Music From the Waves: Sonifying Movement From Surfing to Foster Musical Exploration

Freyja Garbett

Sydney Conservatorium of Music

The University of Sydney

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Statement of originality

This is to certify that to the best of my knowledge, the content of this thesis is my own work. This thesis has not been submitted for any degree or other purposes.

I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

Freyja Garbett

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Abstract

Data sonification has become a useful tool for analysing data sets. While it is common practice to create visual representations of data such as graphs and tables, recent developments have explored experimenting with converting data into audio. There have been applications of this in geoscience (Harding, 2002), astronomy (Diaz-Merced, 2011) and data analysis (Barrass, 1999). While these applications have been for the purpose of interpreting scientific data, there have also been more artistic uses, such as recording the growth of plants and transforming it into music (Ebert, 2022).

By applying the concept of data sonification in a more creative sense, the data collected from movement can be converted into MIDI (musical instrument digital interface) data and used to create music. While there are a few examples of motion sensing technology being used to create music, the idea of linking personal physical hobbies to creativity in this way has not been widely explored. Through this research I have attempted to amplify the link between physical activity and music in a creative way, and explore how this can then inform and enhance one's musical palette.

This project makes use of a semi-waterproof custom-made motion capture device called Moto MIDI, initially developed for capturing and sonifying the movements of surfing. This includes the motions of paddling and duck-diving under waves, to surfing the wave itself. The data collected from this device, in the form of MIDI data, is then imported in Ableton Live and used to create audio representations of these movements, which subsequently serve as springboards for composition and improvisational practice.

This research not only contributes to the field of data sonification, but also provides a novel tool for musicians and composers, who can utilise the Moto MIDI and apply this idea to any extra-musical activity such as rock climbing, running or snorkeling. Drawing from existing concepts such as indeterminate (Oxford Reference, 2011; Popoff, 2014) and generative music (Jauhiainen, n.d; Priestley, 2014), and combining this with modern production techniques, this interdisciplinary study explores new techniques that musicians can use to create new and experimental compositions and improvisational techniques.

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Chapter 1
Introduction

'Movement is key to any way humans operate in the world... Music in its capacity to move us, has an automatic link to a very fundamental aspect of human existence' (Ahtisaari, 2015).

It has been suggested that an intimate relationship exists between surfing and musical improvisation (Schnabel, 2014). Just like surfing a wave, improvisation is a constant reaction and adaption. There are moments of chaos and moments of peace; a dance and interplay of tension and release. The comfortable with the uncomfortable. An attempt to find flow, balance, purpose and meaning. In 'The Ocean, Surfing & Music', Tom Schnabel speaks to this idea of the connection between improvisation and surfing. He says 'just as no two jazz solos are alike, neither are two waves ever identical, and good surfers or jazz musicians find renewal and inspiration in the spirit of improvisation, trying new things, sometimes succeeding brilliantly, sometimes not' (Schnabel, 2014). Schnabel highlights that both accomplished surfers and musicians spend years refining their skills and artistry and developing their unique styles. They 'ride the changes' by navigating the ever-changing nature of waves or chord progressions in their own personal way (Schnabel, 2014).

Improvisation takes time and dedication to develop. As such it is highly rewarding once one can fluently express oneself, either performing solo or with a band. Improvising well is comparable to surfing a wave. It takes intense commitment to master the creative control to take command of unpredictable conditions, whilst stylistically crafting and making them your own. 'You have to step over the edge. No matter how good you are, there's always risk. Like surfing, improvising can be terrifying' (Cooley, 2017). As a surfer and musician, I am fascinated by the interplay between these two disciplines.

This physical and mental link between improvisation and surfing is a concept that has long been pondered by musicians and lovers of waves. In the film 'Life Like Liquid', Australian surfer and percussionist Terepai Richmond puts it succinctly. He says 'there is a certain level of musicianship that you need to develop before you can read signs in improvised music. But it's the same in surfing.' He explains that you must be able to improvise to jam with a band, and to ride a wave without wiping out (Cooley, 2017). Though many surfers have drawn a philosophical connection between surfing and music, the synthesis between them has not been captured and recorded, and in my research, I have set out to generate a new approach that encapsulates and audiates this. It is an attempt to merge these two activities in a creatively inspiring way.

This research is based upon an experiment that, to my knowledge, has not been carried out before, at least not in this way. I have worked with an electronics engineer to develop a water-proof motion sensor, that converts motion into MIDI data, which can then be used to create music. This motion sensor was then attached to my arm and later my surfboard while I rode waves, and the resulting data was used to create music. The conversion of data to sound is known as 'sonification'. Sonification is defined as 'the use of non-speech audio to convey information' (Kramer, 1994). By collecting and sonifying motion data from surfing, I am engaging in a form of generative music driven by the inherent unpredictability of motion MIDI data.

In the methodology, the experiments are laid out in chronological order where the surfing data location and subsequent sonifications and musical explorations related to that data are explored. There were small changes made to the methodology as the experiments progressed. This is because there were some technical difficulties that had to be overcome in order to gather data that was reflective of what I was aiming to capture. These changes to the methodology are discussed in chapter four. The research being conducted is centred around these experiments in capturing and sonifying the motions of surfing. However, an integral component of the research was how improvisation was incorporated during the compositional phase, creating music from the sonifications, which then developed into a suite of music with my quartet featuring Australian saxophonist, Sandy Evans.

The research, experiments, results and creative works exhibited in this study are presented in a mixed-media format. This includes the use of audio samples, photographs, videos, music notation and tables. By publishing this thesis as an eBook, readers can instantly engage and interact with the sonifications, improvisations and creative works pertaining to the text. Video is used to document and display live improvisations, performances and to showcase creative works.

Surfing is at the crux of Australian culture and identity. Of the large percentage of Australia's population who live in coastal zones, particularly those living in small coastal villages, significant meaning and identity is drawn from the surf culture of the local area. Whether it be weekend activities organised by the local boardriders club, after school sport, or just solo recreation, many Australians are drawn to the ocean and surfing. The prominence of surfing in the culture of coastal Australia shapes people as they grow. This surfing culture embodies a lifestyle that promotes respect for nature and the ocean and many Australians will tailor their lives, even into adulthood, to cater for the need to surf. Using surfing as the medium of choice for sonification of movement carries with it the meaning imbued by its deep engraining into Australia's coastal culture and serves to create a musical representation of not just surfing, but the social identity and emotions accompanying it.

Since returning to Australia from Boston in 2017, I have wrestled with the decision to move to a city within Australia or overseas to engage more closely with the contemporary and improvised music scenes. This study has allowed me to creatively connect with my immediate coastal environment and with surfing, a non-musical hobby that has become a staple of everyday life. The approach of creating music from this environment is both a reflection of my interests as a surfer and musician and an exploration of the geographic and cultural context of the Coal Coast, an area in the Illawarra known for its surf locations.

1.1. Conceptual Overview

The ability to experience music by abandoning elements of control is a pursuit that many artists and musicians strive for throughout their lives. By collecting and sonifying motion data from surfing, I have engaged in creating generative music driven by the motion MIDI data. Generative music, much like jazz improvisation, embraces a lack of control by using rules and algorithms to create music that is constantly evolving and never the same twice (O'Rourke, 2014). According to Brian Eno, generative music specifies rules and lets them unfold, creating unpredictable outcomes (Alessi, 2024). There are multiple layers of indeterminacy in this approach to creating music, where the musical output is either partially or fully outside of my control. Once the data controller is programmed, each movement variation while surfing produces a distinct pattern of data, resulting in a limitless array of possibilities. The second layer of indeterminacy comes from the numerous ways of processing the data through plugins, digital and analogue synthesisers, and VSTs (Virtual Studio Technology). The results can differ vastly each time I utilise the same data set. The third and final layer comes to fruition during the recording of the music or improvising in response to the sonifications. By using these surfing sonifications to explore new melodic, rhythmic, and harmonic material, I am expanding my and others' compositional and improvisational palettes.

Marco Donnaruma's 'Notes on Bimodal Muscle Sensing for the Sonification of Indeterminate Motion' (Donnaruma, 2014), offers an examination of a motion-sensing instrument that produces real-time sonification determined by the muscle movements of the performer. In this paper, Donnaruma asserts that the live sampling done by the instrument and the nature of sonifying movement, rather than directly performing music, means that the artist is under no pressure to perform pre-determined movements, and as such creates the sense of unpredictability and indeterminacy.

Although inherently indeterminate, there is still an element of human control imposed in this study. Selective and creative bias' are an inevitable part of this method of motion data sonification and music creation (Neuhoff, 2019). The parameters for the motion controller must be pre-determined and coded into the device before data collection. However, since the coding can be edited at any time, dramatic variations in data are possible under identical environmental circumstances. Once the data is uploaded as MIDI into a Digital Audio Workstation (DAW), the MIDI requires pairing with a VST, an internal live instrument or an external MIDI controller. These steps alone offer a vast array of sounds, instruments, timbres, rhythms, and harmonies. Additionally, there is the option of using effects within the DAW, or external VSTs and plugins such as Soundtoys, Moog and Roland, which offer advanced sound libraries and can further alter the data.

Although there are elements of personal preference in these choices, there is also a great deal left up to chance. Indeterminacy is at the core of incorporating the process of motion data sonification into musical creation, introducing a degree of sonic unpredictability. The data output is as much a surprise to the composer, as it is to anyone else. Depending on the set parameters and level of sensitivity of the motion detector, minor variations in movement can produce vastly different outcomes.

By gathering motion data while surfing and converting it into music, I am exploring an interdisciplinary way to connect my interests and create new music. Technologically, the study focuses on capturing and processing motion data and draws from biomechanics and physiological analysis to understand the physical nature of surfing. On the creative side, the sonified data is used as a foundation for composition and performance, enabling exploration of generative music and sonifications driven by surfing motion data. This interdisciplinary approach enables me to connect my passions and create music grounded in technology and physical movement, potentially inspiring others to do the same.

1.2 Motion Detection Technology

While undertaking this research, I commissioned Ed Kuschel from Elk Elektronik to build semi-waterproof motion detectors. These devices have been essential tools to facilitate my surfing experiments. They allow me to create the raw materials, being motion data, for my research.

While this technology has enabled me to produce data from my movements while surfing, my study focuses on the creative output and musical explorations that have emerged from this data. I approach the sonified data in different ways. At times, I interpret the data freely, using it as a springboard for composition and experimentation rather than following the output note for note. Alternatively, I also allow the sonifications to exist as they are, without adjusting them. In this way, this study is similar to the generative methods used by artists like Steve Reich or Brian Eno. Brian Eno is one of the pioneers of generative music and sums up his perspective eloquently; ‘I set up situations involving abandoning control and finding out what happens’ (Jeffries, 2010). Similarly, I am abandoning some of the traditional ‘rules’ of music, and I am challenging my own preconceived notions. By delving into experimental fields of music creation this research is contributing something new to the vast field of data sonification.

1.3 Research-led Approach

By sonifying data gathered while surfing, I have undertaken a research-led approach to my work. This field, which compliments practice-led research, utilises scholarly research to inform creative practice. Research-led practice has been particularly impactful in disciplines such as new media and music (Smith & Dean, 2009). Roger Dean, a researcher, composer, improviser, and author from the University of Western Sydney, has applied this approach extensively by using computer technology to generate and control musical flow for both composition and real-time improvisation.

Similarly, my work sonifying surfing motion data, demonstrates a ‘research-led practice’ approach. Unlike other studies, where the sonified data is used to interpret data or recognise patterns through sound, my study sonifies the data to inform creativity and practice. There are two primary creative pathways being explored here. Firstly, the motion data informs an experimental form of generative music creation, not requiring further input from myself, the composer. Next, the generative music is informing deliberate practice, composition and improvisation. It is the latter step that falls under the umbrella of ‘research-led practice’.

1.4 Practice as Research

This project also aligns with the broad framework of ‘practice as research’ as defined by Henk Borgdorff in ‘The Debate on Research in the Arts’ (Borgdorff, 2006, pg. 7). He states that artistic practice qualifies as research when it seeks to expand knowledge and understanding through original investigation. It must engage with relevant research questions, employ suitable methodologies, and ensure that both process and outcomes are thoroughly documented and shared with academic and public audiences.

1.5 Practitioner Background: Connecting Nature with Music

As both a surfer and a musician, I’ve always felt a profound connection between the ocean and music.

