Figure 2.6: A User Interacting with the GECO MIDI Controller [8]

2.2.4 Remidi Glove

A MIDI controller that incorporates gesture interactions is the Remidi Glove [83][82].

Figure 2.7: The Remidi Glove [82]

The glove can control sound effects with similar interactions to AeroMIDI [2] and GECO MIDI [9], although it also allows users to play MIDI notes by tapping onto surfaces. However, this method/interaction for creating MIDI note events is limited due to the need for a surface. The glove is heavily inspired by Sama et al [87] and Farella et al [27].

2.3 Digital Audio Workstations

A Digital Audio Workstation (DAW) application acts as the central hub for many digital music projects/compositions and all their related music production tools. Digital and analog instruments controlled by MIDI reside in DAWs alongside other audio sources to form complete musical productions. This section introduces and explains some of the most notable features and characteristics of DAW applications, and how they relate to music production.

2.3.1 Instrument Tracks

An instrument track is a collection of notes and effects that apply to a particular instrument. The track could contain an audio recording of a live instrument like a piano, or it could contain MIDI notes that trigger sounds from a synthesiser or other instrument.

2.3.2 Piano Roll

The piano roll is the interface that visually displays all MIDI notes and their features, such as pitch, velocity, length, and timing. Below is a screenshot of the piano roll in the Logic DAW [55].

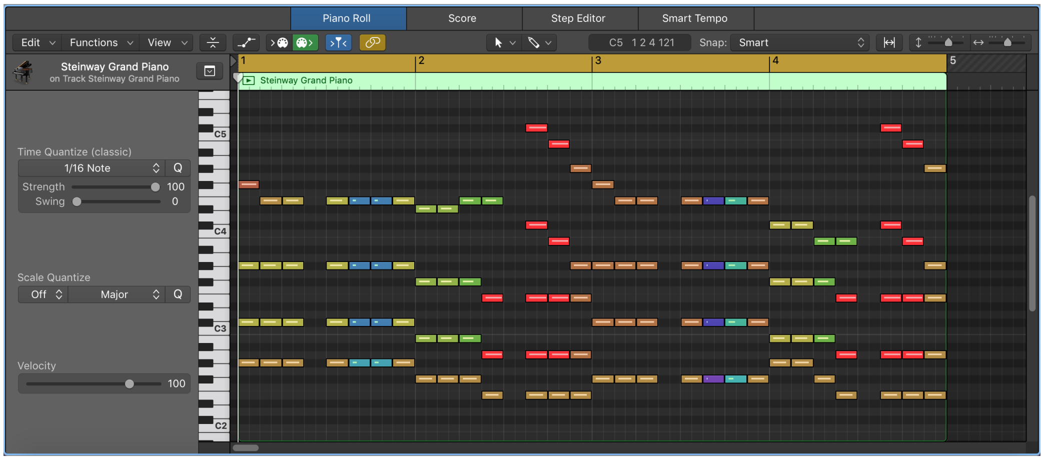


Figure 2.8: The Piano Roll in the Logic Pro X DAW

The MIDI notes are represented by the colourful rectangles. On the left hand side, there are visible keys that resemble the keys of a piano. Hence, the visualisation of the pitch for a MIDI note is based on a note's position on the y-axis. The playback head moves from left to right at a constant speed based on the tempo of the song. Hence, the visualisation of the time at which a note is played is represented by a note's position on the x-axis. The different colours of each note represents the velocity of the note, where blue notes have low velocities and red notes have high velocities.

2.3.3 Mixer

The mixer displays all instrument tracks together with their volume levels and any additional audio effects from plugins. Below in Figure 2.9 is an example of the mixer within the Logic Pro X DAW.

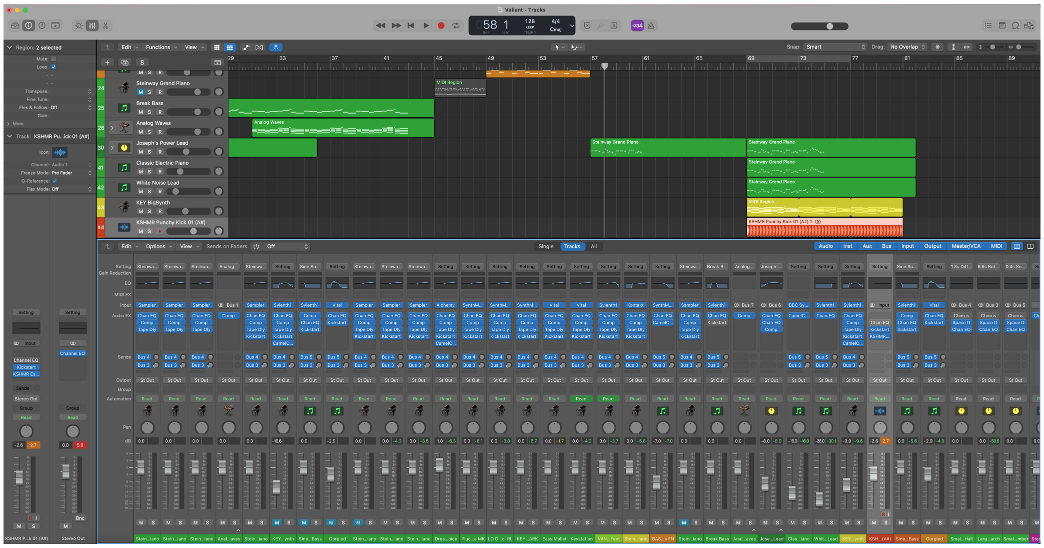


Figure 2.9: A screenshot of the mixer in the Logic Pro X DAW, with instrument tracks situated above it.

The visualisation of this mixer and its interaction are based on the physical analog mixing desks used in studios. An example of such a mixing desk can be seen in Figure 2.10.

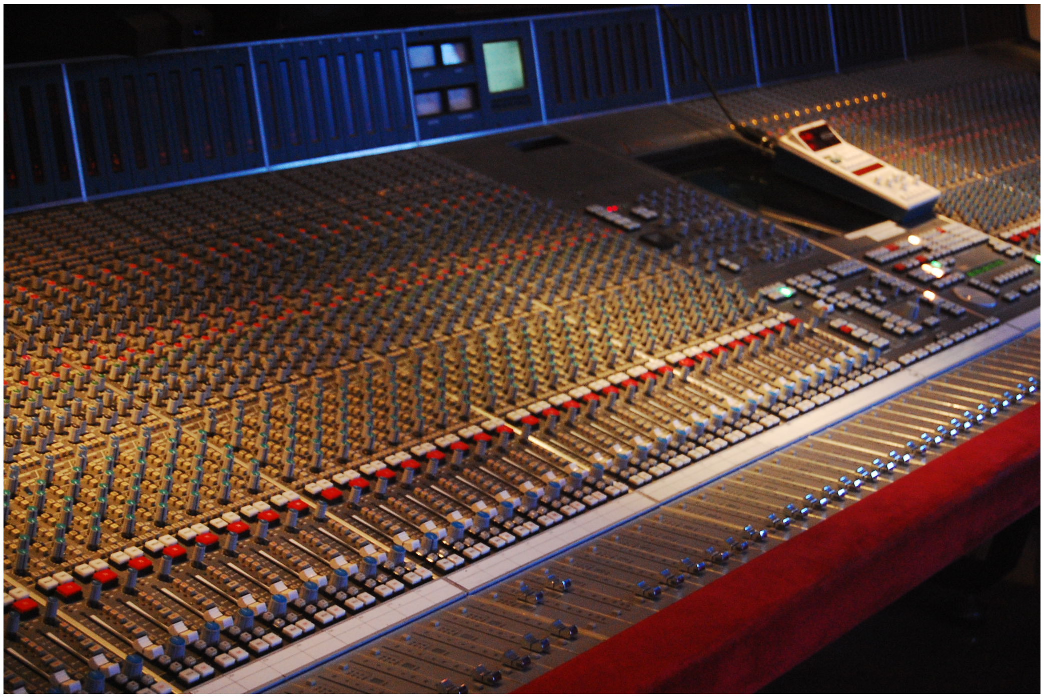


Figure 2.10: A Solid State Logic SL9000J Mixing Desk at The Cutting Room Recording Studios in New York City, USA [109].

2.3.4 Audio Effect Plugins

Audio plugins can be attached to instrument tracks in order to alter the sound of the instrument. An example of an audio effect plugin is an equaliser. An equaliser can reduce or increase the volume of specific frequencies in a sound, hence it can shape a sound into different frequencies which changes an instruments sonic perception. The Equaliser (EQ) plugin from Logic Pro X is shown in Figure 2.11 below.

Figure 2.11: A Screenshot of the Channel EQ plugin from Logic Pro X

2.3.5 Examples of DAWs

There are many different DAW applications that all contain these basic features.

One of the most popular DAWs is Logic made by Apple [55]. Logic is used by many influential artists and composers to create songs and musical scores. Logic is the DAW that will be used in this project.

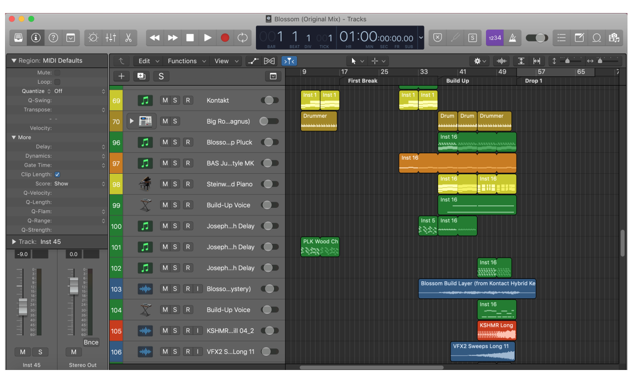


Figure 2.12: Logic Pro X Screenshot

FL Studio [29] is another popular DAW used by music producers. Popular dance music artists have used FL Studio to create some of their most influential songs [29].

Figure 2.13: FL Studio Screenshot

Ableton Live [1] is another DAW that is used to great effect to create many popular songs.

Figure 2.14: Ableton Live Screenshot

2.4 Gesture–Based Interaction

Physical gestures can be utilised as an extremely powerful and novel form of interaction to systems within a variety of domains, and can improve the user experience both in terms of usability and emotional affectiveness [31][5][102]. Furthermore, the use of gesture interaction has been shown to improve user immersion in performing certain tasks if the gestures themselves require little conscious attention from the user [21]. This is all about minimising cognitive load on users and preventing cognitive overload, which is a key factor in developing an optimal and intuitive user experience [17]. Specifically, it has been shown by De Paolis and De Luca that gesture interaction making use of touchless or touch-free gestures in particular results in improved accessibility and efficiency for users [19].

For these reasons, touch-free gestures are considered and explored in this project for creating novel and intuitive interactions for the MIDI controller and its accompanying interface within the domain of musical creativity and music production.

2.4.1 Gesture Recognition Sensors

To accurately detect human gestures as a form of interactive input, gesture recognition sensors are required. Currently, the two leading sensors in gesture recognition are the Leap Motion Controller and the Kinect.

Leap Motion Controller

The Leap Motion Controller is a small USB device developed and manufactured by Ultraleap that is capable of reading the form of human hands and hand gestures to a high degree of accuracy [50].

Figure 2.15: The Leap Motion Controller

It's made up of two wide-angle lens cameras and three infrared sensors that detect light at a wavelength of 850 nanometers [51].

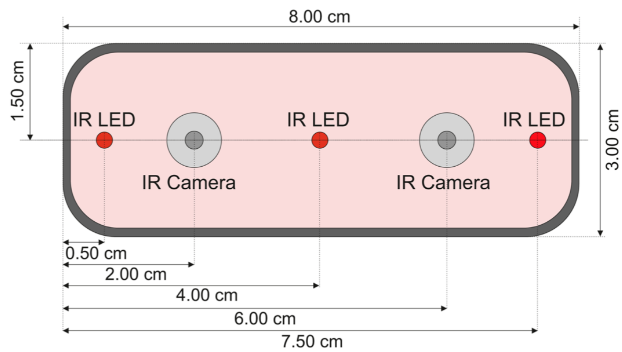


Figure 2.16: Inside the Leap Motion Controller [106]

The controller can detect hand gesture interactions made within an area of 8 cubic feet with a maximum height of 2 feet above the sensors [51].

Along with its hardware, the controller also comes with hand-tracking software and a developer API [103]. The Leap Motion Developer API allows for easy access to the raw data collected from the Leap Motion Controller, which can then be used to interact with any desired software application. The position of each hand and its components can be determined by referring to their x, y, and z axis coordinate positions above the sensor.

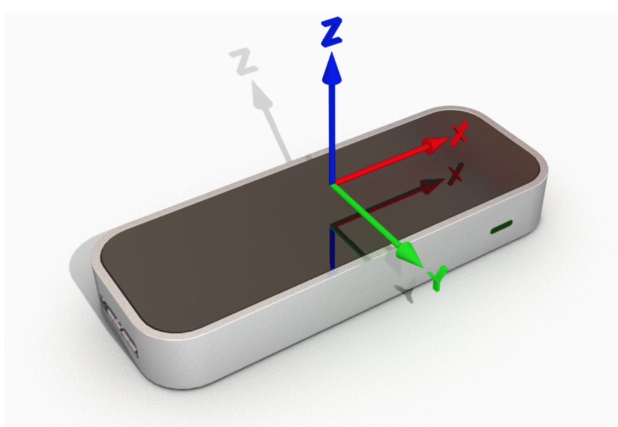


Figure 2.17: The Axes of the Leap Motion Controller [4]

Through the API, individual components of the hand can be accessed by referencing the 'Hand' and 'Finger' classes. Even pre-defined hand gestures such as pinching and swiping can be recognised using the 'Gesture' class to trigger actions within software applications.

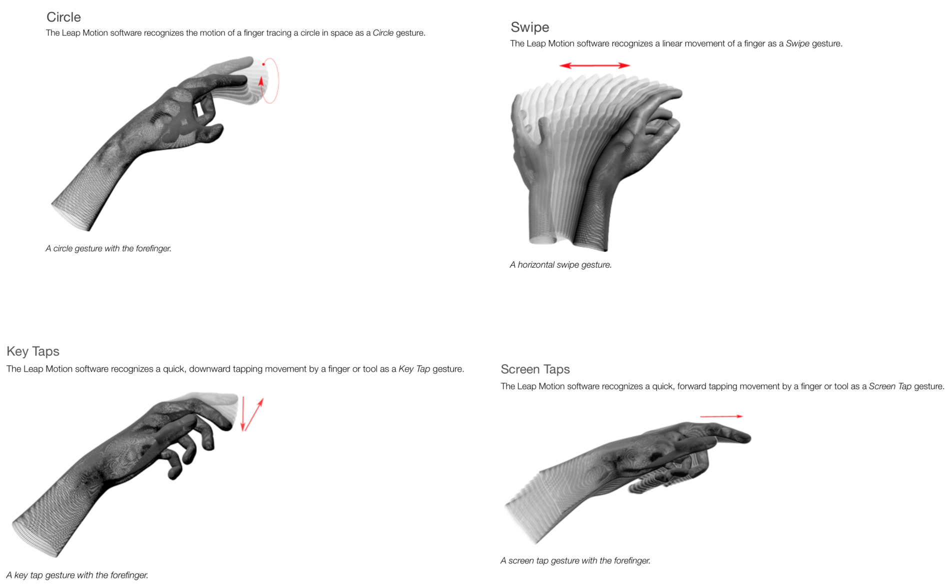


Figure 2.18: Gestures that can be recognised by the Leap Motion Controller through its Developer API [103]

The API can be used with various programming languages such as Java, Javascript, and C++. Each version of the API has superb documentation.

Kinect

The Kinect is a motion sensing device created and manufactured by Microsoft [3].

Figure 2.19: The Kinect [3]

It uses RGB cameras and infrared projectors and detectors to sense depth of objects. As a result, the Kinect can perform full-body gesture recognition in real time with the assistance of artificial intelligence to build up a 20 point skeleton of the human body [30].

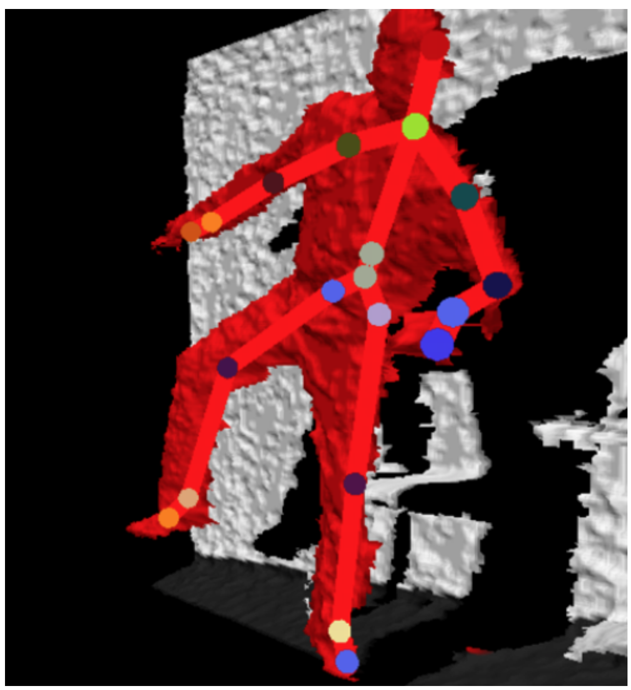


Figure 2.20: The 20-joint skeleton of a user in Kinect [30]

The Kinect also comes with a developer API that can allow developers to track one of the 20 body parts on a user's skeleton and accordingly trigger actions in applications upon user gesture interactions.

2.4.2 Gestures in Music

Gestures through physical movement and music have long been intertwined. Cheironomy is a form of music conducting that specifically relies on hand and arm gestures to dictate musical characteristics in live performance [32]. This use of gesture in conducting can be traced back to ancient Egypt, where hieroglyphic evidence shows individuals making gestures towards musicians as a form of direction [32].

Figure 2.21: Ancient Egyptian Hieroglyph Showing Cheironomy [23]

Today, modern conductors still use gestures with a baton to direct musical performances and their audible characteristics.

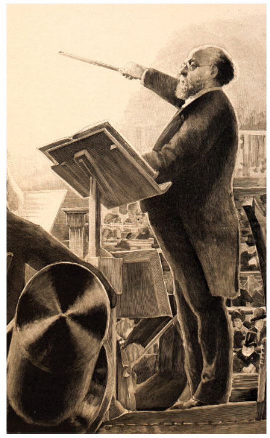


Figure 2.22: A Conductor Conducting with a Baton [86]

2.5 Relevant Principles of Human-Computer Interaction

2.5.1 User-Centred Design

The user-centred design process is an iterative design process that involves the use of various methods and procedures to design products and systems that focus the needs of users at every stage [79][78][45][38]. For this reason, this is the process that will be followed to develop the user-centred MIDI controller in this project.

The four fundamental steps of the user-centred design process are shown in Figure 2.23.

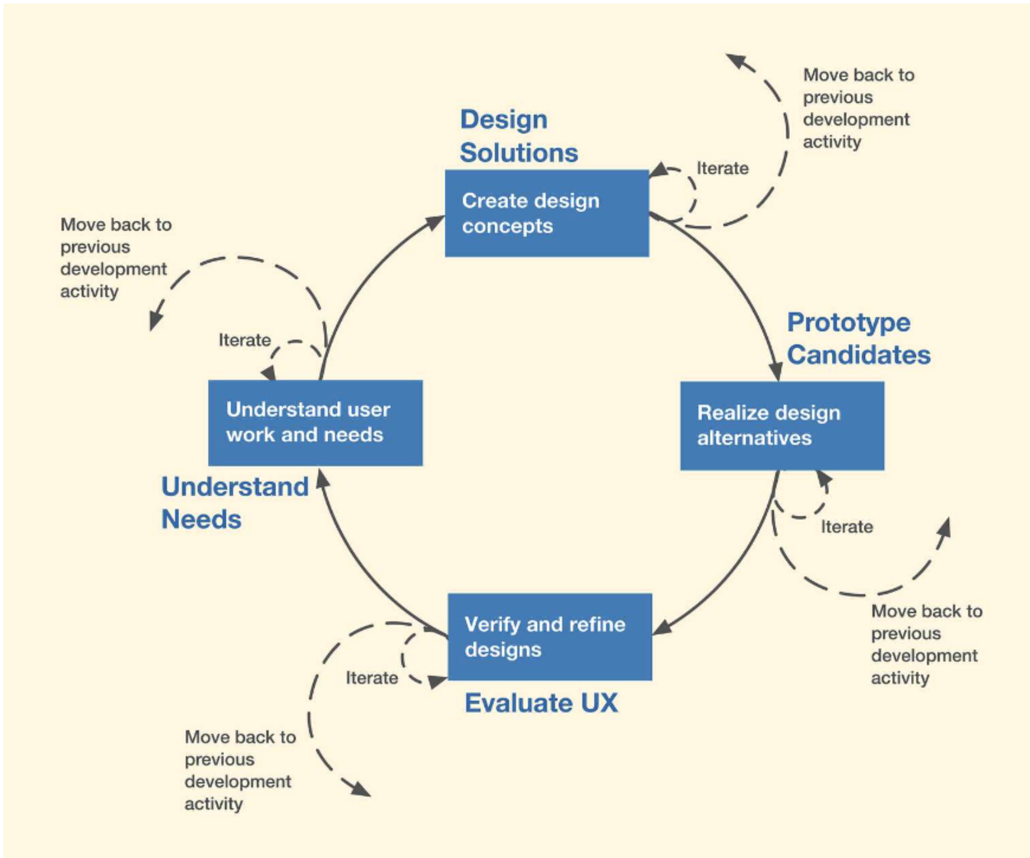


Figure 2.23: The User-Centred Design Process [38]

It's extremely important to notice that this process is iterative, and each step of the process itself may be iterative too. Typically the initial iterations of this process will yield many results, designs, prototypes, and evaluations until one final design emerges as the best for users. Due to time constraints, this project will follow one iteration of the user-centred design process, but each step will be completed true to the principles of the process.

