Dynamic Music
The Implications of Interactive Technologies on Popular Music Making

by

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Thesis

submitted for fulfillment

of the requirements for the Degree of

Doctor of Philosophy

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The University of Newcastle

This research was supported by an Australian Government Research Training Program (RTP) Scholarship

April, 2020

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Statement of Originality

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Tracy Redhead
20th April 2020

Acknowledgments

I really couldn't have completed my PhD if it wasn't for the support of: my Principal Supervisor Professor Richard Vella. His guidance, patience, wisdom and generosity were superlative; and my husband Jonathan Rutherford, who has been incredibly supportive and patient.

I would also like to thank my co-supervisor Associate Professor Jon Drummond, Professor Frank Millward, Dr Florian Thalmann, Professor Mark Sandler, FAST project, Dr Adrian Hazzard, Gary Bromham, Music Tech Fest, Hakan Lidbo, Ginger Leigh, Trevor Brown, Dr Claudia Schnugg, The Ars Electronica, IRCAM, Music Bricks, Ed Wright for editing my work and all the incredible artists and researchers innovating in the area.

Thank you to my family, the Redheads and the Rutherfords, my close friends and to anyone I have forgotten to mention that has helped me on this journey.

Tracy Redhead

The University of Newcastle

April 2020

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ABSTRACT

The thesis investigates the role of interactive technologies on popular music making. Popular music has always adapted to new technologies, however interactive technologies challenge the accepted forms of popular music making. The thesis introduces two interconnected problems for musicians wanting to embrace changes in technology and communication:

1. the relationship between static (fixed) song forms in popular music and dynamic (fluid and adaptable) forms; and

2. the need for a set of criteria that can encompass the relationship between static and dynamic song forms.

The research asks *how can interactive technologies be used to develop new forms of popular music?*

A review of important musical works utilising interactive technologies and relevant literature is examined. With a foundation in game audio, computer music and interactive art approaches, the review identifies the emergence of a new field, Dynamic Music. Dynamic Music is music that can change and adapt to data. In order to create an experience beyond a static form, the music needs to provide many different playback options.

Composing and producing Dynamic Music forms uses very different approaches compared to static music making. It consists of four components; a control system, music and sound content, musical architecture, and experience. Informed by practice-based research and research-led practice, the methodology develops a grounded theory approach in which an aesthetic of Dynamic Music is introduced. The methodology is underpinned by criteria based on the concepts of 'variability' and 'transmutability'. These criteria are directly related to the compositional model presented for Dynamic Music and provide a foundation for evaluating approaches in Dynamic Music making. The criteria provide a clear distinction between Dynamic Music and static music forms. A portfolio of creative works is provided as evidence of the methodological framework for Dynamic Music composition.

The thesis concludes with an argument for the 'Dynamic Music Producer'. This is a new emerging role able to produce new disruptive music forms; develop systems for their playback and performance; and realise immersive music products and performances into the future.

Research Summary

The Research Problem

Digitisation in popular music offers unlimited potential for new ways of listening and experiencing music. Aligned with digitisation has been the emergence of interactivity. Interactive, reactive, generative and algorithmic music and performance forms are gaining in momentum as artists and the music industry endeavour to find new ways to connect with audiences and create value in their products and services. Popular music has a history of adjusting to suit new technology and audience demands. However, the digitisation of popular music, and its consequent ability to be represented by data, has created the potential for music to be entirely transformed by the interactive technologies increasingly coming to dominate our lives on a global scale. This requires new approaches to form and composition which challenge current popular music making approaches which have traditionally relied on the repetition of fixed forms when played back. Two interconnected problems are highlighted for musicians wanting to embrace changes in technology and communication:

1. the relationship between fixed song forms and dynamic composition; and
2. the need for a criteria that encompass the relationship between static and fluid song forms.

Research question

How can interactive technologies be used to develop new forms of popular music?

Research Aim and Objectives

Aim: To develop a framework that addresses the intersection between popular music and interactive music forms.

1. Provides a background to and reviews the relevant issues, current state of play regarding value chains in popular music making, production and audiences.
2. Identifies creative artists whose work is relevant or similar to the author's creative work.
3. Introduces, discusses and unpacks terms concerning the varied approaches to compositions based on interactive technologies and their use in different genres.
4. Provides a conceptual framework for Dynamic Music systems by discussing the components of a Dynamic Music system and a model for the musical design of Dynamic Music.

5. Develops a set of criteria that articulate the emerging field of Dynamic Music and can be applied to relevant works and the author's own creative works.
6. Provides findings based on the author's creative work and discusses the implications for composing Dynamic Music.

Methodology

This thesis uses creative work to demonstrate a methodological framework for Dynamic Music composition. **The creative component contributes approximately 40 - 45% of the total thesis.** Informed by practice-based research and research-led practice, the methodology develops a grounded theory approach in which an aesthetic of and compositional model for Dynamic Music are introduced. This compositional model is supported by two evaluation criteria: transmutability and variability. The methodological framework is based on existing perspectives on Dynamic Music: musical time; structure and forms; and analyses of musical compositions by the author.

Proof of Concept

The musical design of Dynamic Music involves the composition of a control system, sound and musical content, experience and musical architecture. Three works are presented: The Madness of Crowds, GIRD (Gesture-based Interactive Remixable Dancefloor) and The Semantic Machine. All works involved collaborations with other artists. The compositions provide the testing ground for the development of an evaluative framework underpinned by the outlined criteria for the composing of Dynamic Music. The researching artist did the majority of the composition of the music or the system design. Each creative experiment focused on a different type of Dynamic Music approach to highlight how the conceptual and evaluative framework can be applied across different types of Dynamic Music systems.

Scope of the Research

A discussion of the music industry and copyright exploitation is beyond the scope of this research. This thesis focuses primarily on the production and performance of popular music using interactive technologies. While interactive music making has been significant, especially in the computer music and experimental music making circles, this thesis only focuses on those products that have emerged from these discourses.

It is also acknowledged that while user experience (UX) and user design are part of the implementation of Dynamic Music works, this thesis is focused on the affordances and potentials of Dynamic Music itself. UX and user design are part of the puzzle, however a framework for music design is presented from the specific role of Dynamic Music composition and production. It is therefore out of scope to discuss the if and how audiences may engage with Dynamic Music forms.

List of Creative Works

The creative component contributes approximately 40 - 45% of the total thesis. It features three works.

1. The Madness of Crowds
2. GIRD (Gestural-based Interactive Re-mixable Dance-floor)
3. The Semantic Machine

The Madness of Crowds - 2016

The Madness of Crowds performance was presented at the Ars Electronic Festival[1] in 2016. The performance was documented and a video was produced to provide evidence of the work.

The video can be viewed here `https://www.youtube.com/watch?v=RJ6dXnJz6sg`

- Further details of the work are discussed in Section 8.1.
- Impact and publications are listed in Appendix F.
- Further supporting media is listed in Appendix A and can be located in the accompanying support material within the Appendix A file.

Gestural-based Interactive Re-mixable Dance-floor (GIRD) - 2015

The Gestural-based Interactive Re-mixable Dance-floor (GIRD) prototype is showcased as a video here `https://www.youtube.com/watch?v=g7YYoXM2kBU`

- Further details of the work are discussed in Section 8.2.
- Presentations and performances with GIRD are listed in Appendix F.
- Further supporting media is listed in Appendix B and can be located in the accompanying support material within the Appendix B file.

The Semantic Machine - 2018

The Semantic Machine prototype can be viewed here `https://dynamic-music.github.io/semantic-machine`
(Important - to start the music you will need to mouse click anywhere on one of the yellow sliders. The music is not designed to be interacted with. It is contextual-based on weather and GPS data.)

[1] `https://ars.electronica.art/radicalatoms/en/the-madness-of-crowds/viewed15/09/2019`

- Further details of the work are discussed in Section 8.3 and Appendix D.
- Impact and publications are listed in Appendix F.
- Further supporting media is listed in Appendix C and can be located in the accompanying support material within the Appendix C file.