This link has often informed my creative process and led me to ponder the boundaries between music, art, and the patterns of nature. This connection has also helped fuel my journey over the past ten years as I focused on my craft as a pianist, producer, improviser and composer. After moving back to Australia from the United States in 2017, I was struck by the expansive beauty of our eastern coastline and composed an extended work for a ten-piece jazz ensemble entitled 'Bulgo', written about a small shanty village on the southern tip of the Royal National Park, NSW. This piece evolved into my debut album 'Maya', released in 2019 and featuring all original music written for jazz octet. Currently, I lead a contemporary jazz quartet, where I continue to draw inspiration from the ocean.

This study expands on my previous ensemble works, some of which are multi-movement suites combining electro-acoustic sonic palettes with jazz improvisation (Garbett, 2024). Building on this foundation, I have embarked on a study that uses wireless MIDI motion sensors to track my movements as I surf the face of ocean waves. In doing this I am accentuating the connection between nature and music by converting this data into sound. This process stimulates my creative process and seeks to influence and expand my improvisational and compositional craft. In turn, I am creating an original methodology that allows other improvisers to incorporate their extra-musical activities and interests into their musical practice through sonification. Because this study is designed as a music experiment, the emphasis is on artistic expression, exploration, and experimentation rather than on achieving scientific results.

1.6 Important Technical Terms

Accelerometer	An instrument that detects acceleration along specific axis, such as x, y, or z
CPU	Central Processing Unit
CSV	Comma-separated values file
Data logger	An electronic device that records and stores data
DAW	Digital Audio Workstation
Gyroscope	An instrument that detects the orientation of an object in space
MIDI	Musical Instrument Digital Interface
Moto MIDI	Custom-designed motion detection device
Plugins	Extensions installed on a DAW to add audio and MIDI features.
PCB	Printed Circuit Board

SD Card	Secure Digital Card
USB	Universal Serial Bus
VST	Virtual Studio Technology

1.7 Research Design

The methodology in this study involved surfing with the motion controllers in four separate locations, sonifying the collected data, improvising in response to the sonifications, and subsequently developing compositions and a suite of music from these experiments. An overview of this process is outlined below. Each of the locations, experiments and creative outcomes are examined in detail in the following chapters.

1.7.1 Surfing Locations

Location 1: Dry land testing of motion detectors at home, controller worn on arm.

Location 2: Thirroul, NSW, controller worn on the arm.

Location 3: Woonona, NSW, controller worn on the arm.

Location 4: Krui, Sumatra, Indonesia, controller attached to the front of the surfboard.

1.7.2 Data Collection Process

1. Placing the motion detector inside the wetsuit armband or tape it to the front of the surfboard.
2. Surfing and capturing motion data from paddling, duck-diving, and several waves at each location.
3. Paddling back to shore to readjust the detector if it comes loose.
4. Noting of environmental conditions (wave size, wind, tide).
5. Record of technical challenges.

1.7.3 Data Collection Time Frame

Each session varies in length, ranging from 30 minutes to 2 hours, depending on the conditions and the stability of the motion detector.

1.7.4 Data Uploading and Processing

1. Gathering motion data from different surfing locations.
2. Transferring the motion data onto the computer after each session and uploading it into Ableton Live.

1.7.5 Experimentation with Sonifications, Improvisations, and Creative Outcomes

1. Developing sonifications from the collected data using VSTs and synthesisers.
2. Assigning MIDI and audio effects if desirable.
3. Experimenting with various improvisational approaches in response to the data.
4. Developing compositions stemming from these improvisations.
5. Creating a suite of music for a quartet (piano and synths, tenor saxophone, double bass, and drumset).
6. Integrating sonifications and audio samples inspired by these sonifications into the performance.
7. Utilising spoken word narrative, visuals, and lighting effects to enhance the performance.

1.7.6 Research Questions and Contributions

This study is guided by the following research questions:

- How can surfing motion data be sonified to create generative music?
- What impact does incorporating physical movement, like surfing, have on the music composition and the improvisation process?
- How does combining these practices challenge traditional approaches to music creation and performance?

The key contributions of this research are:

- Introducing a new novel approach for generating music from motion data.
- Demonstrating how motion-based sonification can enrich the compositional and improvisational processes in music creation and live performance.
- Providing an interdisciplinary framework that links surfing with music improvisation, laying the groundwork for future research in both fields.

Chapter 2
Literature Review

This chapter explores the existing literature that has provided a background for my project, which uses a ‘research-led’ approach to musical composition and practice, informed by sonifying motion data collected while surfing. The literature review begins by contextualising my research within the existing literature in the field of data sonification and experimental composition, and goes on to highlight how sonification of non-musical scientific data can reveal important patterns that may not have been evident through other means of observation. Throughout this chapter the existing literature is examined in a way that highlights that sonification can not only be used to enhance scientific research, but also to enhance the understanding of scientific data of people external to the research community. Sonification can also be used to inform the creative processes of composition and improvisation, creating an emotional and intuitive connection to scientific data which may not have existed before.

Following on from the wider applications of sonification, I will then explore some examples of how sonification has been used to reflect the natural world specifically. Modern computer technology is now enabling researchers to collect larger and more complex data sets than ever before, which has prompted new techniques to assist in analysing and communicating this data. Dark matter (NASA, 2020), climate change (Renssen, 2017), and the migration of asylum seekers (Kasulis, 2017) are some of the areas where data sonification has recently been applied, and has exemplified not only how useful it can be for interpreting the data, but also for communicating the meaning behind it in a way that can be engaged and empathised with by the general public. Bio-data sonification (Kurundkar et al., 2023), the concept of sonifying data gathered from biological sources, takes this one step further by creating a novel way for people to transfer the vibrations of plants or movements of the human body into sound in real-time.

Next, I explore motion data and movement sonification. Here I place an emphasis on sonification of motion data from dancing, due to its similarity to the movements of surfing a wave. I then examine the existing designs and applications of various motion-detecting instruments. I’ve selected this method as the technical basis of this study relies on the use of a custom-built motion detection system to record my movements in the ocean. There are a number of examples of motion-detecting instruments being used creatively, but these are mostly centred around the user deliberately moving in such a way as to create music directly from their movements, rather than by recording movements performed for another purpose, like surfing, and then translating them to music.

This leads into an examination of methods of sonifying the ocean and waves, with a focus on the sonification of surfing motion data. My project aims to sonify all of my movements while surfing, including riding waves, duck-diving and paddling, and then use these sonifications to explore new musical territory in terms of both composition and improvisation. Only one other application of sonifying surfing exists in the literature, from a motion detection project undertaken by Swedish composer Rosanna Gunnarsson (Gunnarson, 2016). Though conceptually similar, her work differs from mine as she has sonifed fluctuations of human physicality such as heart rate while surfing, rather than the motions of a surfer on the wave.

To contextualise my research philosophically, I have also provided an explication of symbolism, semiotics, and indexical representation, as these concepts underpin one of the aims of my research, which is to symbolically and emotionally communicate the 'feel' of surfing to the listener. By examining these related bodies of literature, I provide a theoretical background for my research and highlight how my study contributes to utilising sonification to interpret and communicate data and expand musical exploration.

2.1 Data Sonification

Data sonification is the process of converting data into sound (Herman, et al., 2011). The process of sonifying data allows researchers to gain a more in-depth understanding of their field of interest (Kramer et al., 1999). Researcher interest in data sonification is timely, since just at a point in history where data is being produced in abundance, the tools for generating high-quality audio output are also becoming widely available on everyday multimedia computing systems (Pauletto et al., 2009).

In my studies, however, I am utilising the data generated by the movement of a motion controller attached to my body and surfboard. This subtype of motion sonification is popular in fields such as real-time interactive dance choreography (Grosshauser et al., 2012), data mining (Halim et al., 2006), physiotherapy (Guerra et al., 2020) and cognitive research (Herman et al., 2011).

Sonifying data sets involves translating data into audible formats. This makes it possible to perceive changes and patterns in data through sound rather than by interpreting graphs or tables. By utilising sonification of non-musical data, we can identify and apply meaning to patterns that may not have been evident through other means of observation. Therefore, sonification not only enhances scientific research but also enables a deeper, more intuitive connection to the data by leveraging our ability to perceive and interpret patterns through sound. As well as providing a new perspective to interpret data, which can highlight patterns in data that may be overlooked by simply analysing it in a traditional sense, 'listening' to data sets can become an enjoyable and insightful activity for the listener. As Sawe et al. (2020) suggests, listening to data, rather than just seeing it, may become a groundbreaking tool for the future, especially when information is being generated so quickly, or when there is a lot of data. They note that as the data is translated to audio, the changing variables become clear through variations in timbre, sonic textures, and musical instruments (Sawe et al., 2020). Unlike a graph, music created from data sonification often uses time series data, allowing listeners to perceive changes over time. Examples include sonifying salmon migration patterns (Hegg et al., 2018) and brain wave fluctuations (Parvizi et al., 2018).

There are many contemporary applications of data being sonified and used as a platform for musical composition (Barrett, 2016), performance (Wolf et al., 2019), dance choreography (Landry et al., 2020), art instillations (Tittel, 2009) and a plethora of other artistic endeavours. In such sonification projects, data is often translated into MIDI, which is then imported into a DAW, and mapped to varying musical parameters at the research composer's discretion. This interdisciplinary approach allows the researcher to combine their hobbies, creative work and technological explorations, whilst simultaneously making data more accessible to a wider audience and expanding the scope of musical and technological exploration. By sonifying surfing motion data, I am applying the concept of audiating data sets to allow for a more creative interpretation of the data, and potentially shifting the way people perceive surfing. There are many ways to map data, and in some cases, this might involve an approach that is audibly digestible to the average listener, allowing them to connect with the data on an emotional level. This is referred to as 'musification'.

2.1.1 Musification versus Raw Sonification

Musification has been defined as the process of creating a musical representation of data (Edlund, 2004). In other words data is sonified in a musical fashion which is relatable to popular audiences, especially in Western society. It is a way of 'going beyond direct sonification' (Coop, 2016) and enabling listeners to connect with the data and become attuned to the story being told. The data is organised to portray simple musical patterns- melodically, harmonically, or rhythmically- often using elements like pentatonic scales or repetitive rhythms. Sonifications may also 'include elements of tonality and the use of modal scales' (Coop, 2016). While I mostly avoided using musification in this study, opting instead to map the data in a more raw form, I incorporated it into one sonification which can be heard in chapter four (audio 4.6) as it allowed me to experiment with a specific VST. For the rest of the sonifications, however, I applied VSTs, synthesisers, and plugins that created a more direct and unfiltered translation of the data into sound. At times these might be interpreted as abrasive, especially to an ear that is not used to this type of sound. This was done to expose the unpredictability of surfing and the ocean, creating a raw audible translation of my interaction with nature.

2.2 Data Sonification of Nature

The natural environment has always been a source of inspiration for musicians. Being in nature sparks innovative ideas and provides a connection that may enhance compositional and musical output. Some notable examples include Antonio Vivaldi's 'Four Seasons' (Vivaldi, 1721), Ludwig Van Beethoven's 'Symphony No. 6, Pastoral' (Beethoven, 1808), Claude Debussy's 'La Mer' (Debussy, 1905), Maria Schneider's 'The Thompson Fields' (Schneider, 2015) and John Luther Adams' 'Become Ocean' (Seattle Symphony Orchestra, 2013). With the advent of advanced computer technology, the ways that nature can be used to influence and inform the creation of music have expanded dramatically and complex data sets gathered from the natural world can be converted to musical data in meaningful ways.

A contemporary example of sonifying nature is the ATLAS data sonification project; a platform for sonifying and interacting with real-time particle interaction and collision data from the Atlas detector. This system was created through a collaboration between the MIT Media Lab and CERN (the European Organisation for Nuclear Research) and has continued evolving since it was originally debuted as a prototype at a workshop entitled 'The Physics of Music and the Music of Physics' at the Montreux Jazz Festival in July 2015 (Miranda, 2016). The creators of this project have shared a website where members of the general public who have an interest in science and music can access and listen to selected audio excerpts of the data being performed by various artists. One of these excerpts is performed by jazz pianist Al Blatter at the Montreux Jazz Festival. It is a ten-minute improvisation where Al is intuitively responding to ATLAS data collected that same day. What makes this project so enjoyable is that the platform allows musicians and composers to 'customise the tempo, instrumentation, and musical scale' to their own aesthetic taste (Hill, 2016). By turning this data into sound, the public can interact with the data and learn about particle physics. Users can also extract the data and feed it through their own specially designed-software. This provides composers and improvisers with new musical territory to explore (Miranda, 2016).