Each of the four main steps is described below.

Understand Needs

The first step is understanding the needs of prospective users for the proposed system/product. Many processes and research methods can be utilised in this step to fulfil the goal of understanding user needs and requirements.

In general, data elicitation practices such as semi-structured non-directed interviews and field studies may be employed to gather insights.

However, before conducting interviews with anyone, or observing anyone, participants must first be recruited to take part in these processes. People are typically recruited via a screener, which is simply a set of questions to check that the proposed participants are valid examples of the target user population that the product will be designed for [47].

Semi-structured non-directed interviews are interviews that include both closed and open-ended questions, where none of the questions should ever be leading or introduce interviewer's bias [47]. It's extremely important that the interview questions are non-directed, as it is a common error for researchers to include leading questions in their interviews, where participants are steered towards answering in a certain manner that the interviewer directs. This should be avoided, as the goal is to understand the participant's point of view, not the researcher's. Including open-ended questions is also important because they allow deep understanding on insights a person may have on certain topics.

Observation studies can also be extremely useful methods of understanding how users interact with systems and uncovering what is present or not present in regard to the user's needs [48]. Typically these studies ask participants to perform an activity while being observed by a researcher. It's also fairly common for participants to think aloud while performing the tasks, to make their thought processes clear to the researcher.

After performing these data elicitation techniques, the data is then analysed to uncover certain themes that are related to the topic of interest. This can be done by using coding, affinity clustering, and grounded theory [90][58]. After analysing the gather qualitative data in this way, the requirements begin to surface. User personas and user stories can then also be created to illustrate the uncovered user requirements.

Design Solutions

The next step in the cycle is to start designing solutions that satisfy the user requirements uncovered in the previous step. Naturally this step involves harnessing a lot of creativity and one of the best ways to express creative ideas is to sketch [76]. Hence, this step of the cycle typically involves lots of ideation brainstorming via sketching. There are two types of sketch that are typically created to convey ideas:

- User Scenario Sketches
- Concept Sketches

User scenario sketches illustrate and explain the situations that users may find themselves in while using the product/system along with proposed user interactions [37]. They help remind designers of scenarios that must be accommodated for in any design.

Concept sketches (also known as wireframes) illustrate the specific details of the proposed system/product itself along with its features [37]. They help to convey product-specific design ideas.

Prototype Candidates

This step involves demonstrating the design(s) that have been established in this previous step with the aim of later understanding how people use the design(s) and whether the design(s) satisfy the requirements established in the first step. Typically, that can be done by implementing prototypes. These prototypes can be either low-fidelity or high-fidelity. Low-fidelity prototypes such as an interactive powerpoint slideshow, or even paper prototypes, can provide much useful insight. High-fidelity prototypes go one step further by behaving in a very similar fashion to the desired end product. They can be software with full interactivity implemented. Due to time constraints in this project, the implementation goal is to produce a high-fidelity prototype to obtain the most detailed evaluation feedback possible from participants.

Evaluate UX

In this final step, the aim is to gain an understanding of how people use the prototype(s) and whether the prototype(s) satisfy the requirements established in the first step. To achieve this, qualitative and quantitative research methods can be used. For this project, both will be used to perform a mixed study for the evaluation. Interviews and observation studies can provide useful qualitative data to analyse. Questionnaires can provide concise and insightful quantitative data for analysis.

2.5.2 Fitts's Law

Fitts's law is a mathematical model that states the time taken for a human to move a pointer to a desired target area. It was established by Paul Fitts in 1954 [28]. The equation for Fitts's law is shown below:

$$Movement\ Time = a + b\ log_2(2 \times \frac{Distance\ to\ Target}{Width\ of\ Target})$$

As shown, Fitts's law is a function of the distance to the target divided by the size of the target. The coefficients a and b are determined by the chosen input device, and would be different values if the mode of input was either a mouse, a touchscreen, or a gesture in space. For this project, Fitts's law will be referenced to determine the size of interaction zones for the MIDI controller and its accompanying interface.

2.5.3 Principles of Interaction Design

In his book "The Design of Everyday Things", Don Norman communicated the following six principles of interaction design that designers should consider when designing interactions for users [78].

Visibility

Users need to know all available options instantly with minimal effort. Ideally, a user should be able to immediately see and identify these options.

Feedback

After users make an action, they should receive an indication or acknowledgement of their action. An example of this would be a sound playing after a significant button click.

Constraints

Users need limits on their interactions within a system. Without any of these limits, it may be easy for users to become lost or overwhelmed. An example of this is the screen size of an interface.

Mapping

Users should instinctively understand the relationship between a control and its effect. For example, when a user drags their mouse pointer along a scroll bar, the page moves accordingly.

Consistency

A system should have a consistent workflow and visual design. For example, an undo button should always perform the undo function, this should not surprise users.

Affordance

Affordance is the relationship between an object's perceived function and its actual function. For example, a pull-only door with a pull handle is a door with high affordance. This is a good measure for how intuitive an interaction is.

Ever since Don Norman published these principles, they have become well respected principles for designers to abide by after rigorous evaluation in many settings. Throughout the design, implementation and evaluation stages of this project, these principles will be used and consulted to inform all interactions and their effectiveness.

Chapter 3

User Requirements Study

This chapter details the user research study that was designed and undertook in order to obtain a clear understanding of the user requirements for the new MIDI controller. This user requirements study fulfils the first stage of the user-centred design process explained in section 2.5.1.

3.1 Purpose of the Study

The main purpose of this study is to gain a deep level of understanding for the needs of users that will use this new MIDI controller. To accomplish this, it's important to gain an understanding in a wide range of topics, from the technical capabilities of a musician, to situations that humans encounter in everyday life with technological and physical objects. Building this holistic view of potential users and how they see the topic of music creation will be beneficial for making informed design decisions during the design phase of the project.

A MIDI controller's main purpose from a technical standpoint is to allow people to easily add, delete, or edit MIDI events. Therefore, an important goal of this study is to figure out what technical requirements users may have from a MIDI controller. For example, should a MIDI controller and its accompanying interface allow users to play chords? How should that action be carried out? With a clear view on what technical functions users would require and expect from a MIDI controller, it will be possible to build a user-centred MIDI controller that people will find productive and useful.

From a human perspective, a MIDI controller's role is to allow humans to create music with the MIDI standard. Here lies an opportunity to craft a tool that enhances the potential for human creativity in music, rather than hindering or complicating the process. To achieve that goal, it's first important to understand:

- How humans interpret and experience music. This includes understanding the characteristics of certain emotions that are evoked in musical activities.
- How humans use technology in their everyday lives. A MIDI controller is a technological device, hence it's important to gain some insight into what forms of technology potential users find enjoyable or frustrating.
- How humans get (and stay) in the mood to be creative, especially with music. Ultimately, people use MIDI controllers as a tool to convey their musical ideas, and it will be advantageous to understand how to cater towards that goal.

3.2 Study Design

This study was designed to be a qualitative research study with two qualitative research methods being used to collect qualitative data. The methods used were semi-structured non-directed interviews and observation studies. The main reasoning for this was that the nature of understanding required on the aforementioned topics is most suitably achieved through qualitative research with these methods.

The entire script used to conduct the research study can be found in Appendix E.

3.2.1 The Screener

The first element of this study was the screener. The screener was designed to filter out people who did not fit the target audience of the proposed MIDI controller being designed. This selection process can be achieved from looking at responses to screener questions. Including this is important, as any insights discovered via recruited participants' responses should be relevant to the wider target audience outlined in section 1.4, rather than being representative of a different user population.

The questions that made up the screener for this study are shown in Figure 3.1.

Screener

Participants were selected based on a simple screener that consisted of 5 questions:

1. **Are you aged over 18?**
2. **What is your background regarding work and/or studying?**
3. **Do you enjoy listening to, or playing, music?**
4. **Are you at all interested in creating musical compositions or sounds?**
5. **Have you ever used/interacted with MIDI (Musical Instrument Digital Interface)?**

Figure 3.1: Screener Questions for Recruiting Participants

The first question ensures that participants will be over the age of 18 to align with ethical requirements. The second question ensures that selected participants will have a diverse range of backgrounds in work and study that is more representative of the target audience. The third and fourth questions ensure that selected participants have some interest or curiosity in the topic of music and its creation, which better represents the target audience. The last question ensures that selected participants will have various backgrounds and experience with regard to MIDI. It's important to gain an understanding from all of these perspectives, as musical beginners and experienced music professionals alike fall within the target audience.

Once people answered the screener questions, appropriate participants could be selected for the study.

3.2.2 The Semi-Structured Non-Directed Interview

The first part of the study that participants undergo is a semi-structured non-directed interview. One of the reasons for placing the interview at the start of the study was that it allows participants to become familiar with the general topic being studied, and to get initially acquainted with the interviewer.

The script of interview questions that were used and followed can be seen in Appendix E.

The questions themselves, the wording of the questions, and the ordering of the questions were all carefully considered to obtain the most relevant, un-biased qualitative data possible.

Justifying the Line of Questioning

Question sections 1 and 2 within the interview script aim to uncover participants' emotional and intellectual thoughts on music, within the context of their musical experiences and background. The second section of questioning ends with asking people to convey their favourite songs to deaf people. The goal here was to prompt users to show how they would think outside convention for musical subject areas. It's exactly this line of thought that may uncover new avenues for user interactions within the music domain.

Question section 3 begins to focus more on a participant's perspective on music composition. These questions provide human-centred insights on the creative process in music.

Question sections 4, 5, 6, and 7 touch on participants' interactive experiences with technological, or everyday, artefacts. The goal of these questions was to uncover successful and non-successful user experiences that would inform design decision-making on interactive features and workflows in the MIDI controller.

Question section 8 specifically focuses on the area of music production with technology, with the aim of providing insights that are directly relevant to this project's topic of better enabling MIDI interactivity for users.

The last section of questioning finishes with an open-ended discussion on participants' feelings on gesture-based interaction. Understanding user perspectives on this is important, as gesture-based interaction was consistently touted as a potential solution to solve the problems mentioned in section 1.1 while conducting the literature review.

Question Wording

As explained in section 2.5.1, it's important for user research interviews to be non-directed, meaning that there is minimal room for bias in the nature of questioning. All scripted questions for this interview were thoughtfully written and asked to not be leading questions.

For example, the first question asked in the fourth section of questioning is:

> *'What form of technology do you use most on a daily basis?'*

The following question is asking the same thing as the previous question but is worded in a leading manner:

'On any given day, what is your most popular form of technology?'

This example question could be considered erroneous because the word *popular* is a leading word as it has connotations of success and joy. It's possible that a participant's most used form of technology is not necessarily fun. Therefore, the original wording of the question used in the script is considered to be more non-directed because it does not subconsciously prompt participants to only consider forms of technology they find fun.

Question Ordering

Kuniavsky et al. suggest following an hourglass structure during interviews, where the interview starts and concludes with general/open questions, and focused questions are asked in the central segments [47].

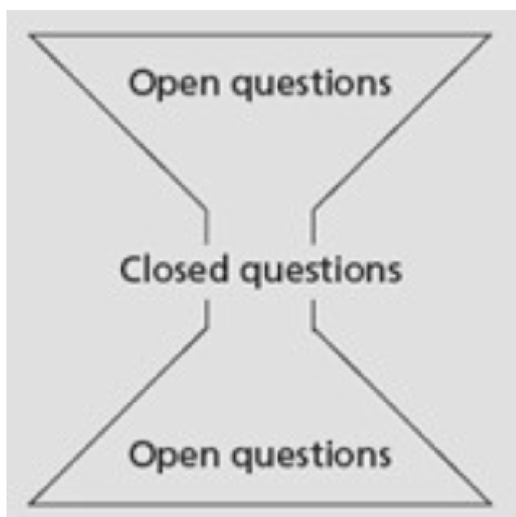


Figure 3.2: The Hourglass Structure for Semi-Structured Interviews

This structure allows interviews to be completed with better flow, as the participant's perspective is optimised. Hence, it was used for structuring this interview.

Questions 1.0.0 to 3.2.3 offer participants a welcoming introduction, which gives them the opportunity to become familiar with the situation. Then, they are ready to answer more concentrated lines of questioning in questions

4.0 to 7.1. Finally, the last questions are concluding questions which give participants a chance to reflect on the session.

3.2.3 The Observation Study

The second and final part of this study is the observation study. The goal with the observation study was to observe users using existing MIDI controllers and interfaces for music creation in a natural environment, and thus gain an understanding on the usability of these existing systems along with their user experience. With the knowledge of what works well or what doesn't work well in existing MIDI controllers and interfaces, many more novel features can be designed to achieve optimal usability and a desirable user experience for a new MIDI controller.

It was decided that the observation studies should be conducted in a calm and friendly manner within an environment where participants feel comfortable. This is important, as it helps to reduce the effect of participants behaving differently in a lab setting compared to the environments where the target audience would use a MIDI controller to create music [48]. As a result, there was scope within the study that allowed it to be conducted where the participant wanted, rather than where the researcher wanted.

To give prompts for participants to start using different MIDI controllers, a script of specific activities was created. This script can be seen in Appendix E.

The goal of activity 1 is to understand how users would use their minds and bodies to interpret and display music. This may inform some novel interactions that may be developed for a new MIDI controller. Activities 2 and 3 are all about comprehending how users use current MIDI controllers and MIDI interfaces. It was decided that asking users to perform tasks on the Logic DAW through both the mouse/keyboard and a MIDI keyboard would best cover this spectrum since MIDI keyboards are the most popular MIDI controllers, and Logic is one of the most popular DAWs.

(a) The Logic DAW setup presented to participants for activity 2

(b) A similar MIDI keyboard & DAW setup to the setup presented to participants for activity 3

Figure 3.3: Apparatus for Activities 2 & 3 of the Observation Study

Activity 4 allows researchers to better understand the creative process in music, with an aim of later designing a system that is more aligned with the user-perspective of the creative process.

3.3 Participant Recruitment

Before the study got underway, advertisements were circulated around the University of St Andrews community. Five participants were recruited after completing the screener. The number of participants was decided to be five because anywhere between three to five participants can give more than enough insight, as explained by Nielsen [74] [75][73] and Lewis [54]. The participants were selected to try and best reflect the target population of the MIDI controller (see section 1.4), and thus act as a reliable sample population. The musical backgrounds of the participants are as follows:

- Participant 1 had completed some piano lessons as a child but later gave them up, citing that they did not enjoy the lessons.
- Participant 2 has lots of experience playing the clarinet throughout their childhood.
- Participant 3 plays bass guitar in a band, has some experience playing piano, and has experience producing music in the Logic Pro X DAW application.

- Participant 4 has never played any musical instruments to a proficient standard.
- Participant 5 played piano during their childhood, and is looking to start playing again at a higher proficiency.

For ethical reasons, only the musical backgrounds of the participants can be shared.

3.4 Study Findings

After every participant completed the interview and observation sections of the study, the qualitative data gathered was then analysed using a grounded theory approach where related themes of information were coded [90][58].

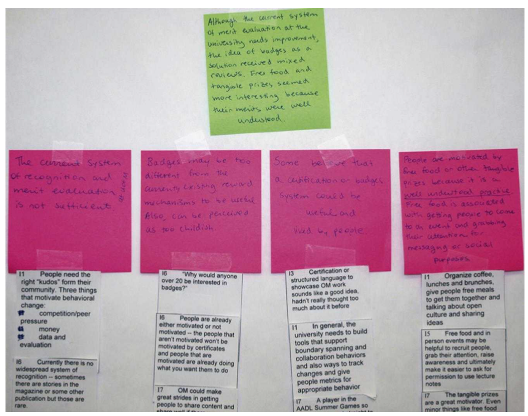


Figure 3.4: An example of qualitative analysis using coding in an affinity diagram from another study [49]

This qualitative analysis uncovered many useful insights into the domain of music, creativity within music, and music production. Many of the insights were also recurring, with multiple participants commenting similar information or performing the same behaviour. These notable insights are illuminated in the following subsections.

3.4.1 Music and its Aspects

Similarities Regarding Emotions and Thoughts Triggered by Music

Remarkably, it was apparent that participants had similar thoughts on certain songs. For example, every participant described the same scene of a crowded bar when asked to convey the song 'Piano Man' by Billy Joel [42] in activity 1. Granted, the music video for the song portrays this scene, however four out of the five participants had never seen the music video. Another example of this occurred when participants consistently described 'Peer Gynt Suite No. 1' by Edvard Grieg [34] as natural landscapes, particularly forests and rivers. Participant 3 made the following quote:

> 'I would describe this like a river, flowing through the forest. I see the natural landscape, and when the music becomes more powerful, that's when the river has approached the top of a waterfall with a vast view.'

Association Between Water & Music

Surprisingly, four out of five participants mentioned at some point that they relate water and music, following on from the quote made about Peer Gynt by participant 3. When describing the differences between the song 'Summer' by Calvin Harris [35] and 'Take Five' by Dave Brubeck [14], participant 2 said:

> 'Summer is like a pool party, where water is splashing around everywhere, it's chaos. Take Five is more like a rumbling wave, travelling across a lake like an undercurrent rumbling away.'

Notable Compositional Elements in Music

All participants conveyed that a song's melody is typically the feature of a song that stands out most to them. Participants 2 and 3 also added that the rhythm elements of songs were equally important, while participant 5 emphasised that lyrics are influential when enjoying a song.

3.4.2 Creativity in Music

Users are Creatively Inspired by Example

When participant 4 was asked to describe steps they would take to create a song in question 3.2, they desired a need to first see examples of other compositions they find inspiring.

> 'My first step would be figuring out how other musicians have created their songs by looking at tutorials.'

Participant 3 also mentioned this is an early step in their process for creating songs. In fact, all participants regardless of their creative background in music cited this as an important step in a creative process they would plan for themselves.

Observing a *Step-By-Step* Creative Process

A common theme that three out of five participants displayed was the practice of concentrating on one thing at a time in the creative process. When participant 2 was recreating their favourite song in activity 3, they first focused solely on the melody, then on the chords, and then on effects. This theme also surfaced in answers to questions 3.0.0 - 3.2.3, with participant 3 mentioning that they had to 'finalise individual parts of a composition idea', whether that's the bassline or the melody, before progressing.

3.4.3 DAW Interactions

Issues with DAW Interactions

When starting activity 2, all participants except participant 3 commented on being overwhelmed by the number of available options upon opening Logic. Furthermore, all participants articulated that there were too many menus to navigate and too many button clicks involved in performing basic rudimentary actions such as opening the piano roll. Participant 2 said:

> 'If you hadn't told me how to find the piano roll, I don't think I would have found it in 10 minutes, let alone 10 seconds! Weird, as that would be the first thing I want to see when I open up this application.'

Similarly participant 1 added:

> ‘I understand why there are so many menus etc, but I don’t feel like they are relevant for me as a beginner. I would rather see a smaller selection of tools that are relevant to my tasks.’

As activity 2 progressed, every participant quickly exclaimed that they wanted to loop a section of the playback. Participant 3 could do this on their own, but every other participant needed assistance to perform this function. Interestingly, every participant except participant 5 wanted to adjust tempo at some point, and only participant 3 could do this without assistance.

During compositional stages in the piano roll, participants 1, 4, and 5 were repeatedly clicking wrong notes and gradually becoming more frustrated when doing so. Participant 5 made the following statement:

> ‘This key would never sound right in Happy Birthday but I keep accidentally clicking it. I want it gone!’

Positive Interactions with the DAW

Every participant overwhelmingly praised the visual interface for seeing MIDI notes on the piano roll. Participants 1, 4, and 5 had never seen a piano roll before, and they especially conveyed positive emotions about it, saying it had given them a refreshing perspective on contextualising what’s going on in the music. Participant 4 expressed:

> ‘I want to spend more time on this piano roll visualising patterns in music.’

3.4.4 MIDI Keyboard Interactions

Negatives

Throughout activity 3, all participants continuously had frustrations with playing ’wrong-sounding’ notes on the keyboard and playing correct notes at the incorrect time. Even participant 3 who had ample experience playing piano, found it tricky to play notes to their favourite song in perfect time. Participant 3 had the following comment:

> ‘I could not rely on this MIDI keyboard alone to recreate or create an idea to a good standard. I would need to also use the piano roll interface, like with the previous activity.’

Participant 4 said:

> 'It's frustrating to strike all of these ugly-sounding notes all the time.'

The pitch wheel also proved to be problematic, as participants 1, 3, 4, and 5 all felt it was difficult to control. Participant 3 said:

> 'I want to bend the pitch slightly, but this wheel always either goes fully up or down. I'd like to find the in-between.'

Additionally, no one willingly played the pitch wheel at the same time as anything else. Rather, they would loop a section of MIDI and then exclusively manipulate the pitch wheel.

Positives

Participants appreciated moving their hands to play notes on the keyboard. Participant 5 remarked:

> 'Moving in this way to make music is definitely engaging. More so than clicking on a grid.'

However, participant 4's frustrations with playing wrong keys on the keyboard surfaced again when discussing this topic:

> 'Oh no! I played a wrong note again! I really want to move my hands to play the notes, but I'm not an expert keyboard player so it's frustrating.'

3.4.5 Gestures and their Perceived Experience

Throughout the study, participants regularly had physical reactions to audible music, whether they were aware of it or not. Tapping along to the beat of a song, or its melody, was a regularly observed gesture, with different taps seemingly representing different notes. The regular occurrence of this observation indicates a certain connection between gestural physical movement and music. Furthermore, all participants resorted to hand gestures at some point to convey certain aspects of music in activity 1.

Chapter 4

Design

This chapter details the design process that was behind creating the design of the Novel MIDI Controller. First, the initial brainstorming phases where various themes of design were explored is explained. Also, the decision-making process behind the main theme of the finalised Novel MIDI Controller design is discussed. Then, the process of arriving to the finalised designs within the chosen theme is detailed and the final design ideas are presented. This chapter fulfils the design phase of the user-centred design methodology explained in section 2.5.1.