Chapter 1

Interactive Technologies and Popular Music: Introduction

> "The emergence of immersive, mobile, wearable, tangible, gestural, embedded, intelligent, autonomous, adaptive, social, networked - the list seems endless - technologies provide digital artists with a rich palette from which to create their art. This, of course, serves to transform the nature of the art that is created... with artworks becoming experiences, and with increasing blurring between genres and forms as an inevitable consequence of digital technology's inherent tendency to transgress conventional boundaries." (Benford, 2014)

1.1 Technology and Popular Music

Popular music is defined as "forms and genres of music-making that are most accessible to, meaningful to and enjoyed by large numbers of people." (Australia Council for the Arts, 2019) It is not to be confused with pop or mainstream music only and includes a wide variety of cutting-edge, niche and established genres. Popular music making includes the composition, performance and production of popular music. Production is also considered as a part of music making given the influence of new broadcast and recording technologies on popular music. (White, 2015) In many ways new technologies have defined popular music's many changing sounds and informed its development. However, at this time many artists and the music industry have not readily embraced emerging products and platforms based on interactivity and the gaming industry.

The research highlights two interconnected problems for artists and the music industry that are impeding the embrace of changes in technology and communication:

1. the relationship between fixed song forms and dynamic composition; and
2. the need for a criteria that encompass the relationship between static and fluid song forms.

The thesis asks: How can interactive technologies be used to develop new forms of popular music?

As well as adapting to new technologies, popular music also has adapted to changing government laws and regulations, and cultural and social changes. The most recent disruption to popular music has been the result of innovations in digitization, communication and globalization. As Benford outlines in the quote beginning this chapter, these changes have transformed the way music is distributed, consumed and produced, and revolutionized traditional value chains. (Baym, 2007; Bockstedt et al., 2006; Bruns, 2009; Clemons et al., 2002)

The distribution of music has changed from a model based on ownership to a model based on access. (Wikström, 2012) In summary, the 'ownership model' dominated the last century with the sale of recorded music in formats like CDs, records and tapes. The 'access model' refers to the rise of streaming and online subscription-based music services like Spotify, Apple Music and Deezer. Wikstrom, 2012 argues, "increasing the economic value created from recorded music is based on context rather than ownership", offering a future model based on context. A 'context model' enables audiences to "do things with music" (Wikström, 2012).

Given popular music makers constantly try to find new ways to create value in their products while, at the same time, audiences push for more immersive and personal experiences, (Baym and Burnett, 2009) could enabling audiences to 'do things with music' provide new value to music products?

The growing success of music-based video games can offer a glimpse into the future as popular music audiences merge with gaming audiences. (Collins, 2008a) New software tools can democratise and innovate music production processes but also provide sophisticated new approaches to music making. These changes have been well documented; however the outcomes are still in flux as musicians and the music industry continue to attempt to establish new income streams and create value in their products.

As music begins to settle in its post-digital environment with its innovative production tools, new forms of consumption, growing music technology sector, increase of musical creators and continuing copyright/royalty debates and lawsuits, the full potential of digitization has yet to be realized. As Pfeiffer's quote below outlines, when music is represented by data it can be easily manipulated.

> "The key aspect of audio is that when it is digitized it can be manipulated. To do this one needs to stop regarding audio as sound and see it for what it really is: data that can be manipulated." (Pfeiffer and Green, 2015)

As always popular music will persist in its ever-changing role of reflecting, examining and dissecting the world it encompasses. However, currently the popular music form is still presented as a static artwork based in approaches that developed with analogue technologies and as such is awaiting its own transformation. How will the popular music form adapt with the rapidly growing innovation of interactive technologies? To offer some insight it is important to trace back to past innovations.

There is a precedent of popular music artists experimenting with interactive themes since the early 1990s. In 1993, WIRED magazine published an article by Fred Davis, 'I Want

My Desktop MTV' (Davis, 1993), which discussed the potential of interactive music in the popular music context.

> "Interactive technology could change both the public's conception of music as well as the economics of the music world." (Davis, 1993)

He writes that the big players in Hollywood's studio and media world wanted a stake in the "latest digital opportunity"(Davis, 1993). At the time CD-ROMs were just gaining popularity as a format that could offer opportunities for interactive music. Twenty-five years on and it can be argued that interactive music is still evolving and has not, as yet, lived up to its potential.

So why hasn't popular music based in interactive technology become a huge success? What is hindering its development? Jac Holzman, in 1993, when asked if interactive music would be significant? answered, "Absolutely, when someone does something miraculous with it." (Davis, 1993) Jac Holzman is now the senior technology advisor to Warner Music Group: "a wide-ranging technology 'scout', exploring new digital developments and identifying possible partners." (Whisperer, 2016)

The concept is still very much a hot topic as the recording industry struggles to find new ways to engage audiences and create revenue. Since the 1990s, CD-ROMs have been replaced by the internet and flash player technology, enabling rich interactivity. New tools and advances in music production technology and software include Web 2.0, mobile devices, the Internet of Things (iOT), wearable technologies, interactive software applications, audio middleware, machine learning software and Artificial Intelligence (AI). With the rate of technological advances increasing quicker than ever before this list will continue to grow.

The issues preventing interactive music in 1993 were listed as being platform based and not having enough compatible platforms for interactive material. Gaming has solved some of these issues with the development of adaptive music and interactive music. Audio software has also evolved dramatically since the early 1990s. There is a new level of sophistication in production and interactive software including Digital Audio Workstations (DAW), Max, Pure Data (Pd), and gaming audio middleware systems, inspiring artists to realize interactive music's potential visualized by innovators in the early 90s and beyond.

For the purpose of this study, interactive technologies are defined as new technology that allows for the design and implementation of interaction with humans and or systems. Interactive technology includes gaming, web 2.0, web and mobile applications as well as trends currently gaining momentum at the time of this research; video games, virtual reality, augmented reality, AI, album apps, mobile apps, gesture sensors and wearables.

Given the participatory nature of music as an artform, it could be argued interactive music forms could offer a richer and more immersive experience for audiences, than current recorded music forms. In popular songwriting and production, the songwriter uses lyrics, melody, harmony, rhythm and performance to communicate sound, emotion and ideas. Interactive technologies present tools that enable music and sound to be experienced and understood in new ways and expand the audience's experience. They present opportunities to:

- reinvent forms of music.

- create immersive worlds to express stories, ideas and works.

The potential impact of interactive technologies on popular music can be highlighted by the introduction of music technology, music hackathons, start-up pitches and interactive technology at all major traditional music industry conferences and festivals, like South by Southwest (SxSW), MIDEM and The Great Escape. (SXSW, 2016) As musicians embrace new technologies in order to engage with audiences and search for new revenue streams to support their art, interactive music products are growing rapidly. (Dredge, 2015; MusicTechFest, 2016; Szirmai, 2015) Methods and artistic approaches in the field of interactive popular music making are however limited.

1.2 Popular Music and Fixed Playback

Interactive technologies allow for opportunities to create music that can change with each playback. Interactive music is not a new concept. Interactivity is defined as the quality of being interactive and music is and has always been interactive. "Interaction means action" (Winkler, 2001). Music is something you do: you play an instrument; sing a song; dance. "Music has always been an interactive art in which musicians respond to each other as they play" (Winkler, 1998). Tanaka provides a thorough description of how music is interactive in a discussion on dynamic relations. He describes the relationship between the instrument and its musician as:

> "a bi-directional exchange of give and take. When a musician plays a violin, this violin is a dynamical system, and organic entity, with which the artist is in a relationship. The violin gives as much back to the performer as the player puts in in energy and verve." (Tanaka, 2006)

He explains the interaction between musicians, and finally the "interaction between the performer and the audience." (Tanaka, 2006) Tanaka highlights these examples not as a part of the digital domain but as a part of the social. "Instrumental music, then, already establishes rich forms of human-machine interaction that catalyse human-human interaction." (Tanaka, 2006). For these reasons music is and always has been an interactive artform. It can be interactive in how a musician plays an instrument, communicates with other musicians, and finally the audience. Audiences interact with music in different ways to; by dancing; listening and; clapping, singing or playing along. This thesis however, is concerned with digitised and recorded music and how these forms can be produced to include interactivity.