Another application of sonification of nature is found in ecology and climate science, where it is used to assist in interpreting data on ecological shifts and the changes to Earth's climate (Renssen, 2017). A particularly well-executed example of this was done as part of a study into the effects of climate change on yellow cedar trees along the south-eastern coast of Alaska (Nijhuis, 2016). Rising temperatures in the region, particularly in the south, have gradually decreased snow cover. As a result, the trees are unable to absorb nutrients, causing them to die off in turn. Nik Sawe and Lauren Oakes, two Standford Ph.D students, wanted to communicate the effects of climate change on these cedar populations to people outside the research community to spread awareness of this issue. They decided to sonify the data gathered from yellow cedar and four other species of populations in Alaska and create music from it. Each species was assigned an instrument, and each note's pitch, duration, and volume represented a tree's height, crown health, and trunk diameter, respectively. Dropped notes represented dead trees. The piece was organised to run from north to south. Organising and representing the data in this way highlights the changes in species assemblages due to climate change as the piece flows (Nijhuis, 2016).

Another example of sonification being used to understand the implications of a changing climate is the application of sonification to seismic data collected from vibrations caused by glacial movement. Composer Glenn McClure is the principal investigator of a National Science Foundation project that aims to translate data into sound (Futurum Careers, 2021). In 2016, Glenn travelled to Antarctica and studied data gathered by seismometers placed on the Ross Ice Shelf. His paper, 'Decentered Listening: Ice Vibrations,' presents vibrational frequencies caused by glacial ice movements as audible data sets. By picking up subtle movements in the ice, the seismometers detected vibrations travelling through the ocean (Futurum Careers, 2021). McClure used the seismological data to compose several pieces of choral music, which told a story of our changing planet. During his time in Antarctica, McClure stated that the algorithms created for his predominantly artistic project might be helpful for scientific applications, not just for making music. When musicians listen to these types of sonifications, they can hear discrepancies that the average person would not hear, which may be more evident when analysed this way rather than by analysing graphs or more traditional forms of data analysis. As such, he identified a need for new strategies that could be employed to analyse large data sets (Futurum Careers, 2021).

Sonification of large complex data sets has also been applied to study dark matter (NASA, 2020). Dark matter is not observable directly, though it is thought to constitute up to 95% of the mass of the universe and is of great interest to physicists. Sonification has become useful in this field as it provides a tool for interpreting data such as satellite imagery to identify areas where dark matter may be present (Bonet et al., 2016). Researcher

Nuria Bonet has explored a method for sonifying dark matter simulations. Her paper, 'The Sonification of Dark Matter,' uses dark matter simulation data to investigate the value of creating sonifications to enhance silent visualisations of simulation data (Bonet et al., 2016). By doing this Bonet has offered a new creative way to explore and sonify these data sets. She has highlighted the significance of certain musical aesthetic choices to enhance the compositional process. She believes that by infusing artistic value into the sonifications, they serve purposes beyond just scientific interpretation of data, and naturally evolve into musifications that can be showcased to the public and promote public interest and engagement in science.

Similarly, Brian Foo, a programmer and visual artist from New York City, applies sonification to another complex dataset rooted in the natural world: human migration. In his work 'Distance from Home', Foo sonifies refugee data collected by the United Nations between 1975 to 2012 by assigning parameters to instruments to create music. The data sonification translates four decades of refugee movement into a musical composition. The instruments are dictated by the size of refugee movements, the distances they travelled between their original countries and where they went to seek asylum (Kasulis, 2017). This provides a compelling narrative that can enhance public understanding and can be much more impactful than simply analysing numbers on a page.

In each of these examples, the researchers have utilised sonification to enhance understanding of an aspect of the natural world. The application of sonification in these examples has been used either to assist in analysing the data itself or to communicate the data, and it's implications, in an emotive way to reach a wider audience.

2.2.1 Bio-Data Sonification

In a similar vein, bio-data sonification takes hidden processes from the natural world and makes them audible, allowing us to 'listen' to the rhythms and movements of plants as they photosynthesise, transpire, and transport nutrients (Electricity for Progress, n.d.). This process translates complex biological sensory data into musical notes, creating musical sonifications representative of plant movements (Hii Magazine, Ebert, 2022). Recent advancements in this field have even enabled researchers to turn the biorhythms, changes in plant physiology over their night and day cycles, into sound (Kurundkar et al., 2023).

Two contemporary designs of organic MIDI output currently dominate the field of bio-sonification (Midi Sprout, n.d.). Midi Sprout was the initial forerunner and uses two probes that measure changes in electrical currents across the surface of a plant's leaf. These fluctuations are converted into notes and control messages that synthesisers and computers can read to generate music and videos (Midi Sprout, n.d.).

PlantWave is the newer iteration of Midi Sprout. It detects slight electrical variations in a plant via two electrodes placed on the leaves. The fluctuations in this biofeedback data are transformed into ethereal hums produced by a synthesiser. Environmental changes such as wind, light, and human touch may also bring variations in pitch, tone, and rhythm; some plants sing louder than others (Sparks, 2019). An older and less widely recognised device, the 'Plantron,' which was designed by Japanese Botanist and artist Yuji Dogane in the early to mid 90s, detects and measures the electrical currents on the surface of the plant's leaves. The device then converts the data into sound using Max, a visual programming language for music (Molley, 2014).

Celebrated composer Mamoru Fujieda used this technology from 1996 to 2011 to create 'Patterns of Plants,' an opus uncovering intricate musical patterns in nature. Fujieda then likened this creative venture to 'searching in a deep forest for beautiful flowers and rare butterflies (PINNA, n.d.).' This series of compositions was created for various ensembles and instruments. These pieces eventually culminated into a solo piano album in 2014 featuring pianist Sarah Cahill and were released via Pinna Records.

Both Dogane and Fujieda utilised methods of bio-data sonification to connect technology and nature. By turning the electrical activity of plants into music, they demonstrated how science can create audible art. This allows us to hear and appreciate the hidden rhythms of nature. While my work seeks to create an audible representation of the motions of surfing, bio-data sonification focuses on the natural patterns in nature by translating the vibrations of biological processes of plants into sound. These are stark examples of how sonification can transform scientific data from the natural world into music. As technology continues to advance, the use of sonification to express scientific and empirical data will continue to grow. To some extent, my work parallels the approach of these researchers and artists who have sonified the natural world, as I have focused on translating motion data from my interaction with the nature into a creative medium to not only expand my musical expression and enhance public engagement but to create a meaningful and artistic expression of surfing.

2.3 Motion Data and Movement Sonification

Movement sonification is often thought of in terms of audiating human movement such as amplitude and speed. This is 'achieved by directly mapping movement and audio features' (Bresin, et al., 2020). These sorts of studies have been widely applied to enhance motor control and learning in sports (O'Brien et al., 2020), as well as therapeutic applications such as stroke rehabilitation (Schmitz et al., 2018), haptic perception (Landelle et al., 2021) and motor neuron learning (Effenberg et al., 2016) to name a few. Sonification of movement has also been widely applied among artistic practices such as dance choreography (Misgeld et al., 2023), electroacoustic music (Whalley, 2015), sound design (Pauletto et al., 2016) and gaming (Goncharov, 2023).

Movement sonification is a process of capturing and then audiating the movements made by the human body. Collecting this data is possible by using motion-tracking devices. These devices include mobile phones, game controllers, gyroscopes with accelerometers, kinematics, GPS, Bluetooth tags, and 3D tracking systems, to name a few. They are capable of recording how the body moves in space. This is compared to a stable unit, the acceleration of movements, the motion of joints and limbs, the electrical activity of the muscles, or changes in heart rate and breathing (Słyż, 2022).

2.3.1 Sonifying Dance

Music and dance are traditionally interdependent art forms. In the article 'An Interactive Music Composition System Using Body Movements' (Morales-Manzanares, 2001), the authors introduce SICIB, which stands for 'Sistema Interactivo para la Composición e Interpretación en Base al movimiento' in Spanish, and translates to 'Interactive System for Composition and Interpretation Based on Movement' in English. SICIB is a system that merges 'if-then rules' from two technological composition tools, Escamol and Aura, with data from motion sensors attached to dancers. This allows for the pairing of specific choreographic gestures with music. Specific movement elements such as position, velocity, acceleration and jumps, trigger specific data output from the system, allowing for variations in the music such as intensity, tone and ostinatos. SICIB offers a fun and unique approach that connects dancers, choreographers, musicians and composers, allowing for freedom and spontaneity in the performance (Morales-Manzanares, 2001).

Surfing can be likened to a form of dancing. Rather than dancing to music, surfers dance with the ocean. An off-beat move while dancing to music becomes evident to an observer and the dancer because it creates a rhythmic dissonance, seen and felt by all involved. Similarly, a wrong move by a surfer can quickly end the wave, as it will often result in the surfer falling off the wave. In this way, as dancers must be attuned to the music they are dancing in order to harness the flow and perform a flawless dance, so must surfers be attuned to the motion of waves, to move in harmony with them, and ride the wave until the end. It makes sense to track the motion of the surfer on a wave, similar to how the SICIB system tracked the motion of the dancers. By doing this, the wave's motion is inherently captured, as the surfer must respond to the wave as they are surfing, and the data is enhanced by also capturing the surfer's motions. Thus, the sonification of this data provides a natural synthesis of the motion of waves and surfing, which is finally conveyed audibly in the music being created. This process is commonly referred to as 'Motion Data Sonification' (Brock, 2012).

2.4 Motion Detectors and Motion Controlling Instruments

As previously mentioned, the technical foundation of this project is based upon audiating my movements while surfing in the ocean. This movement is captured by the Moto MIDI (custom-built motion capture device), which translates my movements while surfing into sound. A similar exploration of motion-driven music is being pursued using contemporary advanced musical instrument technology, such as Alon Illsar's AirSticks (Illsar, 2018). These motion controllers allow the performer to produce music in real-time using motion, as well as incorporating a form of dance. Similar to Wii controllers, the 'AirSticks' are two paired devices, held in each hand. Each movement produces a different sound, allowing the performer to have full control over the rhythm and pitch associated with the movements they make. The design of the AirSticks deliberately factors in the potential uses of the instrument in various musical situations, including collaborative performances alongside more traditional instruments. The devices capture both hand and finger movements, allowing for deliberate and focused control over the musical output. This enables performers to compose, improvise and perform in a controlled manner, using the AirSticks in a way that is parallel to any other instrument. The digital nature of the AirSticks also enables the use of complex sound textures through effects and patches, much like a synthesiser. The AirSticks have now been featured in performances alongside a number of notable contemporary musical artists including Alan Cumming, Thundamantels, Thelma Plum, Hermitude and the Cat Empire (Illsar, 2018).

The potential applications of the Airsticks are vast. They can be performed either solo or in ensemble settings. Because of their flexibility, they are an ideal studio recording instrument. As a drummer, composer, and instrument designer, Illsar's approach to playing The Airsticks is musical. His background as a professional musician enhances his ability to interact tastefully with a band, whether it be during a live performance or a studio session. Monash University's SensiLab, comprised of an eclectic team of creatives, has examined ways to utilise the Airsticks in exciting live performance situations and music therapy applications. Most notably, visual artist Matt Hughes has been working on ways to pair the Airsticks with audio-visual software. Dr. Ilsar generates incredible visual contours complementing the electronic audio output (Illsar, 2018).

Similarly, Imogen Heap's MiMu Gloves have been at the forefront of the wearable electronic musical instrument scene since 2010. Heap developed these cutting-edge gestural motion detection devices for composition, performance, and improvisation (MIMU, n.d.). While wearing the gloves, distinct hand movements and gestures enable the performer to create many sounds and effects in real-time. In 2015 the first collection of gloves were released to the public, creating a buzz through the industry. Pop vocalist Ariana Grande was among the first artists to use the gloves to enhance her live performance during her world tour in 2015, and music and disability charity, Drake Music also pre-ordered and purchased a set. The appeal of the MiMu Gloves is that they utilise the movement of the human body to create electronic music, rather than just programming it using computer software. This creates a platform for a new form of electronic music which is intrinsically linked to the performer (MIMU, n.d.). Imogen's gloves and Dr. Ilsar's PHD work primarily focus on ways to map the movements made by performers, utilising the controllers to create music electronically in real-time. What is dissimilar in my study is that I collect the motion data while surfing and use it as a creative platform for further musical exploration after the fact. What is advantageous to this approach is that I can spend as much time as I need pairing my data with various VSTs, plugins, and analogue and digital synthesisers in the comfort of my studio. This process allows me to focus on how my movements in the ocean while surfing translate into sound.