An important detail to mention is that at the start of this design phase, the name for the new proposed MIDI controller and its interface was decided to be the 'Novel MIDI Controller'.

4.1 Three Initial Design Themes for the Novel MIDI Controller

When carrying out the initial stages of the design process, it was important to first explore drastically differing themes of interaction and application design before deciding on a design theme to continue with. The reasoning for this was to open the possibilities for many out-of-the-box ideas to be ideated and considered before prematurely disregarding them for more mainstream, established, and obvious designs. It also better facilitates ideation with brainstorming, which is crucial for stimulating creativity in design and implementation ideas within the user-centred design process [36].

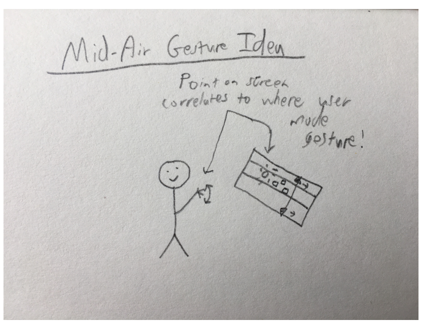
While bearing the findings from the user requirements study in mind, the following three main themes of design were initially explored:

- A Gesture-Based Interaction Design Idea with a Visual Interface
- A Touchscreen-Based Interaction Design Idea with a Visual Interface
- A Tangible Interaction Design Idea with a Tangible and Visual Interface

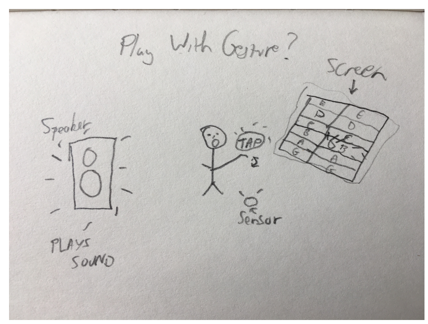
The three themes are detailed below, along with the decision-making process to continue with one of them.

4.1.1 The Gesture-Based Interaction Design Theme

Interacting with touch-free gestures performed in mid-air is the main foundation of the ideas generated within this design theme. Below are some scenario sketches that demonstrate this theme's initial design ideas.



(a) Scenario Sketch of a User Composing a Melody with Hand Gestures



(b) Scenario Sketch of a User Playing a Note via a Hand Gesture

Figure 4.1: Initial Scenario Sketches in the Gesture-Based Interaction Design Theme

Within these initial ideation design sessions, there was much inspiration from the work cited in section 2.2 and participants' positive reactions to the piano roll in the user requirements study. As seen in Figure 4.1, users are able to add notes by performing a hand gesture, where the gesture's location in mid-air in front of them corresponds to the note's time-placement (in the x-axis) and pitch (in the y-axis). There is also an idea displayed for live performance, which takes similar interactions to instead play notes live. Within this theme, there were initially two strong modes of use that appeared, one for live performance that is displayed in Figure 4.1b and one for melody composition displayed in Figure 4.1a.

4.1.2 The Touchscreen-Based Interaction Design Theme

Touchscreens present well-known touchscreen interactions as an option to play musical instruments and compose melodies, by interacting with notes and effects via screen taps and swipes. Sketches for my initial ideas in this theme are shown below.

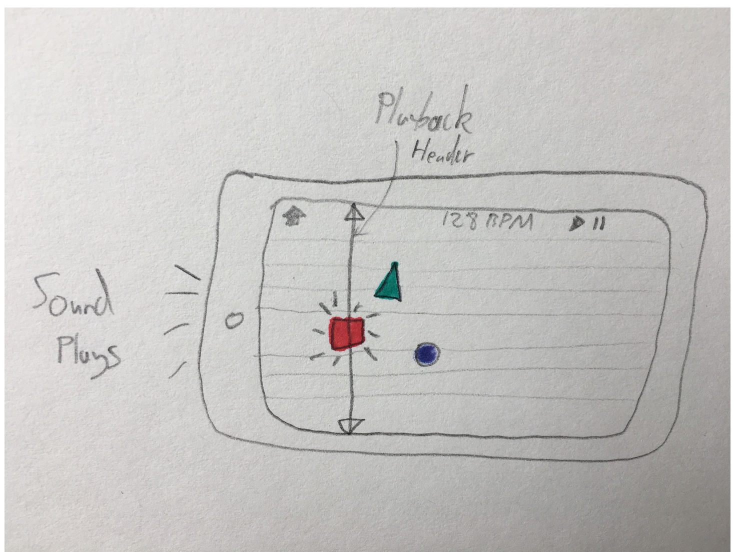


Figure 4.2: Editor Concept Sketch of Touchscreen Design Theme Idea

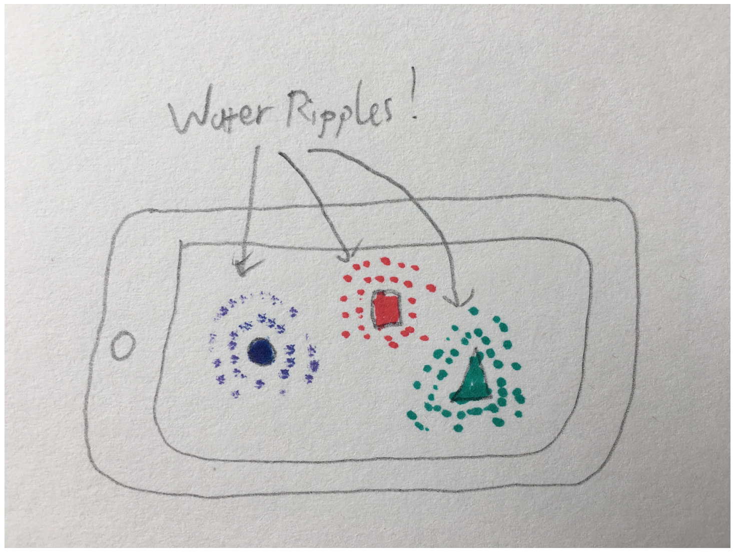


Figure 4.3: Player Concept Sketch of Touchscreen Design Theme Idea

As shown, the main goal with these ideas is to explore different visual cues and signifiers in the visual interface. This particular idea was massively inspired by the interface displayed by the Bloom application created by Brian Eno and Peter Chilvers [26].

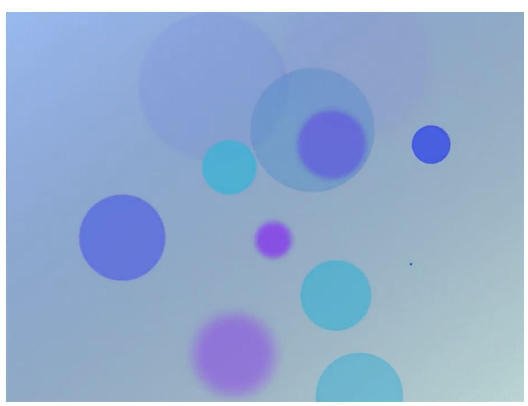


Figure 4.4: The Visual Interface of Bloom [26]

Vibrant shapes and colours can be an interesting way to represent musical notes, chords, and audio effects. Designing water ripples to emanate from the shapes also gives good visual feedback for various actions that users perform, or from sounds and melodies that are played.

4.1.3 The Tangible Interaction Design Theme

This design theme involves using tangible objects for interactive and communicative purposes.

The following sketch visualises the first idea in this theme of using water droplets to show the position of musical notes' pitch and time like the piano roll editor of a DAW.

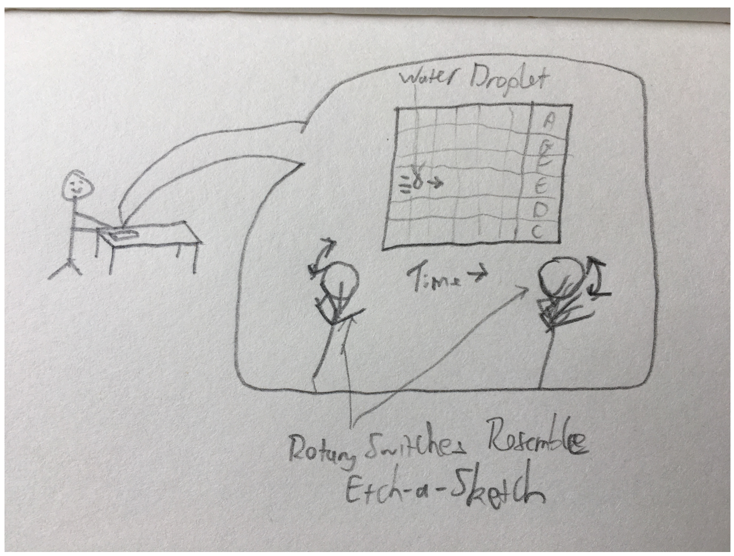


Figure 4.5: Scenario & Concept Sketches of the Tangible Water Droplet Idea

This idea is heavily inspired by the programmable droplets research undertaken by Umapathi et al [104][105], where water droplets can be moved around on an electrically charged surface. The idea of interacting with water droplets in this way was also inspired from the finding of an association between water and music by prospective users in the user requirements study.

Another idea from this theme involved levitating objects, such as water droplets, in mid air to again represent the characteristics of note pitch along the y-axis and time along the x-axis like a DAW's piano roll.

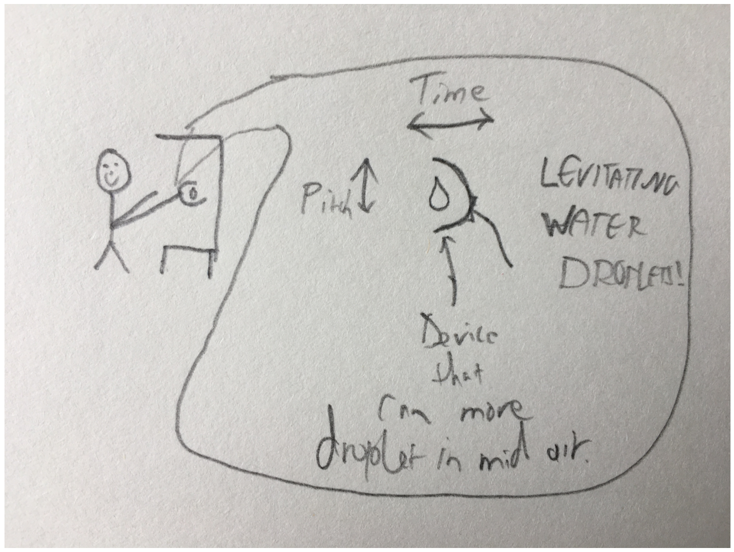


Figure 4.6: Scenario & Concept Sketches of the Levitating Water Droplet Idea

The research of Marzo et al [59] and Shakeri et al [89] inspired this idea.

4.1.4 Choosing a Design Theme

After evaluating the features and suitability of each design theme, and consultation with my supervisors and colleagues, it was decided to move forward with ideating more design ideas in the gesture-based interaction design theme for the following reasons:

- The interactions are novel and useful for the reasons explained in section 2.4 to solve the problems outlined in section 1.1.
- There was confirmation that the equipment required to realise the gesture-based interaction design ideas was readily available.

There were concerns that the touchscreen interactions were not as novel as the gesture-based interactions and may not yield significantly different conclusions than what had already been observed and researched.

The tangible interactions with water droplets are novel, but there were concerns over the feasibility of the hardware and implementation given the time constraints of the project. Moreover for the tangible ideas, it became clear that the designs were singularly focused at composition without further scope for live play and performance. This is another reason why it was dismissed.

4.2 Establishing Design Ideas for Novel and Intuitive Interactions

Based on findings from the user requirements study (see section 3.4), it was clear that users want to move their hands and get physically involved when creating or playing musical melodies. Hence, many ideas for gesture-based interactions that cater to both live play and note editing were sketched.

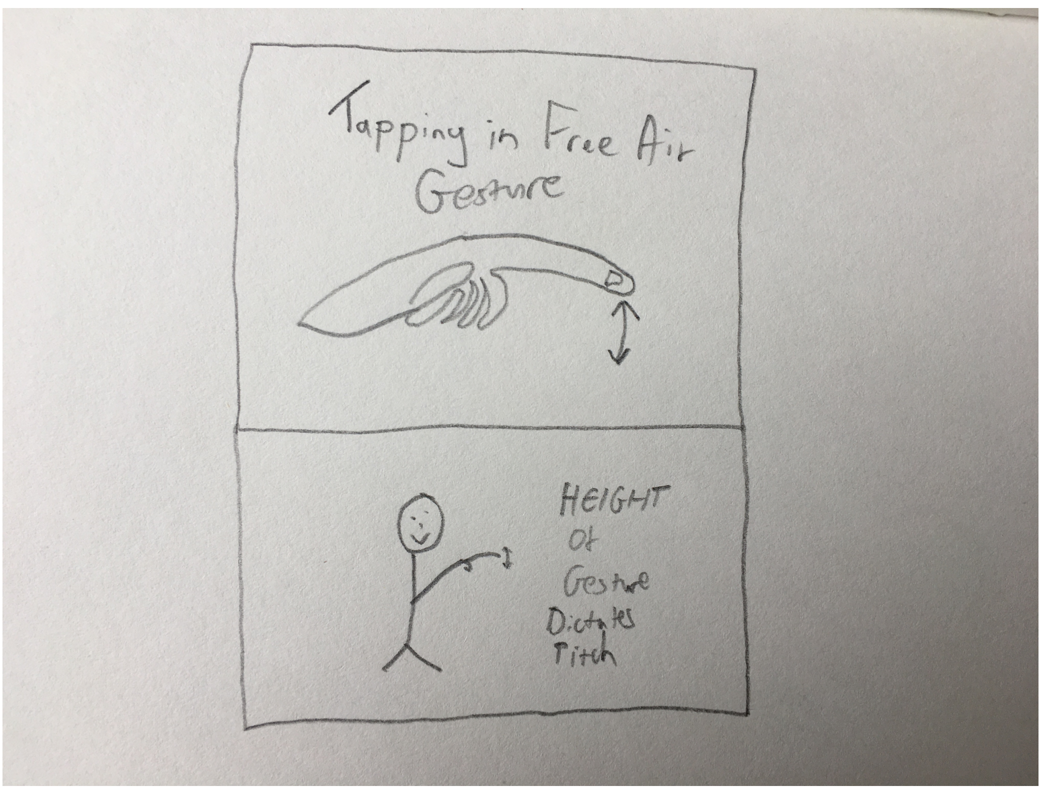


Figure 4.7: Initial Sketch of the Key Tap Gesture

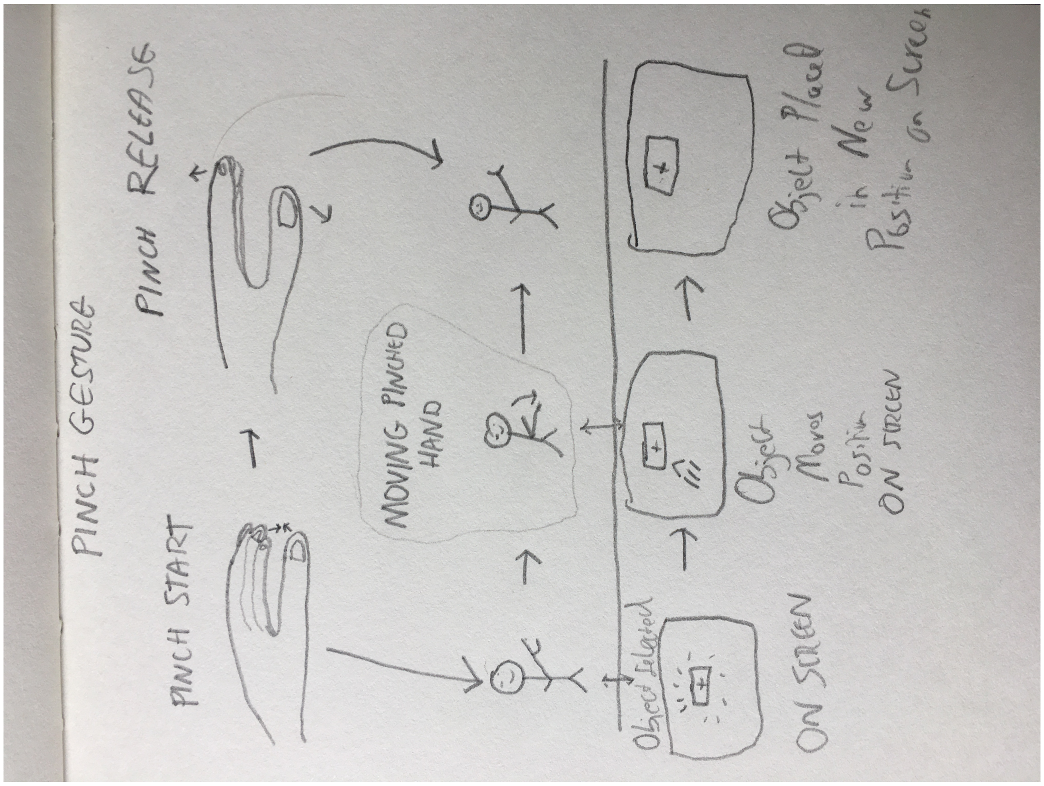


Figure 4.8: Initial Sketch of the Pinching Gesture

Two main gestures quickly became leading candidates. One gesture shown in Figure 4.7 mimics tapping keys on a piano in mid-air. The other gesture shown in Figure 4.8 imitates picking objects up or squeezing objects in mid-air with a pinch.

The key-tapping gesture idea came naturally from its resemblance to playing keys on a piano. The pinching gesture was inspired by the interactive experience children have when playing with LEGO bricks. Picking up objects and manipulating them with our hands has shown been shown to boost creativity [69] which is a key goal of this project. Playing with LEGO blocks certainly appeals to children for this very reason. Furthermore, performing gestures akin to playing with LEGO blocks may inspire many users to subconsciously engage with childlike behaviours from memories or otherwise, which achieves exactly the mood required for users to best engage with the desired creative musical process [63].

Both gesture ideas would be tested later during the implementation stage.

4.3 Establishing Design Ideas for the Interface

After manifesting ideas for gesture interactions, attention turned towards the MIDI controller's interface and its functionality design. With the presence of gestures it was reasonable to look at cheironomy (see section 2.4.2) for inspiration to determine their actions and function. In cheironomy, conductors can dictate pitch from their hand position in space. During the user requirements study, participants were also observed doing this instinctively. Figure 4.9 shows a sketch that illustrates a user's hand position mapping to an area on the interface that corresponds to a certain pitch.

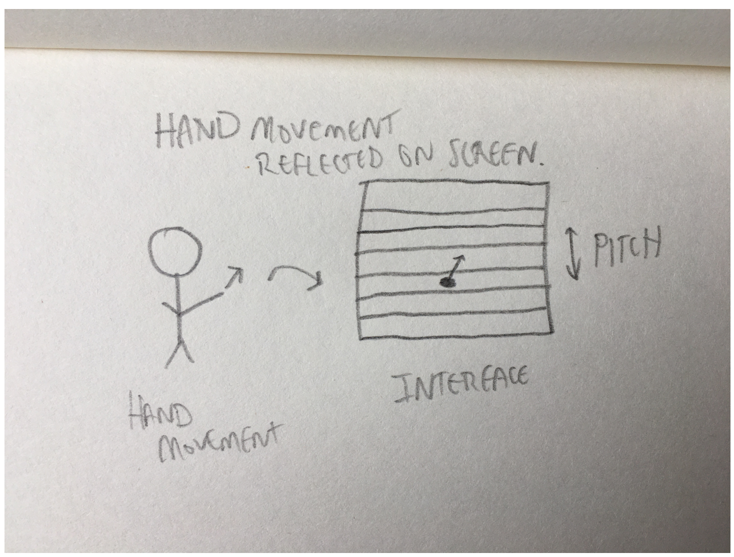


Figure 4.9: Sketch of User's Hand Positions Mapping to their Corresponding Position on a Screen

This interaction satisfies Normans mapping constraint [78] (see section 2.5.3). It's advantageous to map pitch in this way as it matches the logical layout of pitch on a piano that users respond well to (see section A.3.1). However, this posed an issue, as the area for each pitch zone would have to be small to accommodate for every pitch. After considering Fitts's Law (see section 2.5.2), the idea of restricting available pitches to a certain key (see section A.2) was born as a solution to this problem. This also serves as a solution to the usability issue all participants faced in the requirements study where they were frequently playing wrong notes. Furthermore, it satisfies Norman's principle of constraints [78] (see section 2.5.3). Figure 4.10 illustrates the new design idea for the interface users would see when playing live notes.