Before the development of recording technology, music was never perceived as static. As Potts explains music used to be a verb.

> "If the whole recorded music business started from scratch in 2017 would our core product and means of monetizing rights be a static 3-6 minute long WAV file? Before the recording of sound was invented in 1878, for most people, music was something you DID, whether that was singing, playing the piano, or listening to a live performance with others. The situation has now reversed and in the

> current era of the music industry, our default perception of music is the recorded version rather than the live version. Generally, we see live performance as an interpretation of the recorded version". (Potts, 2017)

Over the past 100 or so years the recorded music industry has changed the medium it uses to distribute and playback music, for example, tapes, records, CDs, mp3, minidisk, downloads, vinyl and dating back to the phonograph record. With each new medium came a huge boom in not only the manufacturing of the medium but also with the player or system required to experience the music for example; record, CD and tape players, hi-fi systems, radio, internet service providers, personal computers, smart phones, streaming services and dating all the way back to gramophones. In all this time however, the recorded format of an album and single, has essentially remained the same, even though playback and production tools have become digitised.

> "When you think about it, recorded music is something of a historical oddity. Imagine telling a visitor from 1650 that we like to listen to the exact same performances, over and over again, without any variation... they might well be baffled. Or, as Brian Eno once said, perhaps it is our grandchildren who will be the baffled ones." (Steadman, 2012)

Before the recording revolution, the music industry was dominated by music publishing companies, exploiting sheet music for profit. Music had to played to be experienced by an orchestra, ensemble or any number of willing participants and the instruments of their choice. The concept of fixed music playback originates from analogue recording processes. This truly exciting innovation involved capturing a moment in time and producing copies. The moment in time was a real-time musical performance recording, which would later be mixed, mastered and printed for distribution. The recording of this performance was static, it was a copy of a moment in time, repeating the performance it captured. This concept although now firmly implanted in the status quo, is not a true representation of music as a dynamic and interactive experience.

With changes in technology and recording production innovations like sampling, automation, digital signal processing (DSP), generative systems, AI and multi-tracking, the actual process of recording itself has changed. The studio and the laptop have become an instrument in their own right. Digitization offers unlimited potential for new ways of producing and experiencing music. When music was first recorded it represented a moment in time, now studio processes involved in the recording and production of a song do not represent one performance, one moment in time, so why are they being presented this way?

Static versions of recorded music are nostalgic for past generations. They are not, however, the only way music can be perceived and experienced. Future 'technology native' generations are already demanding new musical experiences. Static recorded versions of music are still important and relevant, but they emerged and were influenced by the technology of the time and pushed by industry to increase revenue. Given that interactive technologies are the emerging technologies of our time, how could they influence new music forms?

What happens if you bring an interactive element into the composition, performance and/or audience role?

This idea that music is fixed in time or it's the same each time it is performed has become the accepted understanding of experiencing recorded music. Changing this perception challenges the foundation of popular music as well as the society it represents. Throughout history changing a musical form has never happened quickly as the form of popular music represents the societal system we live in with its regulations, copyright and media. (Sinnreich, 2010) Yet here we find ourselves in a paradox if music is now digitized (resulting in the loss of much of its monetary value) and can be represented by data, it has the potential to be entirely transformed by interactive technologies.

1.3 Gaming and Popular Music

As the music industry struggles to increase revenue, the video game industry market is rapidly growing. It is forecast to grow 6.2% over the next three years. (Newzoo, 2018) The global industry was estimated at $US 116 billion in 2017. Approximately 2.3 billion people worldwide play video games (Newzoo, 2018) That is approximately one in every three people.

Gamers play video games using gaming consoles, desktop and laptop computers, smart phones and hand-held devices. The largest growing segment is said to be mobile gaming. According to the Global Games Market Report, mobile gaming will be worth $US 100 billion in the next three years.

> "In the span of a decade, mobile gaming will have grown from the smallest segment in 2012 to a 100-billion-dollar industry in 2021. Remarkably, the rise of mobile gaming has not significantly cannibalized revenues from PC or console gaming markets. In the coming years, mobile game revenue growth will continue to outpace the overall games market, growing to $US106.4 billion in 2021. By then, smart-phone and tablet games combined will generate 59% of revenues in the entire market." (Newzoo, 2018)

This highlights the huge potential of harnessing smart phone technology for the future of music. Tessler discusses how popular music and the gaming industry work together in her paper, 'The new MTV? electronic arts and playing music.' (Tessler, 2017) She introduces the idea of video games replacing music videos and discusses a talk by Steve Schnur, a representative of a well-known video game publisher, Electronic Arts (EA) (Tessler, 2017). She quotes him saying

> "the Atari can be considered the gramophone of our culture. Our Sega and Nintendo game cartridges are another generation's 8-track tapes and LPs. Sony's original PlayStation may seem as quaint and almost prehistoric as an Elvis movie today ... the themes from *Pac-Man*, *Donkey Kong*, *Super Mario* and *Zelda* are as crucial to our consciousness as the riffs from 'Johnny B. Goode' or 'Satisfaction' ... Def Jam's 'Vendetta' remains as conceptually ground breaking as

> The Who's 'Tommy'. We remain the same force for change. Today, games can be our Beatles, our Sex Pistols, our Nirvana ... So, are video games the new rock n roll? I say absolutely, yes, video games are the new rock'n'roll. Video games are the new hip-hop. They are the new house, heavy metal, R&B and punk. They are our culture. they are us ... Videogames will become the new radio ... (and) the new MTV" Schnur S via (Tessler, 2017)

Music plays an often overlooked yet fundamental role in video games. However, its real potential is beginning to be realised. Japanese niche audiences have been, in the past, more receptive to the promotion of music from video games. "A major reason the music is viewed differently is that in Japan, video games are played by adults as well as children. In the U.S., adult gaming usually takes place on PCs, and so console systems are seen as children's toys." (Belinkie, 1999) Gaming audiences in the west have now caught up:

> "Interpretive albums, remixes and live performances were also common variations to original soundtracks in Japan... With the first generation of gamers coming to age, this also changed significantly in the West" (Fritsch, 2013)

Licensing popular music to games can help to market and promote the game and the music itself. (Collins, 2008a) Collins notes, "a growing symbiotic relationship between the music industry and the games industry. Commonly, games are being used to promote and sell music, and recording artists are being used to market and sell games." (Collins, 2008a)

> "Statistics suggest that gamers purchase a considerable proportion of music that they hear in a game". (Collins, 2007)

The potential economic impact of popular music and gaming can be highlighted by games publisher EA[1] who has partnered with record labels to market game music. In Australia, independent label Remote Control records recently partnered with video game music label Boss Battle Records. This partnership was because of "a lack of avenues for video game composers to have their music distributed and marketed to the masses. Boss Battle Records was founded as a way to help support independent composers on their path to success." (Jenke, 2017)

However, there are many challenges involved with integrating a song into a game. Collins 2008 highlights the main obstacle being popular music's "limited adaptability." (Collins, 2008b)

> "Games require music to adapt to the gameplay states or player interaction." (Collins, 2008b)

Popular music is produced for fixed playback and is fixed in form therefore its placement in a game is generally limited to titles, credits, cut scenes etc. (Collins, 2008b) Since 2008, new methods of integrating fixed form popular music into gaming through "User-generated content" are being explored (Collins et al., 2015). Given the history of popular music forms and compositions adjusting to suit new technology and audience demands, Collins importantly asks:

[1] Electronic Arts

> "Might the song structure of popular music soon adjust to the needs of the gaming industry?" (Collins, 2008b)

1.4 Popular Music Form

Popular music has changed its form for audiences, media and film composition. Collins discusses how popular music has adapted to work on playback styles such as the length of a record, as well as emphasizing composers that adapt their style for the use of their music in film, using techniques to create more complex music (Collins, 2008b) that is longer in duration and intensity for example.