2.5 Sonification of the Ocean

This research project's connection to the ocean aligns with previous sonification studies involving wave data. For instance, at Plymouth University, a system was created to showcase the new advanced research wave tank at the University's Marine Institute. This system generated waves in a tank and then collected and transformed the wave data into sound. The wave motion was monitored using a floating buoy with depth monitors and motion tracking sensors. A motion sensing device on the demonstrator's arm directly controlled the shape and size of the waves, hence indirectly controlling the pitch and amplitude of the sonifications. The demonstrator would select and trigger different wave patterns using the device, thus creating impromptu sonifications from the wave motion in the pool. The system was demonstrated live during the Marine Institute building's opening (Alexis et al., 2015).

Similarly, Bob L. Sturm's 'Pulse of an Ocean', sonified buoy data off the coast of California, using real-time wave data to create a continuous piece of music by mapping wave amplitude to volume and frequency to pitch (Sturm, 2005). Sturm is a researcher and musician from the United States who is currently an associate professor at the Royal Institute of Technology (KTH) in Stockholm, Sweden. His project involved converting each 30-minute ocean observation into 40-millisecond sound clips, which he then combined to create a continuous piece of music or sonification. Sturm accessed the data from 'The Coastal Data Information Program' (CDIP) in California, which has been collecting ocean data in real-time since 1975 using a series of buoys. His study concluded that the music created from the sonification of buoy data was 'immediately interesting and captivating.' Additionally, Sturm mentioned developing an obsession with surfing during the study but had not yet found a way to sonify the act of surfing (Sturm, 2005). These two studies by Alexis et al. and Sturm, demonstrate the potential of sonification in representing wave motion data. My project takes this concept one step further and provides a way to sonify human motion on waves, specifically while surfing.

2.6 Sonifying Surfing

The precedent for sonifying surfing was set by Swedish composer and sound artist Rosanna Gunnarsson, who in 2016 sonified a selection of physiological and bio-physical parameters of a surfer into musical elements. Heart rate was converted into beats per minute (BPM), speed into rhythmic note values, centripetal force into texture, muscle groups into frequency of pitches, kinetic energy into space, energy expenditure into dynamics, and balance into articulation. Rosanna explained, 'It is the idea to get musical material from physical energy travelling through nature, to people, and into my music' (Gunnarson, 2016). Her goal was to create an audible expression of the physiological changes of a surfer surfing waves and to musically capture this experience during a surfing session at Torö Stenstrand, a famous surf break in Sweden. She enhanced this musical interpretation by incorporating video footage of the surfer, plus field recordings of the environment and waves in the final presentation (Gunnarson, 2016). By translating the physiological parameters of a surfer's experience into musical parameters, Rosanna has created a way to express the activity of surfing through sound. By building on Rosanna's work, my project aims to uncover another way of representing physical activities through music, further exploring the potential of sonification and allowing listeners to connect with surfing in a new, audible form.

2.7 Symbolism, Semiotics and Indexical Representation

In this context, sonification can be linked to semiotics, particularly indexical representation. Semiotics is the philosophical study of signs and symbols and their use in communication. It is the study of how an idea or object, perhaps a sound, feeling, colour, word, or image, communicates meaning, and what meaning it communicates (Chandler, 2007). For example, ‘surfing’ is a sport that evokes health, peace, culture, community, social construct, creativity, and countless other associations (Garrett, 2017).

According to Charles Sanders Pierce’s semiotic theory from the 1860s, there are three kinds of signs: an icon, an index, or a symbol. Indexical representation is a sign that establishes a direct connection between the object or phenomenon it represents and the sign itself (Peirce, 1902). The sign is directly and physically influenced by its object (Vickers, 2013). For example, smoke is an indexical sign for fire, where smoke indicates the presence of fire. Water is an index of a shower, and warmth is an index of the sun. In these examples, the sign has an objective relation to the nature of the object, irrespective of interpretation.

Data sonification can be likened to the study of semiotics, as it relies on creating meaningful sounds, which in this context can be thought of as audible symbols, to convey complex information to listeners in a digestible manner. Following from that, the direct representation of data through sound is a form of indexical representation, as the sounds being produced are directly connected to the underlying data. So sonification of data, and the creation of music from that, is both symbolically significant and directly representative. An example of the use of indexical representation in data sonification is the sonification of seismic data (Davies et al, 2010). In this study seismic data is represented through musical notes that directly correspond to seismic activity. For example, a sudden increase in pitch in the sonification might represent a sharp increase in seismic activity (Davies et al, 2010). Another example of indexical representation is the application of sonification to medical data (Balloro, 2004). In this application each sound in the sonification is representative of a physiological change such as heart rate or blood pressure.

In relation to my work, the sonification of movement data is an indexical ‘signal for the purposes of facilitating communication’ about surfing ocean waves (Vickers et al., 2013). The sounds being produced are directly linked to the data, which is a direct cause of the movement of surfing ocean waves. The music I am creating and the following improvisational techniques directly result from the surfing movements. In this way, the music created using the data collected from the surfing movements satisfies this definition. The actual connection is that the data is translated from movement to MIDI using the device created for this purpose. The fundamental relation is that the music will essentially ‘sound like’ surfing because it comes directly from surfing, regardless of the listener’s interpretation. Overall, using indexical representation in data sonification allows for creating sonifications that are more intuitive and meaningful to the listener, as the sounds directly connect to the underlying data. This can be especially useful when the represented data is complex or difficult to interpret visually.

2.8 Literature Review Conclusion

In summary, this chapter has introduced the reader to data sonification and how it functions in various contemporary scientific, creative, and musical applications. The chapter explores these different sonification applications, specifically in nature, and examines the use of motion-controlled musical instruments and ocean sonification methods. This is gradually narrowed down to focus on the sonification of surfing, justifying my study. Finally, a conceptual overview of symbolism, semiotics, and indexical representation is offered to provide symbolic meaning and insight into how the sonifications 'sound like' surfing, regardless of the listener's interpretation.

Chapter 3
Equipment Procurement Phase: Waterproof Motion Data Capture Device for Surfing

I commissioned Edward Kuschel from Elk Elektronik to develop a waterproof solution for capturing motion data while surfing. This took the form of a small wearable device (Moto MIDI) that was designed to record and store data within the device. The data could later be retrieved from the device via USB, and converted into MIDI notes or commands for audio processing. The Moto MIDI contains an accelerometer and gyroscope, and is specifically designed to capture and store the movements of a person while surfing. See Figures 3.1, 3.2 and 3.3.

Figure 3.1

Initial Moto MIDI prototype enclosure.

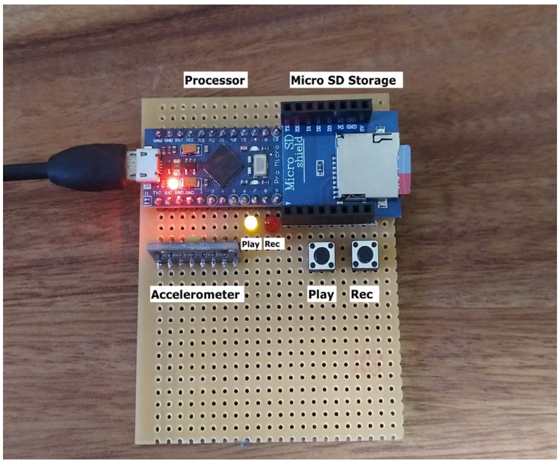


Figure 3.2

Inside view of the Moto MIDI Prototype, showcasing the processor, micro SD storage and card, play and record lights and buttons and the accelerometer.

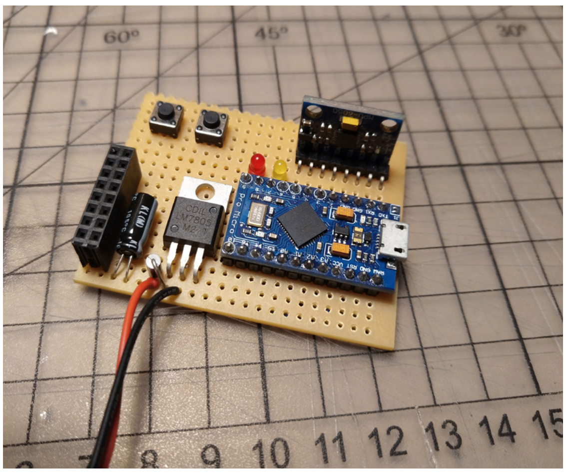


Figure 3.3

Inside view of the Moto MIDI Prototype, placed on a measurement grid for scale.

3.1 Initial Prototype Features:

1. A single gyroscope is worn on the arm to detect yaw, pitch and roll of the arm within the movement envelope. These three parameters are mapped to various MIDI commands including pitch, volume and modulation. See figure 3.4.

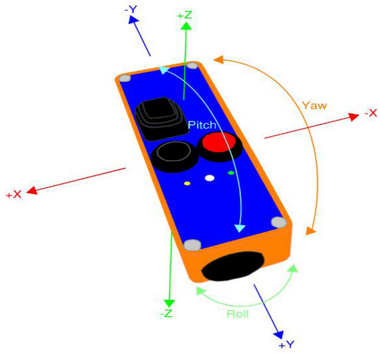


Figure 3.4

Moto MIDI displaying yaw, pitch and roll.

2. Each gyroscope is sealed with resin to prevent the ingress of water.

3. The data logger is housed in a waterproof enclosure that can be opened to retrieve the recorded data.

4. To minimise size, it was initially proposed to have body-worn sensors detached from the datalogger and attached via a cable. For example, the data logger could be worn on the user's back and the sensor on the wrist, arm etc. This was removed from later revisions, with the sensor and datalogger integrated into one device to reduce cabling on the body, minimising the risk of entanglement.

5. The device should not be a distraction to the wearer during surfing activities, so as not to impede data collection, or impact safety.

3.2 Moto MIDI Development Process

Phase 1: Design and prototype

1. An electronic circuit was designed to capture and record data from a 3-axis accelerometer, including a user interface to start and stop the recording and playback.

2. Microcontroller firmware was developed to enable data recording to SD (secure digital) card and to convert data to MIDI for playback via USB (universal serial bus) from SD card.

3. Prototypes were duplicated at the end of this phase, allowing work to begin with one of the units while PCBs (printed circuit board) were developed in Phase two.

Phase 2: PCB design and assembly of functional devices

The functional prototype design was converted into a PCB layout which is more durable and easier to reproduce. This PCB was manufactured and the individual parts were mounted to it. These were manufactured into a waterproof enclosure.

Phase 3: Initial support and calibration

Following delivery of the devices, some necessary adjustments were made and software bugs were corrected during fieldwork prototype testing.

Phase 4: Completed phase support and adjustment consultation

Ongoing support was provided by Elk Elektronik during the normal use of the devices while collecting data for the project.

3.3 Moto MIDI Features

Data Capture:

- Records 3-axis of gyroscope data.
- Converts the data to MIDI messages.
- Stores the resulting data on an SD card.
- Device powered by battery.

User Interface:

- Power Switch: Turns the device ON/OFF for battery use; USB power does not require switching.
- Power/Status Light (Green): Indicates device status.
- Record Button (Red): Starts/stops data logging.
- Play Button (Black): Initiates playback.

Using the Motion Detector:

1. Recording: Press the red record button to start and stop the collection of data. Each recording will be added to previous data take.
2. Playback: Open DAW, connect the device via USB to computer and press the play button. Playback is continuous.
3. Erasing: Hold the record button for 5 seconds to delete file.

Axis Functions:

- X-Axis: MIDI CC (default Modulation Wheel), range 0-127.
- Y-Axis: Pitch & Pitch Bend, range 0-127 for pitch bend and 50-90 for note pitch.
- Z-Axis: Note ON/OFF, range 0-127. Defaults: Note ON Threshold 80, Note OFF Threshold 50.

3.4 Using the Motion Detector to Record MIDI

Recording MIDI

To record data while surfing, I pressed the record button once and the red light would illuminate for the duration of the recording. I then pressed the record button again to stop recording. Consecutive recordings were appended to the previous recordings.

Playing back recorded MIDI

I connected the Moto MIDI via micro USB cable to my macbook pro and waited for the device to show as a MIDI device inside of Ableton Live. To initiate playback, I pressed the play button once. The yellow light remained on until the whole recording was played. Playback could not be stopped.

Erasing the MIDI file

To erase a MIDI file, I held the record button for five seconds. The red light would flash, indicating that the MIDI file was deleted. When no file was present, the play button has no effect and the yellow light did not illuminate.