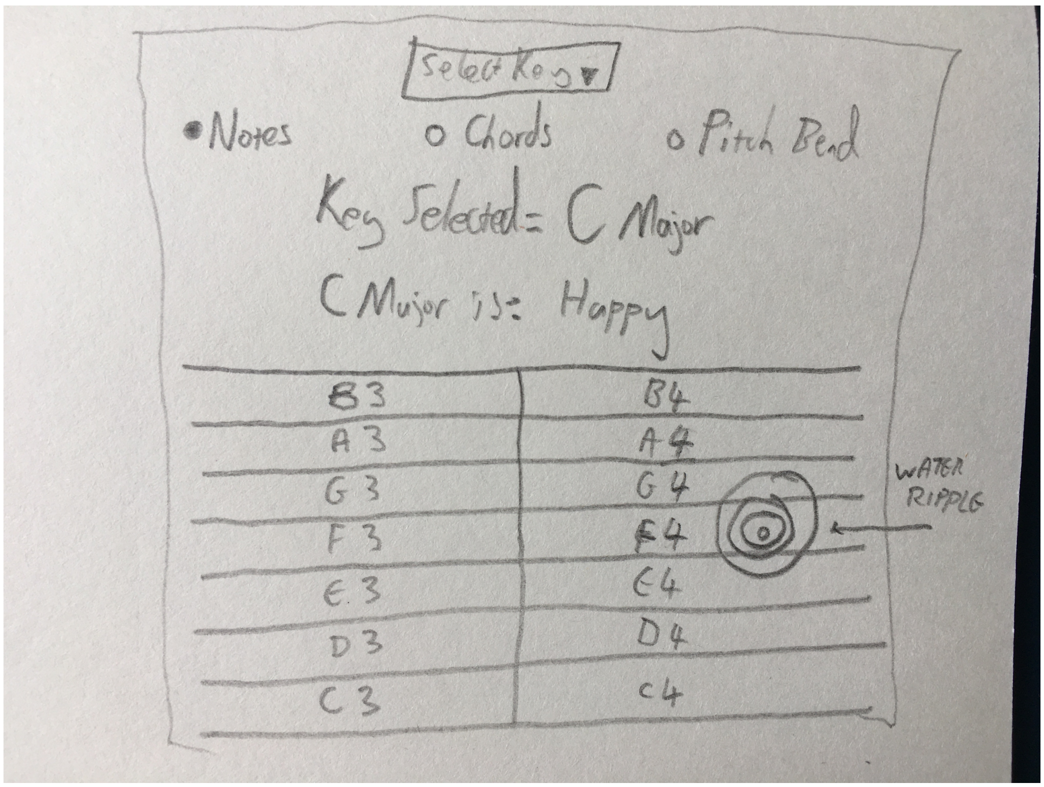


Figure 4.10: Concept Sketch for Restricting Notes to a Key

The key can be selected, where users can also receive a short description of the emotional characteristics of that key. One of the user study findings confirmed that people recognise music in similar ways, so it made sense to help people choose a starting key for playing/composing with these descriptions. Many composers have also characterised keys in this way throughout history [95]. Notice as well that interactive zones allow users to play notes, chords, or alter pitch bend effects. During the user study, many participants struggled with playing chords, even if they had some piano playing experience. Hence, allowing chords within a key to be played with a small gesture will hopefully alleviate that observed usability issue. Figure 4.10 also shows that when a user triggers a note or chord to play, a water ripple on the screen is produced on the same area where the hand was when the user made the gesture. This visual design directly stems from the water-music association finding in the user study.

For composing and editing musical elements it became clear that a separate interface would be required. Figure 4.11 shows a sketch for the design of the editor interface.

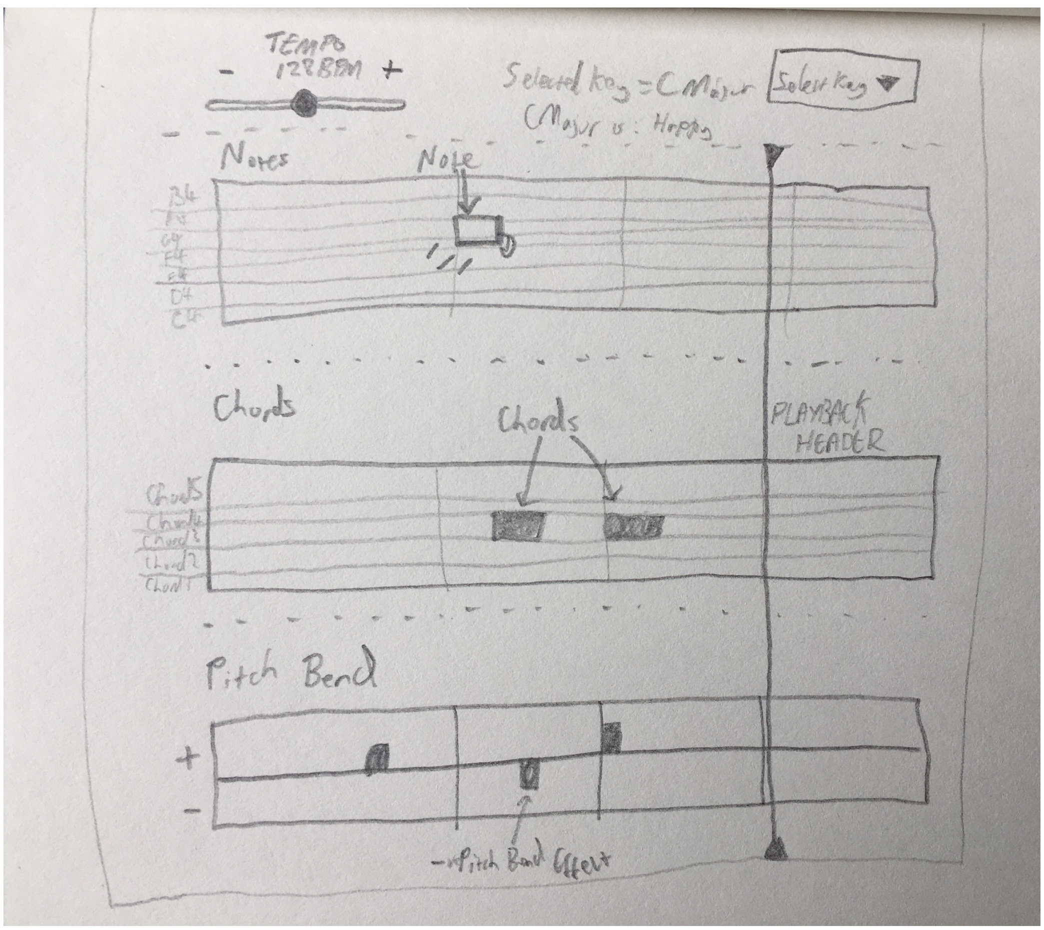


Figure 4.11: Concept Sketch for an Editing Mode

Following from the warm reception of the visual piano roll in the user study, it was decided to use a similar visual piano roll. Except now, users can select and move notes along an additional horizontal axis to determine the timing of notes, as if the piano roll was physically in front of them. The ideas for restricting available notes to keys and playing chords with one tap translate to this editor, where users can pick up individual blocks that represent notes, chords, or pitch bend effects. The pitch bend grid feature of small pitch alterations over time originates from the pitch wheels on MIDI keyboards snapping back to neutral after use. The interface automatically loops for a set number of bars because all participants were observed wanting to perform this feature regularly. The tempo feature is a slider for users to easily adjust tempo, as that was required in some tasks during the user study.

4.4 Finalising an Overall Design

With the emergence of two clear interfaces performing the functions of composing/editing compositions and playing live music, it was determined that an application housing both of these interfaces as options should be created.

Another finding from the user requirements study was that beginner users felt especially overwhelmed when looking at a DAW. From this finding, it was decided to design the overall application to strike a balance between non-musicians and musicians, and the export/save button was added to the design. The app workflow presents enough to satisfy musicians, but acts as a bridge from which musicians and expert users can easily export MIDI compositions to a fully-featured application like Logic if they wish to do so using the export button. Musicians can solely focus on maximising creativity in the Novel MIDI controller, and then get more technical by exporting to Logic if they wish to do so.

Continuing from this theme, an import/load button was also added to the design. This reflects participants' wishes to be inspired creatively by example, by enabling them to import example MIDI files to the application to explore how famous compositions have been made. Of course, this requires example MIDI files to be provided with the MIDI controller.

Finally, it was also decided that traditional mouse and keyboard interactions should still be available to users, in case for some reason gestures cannot be performed. An example of this would involve a user clicking an interactive zone with a mouse instead of hovering their hand and making a gesture. This provides an alternative design idea which can be tested in the evaluation stage, and it can also test the creative workflow of the application without being tied to the gesture interactions.

Chapter 5

Implementation

This chapter chronicles the implementation details for the Novel MIDI Controller application, representing the prototype phase of this project's user-centred design process described in section 2.5.1.

5.1 Selecting Implementation Tools

Before implementing the design for the Novel MIDI controller, it was first crucial to select suitable hardware and software implementation tools to achieve the desired design in a practical prototype.

5.1.1 Leap Motion Controller vs Kinect

As detailed in section 2.4.1, the best options for accurately detecting human hand gestures are the Leap Motion controller and Kinect systems. For the purposes of this project and its scope, it was decided to use the Leap Motion controller instead of the Kinect because the Leap Motion controller specialises in detecting hand gestures accurately, whereas the Kinect is only capable of detecting full-body gestures accurately.

5.1.2 Selecting Software Implementation Tools

Reflecting the design, it was decided the Novel MIDI controller should be a software application with a graphical user interface (GUI). When selecting a programming language for development, it was important that the selected language could be used within and amongst all other hardware and software tools in this project, and that my expertise with the language was high enough to successfully implement all the designed features. After considering many languages, it was decided that Java [40] would be used. The Leap Motion controller and its accompanying API supports Java, and Java has extensive support and documentation for MIDI [39]. Additionally, I have frequently used Java for many assignments throughout my university career. My familiarity with Java made it a sensible option to maximise development efficiency within the project's timeline.

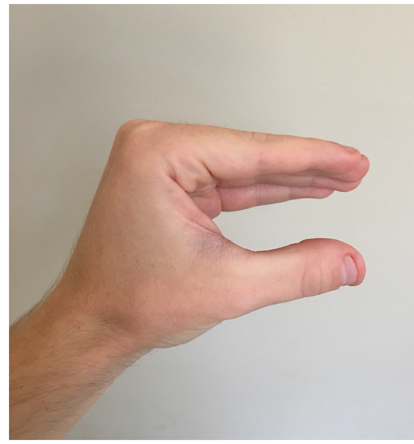
As an extension to Java, it was also decided that the Processing environment [81] would be used to make the Novel MIDI controller application. Processing is essentially Java, except it excels in streamlining the process of creating GUIs and packaged applications compared to traditional Java environments such as Eclipse [24]. This makes Processing a much appreciated addition for the specific requirements of this project.

Finally, it was decided that the Logic Pro X DAW [55] would be used as the DAW that provides access to external instruments and sounds outside the Java programming language and its libraries.

5.2 Implementing the Gesture-Based Control

The first stages of implementation involved writing code to recognise the key-tapping and pinching gestures ideated in the previous design phase (see section 4.2). After some independent use, it was decided to only pursue the pinching gesture. It was more robust in terms of functionality and it was more representative of any instrument or sound that a user wanted to play. The key tap gestures are very reminiscent of piano, but may not transfer well for other instruments. Also, a tapping gesture is very one-dimensional, it's either on or off. Conversely, a pinch gesture involves multiple stages: the pinch initiation (see Figure 5.1b), moving while pinching, and releasing the pinch (see Figure 5.1a).

(a) No Pinch Gesture



(b) Initiation of Pinch Gesture

Figure 5.1: The Pinch Gesture

The Java function that detects whether a pinch gesture has been made or not is the *Hand.getPinchStrength()* function from the Leap Motion Processing library [44]. The threshold for detecting pinches in this implementation is 0.07.

Lastly, many interactions from the design rely on tracking a user's hand position. This was achieved by tracking the palm of a user's hand. Drawing this hand position on the screen to correlate with zones on the screen is then straightforward with the use of the *map* function.

5.3 Implementing Traditional Interactive Features in App

Since the finalised design included two modes that are both accessed from a main menu, it was necessary to implement GUI buttons. Additionally, it was clear from the design that each mode would require multiple menus and radio-buttons to allow users to select different options. These buttons and menus were all implemented using the controlP5 Processing library [88].

The application always keeps track of what musical key the user is playing/editing/switching in/between live and editor modes. This is managed by an integer variable. 0 corresponds to C major and so on until 23 equalling B minor.

In editor mode, two groups of Boolean state variables determine the application's main selection options. Users can either interact with notes, chords, or the pitch bend effect, and users can either compose, delete, or edit notes.

The main purpose of all the controlP5 buttons and menus is simply to change the states/values of the previously mentioned application state variables.

5.4 Implementing The Live Mode of the App

The initial interface presented to users upon entering live mode is shown in Figure 5.2.

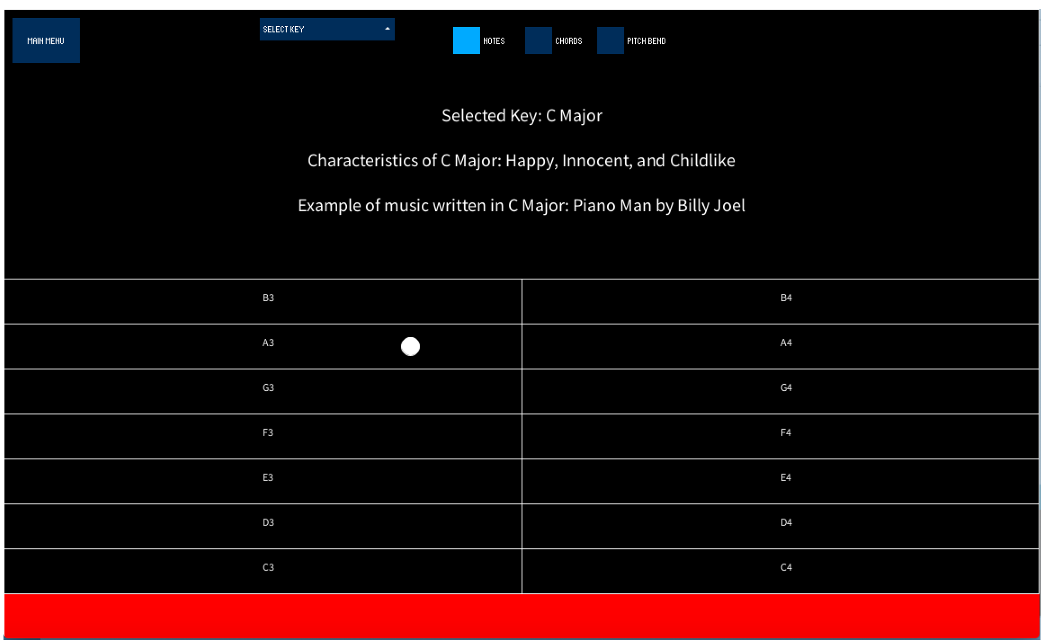


Figure 5.2: Live Mode Interface

It reflects the visual design in Figure 4.10. The white dot reflects a user's hand position above the Leap Motion sensor.

5.4.1 Playing Notes

First, it was crucial to trigger sounds when users made pinch gestures, and to trigger the correct pitch based on a user's hand position. Rather than using Java's default synthesiser, it was decided that triggering sounds by sending MIDI Messages to the Logic DAW [55] would present users with the enhanced capability of playing Logic's sounds and instruments. Hence, a pipeline had to be implemented that could send MIDI messages from the application into Logic. This was done with the MidiBus Processing library [93], by setting up a bus channel which could be recognised as MIDI input in Logic on its MIDI IN port.

When a pinch gesture is detected, a function called *pinchStarted* is called and the location of the pinch on screen is noted. Inside *pinchStarted* a Note-On MIDI message is then sent along the bus to the DAW. The MIDI pitch within the MIDI message is retrieved by helper functions that take the gesture's noted screen position and return the corresponding MIDI pitch. The specific helper function called to perform this is dependent on the currently selected key, as dictated by the top dropdown menu. At this stage, a water ripple visual is also triggered at the location of the gesture. An example of the water ripple can be seen in Figure 5.3. The water ripple visual was implemented by manually updating the pixel array of the GUI.

So far only note-on MIDI messages have been sent. The corresponding note-off messages are sent only when a user releases their pinch gesture. The code that achieves this is located in a function called *pinchReleased*.

5.4.2 Playing Chords

If users interact with chords, then the process is essentially identical to the notes, except now three note on/off MIDI messages are sent to represent three collective pitches instead. Also, the pitch retrieval functions now return three MIDI pitches instead of just one. Figure 5.3 shows the interface when users play a live chord.

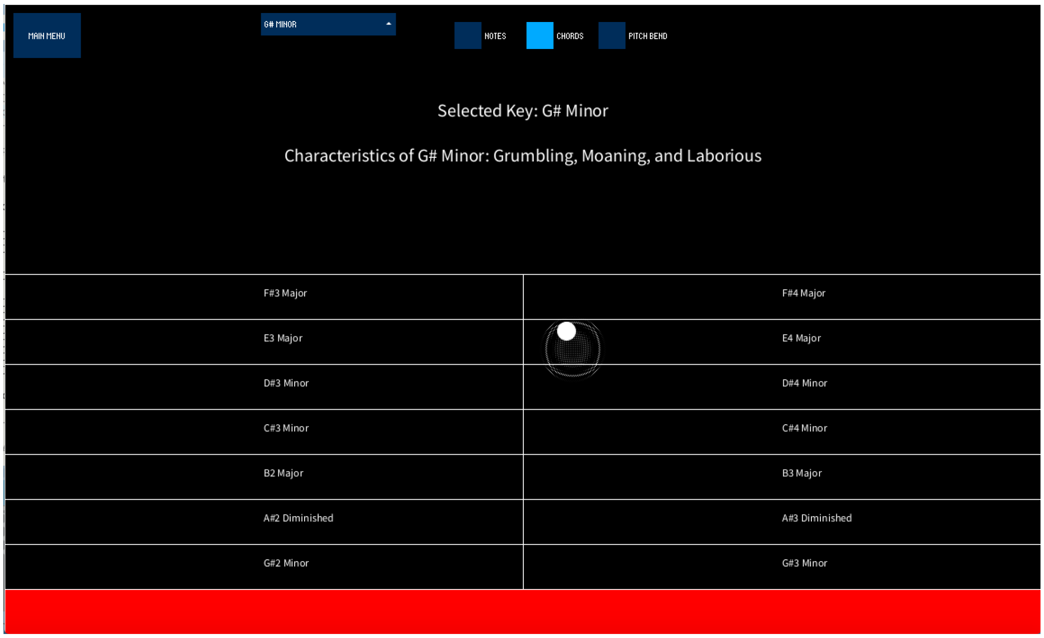


Figure 5.3: Live Mode Interface When a Chord is Played

5.4.3 Playing with Pitch Bend

When pitch bend interactions are selected, users are presented with the interface shown in Figure 5.4.

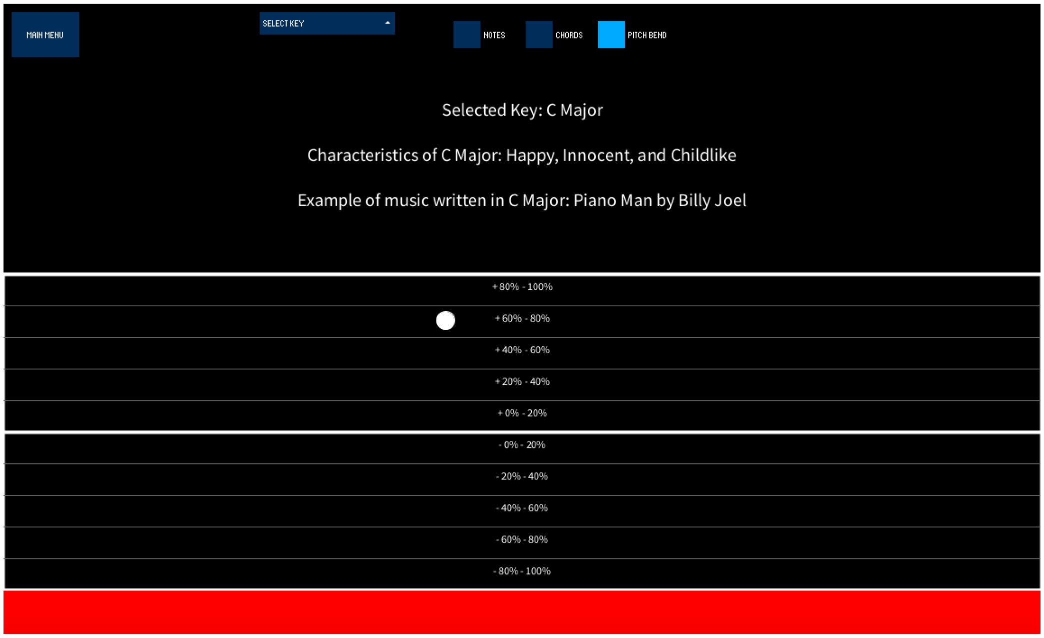


Figure 5.4: Live Mode Interface for Playing with Pitch Bend

Similarly to notes and chords, when users start pinching a pitch bend MIDI message is sent along the bus, and when users release a pinch the neutral pitch bend message is continually sent. However now, users can move their hand around while pinching to achieve different pitches. In a function called *pinchMoved*, the pitch value sent along the bus directly correlates with the y-axis position of a user's pinched hand. Users can release their pinch gesture anywhere and the pitch-bend will snap back to neutral, reflecting the pitch-wheel behaviour on MIDI keyboards.

5.5 Implementing The Editor Mode of the App

The initial interface presented to users upon entering editor mode is shown in Figure 5.5.

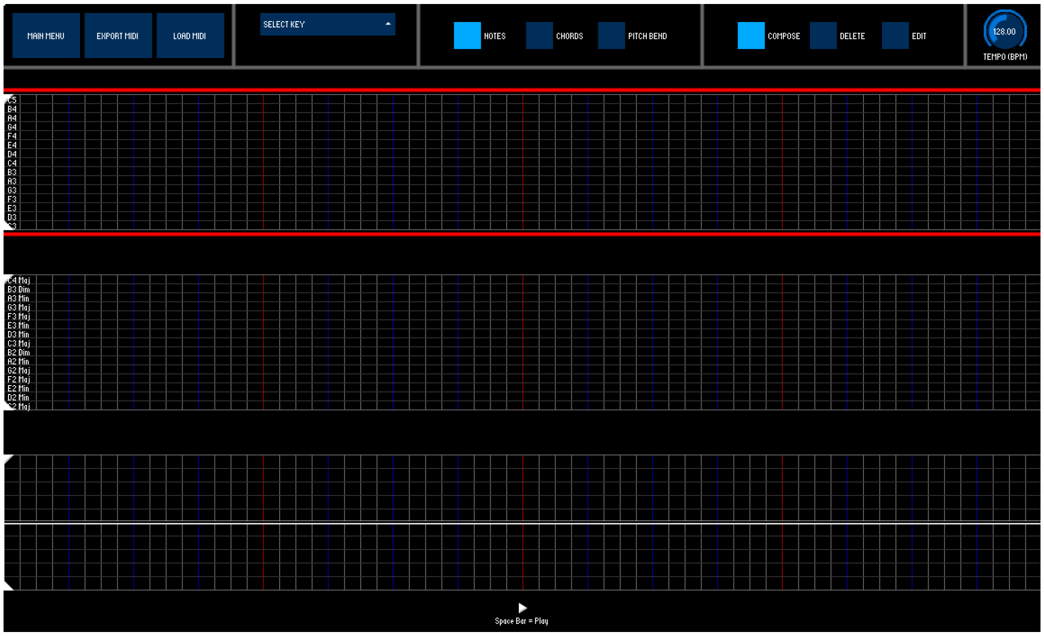


Figure 5.5: The Editor Mode Interface

It reflects the visual design in Figure 4.11. Unlike live mode, there is no MIDI bus present in the implementation of editor mode. Instead, Java's MIDI and default synthesiser libraries [39] are utilised to play sounds and manage MIDI events.