The concept of remixing is also a great example of artists adapting their processes. As recording technology developed, so too did the concept of remixing. Jamaican dance hall culture in the 1960s was a producer-led movement that created rearranged 'dub' versions of popular Jamaican music tracks. (Arroyo, 2008). Artists like King Tubby and Lee Scratch Perry scratched records and cut tape to produce samples and loops. (Arroyo, 2008) This technical process required expert skills and expensive tools. The dub movement later inspired hip hop and electronic genres, which are entirely "premised upon the notions of sampling and remixing" (Hughes and Lang, 2006). Importantly, this was a street-led movement resulting in artists adapting B-sides, versions or extended remixes thereby changing recording methods for their audiences who could then sample their music. (Redhead, 2015a) The brief overview of remix culture is important. Firstly, it gives an understanding of the creative and technological path from producer-led remix to consumer/user/fan-led remixing and secondly, it highlights the historical theme that artists constantly adjust to suit the demands of consumers. Changes in the way audiences consume music and cultural products have led to the concept of transmutability. Hughes and Lang define transmutability as "the technical capability to easily change cultural content products that are encoded as digital data" (Hughes and Lang, 2006).

Hughes and Lang (2006) provide an important theoretical framework for digital cultural products and transmutability based on the following two tenets:

1. Consumer led digital transmutations; unbundling, re-bundling, portability and distribution, personalization and editing/re-editing.

2. Producer led digital transmutations are classified as re-contextualization, extension, recombination/remixing/sampling.

Web 2.0 and new digital production tools enabled consumer and producers' roles to merge resulting in more demand for consumers to access producer led transmutations. This resulted with the gap between the consumer and producer becoming increasingly blurred. (Bruns, 2009) This phenomenon has become central to the music industry's approaches for working within the digital domain.

In this context, transmutability can analogously apply to pre-digitised music products in relation to the playback of music. Traditionally, fixed playback systems like tape, record and CD players have limited control abilities for consumers. The user can press play, pause, stop, fast forward, rewind, skip tracks, record, adjust the volume, pan left to right etc. This control information determines how the audio is played back. The duration of the song is static but can be stopped and started at any time. These limited control actions can be considered as consumer led playback transformations. Although the user cannot change the structure of the song, they are able to create remix tapes as well as lo-fi mash ups or even recontexutualise a recording by cutting up tape or recording snippets. These actions, as limited as they are, can also be considered to be producer-led transmutations where the consumer becomes the producer.

In order to investigate how the form of popular music might be adapted to work with interactive technologies, first an outline of popular music making and its many forms needs to be discussed. This discussion isn't focused on its many approaches, sounds or genres, rather its over-all form in relation to time, architecture and production.

Traditionally, popular music making has been categorized into the following areas;

1. Creation - composing, song writing, arranging, singing and playing musical instruments such as the piano, the electric guitar, the synthesizer, MIDI, sampling and personal computers.
2. Production - recording, live performance, mixing, mastering, producing, 12-inch tape, microphones, compressors, pre amps, DAW, digital plugins and instruments
3. Distribution - sheet music, radio, music shops, TV, music videos, internet, P2P, streaming, online distribution
4. Playback - home amplifiers, records, cassette players, CD players, MP3 players, mobile apps, Bluetooth speakers, web applications

The form of popular music has evolved into a fixed duration and structure that is required for fixed playback recordings. Common forms are prevalent in popular music and the myriad of genres within popular music can often be associated with a particular form. Blues and Rock n Roll which are built upon 12-bar and 32-bar forms for instance. Rock, pop and electro genres heavily rely on the verse/chorus form. Electronic Dance Music (EDM) can also be based in the verse chorus form although often the form includes layering, builds, drops and breakdowns around a number of sections. Popular music is by no means limited to particular forms although it does include characteristics of repetition and importantly variation.

Young believes that the non-linear music composed for gaming might be the catalyst for new music forms.

> "While games are currently the only widely accepted medium that supports this non-linear music, the concepts of adaptive and interactive music may soon be applied outside gaming. A trend of 'active listening' may develop where music is presented as components, and with different variables and outcomes. The listener will decide instrumentation, arrangement, and other elements in much the same way that game engines currently determine the same characteristics

> in dynamic systems. It is very likely that game music will be looked back on as the catalyst for non-linear music's rise in acceptance and popularity." (Young, 2012)

These ideas presented by Young are widely acknowledged, however there is much resistance from an industry, audience and artist standpoint. A pilot study conducted in 2013 confirmed that the "audiences tested would interact with applications that implement remix principles as part of a music listening tool." (Redhead, 2015a) The study looked for possible factors that may influence engagement and the type of audiences that may interact with an interactive music application. It "hypothesizes that music fans that are technologically experienced want to interact and that gaming audiences are more likely to interact than others as well as pay more to purchase an app than non-gamers." (Redhead, 2015a) "It also showed that 95% of participants enjoyed using the app and 87.5% would rate it above average if they downloaded it. Participants also valued this format and would pay an average of $2.55 for an application containing one track or single." (Redhead, 2015a)

In a study by Shakhovskoy and Toulson (2015) consumers and artists were asked about the use of interactive musical content in popular music products. "The response was clearly divided between those embracing the idea and others who suggest that music should be heard in one way only - 'as the artist intended'." (Shakhovskoy and Toulson, 2015) This again highlights the status quo perception that music is fixed in time. However, music can be designed in many forms and built into highly complex systems, the artist may in fact intend the music to be fluid and amorphous. This change of perception presents a huge challenge for anyone working with interactive technologies and popular music.

1.5 Summary

Although revenue from recorded music has fallen, consumers have gained more access and flexibility to popular music than ever before. Audiences continue to demand new experiences in popular music as personification, context-based cultural forms, semantic technology, AI and interactive technologies grow in popularity.

There are many new approaches to how musicians and the industry are designing and producing music products based on interactive technologies. New forms are being released and prototyped around collaboration and interaction with audiences using Mobile apps, Virtual Reality Albums, 360 Videos, Gesture-based products, controllers and wearables like brain interface controllers. However, many artists are using interactive technologies without changing the form of their music. These technologies are mainly used as promotional campaigns and gimmicks to sell recorded music with fixed playback, concert tickets or premium products and do not change the form of the music.

It may be some time before the perception of fixed playback as the way music should sound changes. This will require the conceptualization of new music production and composition approaches which challenge current popular music making approaches, specifically evolved with a goal of producing a fixed playback. One wouldn't use a painting in a video and expect it to suddenly be animated, just as one wouldn't expect a song to suddenly work dynamically in a game. Producing music for interactive purposes requires a different approach to composition, song writing, arranging and producing. Its output or playback is amorphous and has many ways of being heard. (Redhead, 2015a)

With changes in technology, the development of remix culture and recording production innovations, the actual process of recording itself has changed. Digitization offers unlimited potential for new ways of listening and experiencing music. Aligned with digitization has been the emergence of interactivity. Interactive music products and performance forms are gaining in momentum as artists and the music industry endeavour to find new ways to connect with audiences and create value in their products and services. However, for this to be achieved, the popular music form needs to change so it can adapt to the requirements of interactive technologies.

This creates a problem for musicians and the music industry wanting to embrace changes in technology and communication given the static nature of popular music and the non-linear nature of interactive technologies.

By providing an in-depth overview of the technology and artists that are pushing the boundaries of popular music making and interactive technologies, Chapter 2 demonstrates the complexities in the development of works that are not static in form.