Axis Functions

Each axis was assigned a unique MIDI function as outlined below.

X-Axis – MIDI Control Change

The X-Axis generates a MIDI control change, triggering the modulation wheel. This can be easily assigned to a range of programmable parameters, functions, controls in a DAW. The range of values is between 0-127.

Y-Axis – Pitch & Pitch Bend

The Y Axis has two functions, both relevant for pitch control. The position of the Y axis, when a note is turned on by the Z axis, sets the root pitch of the note. Once a note has been turned on by the Z Axis, the Y Axis controls pitch further by transmitting the pitch bend parameter.

Range of pitch bend between 0-127. See Figure 3.5.

Range of Note Pitch between 50-90. See Figure 3.5.

Z-Axis – Note ON/OFF

The Z Axis controls the note on/off timing of the transmitted MIDI data. Once the note on threshold is passed, a MIDI note on command is sent with the pitch determined by the Y Axis position.

When the lower threshold on the Z Axis is passed, a MIDI note off command is transmitted.

Range is between 0-127

Default Note On & OFF Thresholds:

Note ON Threshold: 80

Note OFF Threshold: 50.

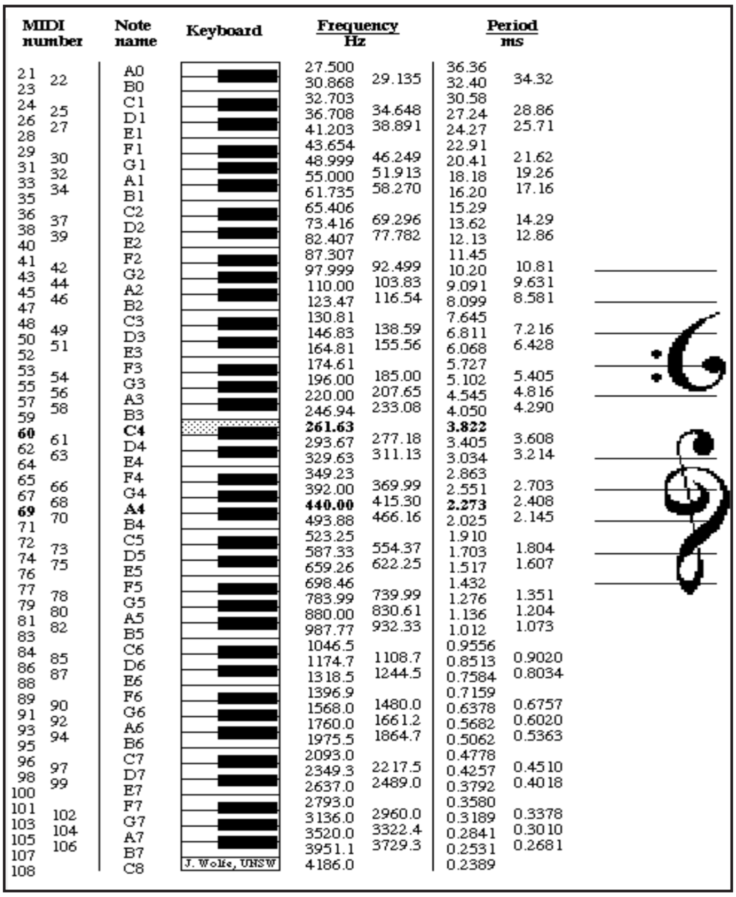


Figure 3.5

MIDI Note Chart

3.5 Second and Third Generation Moto MIDI Prototypes

The second-generation Moto MIDI features a smaller enclosure making it easier to surf with. There were no technical adjustments made to the interior of the device. See Figures 3.6, 3.7 and 3.8. However, I had trouble with the power switch temporarily disengaging while surfing. The third-generation enclosure features a different switch which prevents this from happening. See Figures 3.9, 3.10 and 3.11. This enclosure also has a dedicated battery compartment and the removable panel is on the bottom, making it easier to replace the battery.

Figure 3.6

First-generation Moto MIDI enclosure on the left, with an empty second-generation enclosure without technical components on the right.

Figure 3.7

Photo of the empty second-generation enclosure on my forearm, illustrating where it will be positioned inside the wetsuit armband while surfing.

Figure 3.8

Second generation Moto MIDI controllers with older style power switch.

Figure 3.9

Third-generation Moto MIDI controllers with new power switch and removable base.

Figure 3.10

Direct view of third-generation Moto MIDI controllers with new power switch and removable base.

Figure 3.11

Third-generation Moto MIDI device connected to a micro USB cable and adapter for streamlined data upload to a MacBook Pro.

3.6 Prototype Development and Waterproofing Challenges

Prototype Testing and Issues:

The initial prototype interacted effectively with the DAW, and the buttons, lights, and 3-axis output (Note on/off, pitch, modulation) functioned as expected. However, we encountered a significant issue with waterproofing. Despite a successful recording to the SD card, water ingress was detected through the buttons during ocean tests.

Solutions:

1) **Housing Redesign:**

- Initial Approach: 3D-printed a narrower housing for the forearm, but water seeped through the buttons.
- Revised Design: Redesigned the housing to be backfilled with resin, with controls placed on the 3D printed enclosure and a removable base instead of a lid. Added a separate battery compartment to facilitate battery replacement.
- Power Switch: Initially had trouble with the old-style power switch temporarily disengaging. New enclosure features a different switch.

2) **Waterproofing Difficulties:**

- Sealant Issues: Despite attempts with adhesives, silicone, and resin filling, we struggled to achieve a watertight seal.
- Component Sourcing: Finding compact, waterproof buttons and switches was problematic.

3) **Alternative Solution:**

- Developed an electronic solution for remote recording and MIDI message reproduction, but sealing methods made electronics retrieval difficult and potentially damaging.

4) **Current Approach:**

- Discontinued the resin-sealing method to avoid damaging components. Instead, using a waterproof pouch for the electronics to protect them while collecting data.

3.7 MIDI Note Ranges

One of the challenges faced in the development of the MIDI controller was producing MIDI note values within a meaningful range. An example of this challenge is keeping the notes within the mid-range of the keyboard, while still allowing a broader range of pitch values in response to further extension of motion, without a fixed reference point in space.

Two main features helped account for this:

1. Calibration of a 'home' position at startup: When turning on the controller, it should be oriented in such a position to approximate the central range of motion of all movement axes. The intention of this method is to establish a known reference. When motion is detected, movement on each axis is calculated relative to the Home position and a corresponding MIDI message is output.
2. Provision of thresholds to establish a binary trigger: Two thresholds are provided to generate a hysteresis effect which allows for a distinct 'note on' and 'note off' MIDI event. The two values should not be set at the same value in order to ensure there time for a note to remain on, and not 'chatter' between the two states with small changes in movement.

Calibration of the Home position was developed to occur during the boot sequence and set the home position parameters of the X, Y, Z axis according to the orientation of the controller at that time. This is designed to be a dynamic process and requires no additional user input for configuration. On the other hand, the threshold parameters are set via the controller code and can only be adjusted via the arduino computer interface.

There was some trial and error required to adjust these thresholds in particular; to produce an output which had the most useful musical range. This was difficult, due to the complex nature of calculating the relative motion of the sensor, which led to instances where the sensor would often be too far out of range due to extended motion, and then would not be able to come back down within range of the lower thresholds. This resulted in sustained notes which could not be turned off. Firmware updates were able to improve the usable range of the controller, however, in some circumstances there were still some unexpected MIDI events.

The Motion controller outputs on three axes:
X Axis - Mod Wheel
Y Axis - Pitch Wheel
Z Axis Note ON/OFF with built in threshold

Note on/off thresholds can be set to various points in the range of motion. For example, the total range is 0-127. In the example, 'note on' occurs at 80 and the 'note off' occurs when the device passes back through 50. In this case, the device will turn on when it passes 80. Once it is on, it will stay on for any value between 51-127. Once it hits 50 it will turn off. It will then remain off for any value between 0 - 80. The thresholds are modified in the code. See (Figure 3.12) for ON_THRESH & OFF_THRESH values.

```
#define ON_THRESH 80
#define OFF_THRESH 50

#define RANGE_X 127
#define RANGE_Y 16383
#define RANGE_Z 127

#define START_X 63
#define START_Y 8191
#define START_Z 63
```

Figure 3.12

Calibrated MIDI ON_THRESH & OFF_THRESH values.

3.8 Wetsuit Arm Band

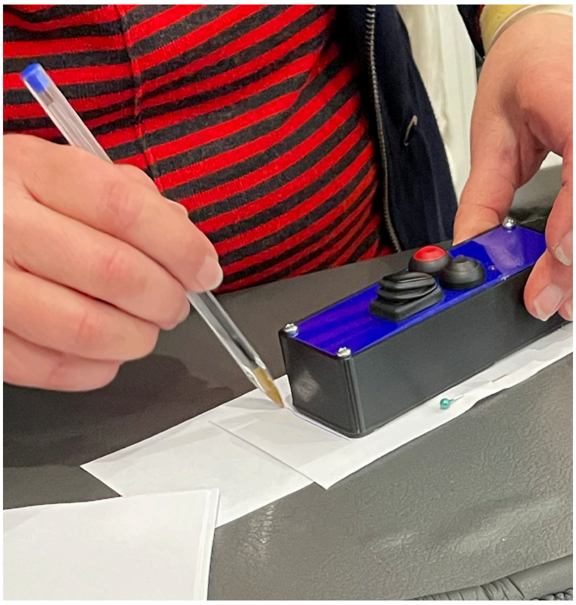
Before conducting the surfing experiments, I collaborated with a local tailor in Corrimal near Wollongong to create a custom wetsuit armband. The tailor designed the armband using neoprene. The armband features a velcro closure and provided a snug fit around my arm without restricting my movement. A small pocket was sewn onto the front of the armband to hold the device in place. See Figures 3.13, 3.14, 3.15, 3.16, 3.17 and Video 3.1.

Figure 3.13

Interior technical components of the first prototype attached to a gardening glove to represent a way to record motion data.

Figure 3.14

Tailor measuring the Moto MIDI device in preparation for the neoprene arm band.



Video 3.1

Moto MIDI device being measured by the tailor.

Figure 3.15

Neoprene armband being measured against arm.

Figure 3.16

Moto MIDI device inside the pouch of neoprene arm band.

Figure 3.17

Moto MIDI device inside the pouch of neoprene arm band strapped to my right arm.

Chapter 4
Motion Data Sonification and Surfing Experiments

The following chapter outlines a series of surfing experiments conducted to capture motion data and translate it into sound. These explorations focus on collecting data while surfing and investigating various methods of mapping this data into sonifications.

An introduction to key surfing terms is provided below for readers who are not experienced surfers.

4.1 Surfing Terms

- Duck-diving: A technique used by surfers to push their board underneath a wave.
- Onshore breeze: A wind blowing from the ocean toward the land, often making the waves messy and difficult to surf.
- Out the back: A place to sit beyond the breaking waves while waiting for the next set.
- Peaky waves: A-frame-shaped waves that often provide a steep entry and extra momentum for the surfer.
- Set: A collection of waves that break in sequence.
- Wetsuit booties: Neoprene footwear that covers the feet and provides protection from the cold and sharp reef.

4.2 Dry Land Testing

Before conducting the full experiments in the ocean, I tested the motion detectors in my home studio to ensure they were functioning and able to capture the appropriate data. By using the neoprene custom wetsuit armband, I attached a motion sensor to my right arm. I simulated the movements I would typically perform while surfing. This involved emulating the pitching, yawing, and rolling motions of my arm, as it would to generate the MIDI data for Note on/off, pitch, and modulation control. All collected data was uploaded in Ableton Live.

4.3 Why I Chose the DAW Ableton Live for Motion Data Sonification

I have spent six years learning to produce and compose music using the digital audio workstation (DAW) Ableton Live. This DAW has become integral to my creative practice and is the perfect production tool for translating the surfing motion MIDI data into sound. This platform's prominent feature is that most essential controls and functions are accessible directly on the main screen (Ableton, n.d.). This allows for quick setting changes and adjustments. Unlike other DAWs such as Pro Tools or Logic, Ableton processes audio and MIDI data almost instantly upon input of modification, resulting in low latency and making it easier to turn ideas into audible music. Additionally, using downloaded VSTs and plugins is straightforward in Ableton and session view also hosts a plethora of built-in instruments and effects (Ableton, n.d.).

4.4 Using Ableton Live to turn Data into Sound

Step 1) The process of retrieving data involved opening the hard case, removing the USB drive, and connecting it to my computer.