5.5.1 Setting Up the Java MIDI Sequencer

Section 2.1 explains that a functioning MIDI system is composed of tracks, channels, and sequencer components. A MIDI sequencer contains tracks, where tracks store MIDI events and their timestamps. The sequencer manages timing and playback for the whole MIDI system. In the Novel MIDI controller's editor mode, the Java MIDI library is used to setup a sequencer and tracks for notes, chords, and pitch bend effects.

The sequencer setup is where the playback is determined to be 4 bars long and loop infinitely. The user study revealed that users prefer to constantly loop short sections of playback (typically 4 bars) when composing and editing musical compositions, so these specifications were determined to be suitable for the scope of this application. The tempo of playback in the sequencer is also determined to be 128 BPM by default. Users can always change this tempo by adjusting the position of the rotary tempo slider seen in the top-right corner of Figure 5.5. Whenever the space bar is pressed, the sequencer playback is played/stopped.

5.5.2 Composing Notes

If note interaction is selected among the notes/chords/pitch-bend radio-button group, and compose mode is selected among the compose/delete/edit radio-button group, then users can add notes to the piano roll grid by performing pinch gestures in mid-air at a spot that corresponds to the desired position on the grid.

It's important to realise that only one grid can be used at a time to maximise space above the Leap Motion sensor and respect Fitts's law [28]. The currently selected grid is always highlighted with a red border. Hence, the marker that maps a user's palm on screen is restricted to the currently selected grid (notes/chords/pitch-bend) only. This also mirrors the finding from the requirements study that participants naturally wanted to do one thing at a time, rather than thinking about notes, chords, and sound effects together.

When a note is added, a note-on MIDI event is created on the notes track within the sequencer, which allows that note to be played aloud upon playback. Again, helper functions return the correct MIDI pitch for the requested note. Notes present in the notes track are drawn to the screen by the *drawNotes* function that continually monitors all events in the track and draws rectangles to the screen in their corresponding x-position for time and y-position for pitch. Furthermore, the text of the note is also displayed within the rectangle to help users recognise the notes. A subtle observation during the requirements study was that participants had difficulties recognising what note a rectangle on the piano represented if it was far away from the note keys on the left-hand side. This is why in the Novel MIDI controller, all notes and chords are also labeled with their pitch as seen in Figure 5.6.

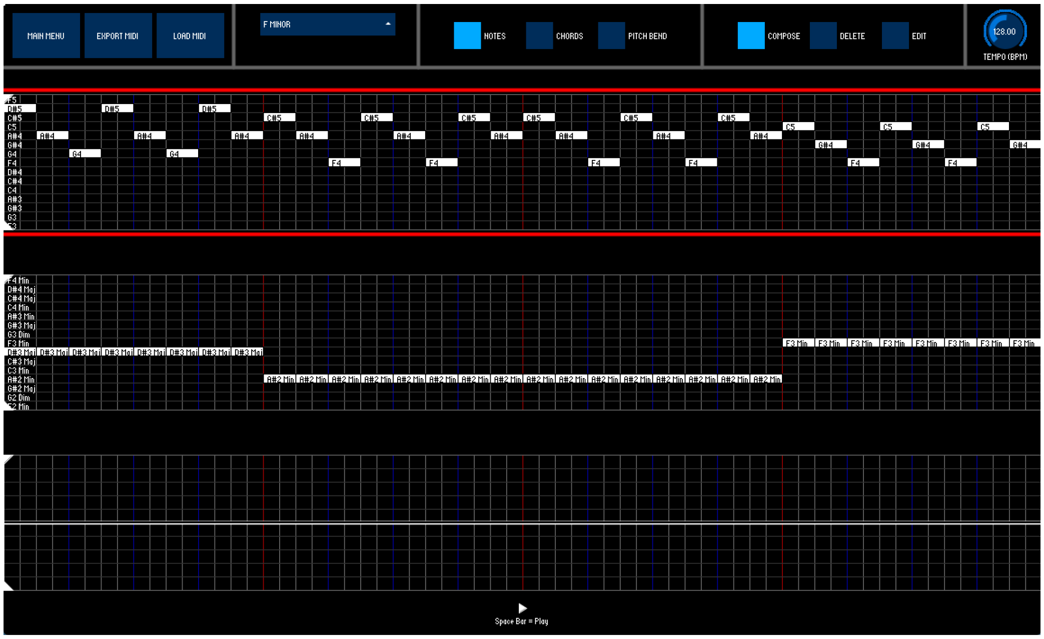


Figure 5.6: Labeled Notes and Chords in Editor Mode

Delete mode enables users to remove notes from the piano roll. This is achieved by first determining whether a note is present at the location of the pinch gesture.

Edit mode allows users to perform both the actions of compose and delete while also giving users the illusion of picking up blocks of notes and moving them around the piano roll. This is achieved by first deleting any note within the area of a pinch gesture initiation on the piano roll. While a pinched hand moves around, a rectangle resembling the note that was picked up, or a brand new note if there was no note to pick up, is continuously drawn at the location of the hand from the *pinchMoved* function. When the user reaches a location to add a note, they can release the pinch and a new note event is created in the same fashion as before with compose mode. If the goal is to delete the note, the user can drag the note outside the grid and release their pinch. In this event, nothing happens, as if the note was dropped into the ether. It's obvious to see that this mode is powerful, as users can create notes out of thin air, pick up existing notes and move them elsewhere, or delete notes entirely.

5.5.3 Composing Chords

With chord interactions, the process is identical to the notes, except three note on/off events are dealt with to represent the three notes that make up any given chord.

5.5.4 Composing Pitch Bend Effects

Similarly to notes and chords, when users select pitch bend and start pinching, a pitch bend MIDI event is created on the pitch bend track. In edit mode, users can move their pinched hand to move the bar up or down and hence alter the value of the pitch bend. The vertical position of the hand changes the value (between 0 and 16383). Users can then release their pinch gesture, and the pitch bend effect for that specific section will be registered on the sequencer. Composing pitch bend in these short bursts reflects the method most participants employed when experimenting with pitch bend in the requirements study. Look at Figure 5.7 to see an example of pitch bend effects drawn in editor mode.

5.5.5 Importing & Exporting MIDI

When users have created an idea, their interface may look something like Figure 5.7.

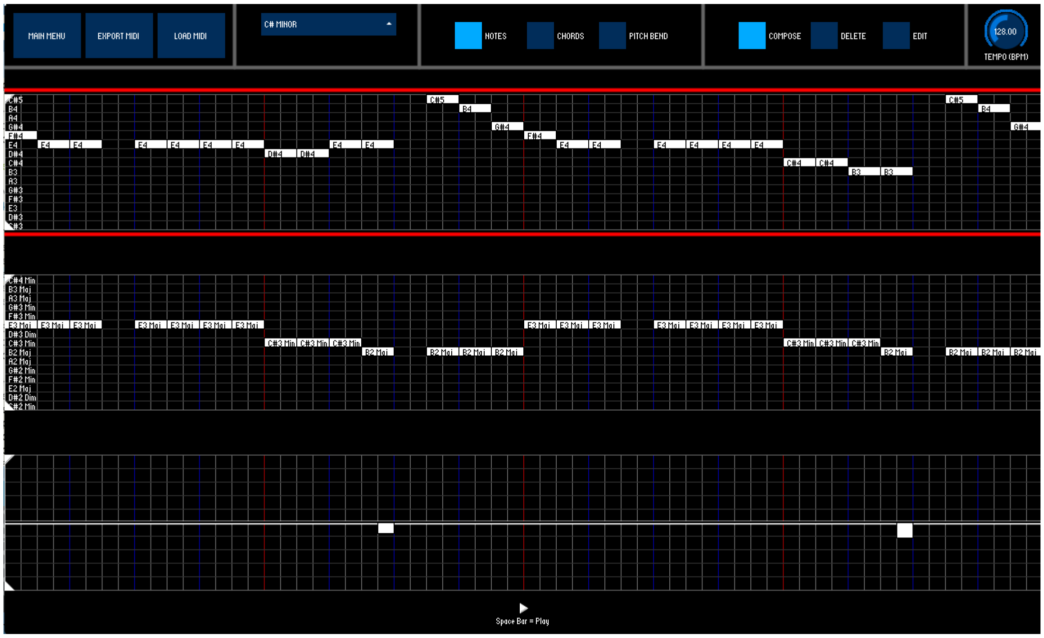


Figure 5.7: Levels by Avicii [52] in Editor Mode

The export button allows users to then save their ideas to MIDI file, which they can use elsewhere. Figure 5.8 shows that all the MIDI information (including pitch effects) from the idea in Figure 5.7 can be exported and then opened again in Logic.

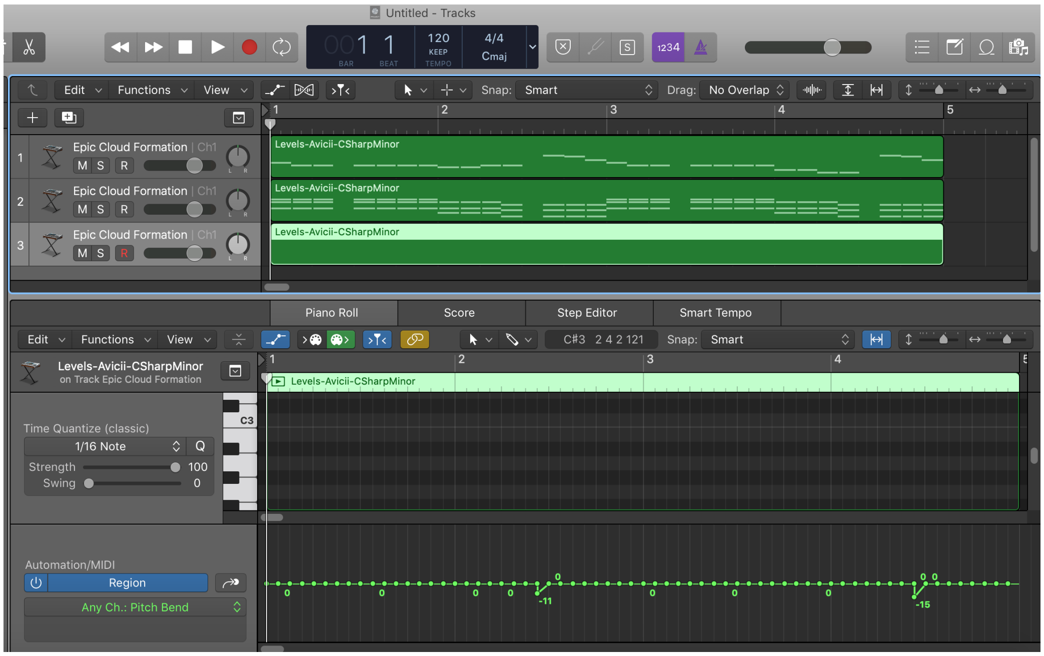


Figure 5.8: The Exported Levels by Avicii [52] MIDI File in Logic

Similarly, the import button allows users to import pre-made examples of famous melodies that are included with the Novel MIDI controller. This stems from the requirements study finding that participants desire to kick-start their creative processes by looking at examples.

5.6 Implementing Mouse Interactions

As mentioned from section 4.4, traditional mouse and keyboard interactions should also be present. They were implemented in the Novel MIDI controller by mapping the code from the *pinchStarted*, *pinchMoved*, and *pinchReleased* functions to Processing's *mousePressed*, *mouseDragged*, and *mouseReleased* functions to achieve identical functionality with a mouse instead of the pinch gesture.

Chapter 6

Evaluation

This chapter presents and explains the study that was designed and performed to evaluate the Novel MIDI controller in terms of its usability, user experience, creative fulfilment, and technical fulfilment. This evaluation study executes the fourth and final stage of the user-centred design process explained in section 2.5.1.

6.1 Purpose of the Evaluation Study

The purpose of the evaluation study was to evaluate the usability and user experience of the Novel MIDI controller with users. Specifically, there was focus on evaluating its influence regarding creativity and productivity in music composition and production. The following research questions were established to reinforce the evaluation's goals:

- How usable is the Novel MIDI controller? How does its usability compare to other MIDI controllers and interfaces?
- What user experience do users encounter with the Novel MIDI controller? How does it compare to the user experience of other MIDI controllers and interfaces?
- How do the gesture interactions affect the usability and the user experience of the Novel MIDI controller? Do they enhance creativity or productivity in music production?

- How does the Novel MIDI controller's workflow of interactivity affect creativity/productivity? How does this compare to the workflows of other MIDI controllers and interfaces?

6.2 Evaluation Study Design

To best answer the aforementioned research questions, it was decided that both quantitative and qualitative data should be gathered. As a result, this study was designed to be a mixed-methods study [91]. Observation studies, semi-structured interviews, and questionnaires were the three research methods used. The full researcher's study script for this evaluation can be seen in Appendix F.

The observation study was chosen to be the first method of evaluation because participants could be immediately exposed to the Novel MIDI controller alongside the other controllers and interfaces while performing carefully chosen activities. Then, the interview and questionnaire methods gathered insights from participants' experiences in the observation study to help answer the evaluation's research questions. In the case of the interview, gathering qualitative data was the focus. For the questionnaire, the main goal was capturing quantitative data and for it to serve as a reflective conclusion to the evaluation, where participants could reveal digestible conclusions that answer the research questions above.

6.2.1 The Observation Study

This observation study (see Appendix F) was loosely based on the observation section from the requirements study (see section 3.2.3) and carried out in a similar manner. Participants were asked to interact with the following four MIDI controller/interface combinations in all activities:

- The Novel MIDI Controller with Gestures
- The Novel MIDI Controller with Mouse Only
- Logic Pro X with Mouse Only
- Logic Pro X with MIDI keyboard

The activities were also good opportunities to measure usability metrics through the following dependent variables:

- Time taken by participants to complete activities (Speed).
- Number of errors made by each participant per activity (Accuracy).

These measurements were compared between every MIDI controller, making this study a within-subjects design, where the independent variable was the MIDI controller/interface combination participants interact with [56].

The activities themselves are designed to evaluate various features and aspects of the MIDI controllers/interfaces. Activity 1 examines controller usability for playing live music. Activities 2 and 3 examine the editing capabilities of controllers. Activity 4 focuses on understanding a MIDI controller's affect on the creative process of composition. Since users can choose what they do in this activity, it was decided that *no quantitative measurements of dependent variables would be made for activity 4*.

Due to the within-subjects design of this observation study, it was important to minimise any possibility of the learning effect, where participants gradually learn how to complete an activity the more they are exposed to it [56]. To counteract this, the Latin Squares counterbalancing technique [56] was employed. The order of what MIDI controllers participants interact with in every activity was always changed to ensure that there is no bias in speed and accuracy measurements for a controller. Figure 6.1 shows an example of a Latin Square used in this study.

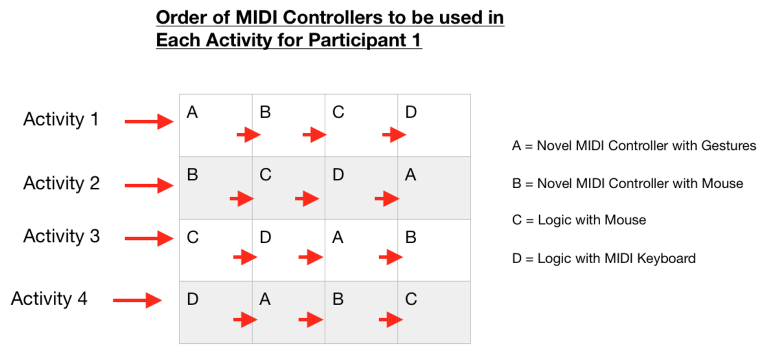


Figure 6.1: The Latin Square that Determined the Order of Partcipant 1's Controllers for Activities 1-4

6.2.2 The Interview

The evaluation interview (see Appendix F) was based on the interview designed for the requirements study (see section 3.2.2), and so the questions were worded and structured in the same way to be semi-structured and non-directed.

6.2.3 The Questionnaire

The questionnaire was made up of multiple statements about all four MIDI controllers and their usability or perceived user experience (see Appendix F). Each statement was presented to participants alongside the Likert scale shown in Figure 6.2.

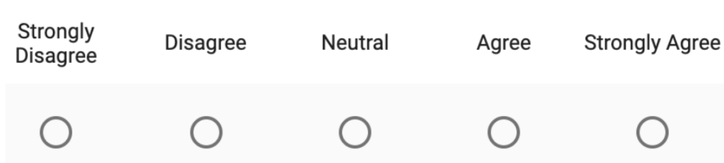


Figure 6.2: The Likert Scale Presented to Participants in the Questionnaire

6.3 Evaluation Study Findings

The evaluation studies were performed by the same five participants from the requirements study. Again, the number of five participants was deemed suitable to gain enough insight [74][75][73][54] .

Similarly to the requirements study, coding and grounded theory was again used to analyse qualitative data (see section 3.4) [90][58]. Gathered quantitative data was communicated visually via charts. No statistical analysis was performed due to the small participant group [15].

6.3.1 User Observations

Measured times for completing activities were rounded to the nearest minute.
A measured error would constitute either a wrong note being played/placed/selected.

Activity 1

Times taken to complete activity 1 on each controller are shown in Figure 6.3, and errors made on each controller are shown in Figure 6.4.

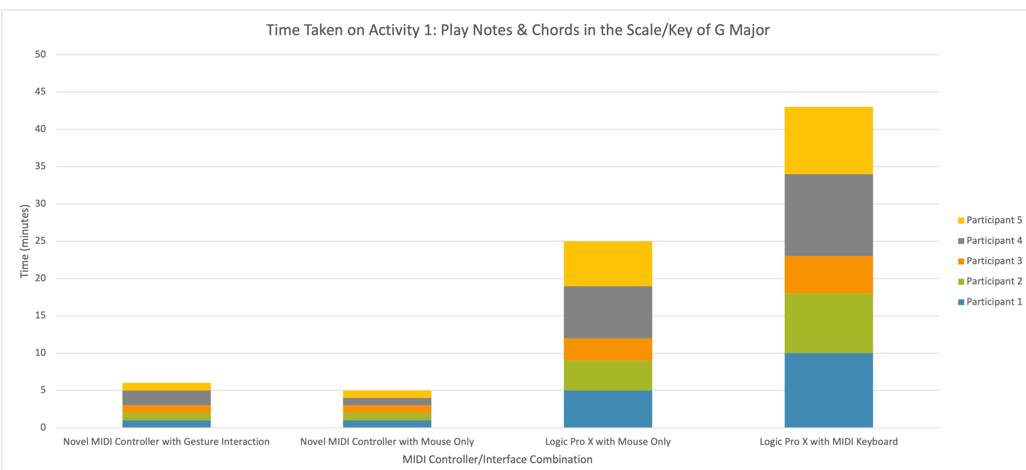


Figure 6.3: Participants' Times Taken to Complete Activity 1

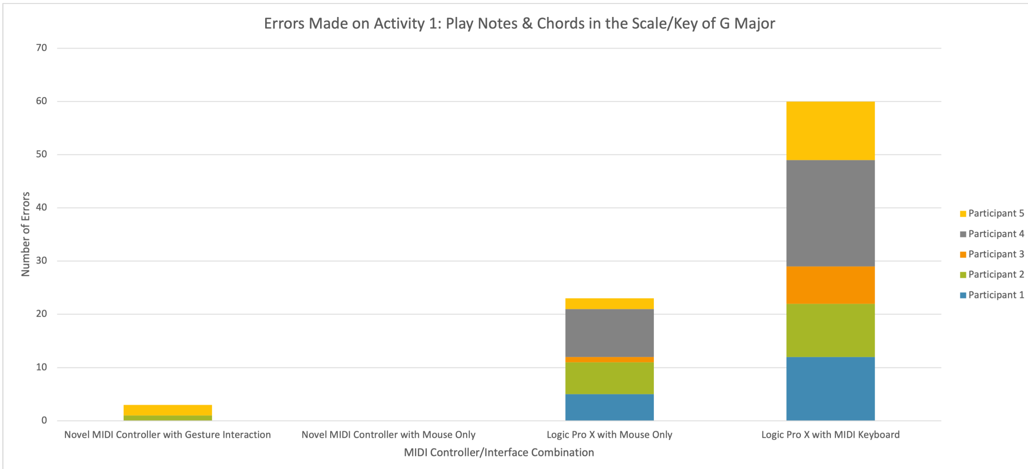


Figure 6.4: Participants' Errors Made in Activity 1

Usability of the Novel MIDI controller had clearly surpassed the other controllers when it came to live play for this user group. All participants loved how the Novel MIDI controller allowed them to play chords so easily. Strikingly, for the beginner participants the error rate had dramatically dropped, with the only errors stemming from mistimed gestures.

Participants particularly commented on how intuitive moving gesture height felt when determining pitch.