1.6 Chapter Outline

Chapters 1 and 2 introduce and examine the following paradox: popular music production has always embraced new technologies which in many ways have defined its many changing sounds and informed its development; however popular music production has not so readily embraced emerging products and platforms based on interactivity and the gaming industry. Chapters 1 and 2 discuss this problem including popular music's approach to new technologies, with a focus on emerging interactive technologies relevant to music, and the game industry's use of interactive technologies. **They posit the research question of what is needed to bring popular music and interactive technology discourses together, or more specifically, how can interactive technologies be used to develop new forms of popular music?**

Chapters 3 and 4 address the above research question by examining and reviewing relevant debates on popular music and interactive music. A contextual review provides an overview of existing platforms/creative works that are pushing the boundaries in ways relevant to the popular music/interactive debate. The literature review identifies any underpinning debates around confusion of terms and standardisation of platforms and works. A gap is identified in the production and composition processes of creating music products and works based on interactive principals. It observes that all the platforms and works outlined fall under a very general term called Dynamic Music however there is much confusion in the deployment of terms in this area. In addressing the research question, a solution is proposed through the recognition of a new music form called Dynamic Music.

Chapters 5 and 6 develop a methodology towards the evaluation of Dynamic Music compositions. They firstly provide an overview of the main components, basic attributes and origins of Dynamic Music. Conflicting or ambiguous claims about Dynamic Music are addressed. Chapter 5 discusses form, structure, process and time in Dynamic Music and provides definitions on the field of Dynamic Music as a point of departure. Chapter 6 introduces the technical requirements needed for the musical design of a Dynamic Music System. It brings together research from related areas in electronic music composition, interactive systems, generative and algorithmic composition, music theory and game music. Following an in-depth discussion of the components of Dynamic Music a schematic model is presented combining the components and musical design aspects of Dynamic Music.

Chapter 7 The framework introduced in Chapters 5 and 6 can be used to evaluate and assist with the design of Dynamic Music works. Chapter 7 presents two criteria for evaluating Dynamic Music design based on the components and schematic model of a Dynamic Music System. A selection of case studies presented in chapter 3 are used to demonstrate the Dynamic Music model and criteria.

Chapter 8 provides a proof of concept with a portfolio of creative works and experiments within the context of Dynamic Music and its relationship to popular music. Each work discussed follows a template format: project overview; compositional model; criteria evaluation; summation.

Chapter 9 provides a summary of the thesis and implications. It offers conclusions and considerations of the emerging role of the Dynamic Music Producer, control and designing Dynamic Music.

Chapter 2

Interactive Technologies and Popular Music: Background

> "What people are going to be selling more of in the future is not pieces of music, but systems by which people can customize listening experiences for themselves. Change some of the parameters and see what you get... Such an experience falls in a nice new place - between art and science and playing. This is where I expect artists to be working more and more in the future." Brian Eno (Kelly, 1995)

Eno's quote from 1995 was at a time when popular music artists were first releasing interactive CD-ROM music works. As technology developed over the past 25 years more artists began to experiment with these concepts; music products based on interactivity and listening experiences. This chapter presents a detailed background outlining how new technologies and important artists have pushed these boundaries. This has resulted in a supported environment for creating immersive listening experiences that now disrupt the form of popular music.

Chapter 1 introduced the first research problem that popular music forms need to be more adaptable; to work with interactive technologies. However, this isn't the only problem highlighted in the creation of music works based on interactive technology. Throughout this chapter issues relating to the complexities of developing interactive and adaptive systems will be discussed.

2.1 Computer Music, Interactive Art, Sound Art and Installations

Interactive technologies are not solely responsible for the development of interactive art. Interactive art is by no means a new area of expression. There is a rich documented history of artists working within this field. (Kwastek, 2015) Kwastek explains that from the early twentieth century "artists have increasingly sought to actively involve the recipient in their works and to stretch the boundaries of the traditional concept of the artwork". (Kwastek, 2015)

Interactive art places the user's actions in the centre of its design. (Kwastek, 2015) Kwastek (2015) defines interactive art as:

> "Digital artworks that require the viewer to engage in some kind of activity that goes beyond purely mental reception... Interactive art is interdisciplinary in nature "and combines elements from visual arts, time-based arts and the performing arts." (Kwastek, 2015)

Drummond (2009) provides an important historical overview of interactive sound installations, performance with interactive systems and the design of new instruments from the 1970s to the early 2000s. (Drummond, 2009b) This important work demonstrates a rich history of artists and the approaches used which in turn have directly influenced the development of interactive music forms.

Ars Electronica in Linz has a rich archive of interactive artworks that have been part of the Ars Electronica Festival and Prix awards since 1990. (ArsElectronica, 2016) These artworks combine many elements and form an interesting time-line of the development of interactive technologies over the past 36 years. This interesting framework can be merged into today's popular music making. It is important to investigate techniques and frameworks that apply to Interactive Art given the interdisciplinary nature of developing music products in a digital environment. Many new music products involve visual arts, video art, gaming and design in their development.

Sound artists and interactive artists have been developing interactive software and artworks in the media arts discipline since the early 1960s (Sweet, 2015). This incorporation of other inputs has been acknowledged by Sweet, who attributes these early techniques as having "paved the way for future composers to become more experimental with compositional techniques." (Sweet, 2015) He writes:

> "Before the twentieth century composers began to experiment with compositions by adding elements that would allow musicians to pick between different musical options at the time of performance, including phrase order and choices made about the instruments that make up an ensemble." (Sweet, 2015)

Composing music for interactive, adaptive and context based music has been formalised with approaches such as chance, aleatoric and indeterminate music. (Sweet, 2015) However no specific formalisation has been found in song-based popular music. Henceforth we rely heavily on methods and techniques found in game composition, generative music, adaptive music and interactive composition.

Chadabe, a mid-20th century pioneer in interactive music composition, first coined the term Interactive composition in 1967. He describes it as "a method for using performable, real-time computer music systems in composing and performing music". (Chadabe, 1984) Since 1967 this concept has grown. He had originally proposed "the design of a sequencer-programmable analogue synthesis system." (Chadabe, 1984) It was built by the R.A. Moog Co and installed at State University of New York in 1969. Using this tool, he was able to create several compositions, including 'Ideas of Movement at Bolton Landing' (1971) which "involved the control of timbre and rhythm interactively with automated controls generated by sequencers." (Chadabe, 1984)

Chadabe (1984) writes: "Interactive composing is a two-stage process that consists of:

1. creating an interactive composing system and
2. simultaneously composing and performing with that system as it functions.

Creating the system involves bringing together a programmable computer, a synthesizer and at least one performance device, and programming the computer with algorithms that function automatically and in real time to;

- Interpret a performer's actions as partial controls for the music
- Generate controls for those aspects of the music not controlled by the performer
- Direct the synthesizer in generating sounds" (Chadabe, 1984)

This highlights the need to develop a system to support the interactive artwork. This system acts the same way as a music control system, which might be notation for example. Interactive music systems are further discussed in Chapter 3.

As well as computer music and interactive arts, technology has also developed from video game innovations.

2.2 Music Video Games

Music video games like *Guitar Hero*, *SingStar* and *RockBand* have merged music and gaming audiences.(Collins, 2008a; Peerdeman, 2010; Redhead, 2015b; Stewart et al., 2010) This has resulted in a "new breed of musical talents that enjoy music in a more artistic way than before." (Peerdeman, 2010) A music video game is a small genre of video games where the focus of the game is on the music, so the player interacts with a musical element, whereas in a video game the music plays more of a background role. (Pichlmair and Kayali, 2007)

Pichlmair and Kayali (2007) present two categories of music video games, the rhythm game and an instrument game. They also list a number of audio art pieces distributed outside the context of the gaming industry, *Fijuu* (Julian Oilver) and *Small Fish* (Masaki Fujihata). Pichlmair and Fares's important 2007 paper, 'Level of Sound', provides seven features of music video games: active scores; rhythm action; quantization; synaesthesia; play as performance; free-form play; and sound agents (Pichlmair and Kayali, 2007). Liebe (2013) provides a summary of these features;

> "**Quantization** means that the game offers game modes that feature the "process of aligning a note to conform to a grid" (Pichlmair and Kayali, 2007). It limits the players in their musical expression but greatly eases it, making the results aesthetically appealing as the grid provides a predefined selection of compliant tunes.