Step 2) One or multiple MIDI tracks were created inside the Ableton Live session view. The converted motion data was directly uploaded into these tracks. When using more than one track, either different data takes were layered or one take was multiplied.

Step 3) Various instruments and Virtual Studio Technologies (VSTs) like DIVA were used to play the MIDI sequences. Each VST or instrument played back the data in a unique way. For example, a synthesiser like Serum created ambient and evolving sounds, while a sampler like Kontakt replicated real instruments.

4.5 Experimentation with Virtual Studio Technology

While searching for suitable sound patches, I explored various VSTs. Initially, I experimented with the Valhalla Supermassive VST, which reminded me of the dinosaurs in 'Jurassic Park'. Figure 4.1 and Video 4.1. There was a lot of variation in rhythm in this data take, but the pitch range was relatively narrow.

Figure 4.1

Image of data paired with Valhalla Supermassive VST displaying the pitch bend envelope.

Video 4.1

Video preview of data being paired with Valhalla Supermassive VST.

Next, I used the Diva VST, layering two separate data takes and assigning the MK Flute to both. See Audio 4.1. This was reminiscent of whales conversing, creating an ambient and eerie sound.

Audio 4.1

Diva VST featuring the MK Flute patch layered.

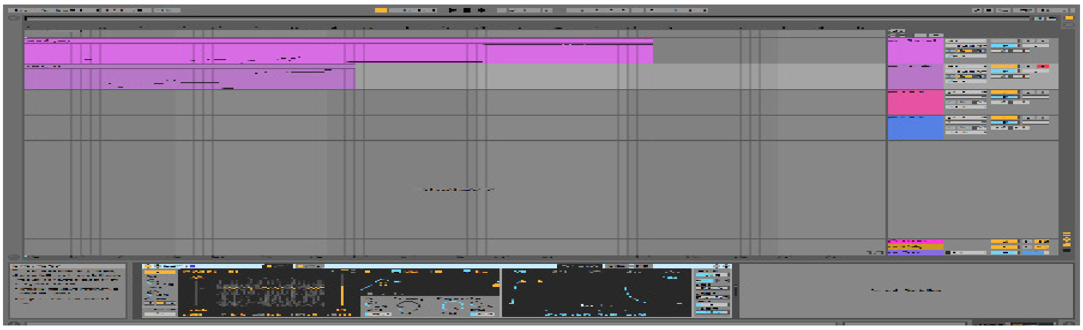
I then coupled the Levitate and Floating keys patches, Audio 4.2, creating a harmonic bed beneath the more rhythmic whale sound. See Figure 4.2 for a visual of this session opened in Ableton Live.

Audio 4.2

Sonification using U-He DIVA sound patches Levitate and Floating Keys to process the surfing motion data.

Figure 4.2

Visual in Ableton Live of data layered and processed using DIVA Levitate and DIVA Floating Keys.



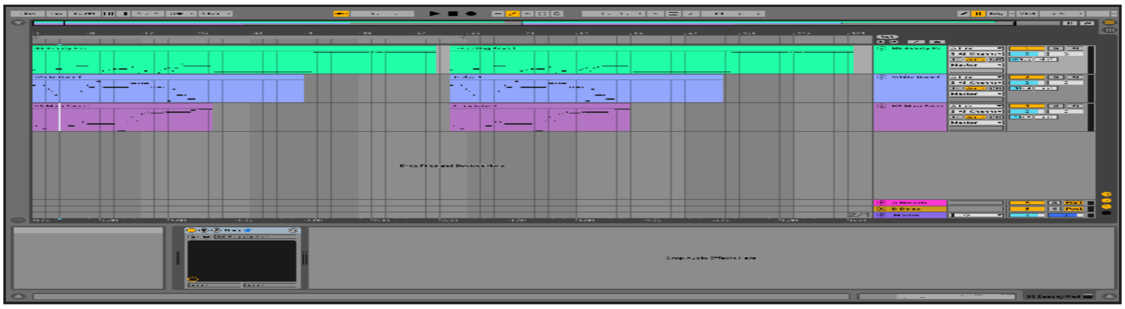
The third sonification utilises three separate DIVA patches. See Figure 4.3 and Audio 4.3. One data sample is processed using HS White Dwarf and the second data sample is duplicated and processed using BS Beauty Pad and HS Maxi Swoop.

Audio 4.3

Sonification three featuring three U-He DIVA sound patches.

Figure 4.3

Session view in Ableton Live of three separate DIVA patches: HS White Dwarf, BS Beauty Pad and HS Maxi Swoop.



Additionally, Figure 4.4 displays a transcription of a small portion of Audio 4.3 in an attempt to explore pitch and rhythmic variation present in the sonifications. Initially I had considered analysing rhythmic variations against an 80BPM grid and examining note length and pitch within a three-octave range. However, this did not end up being a necessary step in the evolution of this study. I decided, instead, to use the raw output of each sonification to inspire improvisation and composition.

Figure 4.4

A notated transcription of layered data takes from Audio 4.3. The vibrato signifies pitch modulation.

Lastly, Figure 4.5, displays an image of the U-He DIVA VST with the HS Canterbury Creeper patch selected. This is to provide insight into what this VST looks like opened inside a DAW and has been designed to visually emulate a physical analogue interface.

Figure 4.5

U-He DIVA VST open inside of Ableton Live with the HS Canterbury Creeper patch selected.

Upon hearing the initial sonified output of the motion detectors, the data seemed to translate into sounds that provided an interesting sonic representation of my movements, though without context it lacked a connection to surfing. This lead me to think about different approaches and outcomes that could now be taken. Firstly, I could use the data directly, creating sonifications that were based completely off the raw data. In this case, only the sound of the data was manipulated to create sonifications. I could also use the data and resulting sonifications as ambient sonic lansdcapes to improvise to. Lastly I could take elements of sonifications or discoveries made during the improvisations to use in deliberate compositions. As a result, I was expanding my improvisational and compositional palette and creating a musical indexical representation of surfing. See chapter 2.7.

4.6 Surfing Locations and Resulting Sonifications

Following this dry land experiment, three surfing locations were selected, including Thirroul Beach and Woonona Beach in Australia, as well as a location in Sumatra, Indonesia. These experiments are outlined consecutively below.

4.7 Location 1: Surfing Thirroul - July 21st 2022

Thirroul Beach is in the northern suburbs of Wollongong. The rock shelf to the north and the nearby creek outlet shape the sandbanks, often producing good quality consistent waves. On the day chosen to collect data, the conditions were not optimal. There was a slight onshore breeze, which caused the waves to become bumpy and more unpredictable, but there were still plenty of surfable waves. The motion detector was attached to my right arm using the wetsuit armpiece.

This data-collecting session lasted 45 minutes. The motion detector was switched on prior to catching a wave and then off after surfing. Some waves were not completely recorded due to problems with the on/off switch disengaging. However, enough data was collected to suit the purpose of the experiment. These sonifications are provided below. See Audio 4.4, 4.5 and 4.6. Beneath each audio segment is a table providing an overview of the sonification. See Tables 4.1, 4.2 and 4.3.

Audio 4.4

Thirroul Beach sonification one.

Table 4.1

Table of events within Sonification one.

VST Synthesiser	• U-he DIVA (Dinosaur Impersonating Analogue) synthesiser
MIDI Patch	• HS White Dwarf
Musical Elements	• Walking around in 5ths, 3rds, tones and semitones • Not in time • Hovering in some areas and moving quickly through others
Modulation	• Subtle modulations from LFO or envelopes affecting oscillator pitch • Creates a meddling sound • Hard to tell whether data is effecting modulation
Mixing effects	• Reverb • Compressor applied in master track
Other Characteristics	• Eerie • Ambient • Haunting • Evolving • 25 cents flat quality

Audio 4.5

Thirroul Beach sonification two.

Table 4.2

Table of events within Sonification two.

VST Synthesiser	• U-he DIVA (Dinosaur Impersonating Analogue) synthesiser
MIDI Patch	• MM Choir in the Clouds
Second layer MIDI Patch	• RC Rhythmic Reel
Musical Elements	• Limited pitch range with movement within a minor third • Due to limited note On/Off threshold during data capture • Low octave (C-C2) • Rhythmic reel adds consistent rhythmic element
Other Characteristics	• Brooding • Menacing • Ambient
Applied effects	• Reverb • Compressor in master track

During these experiments I realised that by assigning the patch 'Float Chords' to the third Thirroul sonification, an aesthetically pleasing sound patch would allow me to musify the data. See Audio 4.6, Table 4.3 and Figure 4.6. It was important to consider whether the purpose was to gather and analyse the raw data or create whatever output occurred at the time to propel creative exploration. I decided, for the most part, to process all of the data in an open exploratory way, only applying musification to this singular sonification.

Audio 4.6

Thirroul Beach sonification three.

Table 4.3

Table of events within sonification three.

VST Synthesiser	• Vital
MIDI Patch	• Float Chords
Musical Elements	• Remains in D major and/or B natural minor • Light disconnected melodic elements • Interspersed with low note swells adding depth
Other Characteristics	• Dainty • Music box quality • Pretty • Example of musification

Figure 4.6

U-He DIVA VST open inside of Ableton Live with the HS Canterbury Creeper patch selected.

4.7.1 Hardware Considerations and Maintenance

While using the motion detectors to gather data at Thirroul Beach, a wire became disconnected inside one of the motion detectors causing it to malfunction. This made it apparent that I would need to maintain ongoing communication with Elk Elektonik to ensure that the motion detectors were attended to and if necessary, re-paired, while undertaking the experiments.

4.8 Location No. 3: Surfing Woonona Beach - August 6th 2022

Woonona beach is a local favourite. The rocky point and the well positioned rocky reefs shape the swell into peaky waves that are known for their quality. The motion detector was once again attached to my right arm via the wetsuit arm piece. The waves were small and well formed, making them optimal to collect data using the motion capture device.

This time the device was activated upon paddling, enabling it to capture the movements of paddling out and duck-diving. The device was toggled off once I was out the back, ready to record each wave as normal. The data from four waves was captured during this session.

In addition to the device fault, the weight of the device had started to stretch the wetsuit arm piece, which was no longer staying in position and increased the risk of losing the device in the ocean. As the waves in Sumatra generally have more power, and break over shallow reef, and with only one week before departing for Sumatra, there was not enough time to modify the arm piece. There needed to be another way to attach the device in order to capture data. The solution to both problems was found in a waterproof smart phone pouch.

However, due to the size of the pouch, the device could no longer be attached to my arm, and so had to be taped to the nose of my surfboard using duct tape. I also packed a small waterproof plastic hard case as a back up plan. See Figure 4.7.

Figure 4.7

Waterproof smartphone pouch (bottom) and hardcase (top).

4.8.1 Routing MIDI to Synthesiser and Recording Back into Ableton

After uploading the MIDI data in Ableton Live, I then processed it through a Sequencial Pro 3 Multi-Filter Mono/Paraphonic Synthesiser. The synthesiser's output was then recorded back into Ableton. See Audio 4.7 to hear the data layered and processed using two separate preset patches, 'Beatbox' and 'Waveseq Arp'.

Audio 4.7

An audio sample of the Woonona Beach surfing motion data processed using the Sequential Pro 3 Multi-Filter Mono/Paraphonic Synthesiser.

While processing the data through the Pro 3 and recording the audio output, I adjusted various parameters in real time. This included experimenting with envelopes, effects, oscillations, Amp and LFO to see how they affected the signal and changed the audio. After each track was recorded, effects were applied such as convolution reverb, Sound Toys Crystalliser, and FilterFreak. I also added an auto filter and multiband compression to the master track. Depending on the selected synth patch, the audio output varied from drone-like soundscapes to more rhythmic sequences. Overall, the audio outputs varied depending on the selected monophonic, polyphonic or layered sequence patch. The resulting musification sounds organic yet alien. The synthesiser patches used bring the piece into the realm of a 1980s science fiction film. A photo of this session is provided below. See Figure 4.8.

Figure 4.8

A photo of the surfing MIDI data being processed by the Sequential Pro 3 Multi-Filter Mono/Paraphonic synthesiser and recorded into Ableton Live.

4.8.2 Managing High CPU Usage in Ableton

While processing the MIDI in Ableton I encountered crackling issues. This usually became worse when I applied effects or layered takes. The issue appeared to be due to high CPU (central processing unit) usage and was mostly resolved when I flattened and froze the MIDI tracks, turning them into audio. Although the crackling was noticeable, it didn't become too severe and I was able to export audio without any issues.