> 'Moving my hand up and down like this feels very natural.' [Participant 3]

The other stand-out observation was that participants felt connected to their play through dictating note length with the length of their pinch gestures.

> 'I love pinching for a while to keep the note playing longer.' [Participant 4]

> 'It's pretty cool to match the note length to the length of the pinch.' [Participant 5]

Furthermore, every participant expressed positive thoughts on the water ripples giving visual feedback to their actions.

Activity 2

Figures 6.5 and 6.6 show that the Novel MIDI controller with mouse input enabled the most accurate and quickest interactions when participants were tweaking the melody to Levels by Avicii [52].

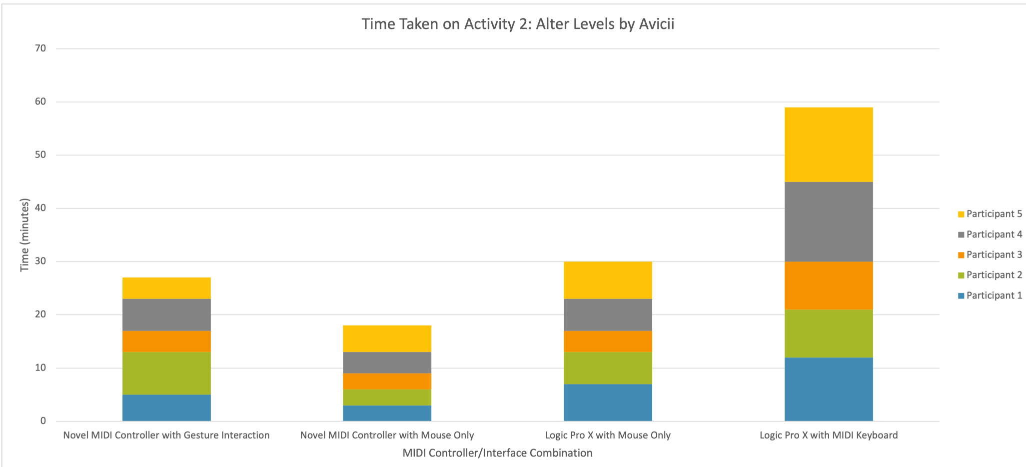


Figure 6.5: Participants' Times Taken to Complete Activity 2

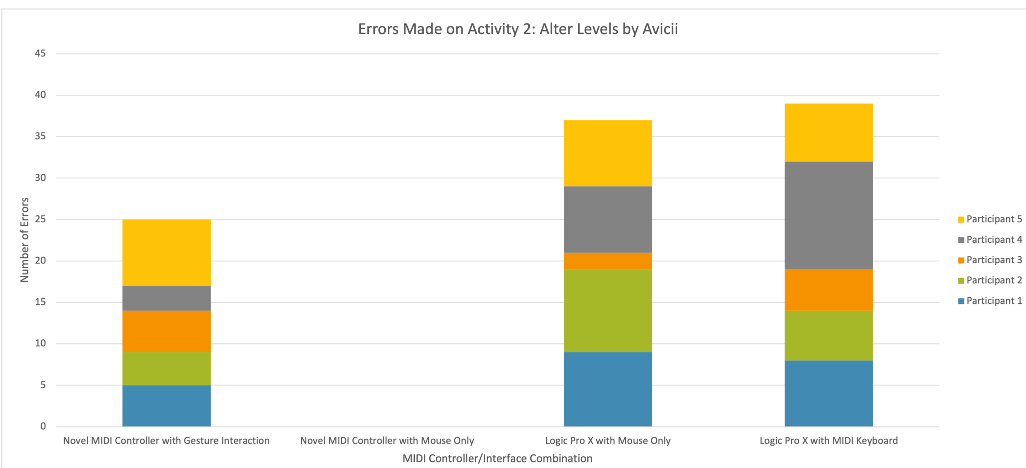


Figure 6.6: Participants' Errors Made in Activity 2

Notably, participants praised the simplicity of seeing and interacting with chords as a singular object, rather than multiple objects like in Logic or on the keyboard.

Occasionally when using gestures to pick up notes/chords and move them, participants would mistime the pinch gesture and miss the target zone. Interestingly though, this phenomenon seemed to be diminish over time and users seemingly got more focused on the task at hand, more so than with the other interaction methods.

Activity 3

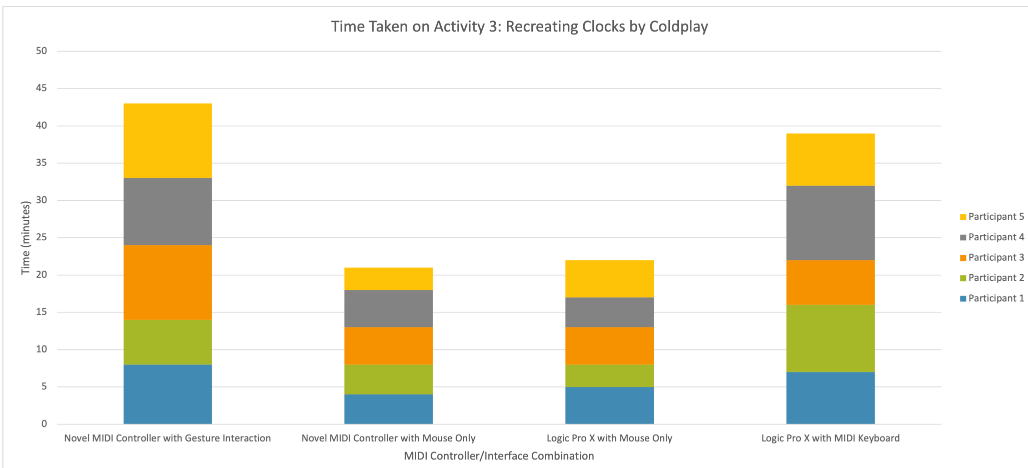


Figure 6.7: Participants' Times Taken to Complete Activity 3

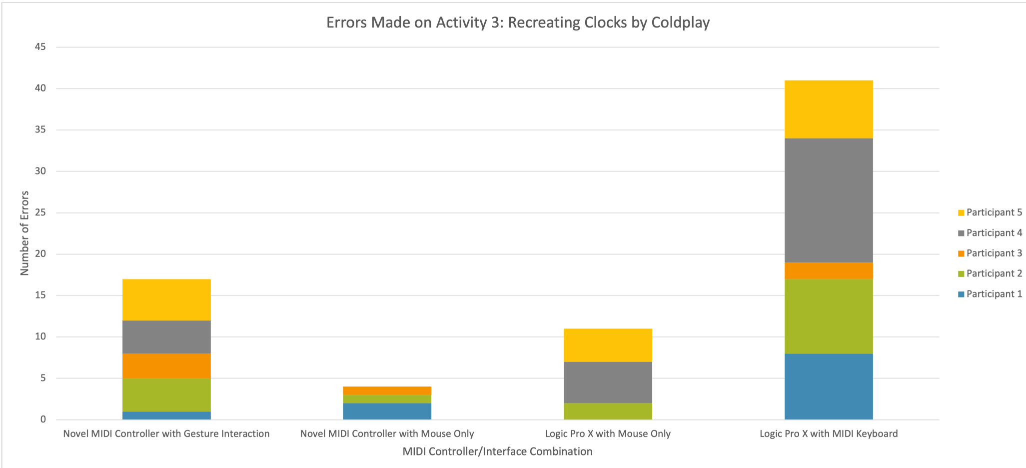


Figure 6.8: Participants' Errors Made in Activity 3

From observation, the Logic interactions started slower, and contained more errors simply due to the participants' lack of expertise in music. However, once they figured out where notes and chords were positioned in the DAW or on the keyboard, they could easily use the copy-paste function to efficiently duplicate sections of notes. This was a feature that was missing from the Novel MIDI controller, where users had to enter every note/chord. Figures 6.7 and 6.8 show similar results between the controllers, but this observation proved otherwise.

Activity 4

Every participant immediately gravitated towards using the Novel MIDI controller via gestural interaction when asked to come up with a composition. Participants 1, 3, and 5 opened up the live mode and selected a key to start playing notes and chords in based on the provided description.

> 'These descriptions for keys are very useful, and can prompt me to decide which key to use.' [Participant 1]

Participants 2 and 4 opted for the editor mode and started immediately laying down MIDI notes and chords.

By observation, it was clear that all participants had a clear understanding of how to move their hands to achieve their goals. The vertical movements for pitch were very natural.

The only participant to actively use another controller at some point was participant 3. They exported their idea to Logic, citing that they wanted to change note lengths, which isn't possible in the Novel MIDI controller.

6.3.2 Interview Responses

Here were some notable and self-explanatory responses from participants:

Responding to Question 2:

> 'My favourite was definitely the Novel MIDI controller with gestures. I just felt more connected with the creative process.' [Participant 2]

Responding to Question 3 (Advantages of Novel MIDI Controller):

> 'I really enjoyed creating with Novel, and felt like I was learning from it too. Seeing the description of each key and easily spotting patterns in chords and notes made it easier for me to express emotions while creating a melody. In Logic I felt more lost, as I couldn't comprehend what the theory meant in the same way.' [Participant 1]

Responding to Question 3.2:

> 'The Novel controller is for sure the most accessible, with either the mouse interactions or gestures.' [Participant 5]

Responding to Question 4:

> 'I most enjoy using the Novel controller with gestures when I have no idea what to write and I'm just winging it.' [Participant 3]

Responding to Question 5:

> 'To be honest, if I had a specific idea in my head, I would probably first go to Logic because I'm aware of the limitations Novel has in terms of timing, fixed note length and so on. The likelihood of a random idea matching all those specs is unlikely in my view.' [Participant 4]

Responding to Question 6:

> 'Using the Pitch Bend grid in Novel is so much easier than the pitch wheel. I feel like it allowed for much more detail. The pitch grid in Logic was just hilariously clunky by comparison as well because of all the drawing.' [Participant 1]

6.3.3 Questionnaire Responses

The questionnaire provided data representing participants' opinions on the Novel MIDI controller in the following domains.

The Live Mode Interface

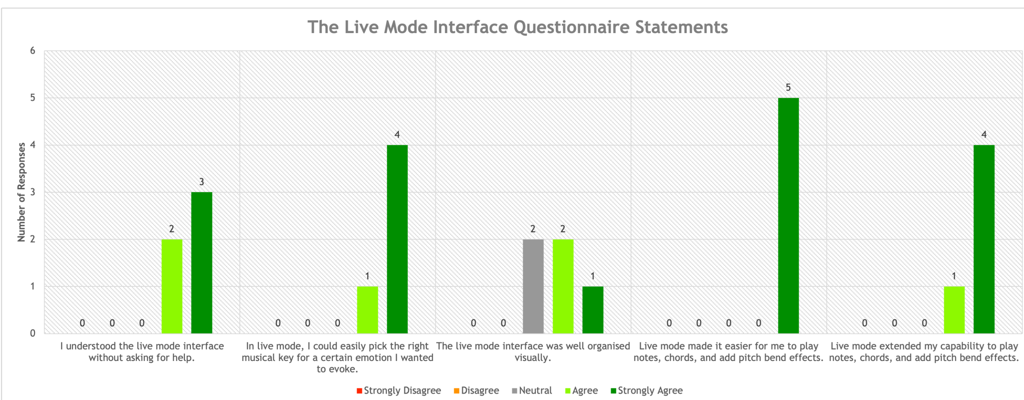


Figure 6.9: Participants' Questionnaire Responses for the Live Mode Interface Statements

Figure 6.9 confirms that participants found the interactions and features of live mode intuitive, useful, and rewarding. They especially agreed with live mode improving ease of playing notes, chords, and pitch effects.

The Editor Mode Interface

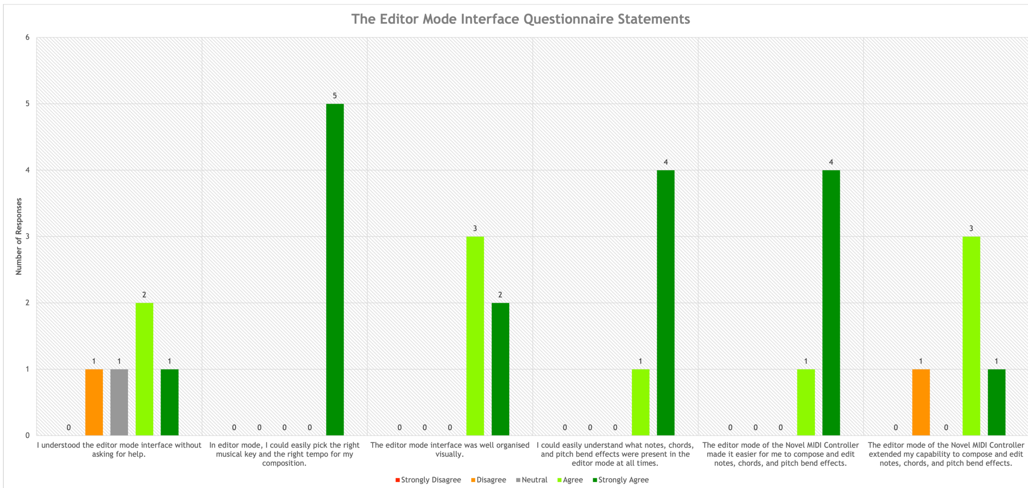


Figure 6.10: Participants' Questionnaire Responses for the Editor Mode Interface Statements

As evidenced by Figure 6.10, Editor mode clearly excelled at improving accessibility to interacting with and creating music compositions. Even though some participants were not naturally as confident when getting to grips with it, editor mode's convenience shone through.

Gesture Interactions

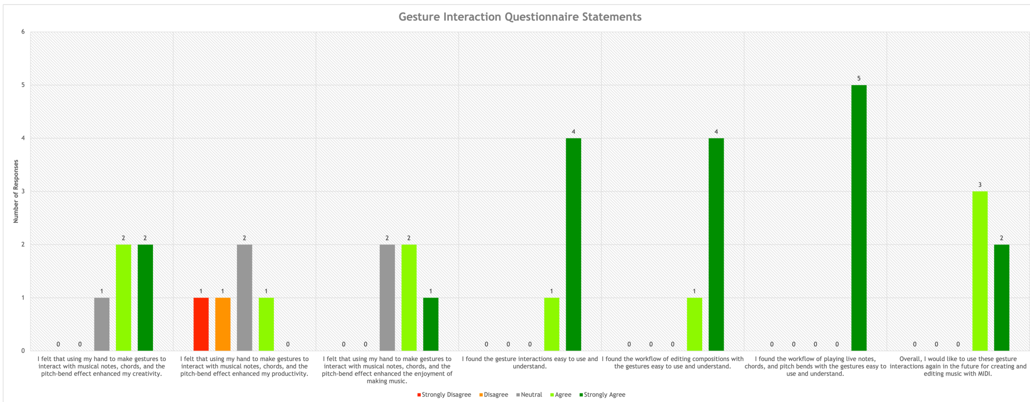


Figure 6.11: Participants' Questionnaire Responses for the Gesture Interaction Statements

According to responses illustrated in Figure 6.11, the pinch gesture interactions were not considered the most productive form of interaction by participants, but they were certainly credited with boosting creativity and enjoyment overall.

Summary of the Novel MIDI Controller

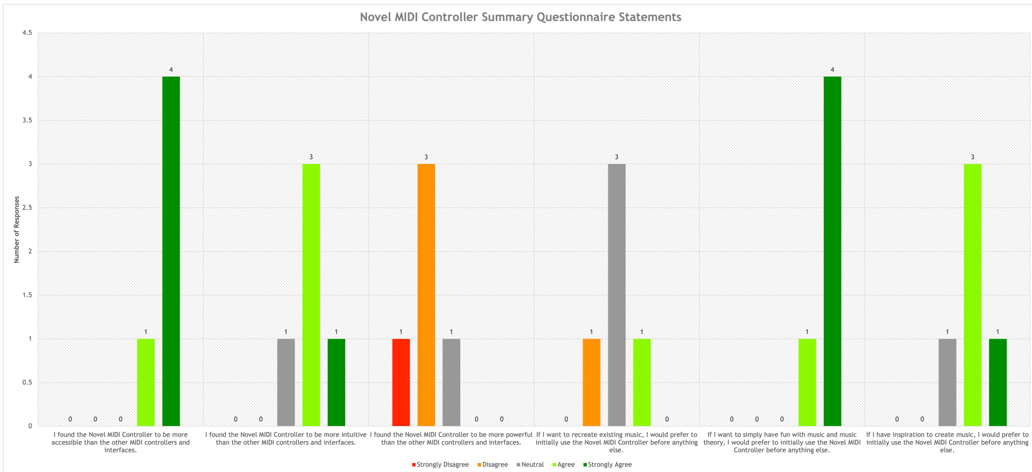


Figure 6.12: Participants' Questionnaire Responses for Novel MIDI Controller Summary Statements

When asked to give their final verdicts on the Novel MIDI controller, Figure 6.12 shows that participants found it more accessible, intuitive, and creatively inspiring. However, it was not deemed powerful enough in its technical capability to completely replace the other DAW systems tested during the evaluation.

6.4 Evaluation Summary & Discussion

From looking at all the crucial findings of the evaluation study, a few statements about the Novel MIDI controller can be made:

- Participants enjoyed generating musical ideas with the Novel MIDI controller, almost like a brainstorming tool for composition.
- Beginners and non-musicians gained more confidence for playing and composing music in the Novel MIDI controller.
- Gestures were not necessarily the most accurate or functional forms of interaction, but they were more engaging and fun.

- The interactive workflow of the Novel MIDI controller independent of gestures was appreciated by participants.

- Novel MIDI controller needs a few more key usability features implemented such as copy/paste and note-length editing to really enhance productivity for more advanced users.

Comprehensively, the Novel MIDI controller certainly broke new territory by enabling gestural interactions to not only manipulate sound effects like the MIDI controllers surveyed in section 2.2, but to also create and edit musical compositions. Furthermore, the existing work in this field (see section 2.2) had previously focused on functionality and technical capabilities, whereas the Novel MIDI controller uniquely focused on creativity and accessibility.

Chapter 7

Conclusion

Overall, the objectives that were conceived at the start of this project have been realised (please refer back to section 1.2).

Regarding the primary objectives:

1. Completing the literature review (see chapter 2) accomplished this objective and more. The MIDI specification was reviewed alongside existing MIDI controllers with an array of interactive features.

2. Reviewing gesture-based interactions in section 2.4 and exploring different themes of design during the project's design phase (see section 4.1) enabled impactful and influential research on what novel interactions could be applied to a MIDI controller.

3. The editor mode of the Novel MIDI controller application successfully allowed users to create and edit melody ideas while utilising MIDI events. Moreover, these melodies could be created and edited with the pinch gesture interactions or a mouse and keyboard.

4. The live mode of the Novel MIDI controller application successfully allowed users with any musical background to play notes or chords aloud. Furthermore, these notes and chords could be played aloud using any instrument available in an accessible DAW due to the MIDI Bus pipeline that was implemented.

5. The entire user-centred design process was successfully followed throughout this project. The user requirements study allowed user needs to be

understood, the design phase produced a novel design that was then implemented as a usable Processing application in the implementation phase which was evaluated with users in the final evaluation phase.

6. The user requirements study proved invaluable when designing and implementing a user-centred MIDI controller. This was due to the careful nature in which the study was planned. That allowed relevant insights on suitable topics such as MIDI controllers and creativity in music to be made.

Concerning the secondary objectives:

7. The evaluation study rigorously assessed many aspects of the Novel MIDI controller and its novel gestures.

8. The Novel MIDI controller allows users to customise many options including: the musical key for playing or composing melodies, playing or composing notes, chords, or pitch bend effects, and specifying the tempo for playback.

9. Multiple design recommendations can be made at the conclusion of this project. Firstly, when considering gesture interaction, it's important to design gestures that have low cognitive load. This way users will be able to get focused on their activity at hand. Secondly, when designing an intuitive MIDI controller, it's crucial to present users with bitesized tasks rather than a plethora of options at once.

Considering the tertiary objectives:

10. Users can interact with MIDI's in-built pitch bend effect through pinch gestures in the Novel MIDI controller, and the participants of the evaluation study confirmed this to be a fruitful user experience.

11. The evaluation study showed that participants with little expertise in music or its theory felt considerably less intimidated by the Novel MIDI controller compared to other controllers, and hence more inspired to create musical ideas.

7.1 Future Work & Limitations

The user-centred design process is an iterative design process. As mentioned before in section 2.5.1, this project followed one iteration of the process due to time constraints which was a big limitation of this project. With ample time, it's possible to perform multiple iterations of the whole user-centred design process and/or its individual steps. Therefore, a logical avenue for future work would involve repeating the steps of the user-centred design process outlined in this dissertation multiple times, with the aim of refining the MIDI controller design to better achieve the requirements of users. Performing the process in this way may also enable an even more robust evaluation, where multiple synthesised design ideas for gestures and so on could be evaluated against each other along with other MIDI controller systems.

The resulting MIDI controller was extremely successful within certain parameters, such as looping 4 bar melodies in 4/4 time or exclusively editing chords using 1/8th notes. To be considered more complete in the future however, the Novel MIDI controller would have to incorporate many more customisable features. The evaluation study highlighted some of these areas in the MIDI controller's design and implementation that can be improved in future work. Most notably, future work should seek to enable users to select customisable timing options, such as changing note length and chord length. Users should also be provided with copy/paste and undo/redo functionality.

Finally, future work should aim to perform the requirements and evaluation studies again with a larger number of participants. The other notable limitation of this project was the small sample size in each research study, and the reuse of the same participants from the requirements study to the evaluation. Time constraints forced this to be the case in this project.

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Appendix A

Supplementary Background Material

A.1 Sound & Digital Audio

From a physics point of view, sound is simply a variation in air pressure propagated through space, where air pressure corresponds to the number of air molecules [108]. The oscillation produced by the moving air molecules can be represented as a sound wave, as shown in Figure A.1.