> ***Sound agents*** *indicate the presence of specific game elements that enable interaction with sound but have a behavioural pattern on their own. Music is generated while exploring the function and characteristics of these agents.*
>
> ***Rhythm action*** *refers to game mechanics that ask the players to react to rhythmical sequences. The sequences form the challenge of the game and the more accurately the players manage to follow the rhythm, the more points are scored.*
>
> ***Active score*** *refers to a concept for a musical score that can be adapted for each performance. It creates a dynamic sound track for the game.*
>
> ***Free-form play*** *is characteristic for digital toys rather than games. These programs do not have a clear goal to achieve. This method is found as a special mode in many music games.*
>
> ***Synaesthesia*** *refers to a neurological state in which visual metaphors for audio are cued. The gameplay seeks to attract both the visual and the sonic sensors at the same time.*
>
> ***Play as performance*** *is a game mechanic in which the physical performance of the players is key. It allows for a wide range of expression and bodily engagement." (Liebe, 2013), summarized from (Pichlmair and Kayali, 2007)*

Collins (2008a) describes three categories of games which utilise music as the "primary driving motive or narrative element"; "music-themed games, creative games and rhythm-action games". She describes music-themed games as including bands or artists as characters in the game. (Collins, 2008a) In 1982 the band Journey were the first band to appear in a video game. (Collins, 2008a) [1]

According to Webster (2009) the first music video game was released in 1987. It was called *Dance Studio* and players would mimic a dance instructor in time with the music using a NES Power Pad. (Webster, 2009) However, Pichlmair and Kayali (2007) list *Otocky* (ASCII corporation) 1987 and *To be on the Top* (Rainbow Arts) 1987 as the beginning of music video games. All were released in the same year, four year after *Journey's Escape*.

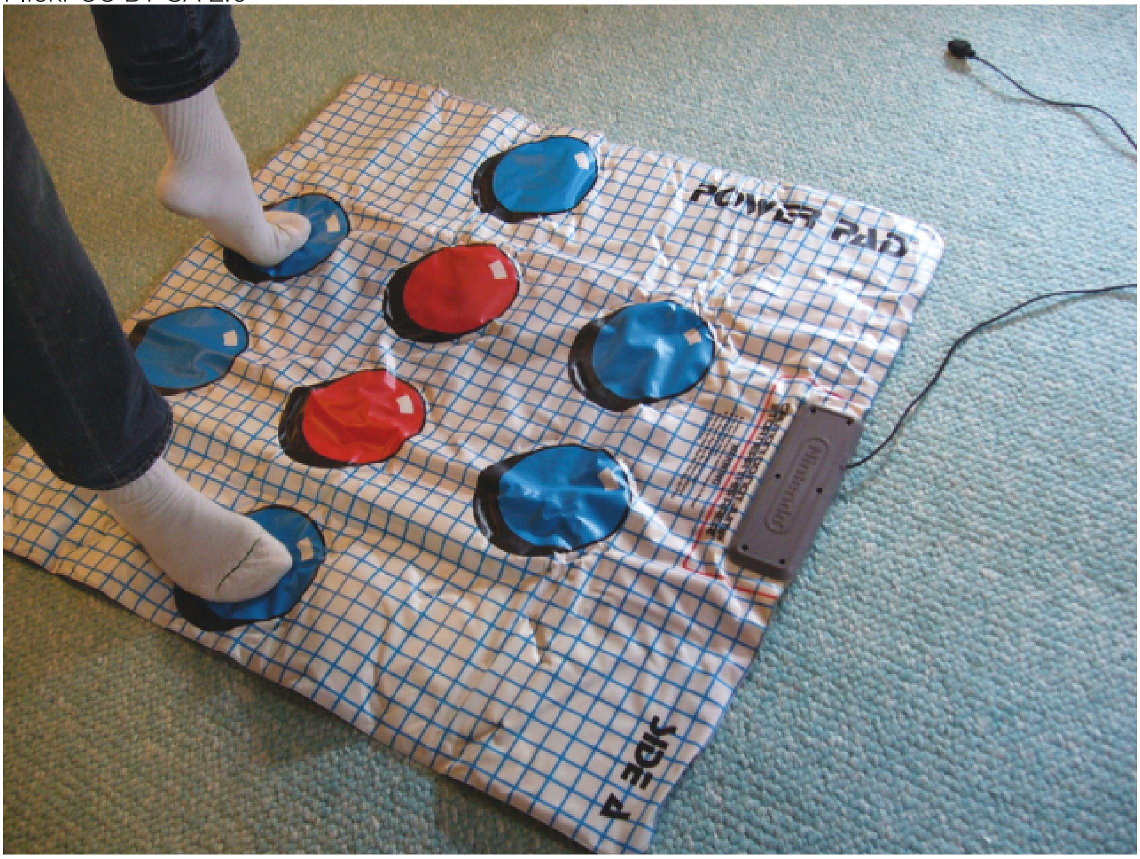
Webster (2009) gives an overview of the history of music video games, he discusses *PaRappa the Rapper* where the user follows on-screen cues to push the correct button to match the rhythm. Every time a button is pressed PaRappa raps.

Dance Studio and *PaRappa* among the music video games that became very successful in Japan, inspiring a movement of "prominent developers creating new games in the genre". (Webster, 2009) Interestingly the co-developer of PaRappa, Matsuura had a background in music before games. In an interview with Webster, Matsuura stated:

> "I started to believe that in order to realize the music I aspired to, I would have to choose and develop the media myself. I think that what drew me to the concept

[1] The Atari game by Data Age was called *Journey's Escape*. Collins (2008a) describes the game which a few months later came out as an arcade game. She notes the game "relied on built-in sound chips, but during a special bonus concert scene, a hidden cassette player inside the arcade machine would play their hit *Separate Ways"(Collins, 2008a)* Many popular music artists have since released musician-themed games including Michael Jackson (1990), Aerosmith (1994)

Figure 2.1: Dance Studio's Power Pad - image by Joshua Wickerham (kafka4prez) from Flickr CC BY-SA 2.0



of interactive media is the notion that the player can experience a sense of joint ownership by taking part in the musical expression." (Webster, 2009)

Collins (2008a) gives an overview of the development of rhythm-based games. She discusses Britney's *Dance Beat* released in 2002 on the Sony Play Station 2 (PS2). The user went through a series of dance auditions with the hope of joining Britney on the road. Pushing specified buttons on time caused your character to dance to Britney's tracks. If you did well, you could get bonus time and see Britney's character dance till the end of the song. The audio contained in this release are fixed as per Britney's album and single recordings.

Remixing and sing-along games were also popular, including *FreQuency* and *SingStar*. *FreQuency*, the remixing game by Harmonix, featured 27 popular music artists including electronic artists, DJs and pop bands. Popular bands included in the game were The Crystal Method, No Doubt, Paul Oakenfield and Orbit. (Wikipedia, 2018) In an interview with website Gamasutra, game creator Lesser stated the game was hard to sell as it was visually too complicated. (Alexander, 2004) Their follow-up game *Amplitude* featured artists Garbage, Herbie Hancock and Pink. An interesting point about the remixing games was that the music from popular musicians was remixed to work in the game. The tracks were not composed specifically for this format only supplied as a remix of their official single version. The company reportedly lost money on the two releases within a 10 year period. Harmonix were also behind the hugely successful *Guitar Hero* and *Rockband*.