4.9 Location No. 3: Surfing Krui, Sumatra - August 10th - 22nd 2022

In mid-August 2022, I embarked on a two-week data collection surf trip to Krui, Sumatra, Indonesia. I stayed at a surf camp in Krui called 'Secret Sumatra'. This location was initially chosen because of its reputation for consistent mechanical waves. This seemed like a perfect controlled environment for data capture. While staying at the camp, my mornings were dedicated to searching for waves and then surfing until midday. At 5 am each morning, our surf guides drove us to the optimal surf break location based on the daily wind, swell, and tidal conditions. I surfed with the motion detector at Krui Right, a fast right-hander with a steep drop and quick barrel, and Krui Left, a more mellow reef break that also often barrelled.

Due to technical challenges just a week before the trip, I resorted to duct-taping a motion detector to the front of my surfboard to collect data. See Figure 4.9. Unfortunately, the duct tape had trouble sticking to the wet fibreglass board, especially with the high humidity (80-90%). This caused the motion detector to frequently come loose after only a few waves. Frequent breaks were needed to paddle back to shore and re-tape it, which would take at least 20 minutes, if not more and this became an exhausting obstacle.

Figure 4.9

Photo of the Moto MIDI inside of the waterproof smartphone pouch taped to the nose of the surfboard.

The waves in Sumatra are renowned for their speed and exposed dry reefs. This makes them difficult to surf. In August, the breaks in Krui feature fast-moving swells, usually between three and six feet (one to two meters), coming mainly from the southwest. Surfing in these conditions took some getting used to and on the larger days, the difficulty of keeping the motion detector in place often prevented me from collecting data. There was a significant risk of being pulled into barreling waves and falling onto dry reef. Photos of me surfing in Sumatra are provided below. See Figures 4.10, 4.11.

Figure 4.10

Surfing Krui Lefts.

Figure 4.11

Surfing Krui Rights

Video 4.2 provides GoPro footage of me walking into the ocean with the device taped to the nose of the surfboard.

Video 4.2

POV footage of walking towards the water and paddling out the back in Krui, Sumatra.

To minimise the risk of injury to myself, and to maintain control of my board and the device, I wore wetsuit booties. This allowed me to stand on the Sumatran reefs without injury to my feet. However there were still times when the board and motion detector hit the reef, and so did I, resulting in a few reef cuts and abrasions on my legs.

Fortunately, no motion detectors were lost to the ocean. Additionally, somewhere between the multiple flights and seven-hour drive it took to get to my destination in Sumatra, a micro USB to USB cable was misplaced. In order to download the data and work with it I needed this cable, and it took seven days before a new one arrived. See Figure 4.12. Luckily I had enough motion detectors to keep in rotation so that none of the data was overwritten and I was still able to collect enough data to advance my research.

Figure 4.12

A photo of the motion detector sitting on top of my surfboard in Krui, Sumatra and connected to the USB to micro-USB cable and adaptor.

4.10 Chapter Summary

This chapter outlined motion data collection methods and processing techniques used to create sonifications. It began with a dry land experiment to test the motion detector, followed by results from three surfing locations, Thirroul, Woonona, and Krui, Sumatra. Despite varying surf conditions, the diverse sonification techniques prevented clear correlations between conditions and surfing manoeuvres.

During the surfing experiments in Thirroul and Woonona, I used a custom-made neoprene pouch to hold the Moto MIDI on my arm while surfing. Although this was mostly effective, the device occasionally slipped down my arm. Keeping the device dry was also a challenge. Despite efforts to waterproof the Moto MIDI, water began to seep in through the record and on/off buttons. I was flying to Sumatra within a week, so the timing was not ideal. I decided to place the device inside a waterproof plastic phone pouch and duct-taped it to the front of my board. However, surfing in Krui, Sumatra was not easy. The waves were often fast and barreling and there was a chance of landing on dry reef. On top of physical challenges, the duct tape would often come unstuck due to water and humidity. This required me to regularly paddle to shore to re-tape the device to the board. Regardless of these technical roadblocks, I was still able to collect sufficient data while in Sumatra.

Further experimentation in challenging surfing environments such as Sumatra would benefit from prolonged initial experimentation to first test the technology in safe conditions to determine its reliable functionality. Ensuring that it will not be a practical hindrance to the wearer in the data collection process is essential. An alternative viable option is to carry flexible means of collecting data such as well-tested off the shelf technology including mobile phones.

Technical challenges were also encountered and listed. As a result of these challenges and following these experiments, an alternative method for recording and processing the surfing motion data began to emerge as an option for future experiments by using an i-Phone to record movements while surfing. Mobile phones have a range of sensors built-in which can be used to collect data, using onboard memory. This approach offers several benefits, including durability, portability, and simplified data manipulation as the hardware is well-tested, readily accessible and reliable. By securing the phone in a waterproof pouch and attaching it to the surfboard or the surfer's back, motion data can be easily collected and saved as a CSV (comma-separated values) file using the phone app Sensor Logger. As this approach might streamline the motion data collection process, it is a strong consideration for future studies. However, I still managed to conduct experiments using the Moto MIDI and generate enough data to satisfy the initial aim of the study. This alternate means of collecting data also poses questions about the effectiveness of developing custom technology versus repurposing readily available consumer technology and is a consideration for data sonification research.

Chapter 5
Creative Works 1, 2 & 3

This chapter explores the capture, analysis, and sonification of my movements while surfing. It focuses on three creative works that translate the surfing experience into sound through musical improvisation, anologue synthesis and digital processing and live performance.

5.1 Creative Work 1: Combined Location Motion Data Sonification and Improvisation

Two days were spent at guitarist, producer, and composer David Rodrigues' home studio, where the data from all four experiments was simultaneously processed through various midi synched analog synthesisers, a drum machine and effects. The audio output was then channeled through non midi synced effects pedals. Finally, an improvised session was conducted and recorded in response to the resulting generative sonification using a digital synth, percussive sounds, an acoustic piano and effects. This included sitting underneath an upright piano, mic'd from beneath and above, tapping various percussive objects against each other or on the legs and strings of the piano, plucking the strings, and occasionally playing the piano keys. The entire session was recorded to tape.

The following drum machine and synths were receiving the same midi information:

- Arturia drumbrute drum machine
- Dave Smith Tetra
- Juno 106
- Prophet

MIDI synched effects:

- Digital delay
- Moog Moogerfooger clusterflux analog chorus
- various guitar fx pedals with midi control

Non-MIDI synched effects:

- Roland space echo 201 tape echo delay
- AKG BX20 spring reverb
- Tube spring reverb

5.1.1 Resulting 21-minute Sonification

The music generated by running the motion MIDI data through the synthesisers is tense and unpredictable. Combining the synthesisers and layering MIDI tracks created a sense of instability. Because there are so many “layers, there are some harmonic clashes. This is also because the tracks are fueled by unpredictable motion data. Despite the harmonic dissonance, the different layers still seem to blend and interact. In addition to me-lodic and harmonic clashes creating a sense of unease, the music moves from one state to the next, never quite finding a point of resolution. In this way, it could be interpreted as reminiscent of an ever-changing ocean. Arturia DrumBrute, and piano percussive sounds assist in adding a sense of rhythm to the sonification and texturally enhance the music. The Roland Space Echo and Moog Moogerfooger Clusterflux contribute to the eerie nature of the music by adding layers of echo and modulation. This is a form of indeterminate generative music that I would not deliberately be able to compose. See Videos 5.1 and 5.2.

Video 5.1

A video of the data being processed using analogue synthesisers and effects.

Video 5.2

An additional video of the data being processed using analogue synthesisers and effects.

Audio 5.1

21-minute surf motion data sonification

5.1.2 James Kates Surf Film: ‘Mash’

Surf film maker James Kates asked to include segments of the 21-minute sonification made with Dave Rodrigues in his 2023 surf film ‘Mash’ (Kates, 2023), featuring free surfer Noa Deane. Please find segments of this film accompanied by my sonification below in Videos 5.3 and 5.4. See Video 5.5 and Figure 5.1 for the film’s premiere in November 2023 at ‘The Servo’ in Port Kembla, NSW.

Video 5.3

First preview of Mash featuring segment of Audio 5.1.

Video 5.4

First preview of Mash featuring segment of Audio 5.1.

Figure 5.1

Premiere of surf film ‘Mash’ at The Servo in Port Kembla.

Video 5.5

Premiere of surf film 'Mash' at The Servo in Port Kembla.

5.2 Creative Work 2: Piano Improvisations in response to Illawarra Sonifications

The videos provided in this chapter feature excerpts from four separate sessions in which I conducted improvised experiments on a Kawai grand piano, responding to the surf data sonifications from Woonona, Thirroul and Sumatra. See Videos 5.6, 5.7, 5.8 and 5.9. These sessions were recorded using my iPhone at the Wollongong Conservatorium of Music. The resulting videos were then uploaded into Ableton where effects such as reverb and delay were applied. Following each video, a table presents a breakdown and analysis of each improvisation in Tables 5.1, 5.2, 5.3 and 5.4. Following the tables, a reflection is offered regarding the details of the data.

Video 5.6

Improvisation one.

Table 5.1

Table of events within improvisation one.

Chordal Movement	Starts in Dmaj7, then moves to Bb minor/Dbmaj, followed by Bmajor7
Chromatic walk down	Walks down chromatically from F to Eb and hovers on Eb-9/11
Time Grid	No fixed time, moves relatively quickly and consistently through various harmonic areas

Video 5.7

Improvisation two.

Table 5.2

Table of events within improvisation two.

Chordal Movement	Sustained E-7 9/11 chord --> D7sus --> B7 altered
Descending chromatic Suspense chords	From F to D
Upper structure triads chordal sequence	F#/E7, G/F7, F#/E7, F/Eb7 --> C#/B7, D/C7, C#/B7, C/Bb7 --> F#/E7, G/F7, F#/E7, F/Eb7
Final chord progression	E-9/11 to B7#5#9

Video 5.8

Improvisation three.

Table 5.3

Table of events within improvisation three.

Initial pitch structure	Gb, G, Db, D
Chord progression	Bb-b6 --> Gbmaj7#11, Fmaj7#11, Emaj7#11, Dbmaj7 --> Bb-79
Second pitch structure	F, Gb, C, Db
Uncommon chord structures	- Chord 1: E, D#, A# - Chord 2: C#, D, A - Chord 3: F#, F, D - Chord 4: Bb, Gb, F, Db - Chord 5: Gb, D, F, F - Chord 6: F, C, E, E - Chord 7: E, B, D, D
Chord progression	Bmaj7 over F# --> F-7, Emaj7, Dbmaj7, Bmaj7
Upward Movement	On Bb-b6 chord with added major 3rd; very high right hand and low fifths with melodic movement on Emaj#11 to Dbmaj7
Downward Movement	Right hand returns to mid-octave, playing the same melodic figure over chords Bmaj7 to Bb-7
Ending	Descending left hand and ascending right hand, finishing on Eminor 9/11

Video 5.9

Improvisation four.

Table 5.4

Table of events within improvisation four.

Initial idea	Low E octave in LH with 8th note quaver light fifths (E and B) in RH
Parallel Movement	Moves the same structure in parallel to D, then back to E
Sustained Section	Sits on E Suspended
Parallel Movement	Parallel movement with the same structure up to F#, then G#, and A
Sustained Chord	Sits on E9 chord
Chord Progression	C#7sus, D7sus, E7sus --> F#, G#, C# in RH over F# octave in LH bass
Repetition of Initial Motif	E and B fifth in RH over low E octave in LH, then same structure parallel movement to D
Arpeggios	Arpeggios on C#7sus
Ending	Finishes on E-9 chord

5.2.1 Piano Improvisations Reflection

Listening back to my improvisations was helpful for a number of reasons. Firstly, I was able to hear myself playing in response to music not generated by a human being. There was no precise time grid, and even though specific pitches can be heard in the sonifications, it was harmonically freeing. There was no order to the way the dynamics shifted and my placement of ideas sounded different to usual. This helped me let go of pre-conceived notions about how I 'should' be improvising. At times I found myself gravitating towards upper structure triads and diminished major seventh chords. I also repeatedly played fifths in the left hand with a dyad in the right hand, or single note melodic lines. When uploading these recordings into Ableton, I used effects such as reverb and delay and even the Sound Toys crystalliser to create a more cohesive sound within the realm of the sonifications.