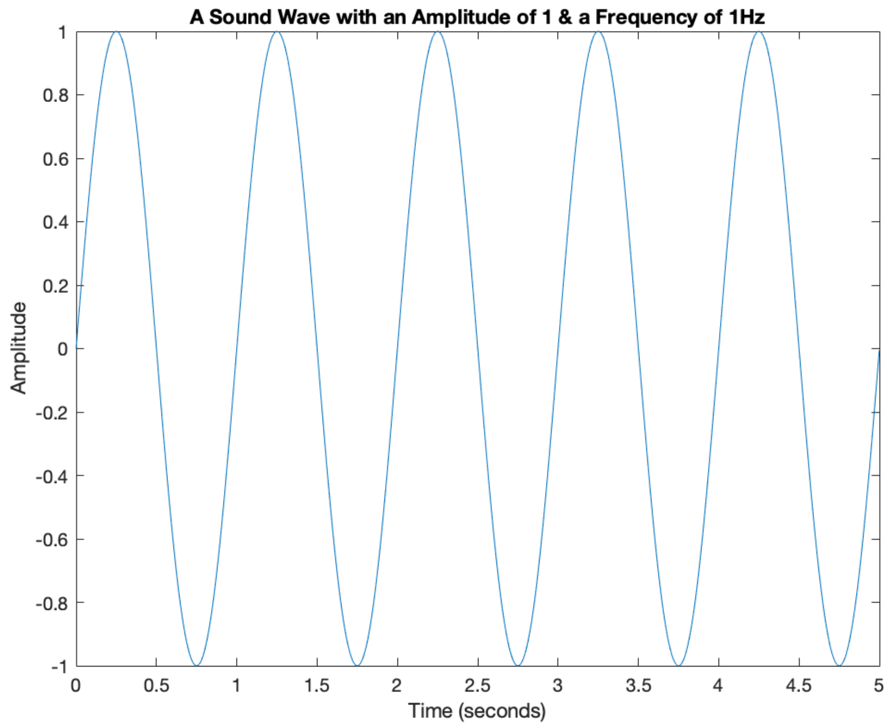


Figure A.1: A Visual Representation of a Sound Wave

It's important to note that the air molecules do not travel, but the energy from the oscillation such as that shown in Figure A.1 does indeed travel at a speed we know as the speed of sound.

The intensity and frequency (derived from the period) of the sound waves, as shown by Figure A.2 below, are the factors that can be perceptually sensed by humans to differentiate sounds in music. The period of a sound wave refers to the time taken for one full cycle of a wave to propagate. The frequency of a sound wave refers to how many full cycles of a wave are propagated per second, hence frequency is derived from the period using the following equation:

$$Frequency = 1/Period$$

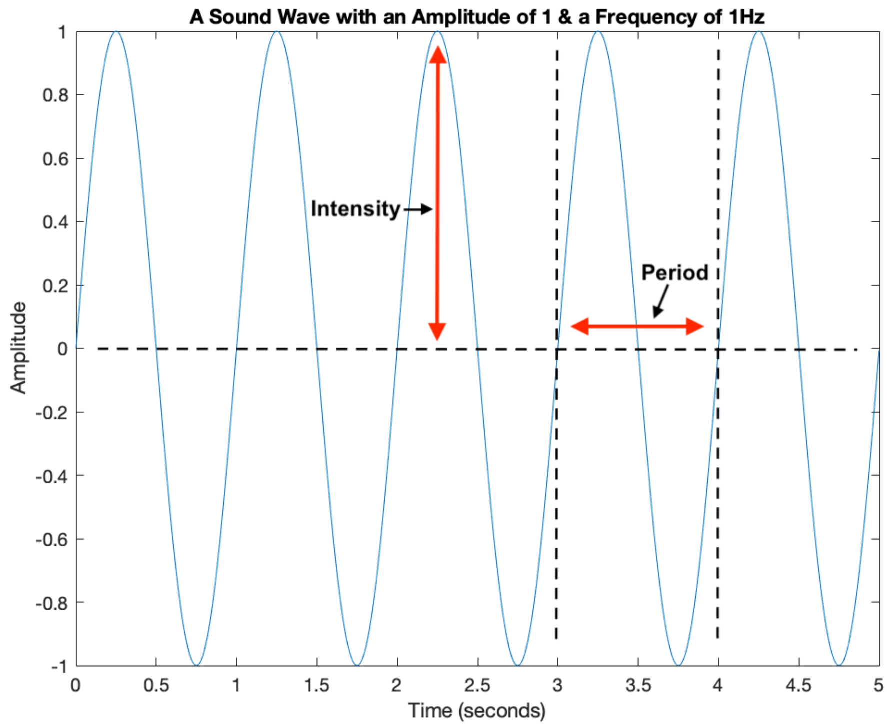
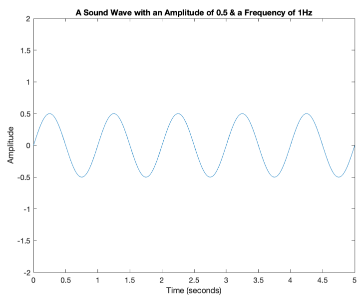
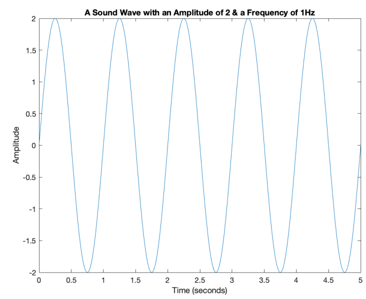


Figure A.2: The Intensity & Frequency of a Sound Wave

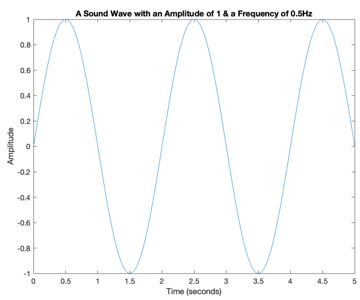
The intensity of a sound wave, or its amplitude, is perceived as loudness by humans, and the frequency of a sound wave is perceived as pitch by humans [108]. A sound wave of higher intensity is perceived as a louder sound by humans, and a sound wave of higher frequency is perceived as a higher pitched sound by humans. This is shown in Figure A.3 below.



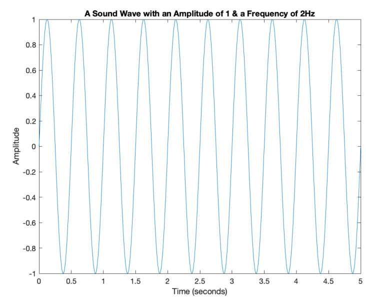
(a) Low Intensity/Quiet Sound Wave



(b) High Intensity/Loud Sound Wave



(c) Low Frequency/Low Pitch Sound Wave



(d) High Frequency/High Pitch Sound Wave

Figure A.3: Human Perception of Intensity and Frequency in Sound Waves

Sound can be represented and created in digital systems by a process known as quantisation. Quantisation means that samples are stored at discrete intensity levels over time-intervals determined by the sample frequency. Figure A.4 below shows how the analog sound wave shown in Figures A.1 and A.2 can be represented digitally via quantisation.

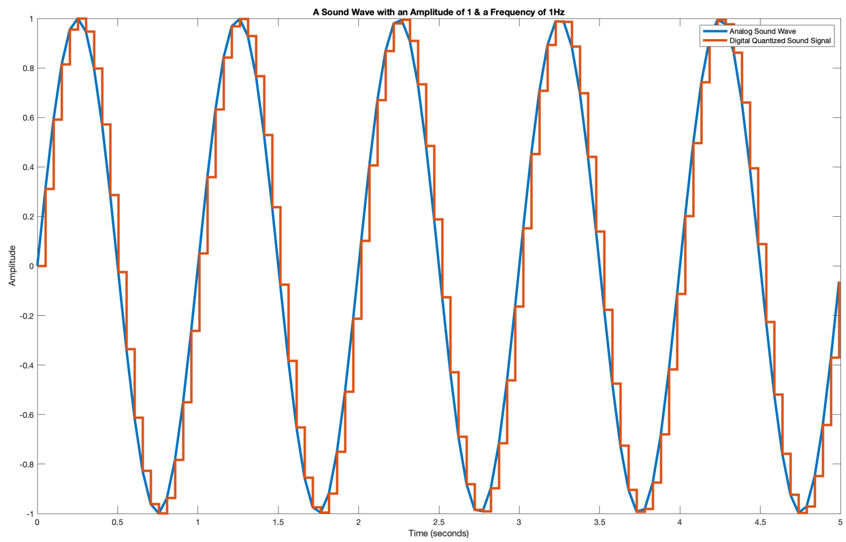


Figure A.4: The Digital Representation of a Sound Wave via Quantisation

A.2 Relevant Music Theory

Western music notations identify the pitch of a sound wave by assigning letters to the corresponding pitch called 'notes'. The letters used to denote these pitches are C, D, E, F, G, A, and B, along with their corresponding sharp(#)/flat(b) notes. A full octave consists of 12 notes as shown in Table A.1.

Musical Note	Frequency (Hz)
C4	261.63
C#4 / Db4	277.18
D4	293.66
D#4 / Eb4	311.13
E4	329.63
F4	349.23
F#4 / Gb4	369.99
G4	392.00
G#4 / Ab4	415.30
A4	440.00
A#4 / Bb4	466.16
B4	493.88

Table A.1: Frequencies of Musical Notes in the 5th Octave [96]

Each of these letters within an octave refers to their corresponding pitches within a specific frequency range. Higher octaves refer to the same notes but in a higher frequency range and vice versa.

When creating a musical composition, it is typical to do so in a particular musical key. A key is a collection of musical notes that form the basis for a composition. The collection of permitted notes for a musical key is called a scale.

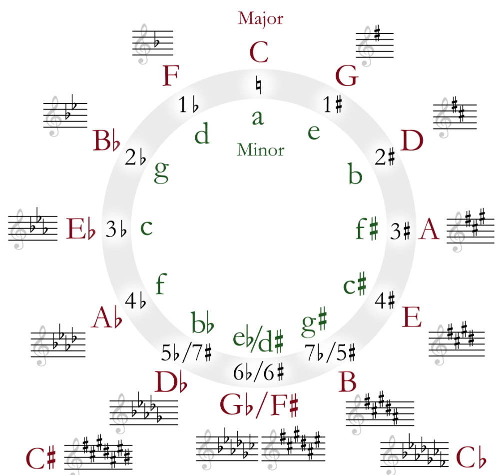


Figure A.5: Circle of Fifths Diagram Illustrating the 24 Musical Keys [10]

This theory exists because humans perceive only certain groups of notes to sound pleasant together. For example, when composing a melody in the key of C Major, only the notes of C, D, E, F, G, A and B are recommended for use. This is because these notes sound harmonious together given the tone of the C major key, which is happy and uplifting. Playing a G# note amongst these notes would suddenly jar listeners, as the pitch would not fit with the happy atmosphere encouraged by the key. Along with individual notes, there are also chords that can be played within each key. Chords are sounds that are composed of three or more individual notes. For example, the chord of C major consists of the notes C, E, and G. Every note permitted within a key has its corresponding major or minor chord depending on the key. Figure A.6 shows the chords of the C major key.

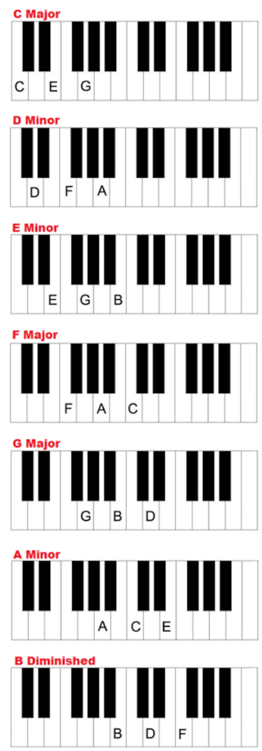


Figure A.6: Chords in the Key of C Major [18]

A.3 A Survey of Musical Instruments & Their Interactions

Throughout human history, music has always been created by producing sound from either our own bodies through our voices, or by interacting with musical instruments such as flutes or pianos. Considering conscious and sub-conscious processes that humans use to create sound is important when initially designing a new user-centred MIDI-controller.

A.3.1 Traditional Hardware Musical Instruments

Key–Based Instruments

Pianos and other key-based instruments are extremely popular mainly due to their interaction. To play these instruments, musicians simply press the keys with their fingers.

Figure A.7: A Piano [6]

An important part of this interaction that differs from other instruments is the logical layout of the keys presented to pianists. Keys are laid out linearly in the order of their pitch, making it very straightforward for a human to quickly see and feel the patterns of pitch in melodies.

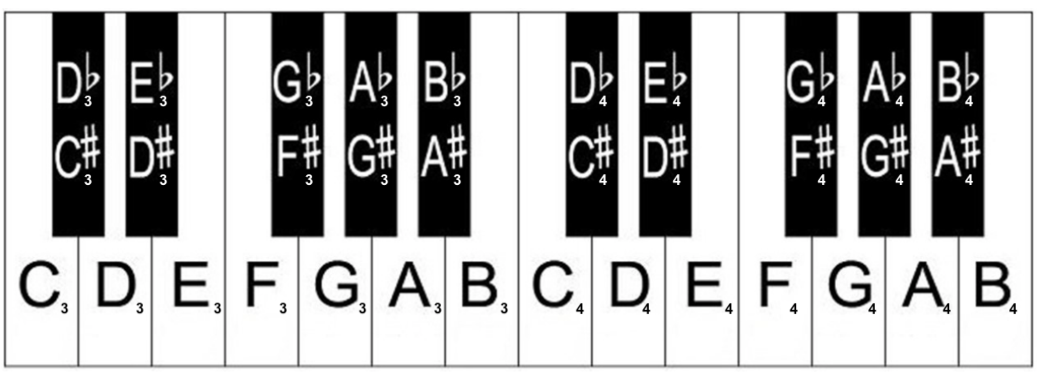


Figure A.8: Piano Keys & Notes

This contrasts sharply to the interface provided by other instruments, where the order of differing pitches and octaves may not be so obvious (see the guitar below). Additionally, players can press keys at differing strengths to achieve different feelings and emotions in music.

String–Based Instruments

The typical mode of interaction for playing string-based instruments involves vibrating strings with one hand, and then anchoring those strings with the other hand in order to change the string lengths.

From a human perspective, interpreting pitch is slightly more complicated with string-based instruments compared to the linear scale of piano keys. Changing a string's length while it is vibrating will produce sound waves of different pitches. However, string length is a limiting factor. The full length of a string should always be within reach of a musician. To overcome this, multiple strings of different properties are offered, to provide differing ranges of pitch. As a result, chords on a guitar are typically played in non-ordered locations on a fretboard.

A unique interaction that string-based instruments can offer is that musicians can finely control the pitch of their performances by subtly moving the strings they are vibrating with their anchoring hand. This extra movement can allow musicians to achieve detailed pitches between traditional notes. Audibly, this interaction sounds like the musician is 'bending' the pitches of their notes and is an effect called 'pitch bend'.

Woodwind Instruments

Woodwind instruments are instruments that create sound by forcing air to contact sharp surfaces, such as a small hole or reed. In flutes, the pitch of a sound depends on the positions of open holes along a tube.

Figure A.9: Musician Playing a Flute [46]

The players of woodwind instruments can finely control the velocity of air passing through the instrument by altering their breath. Furthermore, they can minutely alter their finger position/strength on a hole to alter the sound produced. A combination of these factors can 'bend' pitch and/or alter the velocity/power of each note, adding plenty of character to any musical performance.

A.3.2 The Human Voice

The human voice is an instrument with the most intuitive form of interaction and it is an instrument we learn to acutely control throughout our entire lives. Humans control sound from the vocal tract by managing breath from the lungs, contracting muscles in the larynx, and contracting articulator muscles along the vocal tract [110]. Each of these mechanisms can be finely controlled to produce a wide variety of pitches and sounds, from normal speech, to crying, and of course singing. The voice has a similar mechanism to woodwind instruments for producing different sounds, hence effects such as pitch bend can also be achieved.

A.3.3 Technological Instruments

Musical instruments can of course also exist outside the world of hardware-only devices. Many instruments can utilise technological and software components to aid their properties, which can result in fascinating user interactions.

Analog and Digital Synthesisers

Synthesisers are instruments that generate sound by 'synthesising' sound waves. The technique to achieve this dates back to the paper titled "A New Form of Harmonic Synthesiser" authored by James Robert Milne in 1906 [62]. This paper introduced the dawn of analog synthesisers such as the Hammond Organ [16] and the Trautornium [101]. Digital synthesisers use digital signal processing techniques to generate sounds electronically as digital wave forms with quantisation (see section A.1).

Many analog and digital synthesisers utilise keyboard-style modes of interaction for users to play sounds. However, these instruments provide users with plenty of scope to craft their own sounds before and during live performance. In analog synthesisers, users can create sounds by physically connecting wires to and from components.

Figure A.10: The Moog Analog Synthesiser [67][12]

In digital synthesisers, sounds are typically created via menu interactions and fiddling with dials and knobs around the keys.

Figure A.11: The Korg M1 Digital Synthesiser [99][20]

The Theremin

The theremin is an electronic instrument that is played without physical contact. It was invented by Leon Theremin in 1920 and is unique among instruments because of its user interaction [33]. Users can play different audible pitches by moving one of their hands to different positions in free air around the instrument. Their other hand is used to control volume in the same manner.

Figure A.12: Leon Theremin playing the Theremin instrument [7]

Software Synthesisers

These synthesisers are intangible, as they exist only as software in a computer. Typically, users interact with them via traditional mouse and keyboard actions such as button clicks and mouse drags.

Figure A.13: The interface of the Sylenth1 software synthesiser [97]

Appendix B

Ethics Approval Form

University of St Andrews | FOUNDED 1413

School of Computer Science Ethics Committee

28 July 2022

Dear Joseph,

Thank you for submitting your ethical application which was considered at the School Ethics Committee.

The School of Computer Science Ethics Committee, acting on behalf of the University Teaching and Research Ethics Committee (UTREC), has approved this application:

Approval Code:	CS16446	**Approved on:**	28.07.22	**Approval Expiry:**	28.07.27
Project Title:	Designing and Implementing a Novel MIDI Controller using a Leap motion gesture interface through the User-Centred Design Process.				
Researcher(s):	Joseph Cameron				
Supervisor(s):	Mr Kenneth Boyd				

The following supporting documents are also acknowledged and approved:

1. Application Form
2. Participant Information Sheet
3. Participant Consent Form
4. Participant Advert
5. Representative Questions

Approval is awarded for 5 years, see the approval expiry data above.

If your project has not commenced within 2 years of approval, you must submit a new and updated ethical application to your School Ethics Committee.

If you are unable to complete your research by the approval expiry date you must request an extension to the approval period. You can write to your School Ethics Committee who may grant a discretionary extension of up to 6 months. For longer extensions, or for any other changes, you must submit an ethical amendment application.

You must report any serious adverse events, or significant changes not covered by this approval, related to this study immediately to the School Ethics Committee.

Approval is given on the following conditions:

- that you conduct your research in line with:
  - the details provided in your ethical application
  - the University's Principles of Good Research Conduct
  - the conditions of any funding associated with your work
- that you obtain all applicable additional documents (see the 'additional documents' webpage for guidance) before research commences.

You should retain this approval letter with your study paperwork.

School of Computer Science Ethics Committee
Dr Juan Ye/Convenor, Jack Cole Building, North Haugh, St Andrews, Fife, KY16 9SX
Telephone: 01334 463252 Email: ethics-cs@st-andrews.ac.uk

Yours sincerely,

Wendy Boyter

SEC Administrator

Appendix C

Participant Information Sheet

Participant Information

Designing and Implementing a Novel MIDI Controller through the User-Centred Design Process.

Joseph Cameron, Kenneth Boyd

University of St Andrews

What is the study about?

This study is being conducted as part of our group's study of Interaction Design at the School of Computer Science, University of St Andrews.

Why have I been invited to take part?

We invite you to participate in a user study because you are someone who might use a product / service we are interested in. We are seeking adults who are over the age of 18.

Do I have to take part?

This information sheet has been written to help you decide if you would like to take part. It is up to you and you alone whether you wish to take part. If you do decide to take part you will be free to withdraw at any time without providing a reason, and with no negative consequences.

What would I be required to do?

We will ask you to answer several questions about topics that are relevant to our project. You can choose not to answer any of the questions if you do not wish to. You will also be asked to complete a series of tasks that are relevant to you as a user or as an expert. We might ask you to use an existing system related to design brief the students are working on. We will observe and record you as you use an existing system or carry out tasks related to the project. We might ask you to simultaneously describe "thinking aloud" what you are doing and why.

Meetings will take place in person or online (using video conferencing software). You can choose which of these you prefer.

Are there any risks associated with taking part?

There are no risks associated with this research that exceed those of everyday life. We will collect data as part of this study that contains potentially identifying information about you. However, this raw data will only be available to the researchers.

Informed consent

It is important that you are able to give your informed consent before taking part in this study and you will have the opportunity to ask any questions in relation to the research before you provide your consent.

What information about me or recordings of me ('my data') will you be collecting?

We will be collecting the answers you provide as part of the online questionnaire or interviews. With your consent we may audio- and video-record the meetings taking place. The data we will be collecting could be used to identify you (e.g., through your voice or face visible in the video recordings).

Data will be anonymized prior to any reports or presentation (e.g., by transcribing the audio and video recordings).

Statements will be modified to omit content that may be used to reveal the identity of participants.

Should you accidently share any content that you did not wish to share such as screen content, you can ask us to delete any record of the content which may be a section of video recording.

No data about participants being from protected categories will be collected.

How will my data be securely stored, who will have access to it?

The raw data will be stored in a **FULLY IDENTIFIABLE** form until 16/08/2022. Your data will be stored on the University of St Andrews' Microsoft account and only the researchers listed above will be able to access it.