Figure 2.2: Harmonix Music System's Amplitude - CC some rights reserved BagoGames

Other important music video games that have been well documented due to their huge influence on music video games and game audio are *Electroplankton* and *Tenori-On*.

In 2007 *Year Zero*, an alternative reality video game, was released by 42 Entertainment. The game was based on Nine Inch Nail's (NIN) concept album *Year Zero*. The game is described by Trent Reznor (NIN) as "a new form of entertainment", he goes on to say that is is not a gimmick or part of a marketing plan but is the art form. This is the first example of a game-based concept album. (Wikipedia, 2011)

The examples listed here are mainly based around popular music examples of music video games. It should be acknowledged that there are many more cutting edge and interesting music video games, however here we focus on the development of popular music based forms.

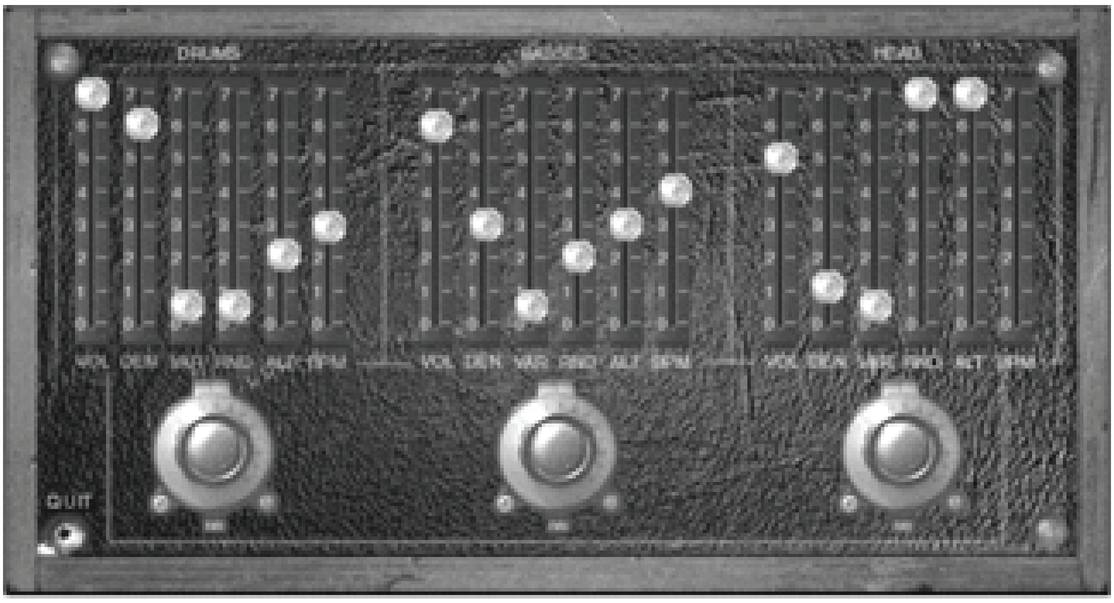
2.3 Interactive CD ROM

In the early 1990s popular music artists began to experiment with music video game concepts as a result of the development of the CD-ROM format. The CD-ROM was the first opportunity to have recorded audio longer than a sample in games instead of wavetable synthesis and FM synthesized MIDI techniques. (Collins, 2008a) "CD-ROM technology ensured that composers and sound designers could not only know how the audio would sound on most consumer configurations; they could also now record sound effects, live instruments, vocals, and in-game dialogue." (Collins, 2008a)

This lead to what Young (2010) describes as a mini-boom of popular music artists releasing CD-ROM works in the mid 90s. These works were limited in their interactive audio component due to the available technology. However, the 3D graphics were cutting edge and enough to make these works innovative. Early examples were *Xplora1* by Peter Gabriel, Prince's *Interactive*, *Puppet Model* by Laurie Anderson and *Jump* by David Bowie, which were all released in 1994. (Young, 2010)

In 1997 Cold Cut released their album *Let us Play* which included Hex's CD-ROM, *Playtools*. The CD-ROM offered a high level of interactivity for its time. It contained an "interactive toybox full of games and toys and several digitized music videos" (Stilwell, 2017) VJAMM a sequencing program for audio and enabling users "to remix several of Coldcut's music videos" was also included. (Stilwell, 2017)

Figure 2.3: The playtime interface Coldcut's Let us Play CD ROM reprinted from (Pepperell, 2002)



Playtools offered a series of sliders which modified three banks of sound; drums loops; bass loops; and head noises. The audio loops played in sequence with one another to create music with an electronic dance flavour. Changing the position of the various sliders allowed the user to manipulate the way in which the program cut up or rearranged the sound loops, thus creating complex levels of variation and modulation that kept the music fresh and interesting." (Pepperell, 2002)

The functionality was developed based on the work *Generator*, an installation at the Glasgow Gallery of Modern Art. (Pepperell, 2002)

> "*Generator* consisted of two consoles supporting button banks, a set of computers, a video projector and speakers. One console controlled sound and the other images. The buttons on the sound console were organised into three

> rows each representing a channel of audio and into eight columns each representing a common musical genre such as rock, hip-hop, opera, jazz, and so on. By pressing different buttons (each of which was labelled with icons) the user with no previous musical training or aptitude could select, say, a piece of rock music to play at the same time as a piece of opera and a piece of hip-hop." (Pepperell, 2002)

Generator was highly successful and not only led to the development of *Playtools* but also further commissions. (Pepperell, 2002)

Playtools formed the basis of the band Coldcut's *The Let us Play* and *Let us Replay* packages, which Stilwell describes as "an interesting departure from standard pop music artefacts" (Stilwell, 2017) He states that "both CD-ROMs offer quite a high level of interactivity: they transform the passive listener/viewer into someone who is invited to involve themselves actively in the presentation process" (Stilwell, 2017)

Young (2010) discusses that the CD-ROMs being released included videos and or interactive elements. Users were able to pan/scroll and have focused interaction including remixing. (Young, 2010) Young stresses that these works were very expensive to produce therefore became very same-ish. This resulted in audiences losing interest in the format. The CD-ROM boom, innovative as it was for its time, was short lived. This was due to rapidly changing technology and the emergence of the web as a viable alternative.

2.4 The Web - Browser-based Audio - Internet Audio

The web increasingly provided a new playground for popular music artists to experiment further with interactive experiences. In 2000 Adobe Flash 5 was released which included Action Script. This enabled developers to author more complex interactions and interfaces. (Warren, 2012)

BBC and Fat Boy Slim released a browser-based, Adobe Flash based remix game and competition in 2001. The samples were created by Fat Boy Slim and the player by the BBC. (BBC, 2001) The game loads then takes the user to an empty dance floor and asks to help create atmosphere and "get mixing to fill the dancefloor". (Fat-Boy-Slim, 2004) By clicking on the mix page, four groups of audio are presented: drum loops; effects; vocals and samples. Within each group are four loops. The game is simple and the loops don't always transition well. The mixing interface allows the user to drag loops to a grid. There are 14 slots or bars in the grid offering four tracks. The user can place any of 16 loops in any order to create a mix. The game can still be experienced in a browser, which is unusual considering most examples of works from this time can no longer be accessed. This is because many older platforms have become out of date. Due to this issue many of musical Adobe flash based experiences are no longer available.

There are some examples of Adobe Flash based interactive music experiences that are still successful, one of those being *Incredibox* [2] . *Incredibox* is a fun musical experience

[2] http://www.incredibox.com/

where the user can create music with a cool looking character. The project was started in 2009 and has succeeded with 3,790,000 mixes recorded and 400,000 followers.