An enlightening element to exploring this new style of improvisation was that I had to remind myself to refrain from judging the performance before, during, or after playing. I needed to remain present and connected with the music. This proved to be an important lesson in general for future practice sessions and performances. The unpredictable harmonic and rhythmic nature of the sonifications were not typical of the structure or arrangement of compositions made by a human. Prior to this research, my improvisational choices have been deeply rooted in years of practice and past decision-making, which has in turn been informed by well-established norms and paradigms of the music world. As a result, I was initially apprehensive when improvising over these sonifications, however, as I progressed I was able to break free from some of these ingrained boundaries. Once I became familiar with this new way of thinking, I was able to familiarise myself with the music of the data and then explore new, and often dark and mysterious aspects of my playing.

This experience opened my ears and introduced me to experimental German pianists like Moritz Fasbender, whom I saw perform at South by Southwest in Texas in May 2023. It inspired me to delve into the work of many artists signed to the progressive instrumental XXIM Record label, including Alexandra Stréliski, Eydís Evensen and GoGo Penguin. Listening to these artists and their approach to composition helped contribute to the process of composing a new suite of music for saxophone, piano and synths, double bass, drums and production.

5.3 Creative Work 3: Composed Suite and Performances

After conducting these experiments recorded in chapters nine and ten, and analysing my improvisations in response to the motion data sonifications, I felt inspired to incorporate elements of this into a suite of music. ‘Music from the Waves’, composed during 2022 and 2023, is a one hour set of new compositions for quartet featuring Sandy Evans on tenor saxophone, Maximillian Aluduca on double bass, Miles Thomas on drums and myself on piano, vocals, synthesisers and production. The work has not been formally recorded, as such, this chapter will provide video segments of live performances of the work. A studio recording will be available in 2025.

In Video 5.10, an excerpt is provided from my original composition ‘Corduroy Ocean’ performed live at Rancom St Studios in Botany, Sydney, as part of the 2023 Sydney International Women’s Jazz Festival. This is a portion of my solo in 5/4 incorporating elements of the improvisations in response to the sonifications, such as upper structure triadic movement and diminished major 7th chords.

Video 5.10

Excerpt from ‘Corduroy Ocean’

The performance of this suite of music is interspersed with audio samples I built in response to the data sonifications. The band often improvises, and they serve as the glue and create a more cohesive suite. See Video 5.11. They are also complemented by spoken word narratives about the ocean and surfing. These narratives are often delivered while the band improvises in response to the audio samples. The elements of the spoken word and tracks place us in a different frame of mind while we perform.

Video 5.11

A band improvisation performed live at Rancom St Studios in Botany, Sydney, over an audio sample I produced in Ableton Live, in response to a data sonification.

Another feature of this suite of music is a solo synthesiser segway I perform between two original compositions 'Blissing' and 'Inevitable Convergence'. See Video 5.12. This serves as another way to integrate the essence of surfing and the sonifications into this suite of music.

Video 5.12

Solo synthesiser segway recorded live by 'Oh Jazz' at the 'Jazz Lab' in Melbourne.

Before the improvisational exercises from chapter nine were conducted in response to the sonifications, I had yet to consider incorporating entirely open improvisation into my music. Because of the nature of this suite, it feels like the narrative guides the improvisations. There is a conviction to the delivery, and the set concludes with an open improvisation led by Sandy and our drummer, Miles Thomas. Our bassist, Max Alduca, and I gradually join the interaction as it spirals into what I perceive as a rhythmically and harmonically busy, chaotic beauty. See Video 5.13. The music resolves differently each time. This musical exploration is another way of manifesting my relationship with surfing and viewing it through a creative prism.

Video 5.13

A segment of the final open improvisation that concludes the 'Music from the Waves' suite.

As previously mentioned, during 2023, this band set out on a small east coast tour of Australia. We also performed at the Sydney Conservatorium Jazz Festival in May 2024. During these performances, I played some of the 21 minute sonification created with Dave Rodrigues as the audience entered the venue and settled into their seats. The tension of this audio contrasted starkly with the calming quality of the first sample played at the beginning of our set. This acted like an auditory palette cleanser.

At our Phoenix Central performance in May 2023, advanced lighting and effects were used to enhance the performance and further encapsulate the feeling of the ocean. See Videos 5.14 and 5.15. As part of the engagement process with performing artists, Phoenix Central surveys audience members post-performance for feedback, which they forward to performers. Some of the responses included:

"The performance was too beautiful. The music itself was inspiring, intriguing, and healing. Got so much dopamine while listening to it."
"Such an amazing experience. Loved the musicianship and Freyja's inspiration from capturing sound waves while surfing."
"Beautiful, intimate, transformative experience!"
"Brilliantly rich sonic experience, highly professional gig, these artists have real chops."
"Completely loved it! Fabulous artistry, great concept, tight band, and the arc of the performance was so well conceived and executed. Fantastic. Freyja delivered a virtuosic composition and performance."

Video 5.14

A segment of my original composition 'Blissing' performed live at Phoenix Central Park, Sydney, in May 2023.

Video 5.15

An additional segment of 'Blissing' performed live at Phoenix Central Park.

The audience's reaction to our performance was humbling. Through the integration of audio samples, spoken word, improvisation, and lighting effects, they seemed to feel connected to the ocean, surfing, and our performance as a band.

A final video is provided below showcasing a segment of a piece entitled 'Inevitable Convergence', written about the gradual merging of two tides in a vast ocean of corduroy. See Video 5.16. The harmonic tonaility of this piece is in E major and minor. Prior to conducting the improvisations in response to the sonifications, I had never composed in these keys. I perceived them as guitar keys, and not something I would utilise as a pianist. However, during these experiments I began exploring these keys and realised how bright and effective they can be.

Video 5.16

My original composition 'Inevitable Convergence' performed live at Rancom St Studios, Botany, Sydney.

For two performances in November 2023 at Rancom Street Studios in Botany, and Finding Fillmores in Kiama, I brought along a projector and screen to display stagnant and moving imagery from two local artists. This was the work of international award-winning ocean photographer, Ray Collins, and surf filmmaker, James Kates. Many of these visuals feature surfers riding waves along the east south coast of Australia, further enhancing the geographic resonance in my work. Ray's footage also showcases waves in Sumatra, some of which was captured in Krui during a stay at Secret Sumatra, where my third surfing experiment from chapter 4, was conducted. Over the years, Ray has become somewhat of a local celebrity there and his work is featured on the walls of the resort.

Composing and touring this body of work allowed me to share my music with others and witness how audiences connected with the narrative. It was also wonderful to hear how the music evolved throughout the tour and how my band members interpreted it differently each night. Eventually, performing the set live felt natural, and we applied our creative prowess and improvisation skills to lean more deeply into the narrative of the suite. This seemed to evoke a more profound connection with surfing and the ocean for us and the audience. After a performance at ‘The Great Club’ in Marrickville, I received an email from an audience member who did not realise I’d composed the music on the Coal Coast. They mentioned that it reminded them of their time living in the area and were delighted when I told them I had created the music in that same location.

5.4 Chapter Summary

This chapter examined methods of capturing, analysing, and sonifying movement while addressing a range of creative possibilities and challenges of working with motion data captured while surfing. Some of the approaches explored included analogue synthesis and digital processing, the role of improvisation in interpreting the data musically and real time live performance applications.

Chapter 6
Conclusion

This interdisciplinary research study aimed to sonify and create music based on the motion data gathered while going surfing at two Australian locations, Thirroul Beach and Woonona Beach, and one Indonesian, in Sumatra. The resulting sonifications were used to enhance my compositional and improvisational repertoire. I experimented with the motion data by processing it through various analogue and digital synthesisers and effects. I then improvised based on the sonifications produced. By taking this indeterminate, generative approach to making music and essentially letting the music compose itself from the motion data during the sonification phase, I have gained new insights into how music can be composed. By improvising to this music, I have broken down some traditional boundaries and allowed myself to explore new aspects of improvisation. The insights and lessons gained from these sonifications and improvisations have helped to expand my musical vocabulary and inspired me to develop a new suite of compositions that draws heavily from the motion data sonifications and my experiences along the way. These personal developments extend more broadly and offer a framework for using motion detection technology to create music from non-musical interests.

In Chapter 1, I introduced the philosophical connection between surfing and improvisation, along with an introduction to the project, methodology, and study design, and identified the need for a study that sonifies motion data from surfing. I then provided the conceptual overview underpinning the study, contextualising it within the research surrounding various applications of data sonification. In Chapter 2, I explicated the literature on data sonification to contextualise my study within the current state of knowledge in this field. Overall, studies tended to use data sonification as an alternative tool to interpret data and communicate information in an impactful way. Lastly, I provided a methodological framework for the study. In Chapter 3, I outlined the development and features of the Moto MIDI. In Chapters 4 and 5, I displayed the process and resultant creative outcomes of the surfing, sonification, improvisational and compositional experiments.

This unconventional approach to music aligns with my intuitive process as a creative practitioner. I generally prefer to follow my instincts and only draw on other practitioners' methods when necessary. This way of creating and living has influenced my decision to stay on the mid-south coast of New South Wales. Overall, this study has opened up a new creative way to connect with my immediate environment, express myself more authentically, and further align my interests as a surfer and musician. It also serves as a model for integrating motion detection technology into creative practice and everyday life.

By using the Moto MIDI to collect data from surfing and Ableton Live to discover unique ways to process the resultant motion MIDI data, my technological knowledge and production skills expanded. By playing the piano and interacting with the sonifications, I was able to broaden my improvisational palette. Spending time analysing these improvisations led to the development of new compositions for my quartet that were harmonically, rhythmically or melodically inspired by the sonifications.

The research and experiments carried out in this study establish a connection between human movement, the natural world, science, and music. The numerous creative outputs of this study provide unique auditory representations of the experience of surfing. This adds a new dimension to the field of data sonification. The application of the custom-built Moto MIDI device contributes to the field of motion data technology, providing a contemporary way to expand scientific understanding and musical exploration. The methodology carried out in this project is easily adaptable and applicable to many movement-based activities, such as walking, running, rock climbing, and yoga. It offers improvisers and musicians of all kinds an opportunity to integrate their non-musical hobbies into their practice. Another research direction might be to use alternative motion detection devices while surfing in different locations and conditions which demand adaptation of surfing techniques.

Despite these successful creative outcomes, the research faced several setbacks that caused timing delays and forced the study to change direction. The majority of these challenges were technically based and occurred during the development stages of the Moto MIDI controller. While initially conducting the surfing experiments, it took effort to ensure the device was positioned so that the MIDI note values remained within a recordable threshold. Two set points were calibrated to trigger the start and stop of a note. Since these points were not the same, the note would frequently stay on and if I didn't move a certain way, it would get stuck, minimising the variation in the data collected. This resulted in numerous drone-like sonifications. Firmware updates were also used to improve the controller's functional threshold, but at times there were still unpredictable MIDI data results. Broader lessons for future researches in this field might be to spend more time developing this technology before conducting experiments. This would ensure the data is recorded without interruption. Expanding this study to create a more accurate representation of the motions of surfing may also be beneficial. This is achievable by using multiple gyroscopes to approximate the position in the movement envelope of an endpoint. For example, the position of the wrist could be approximated based on the length of the forearm, upper arm and the gyroscopic relationship of each. This position may then be used to construct MIDI data. Modifications were made to the device throughout the beginning stages of the project.

These included replacing the power switch and addressing waterproofing issues. Despite numerous attempts to construct an entirely waterproof and compact device, there was no easy solution that was affordable within the study timeframe. These technical issues were not anticipated in the initial study design and are considered outcomes of this study.

Regardless of the technical setbacks encountered, the results align with the initial objectives in the introduction. This study demonstrates the benefits and challenges of using a custom-made motion collection device to collect data while surfing and using the data to create sonifications to fuel musical explorations. This study also creates a unique auditory representation of surfing. I hope this original methodology sets the stage for other creative practitioners to sonify motion data from personal motion-based hobbies, expanding their musical palette. The significance of my research within the field of data sonification is that it is contributing something novel to the field. Although motion detection has been used in sonification, it has not been used in this way, to create music from the motions of a recreational water-based activity such as surfing. Surfing has been used in sonification before (Gunnarson, 2016), however that research was focused on physiological fluctuations, such as heart rate, rather than on the actual motions of surfing. My research is also the first example, as far as I am aware, of the application of data sonification to inform new improvisational approaches in music. As the field of data sonification continues to grow, this study provides a model for integrating motion data into creative musical work. It opens the door for further exploration in music and technology, demonstrating how movement, nature, and digital processing can intersect in a new way.

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