How will my data be used, and in what form will it be shared further?

Your data will be used to inform design projects. The results will be finalised by approximately 16/08/2022 and written up as part of reports / published papers. Data collected from recordings will be transcribed and raw data deleted 16/08/2022. Statements may be modified to omit content that reveals the identity of you or others. Your data will be in an **ANONYMISED** form, which means that no-one could use any reasonably available means to identify you from the data. Only anonymised data will be included in reports.

When will my data be destroyed?

Your data will be destroyed at the end of the project, specifically before *16/08/2022*.

Will my participation be confidential?

Your participation will be known to the study authors.

Use of your personal data for research and data protection rights

The University of St Andrews (the 'Data Controller') is bound by the UK 2018 Data Protection Act and the General Data Protection Regulation (GDPR), which require a lawful basis for all processing of personal data (in this case it is the 'performance of a task carried out in the public interest' – namely, for research purposes) and an additional lawful basis for processing personal data containing special characteristics (in this case it is 'public interest research'). You have a range of rights under data protection legislation. For more information on data protection legislation and your rights visit https://www.st-andrews.ac.uk/terms/data-protection/rights/. For any queries, email dataprot@st-andrews.ac.uk.

You will be able to withdraw your data within one week of the project starting, specifically 18/07/2022 at 12:00pm. If your data is anonymised, we will not be able to withdraw it, because we will not know which data is yours.

Ethical Approvals

This research proposal has been scrutinised and subsequently granted ethical approval by the University of St Andrews Teaching and Research Ethics Committee.

What should I do if I have concerns about this study?

In the first instance, you are encouraged to raise your concerns with the researcher. However, if you do not feel comfortable doing so, then you should contact my Supervisor or School Ethics Contact (contact details below). A full outline of the procedures governed by the University Teaching and Research Ethics Committee is available at https://www.st-andrews.ac.uk/research/integrity-ethics/humans/ethical-guidance/complaints/.

Contact details

Researcher(s)	Joseph Cameron, Kenneth Boyd	**Supervisor(s) / School**	School of Computer Science University of St Andrews. kmb6@st-andrews.ac.uk
		Ethics contact	ethics-cs@st-andrews.ac.uk

Appendix D

Participant Consent Form

Consent Form

Designing and Implementing a Novel MIDI Controller through the User-Centred Design Process. Joseph Cameron and Kenneth Boyd (School of Computer Science)

The University of St Andrews attaches high priority to the ethical conduct of research. We therefore ask you to consider the following points before signing this form. Your signature confirms that you are willing to participate in this study, however, signing this form does not commit you to anything you do not wish to do and you are free to withdraw your participation at any time.

Please initial box

- I understand the contents of the Participant Information Sheet (marked 'PIS_11/07/2022_1_Designing and Implementing a Novel MIDI Controller through the User-Centred Design Process'). ☐
- I have been given the opportunity to ask questions about the study and have had them answered satisfactorily. ☐
- I understand that my participation is entirely voluntary and that I can withdraw from the study at any time without giving an explanation and with no disbenefit. ☐
- I understand the precautions that will be in place to reduce the risk of coronavirus and how I can help reduce this risk. ☐
- I understand who will have access to my data, how it will be stored, in what form it will be shared, and what will happen to it at the end of the study. ☐
- I understand that I will be able to withdraw my data before 18/07/2022 at 12:00pm, and I understand that if my data has been anonymised, it cannot be withdrawn. ☐
- I agree to take part in the above study ☐

Photographic images / audio recordings / video images

I understand that part of this research involves recording images/audio/video data. These will be kept securely and stored separately to any identifiable information, i.e. consent forms and questionnaires.

- I agree to being audio recorded and to being filmed. ☐

I confirm that I am willing to take part in this research

	Print name	Date	**Signature**
Participant			
Person taking consent			

Appendix E

User Requirements Study Researcher Script

<u>User Requirements Study Interview Script & Observation Activity Script</u>

<u>Screener</u>

Participants were selected based on a simple screener that consisted of 5 questions:

1. Are you aged over 18?
2. What is your background regarding work and/or studying?
3. Do you enjoy listening to, or playing, music?
4. Are you at all interested in creating musical compositions or sounds?
5. Have you ever used/interacted with MIDI (Musical Instrument Digital Interface)?

<u>Interview Script</u>

First, I introduce myself and the participant introduces themselves.

1. Do you play any musical instruments?
    1. If so, which instruments do you play?
        1. Why do you enjoy playing those instruments?
        2. Are there any other instruments you would be interested to start playing or try? Why?

2. What genre(s) of music do you enjoy listening to (or playing (depends on previous answer to Q1))?
    1. What specific aspects of that genre capture your attention? Do you focus on the melody/ chord progressions/rhythm/lyrics? Explain further.
    2. What happens when you listen/play that music? Take me inside your brain/body and describe what's going on.
    3. Have you ever noticed your instinctive/natural reactions when you listen to/play those genres of music?
        1. Do you naturally react physically by dancing/gesturing?
        2. Do you naturally react emotionally/mentally by thinking of certain memories/thoughts?
    4. What are some of your favourite songs? How would you convey these songs/genre(s) of music we discussed before to a deaf person? We can play the music to give you a reference.
        1. How would you do this without your hands? How effective do you feel it is to not use your hands?

3. Have you ever attempted to create an original musical composition, song, or lyrics?
    1. If so, can you take me through the process you employ to create the song/composition?
        1. What was enjoyable about that process?
        2. What was productive/rewarding about that process?
        3. What was not enjoyable about that process?
        4. What was frustrating/counter-productive about that process?
        5. Did you ever feel like your creativity was encouraged and/or hindered during that experience? Explain further.
    2. If not, can you describe the steps you would take to create a new musical composition/ song?
        1. Which of these steps do you feel is most important to accomplish?
        2. Which of these steps do you feel is most challenging to accomplish?
        3. Which of these steps do you feel is most straightforward to accomplish?

4. What form of technology do you use most on a daily basis?
    1. What function is that technology used for? Explain.
    2. What do you like about that technology? Explain.
    3. What do you dislike about that technology? Explain.

5. Can you recall any particularly notable interactions with technology within recent memory?
   1. Any particularly enjoyable interactions with technology within recent memory?
   2. Why was it so enjoyable/memorable?
   3. Any particularly frustrating interactions with technology within recent memory?
   4. Why was that experience so frustrating?

6. Similarly, can you recall any notable interactions with everyday objects within recent memory?
   1. How did your body interact/achieve the desired task?
   2. Why was that experience enjoyable?
   3. Why was that experience so frustrating?
   4. Examples of prompts to give if participants are not giving any examples: Do you drive? How does your body operate while driving? Do you sow? How does your body operate a traditional sowing machine? What do enjoy about this? What frustrates you about this?

7. While thinking of your previous experiences with technology, can you ever recall a scenario where you wished for a certain feature in the moment, but it was not available?
   1. Elaborate further on this experience, what your desired feature was, and how it relates to the problem.

8. Have you ever used technology for the purpose of producing/playing music? Music technology includes playing sounds on a computer, or using a MIDI keyboard etc.?
   1. If so, can you describe the most enjoyable aspects of this experience? Why? Explain further.
   2. If so, can you describe the least enjoyable aspects of this experience? Why? Explain further.
   3. If not, that is absolutely fine! You will have the opportunity to interact with music production tech etc later (a digital audio workstation) later. In the meantime, could elaborate on any features/interactions you would wish to see in such a system?

9. Have you ever interacted with technology via only gestures? Have you ever interacted with a Kinect etc…?
   1. If so, what did you enjoy about it?
   2. If so, what did you not enjoy about it?

If this participant is doing the observation activities on another day, conclude the session, thank them for their time, answer any questions, and agree on a later time to do the observation activities.

<u>*Observation Activities Script*</u>

These activities are designed to allow the interviewer (me) some insight into what a user actually does and experiences when interacting with existing MIDI interfaces for music production.

Furthermore, these observation exercises will allow users to explain to me what they are thinking at all times when going through a certain process, as I will prompt them to do so. If a user mentions an interesting topic spontaneously during the activity, it would also be possible for this exercise to take on the same style of an interview about that topic on the spot.

If a user ever has any difficulty to do something, take that as an opportunity for them to explain why it's difficult, and what they would want in this situation instead. Make the participant feel comfortable with this notion as well.

Activity 1 (Convey music visually, as if you're conveying it to a deaf person):

I have a selection of music and songs that I'm going to play for you. The five songs I will play are: Piano Man by Billy Joel, Chariots of Fire by Vangelis, Summer by Calvin Harris, Peer Gynt Suite No. 1 by Edvard Grieg, and Take Five by Dave Brubeck. I would like you to try and convey that music to a deaf person. What movements, colours, or moods would you use to convey it? Get creative with it.

Activity 2 (Recreate the melody to Happy Birthday and Twinkle Twinkle Little Star in Logic by drawing the melody):

We're going to open up a digital audio workstation application called Logic. Are you familiar with what a DAW is? (If not explain). Go to the piano roll. If they can't find it, show them were it is. Get an idea of the participant's initially feeling for the application. Do they know where the project tempo is? Do they know where to get instrument sounds etc?

Now that you are familiar with the piano roll, can you recreate the melody behind Twinkle twinkle little star? Do you know the song? Shall I play the melody for you? If you want to add chords, show me how you would do that.

Now repeat this process with Happy Birthday.

Continuously ask the participant to elaborate on what they like/dislike about the workflow.

If the participant is getting on really well at this stage, perhaps invite them to recreate melodies of their favourite songs as well.

Activity 3 (Recreate the melody to another famous song of the participant's choice using a MIDI keyboard):

You now have a MIDI keyboard in front of you. This is another popular way of entering music notes/MIDI data to the computer. Play around with the keyboard and tell me if you notice any cool features with it.

What happens when you press harder on the keys? Do the notes in the piano roll change colour?

Prompt the user to play with features like the pitch bend wheel if they don't seem to notice it.

Continuously ask the participant to elaborate on what they like/dislike about the workflow.

Now, pick a famous song, any song that you have mind and attempt to recreate its melody/chord progression with the MIDI keyboard.

Activity 4 (Create your own musical composition):

Now that you have attempted to recreate some famous melodies using either the Logic application on its own, or the MIDI keyboard, let's have a go at creating an original composition/song? You can use any workflow you like? Ask the participant why they are using or not using certain pieces of equipment during this process.

Ask the participant to always explain what they are thinking out loud when creating the music or interacting with aspects of the application/MIDI keyboard. This way, I hope to notice trends that people subconsciously follow when creating/producing music with these forms of technology.

Conclusion

Thank you so much for taking part in this study, and I hope you had fun along the way as well! Formally conclude the session, thank the participant for their time. Any questions? Answer any questions the participant may have.

Appendix F

Evaluation Study Researcher Script

Evaluation User Study Researcher Scripts

Overview

Participants will be presented with tasks and activities to complete using 4 main modes of interaction:

1. My Novel MIDI Controller with Touch-Free Gesture Interactions
2. My Novel MIDI Controller with Traditional Mouse & Keyboard Interactions
3. Logic Pro X DAW Piano Roll with MIDI Keyboard Interactions
4. Logic Pro X DAW Piano Roll with Traditional Mouse & Keyboard Interactions

The order of the controllers used to perform these tasks will be different to reduce the skill transfer effect. The order of each activity will be determined from the Latin Squares method.

Following the activities, each participant will answer some questions from a semi-structured interview and answer some questions in a short questionnaire. The observations and responses will be used to evaluate the performance of my Novel MIDI Controller, with some insight into how it compares to traditional MIDI controllers such as keyboards and DAWs like Logic Pro X as well.

Observation Activities Script

These activities are designed to allow the observer (me) some insight into what a user actually does and experiences when interacting with the various MIDI controllers and interfaces for music production.

Furthermore, these observation exercises will allow users to explain to me what they are thinking at all times when going through a certain process, as I will prompt them to do so. If a user mentions an interesting topic spontaneously during the activity, it would also be possible for this exercise to take on the same style of an interview about that topic on the spot.

If a user ever has any difficulty to do something, take that as an opportunity for them to explain why it's difficult, and what they would want in this situation instead. Make the participant feel comfortable with this notion as well.

Activity 1 (Play all the notes and chords in the G major scale/key):

I want you to play all the notes in the G major scale. Now, can you play all the chords in the G major key? Obviously, I shall provide guidance if the participant does not know the G major scale/key notes and chords.

Next I want you to make a recording of you playing all the notes in the G major scale.

Let's play the recording on loop. Now make an attempt at shifting the pitch of notes playing in realtime.

Get Quantitative Data for this by timing how long this takes. Also measure how many errors were made.

Continuously ask the participant to elaborate on what they like/dislike about the workflow.

Activity 2 (Load up an existing composition and then alter it (Alter Levels by Avicii)):

I have the MIDI file for the song Levels by Avicii. If the participant does not know the song, play it for them.

First, I would like you to load up the MIDI file into the interface (either the Logic Pro X DAW, or my Novel MIDI Controller app). Create a loop to play those 4 bars again and again.

Next, I would like you to simply play the MIDI and try and explain any patterns that you notice to me. Can you tell me what chords are played throughout the music? Can you tell me what the highest pitched note is? Can you tell me what key/scale the song is in?

Can you tell me what tempo the song is in? The tempo of the song is 128 BPM. Now, can you change the tempo to 120 BPM?

Now, you're going to alter this composition slightly. I would like you to first alter the top notes. Move the first F# to a D#. Move the first C#s to F#s. For the descending notes from C# to F#, I want you to flip them horizontally. Next, scan along to the C#s and move to up to As. Move the Bs up to G#s. Delete the next C# and instead add an F# in its place. Flip the last two notes horizontally. Take a listen. Sounds pretty weird? Next, you're going to change the chords to make it sound better. Try and change the C# minor chords to F# minor chords. Change the 1st and 5th B major chords up to G# minor chords. Play again. It's sounding a bit better, but the pitch bends don't seem to gel anymore. Turn the first pitch bend into a positive pitch bend that's small. Add some small positive pitch bends to the second half of each B2 major chord in the second bar. Add some small negative pitch bends to the second half of each F# minor chord in the fourth bar. Now play the track. How fun/easy was that to alter?

Get Quantitative Data for this by timing how long changing the notes/chords/pitch-bends this takes. Also measure how many errors were made in each.

Continuously ask the participant to elaborate on what they like/dislike about the workflow.

Activity 3 (Recreate an existing composition (Recreating Clocks by Coldplay)):

We're going to recreate an existing song in the key of F Minor, with a tempo of 131 BPM.

Adjust the tempo to 131 BPM. Now, enter 8th note D# chords for one bar. Next enter A# minor chords of the same length for two bars. Now, enter F minor chords of the same length for one bar. Loop this section (4 bars) and play it. If you're curious to hear the music as you're creating it you can leave the loop playing while we put notes in. Recognise it?

Now, we're going to add the melody. Enter an 8th note D# in a higher octave at the start. All notes will be the same length and will follow each other. Next, add a lower A# note followed by an even lower G note. Repeat this pattern until the end of the bar. Notice that the last G note is cut off. Now at the start of the second bar, enter a C# note, followed by a lower A# note, followed by an even lower F note. Repeat this pattern until the end of the second bar like before, where the last F note is dropped. Now, the third bar of notes is exactly the same as the second bar, so add all those same notes again. At the start of the fourth bar, add a C note followed by a lower G# note, followed by an even lower F note and repeat until the end of the bar where the last F note is dropped. That's Clocks by Coldplay!

Get Quantitative Data for this by timing how long adding the notes/chords takes. Also measure how many errors were made in each segment (initial setup, adding notes, and adding chords).

Now that you have recreated a famous song, you can pick any song you like and we can have a go at recreating it if you like?

Continuously ask the participant to elaborate on what they like/dislike about the workflow.

Activity 4 (Create your own musical composition):

Now that you have attempted to play notes and chords, and recreate some famous melodies, let's have a go at creating an original composition/song? You can use any workflow you like. You may start from scratch or load up one of the existing MIDI files as a start point. Ask the participant why they are using or not using certain features during this process.

Ask the participant to always explain what they are thinking out loud when creating the music or interacting with aspects of the MIDI controller/application. This way, I hope to notice trends that people subconsciously follow when creating/producing music with these forms of technology.

Now at this stage, the participant would perform the tasks again on different controllers with different interactions until they have tried all four. After trying all four, the participant is then invited for a quick follow-up interview.

Interview Script

1. As a quick reminder, what is your level of expertise in playing or creating music?

2. After interacting with all the different MIDI controllers and interfaces can you rank them from most favourite to least favourite and explain your rationale for this ranking?

3. For each MIDI controller/interface, can you explain the advantages and disadvantages of it?
    1. Rank the MIDI controllers in terms of labour/effort to use.
    2. Rank the MIDI controllers in terms of accessibility. Your thoughts on how much skill (either playing instruments such as piano or otherwise) is required to effectively create good compositions with each MIDI controller.

4. If you wanted to create a composition from scratch without any initial ideas, which MIDI controller would best serve you and your creativity?
    1. Can you explain why that controller helps your creativity?
    2. Explain the advantages and disadvantages of the other controllers in terms of creativity.

5. If you already had a composition idea in your head, which MIDI controller would you seek to use?
    1. Explain why/what features of that MIDI controller help you get the idea out of your head.
    2. Explain the advantages and disadvantages of the other controllers in terms of making composition ideas tangible.

6. If you wanted to tweak the pitch of an existing composition using pitch bend, which MIDI controller would you seek to use?
    1. Explain why/what features of that MIDI controller help you bend pitch.
    2. Explain the advantages and disadvantages of the other controllers in terms of making sound effects such as pitch bend.

7. Which MIDI controller did you feel was most enjoyable and fun to use? Disregarding the quality of the music compositions, which one would use if you just wanted to have a good time?
    1. Explain why/what features of that MIDI controller promotes fun.
    2. Explain the advantages and disadvantages of the other controllers in terms of making music composition fun.

8. Focusing on the Novel MIDI Controller, what were your thoughts on it?
    1. Did you enjoy using the touch-free/gesture interaction? Explain why?
    2. Did you find the touch-free/gesture interaction productive? Explain why?
    3. How does the touch-free interaction affect your creativity and/or productivity?
        1. Compare this to the MIDI keyboard.
    4. Did you enjoy using the mouse & keyboard interaction? Explain why?
    5. Did you find the mouse & keyboard interaction productive? Explain why?

6. How does the mouse & keyboard interaction affect your creativity and/or productivity?
    1. Compare this to the Logic DAW Piano Roll.
7. Which mode of interaction do you prefer? Which scenarios would you use one mode of interaction over the other?
8. What were your thoughts on the pinch interaction in general, where you could pinch to play/pick up notes/chords/pitch-bend effects?
9. Could you elaborate on any other ideas you had when interacting with the Novel MIDI controller, either through gesture or mouse & keyboard?

9. Do you have any other thoughts or suggestions you wish to share for the Novel MIDI controller (or any of the other controllers) that have not already been mentioned?

Now conclude the interview session and thank the participant for their time, answer any questions, and hand over the questionnaire for them to fill out.

Questionnaire

The questionnaire is made up of multiple questions that make use of a Likert scale with the “Strongly Disagree”, “Disagree”, “Neutral”, “Agree”, and “Strongly Agree” options to statements. The main purpose of the questionnaire is to gather data on participants’ feelings about my Novel MIDI Controller in particular.

Here are the statements presented to participants:

Regarding the interfaces of the Novel MIDI Controller:

1. I understood the live mode interface without asking for help.
2. In live mode, I could easily pick the right musical key for a certain emotion I wanted to evoke.
3. I understood the editor mode interface without asking for help.
4. In editor mode, I could easily pick the right musical key and the right tempo for my composition.
5. The live mode interface was well organised visually.
6. The editor mode interface was well organised visually.
7. I could easily understand what notes, chords, and pitch bend effects were present in the editor mode at all times.
8. The live mode of the Novel MIDI Controller made it easier for me to play notes, chords, and add pitch bend effects.
9. The live mode of the Novel MIDI Controller extended my capability to play notes, chords, and add pitch bend effects.
10. The editor mode of the Novel MIDI Controller made it easier for me to compose and edit notes, chords, and pitch bend effects.
11. The editor mode of the Novel MIDI Controller extended my capability to compose and edit notes, chords, and pitch bend effects.
12. Overall I found the interfaces intuitive.

If you have any additional comments please leave them here:

Regarding the Interactions with the Gestures on the Novel MIDI Controller:

1. I felt that using my hand to make gestures to interact with musical notes, chords, and the pitch-bend effect enhanced my creativity.
2. I felt that using my hand to make gestures to interact with musical notes, chords, and the pitch-bend effect enhanced my productivity.
3. I felt that using my hand to make gestures to interact with musical notes, chords, and the pitch-bend effect enhanced the enjoyment of making music.
4. I found the gesture interactions easy to use and understand.
5. I found the workflow of editing compositions with the gestures easy to use and understand.

6. I found the workflow of playing live notes, chords, and pitch bends with the gestures easy to use and understand.
7. Overall, I would like to use these gesture interactions again in the future for creating and editing music with MIDI.

If you have any additional comments please leave them here:

Summary of the Novel MIDI Controller:

1. I found the Novel MIDI Controller to be more accessible than the other MIDI controllers and interfaces.
2. I found the Novel MIDI Controller to be more intuitive than the other MIDI controllers and interfaces.
3. I found the Novel MIDI Controller to be more powerful than the other MIDI controllers and interfaces.
4. If I want to recreate existing music, I would prefer to initially use the Novel MIDI Controller before anything else.
5. If I want to simply have fun with music and music theory, I would prefer to initially use the Novel MIDI Controller before anything else.
6. If I have inspiration to create music, I would prefer to initially use the Novel MIDI Controller before anything else.

If you have any additional comments please leave them here:

Conclusion

Thank you so much for taking part in this study, and I hope you had fun along the way as well! Formally conclude the session, thank the participant for their time. Any questions? Answer any questions the participant may have.