As we can see from past examples, technology changes quickly. Adobe Flash player is currently being phased out and will end updates and distribution at the end of 2020. Plugins like Flash are no longer required with the development of open standards like HTML5, Web GL and WebAssembly. (AdobeCommunications, 2017)

The web audio application programming interface (API) has now been integrated into all mobile and desktop browsers, significantly simplifying processes in developing music-based apps and experiences. In combination with Javascript "sophisticated web-based games or audio production applications" can be produced "where the audio can be dynamically created and modified." (Pfeiffer and Green, 2015) "It also enables the visualization of audio data and the analysis of the data, for example, to determine a beat or identify which instruments are playing or whether a voice you are hearing is female or male." (Pfeiffer and Green, 2015) The web audio API also allows for multi-track playback, synthesis and effects. The Chrome music lab[3] showcases the way audio can be created and transmuted using available web audio API packages available on Git Hub.

Browser-based apps can now be experienced across desktop and mobile devices. "Given the browser's ubiquity on both desktop and mobile devices it is arguably the most widely distributed run-time in history, and is rapidly becoming a write once, run anywhere solution for musical interfaces." (Roberts et al., 2013) Web apps can now also "incorporate accelerometers, multitouch screens, gyroscopes, and fully integrated sound synthesis APIs." (Roberts et al., 2013)

Browser-based musical works have not been embraced by the popular music industry as an income stream. This may be due to the difficulties of monetisation and the past difficulties in development and compatibility across browsers and devices. With the predicted rise in mobile use, the ability for browsers to work across media and the potential of the web audio API, there are many opportunities to develop music-based experiences.

2.5 Mobile and Smart Phones

Interactive technologies now influence our everyday lives. Mobile devices "have developed into compact multi-sensory computers, bringing novel ways of interaction, such as multi-touch gestures, accelerometer control or geo-location tracking into everyone's hands and pockets." (Essl and Rohs, 2009; Thalmann et al., 2016) Mobile phones are sound generating devices designed for "speech signals for telephony and pre-recorded music for mobile entertainment". (Essl and Rohs, 2009) Their wide-ranging sensor capabilities allow for interactivity in live and recorded music. (Essl and Rohs, 2009).The emergence of mobile phone technology has again influenced popular music.

Gaye et al (2006) introduce a new field 'Mobile Music' which is "concerned with musical interaction in mobile settings, using portable technology." (Gaye et al., 2006) Essl and Rohs (2009) give a brief overview of artists that have used the mobile phone as an instrument

[3]https://musiclab.chromeexperiments.com/

including Tanaka (2004), Geiger (2003), Schiemer and Havryliv (2006). Building on this work, popular music artists also began to experiment with this new format. (Essl and Rohs, 2009; Geiger, 2003; Schiemer and Havryliv, 2006; Tanaka, 2004)

Mobile apps are "low-cost, function specific and downloadable". (Dibben, 2014) They are software applications with the "widespread availability of smartphones and digital distribution". (Dibben, 2014) Their popularity has grown exponentially.

Popular music artists began releasing apps in 2009. (Dibben, 2014; Dredge, 2016) Most of these examples, however, were used only as promotion for an album release and were similar to a band's website.

> "Custom-made apps are expensive; therefore, many artist apps are based instead on a toolkit comprising a selection from different modules including free streaming services for an artist's audiovisual content, photographs, news, chat rooms, and the option to buy music, tickets, and other merchandise." (Dibben, 2014)

Geere (2011), in his WIRED article, gives a good argument of where mobile apps and music could go. "Pretty much all band-related apps are the same, and they're mostly rubbish." (Geere, 2011) Given bands have their own websites there is no need to also have an app with the same information, which in 2011 many bands were doing. "But there's another way that apps can be useful to a musician. They can be art in their own right, rather than just bad marketing." (Geere, 2011) He describes music as architecture which could use contextual data to influence the music instead of just being a fixed recording. He points out the many capabilities and sensors available on a mobile device like weather, gyroscope which could be used to influence the music. He lists Reality Dj (RjDj) as an innovative new start up that is providing this service to artists.

Dibben (2014) outlines types of music apps including;

1. Promotional apps which may serve as a gateway to a band's website and used to promote an album release.
2. Remix Apps which provide options for users to create new versions of an artist's song. For example Remix David Bowie (2009) iDaft (2010) and Goldfrapp Pinball (2010)
3. Instrument and Sequencer Apps can generate sound or the user can create music based on samples. Examples Kraftwerk's *Kling Klang Machine* (2011)
4. Sing and play along apps allow the user to perform with the music. For example *Piano Complete* by Elton John (2011) and David Archuleta's *Open Mic* (2011)
5. In music action game app "the user performs missions within an artist-themed virtual world" (Dibben, 2014) For example Linkin Park *8-Bit Rebellion* (2010), Gorillaz *Escape to Plastic Beach* (2010).
6. New audiovisual music album releases, which is a very vague term that can be expanded upon given the amount of experimental music apps that have been released in

the past five years. She provides two examples: *2manyDJs' RadioSoulwax* which "is a series of 24 one-hour mixes of classic tracks with animated album cover art synchronized with the music sampled; and Bluebrain's *The National Mall*, a site-specific app whose music changes according to the listener's proximity to particular locations." (Dibben, 2014)

2.6 RjDj

RjDj was founded in 2009 by Michael Breidenbruecker. "The idea of Last.fm was based on RjDj. Both platforms are based on the concept of personalized music. But Last.fm is actually personalizing playlists and not music whereas RjDj is personalizing the song itself. This only became possible because of advances in the technology sector. It took audio technology almost 10 years after my initial idea to get into shape for RjDj." Michael Breidenbruecker in (Nordgren, 2009)

A range of popular music artists produced mobile apps with "reactive music" of which a collection is reviewed in Chapter 3. Instead of a fixed playback and form, "reactive music is software that uses input data and transforms it into audible formats for the listener. This mechanism allows the generated music to adapt to the listener and her or his environment by using, for instance, the built-in sensors (e.g. camera, microphone, accelerometer) of mobile devices." (Bauer and Waldner, 2013)

At the end of 2010 Waldner et al. (2011) claim RjDj had more than 15 million distributed 'reactive' music works and 3 million downloads. (Waldner et al., 2011) Interestingly, it's the software itself being distributed which generates the musical experience, and as Waldner et al. (2011) explain this allows for the music to be modified and extended. "Similar to software products, it is then possible to sell virtual commodities like add-ons and upgrades to a piece of music" (Waldner et al., 2011). This concept highlights the quote by Brian Eno at the beginning of this chapter. However as concluded by Waldner et al (2011) it may be some time before "distributing music as software" enters the mainstream. RjDj, unfortunately, was ahead of its time and closed down in 2013.

2.7 Interactive or Multi-track Formats

In the mid 2000s popular music artists began to release stems [4] Remix competitions using stems by music artists were also popular. (Redhead, 2015a) In the same way that artists released 12-inch singles in the 1980s, so fans and DJ's could create mashups and remixes. Artists were releasing stems in the 2000s, in order to meet the growing demand from consumers to participate more with digital cultural products.

Nine Inch Nails have released many albums and singles since 2005 in a stem format via a specially focused website www.remix.nin.com (Nails, 2013). This website also provides

[4] Stems are the multi-tracks of a mixed song version. For example, a radio edit is made up of a large number of tracks including instruments and vocals. When a mix is finalised the engineer or producer may bounce a series of stems as well as a final mix of the track. The stems may include a drum stem which may be all the tracks of drums recorded mixed down.

free downloads of simple remixing software. Other artists that have released stems include R.E.M (Elliott, 2008), Radiohead (Radiohead), Kylie Minogue (SoundCloud), Beyonce (Pandora), Kanye West and William Orbit. This is an important development with regard to interactive music as it shows that many artists were open to giving audiences a closer look into their production processes, thereby encouraging them to remix and recontextualise their music. Remix competition websites are also a popular example of more active listening experiences, such as Indaba Music, ccMixter and SKIO communities.

Korean based Audizen and French company Iklax released some browser-based apps in 2007-2008 by high-level pop artists. Audizen offered a listening experience where the listener could change the song's structure and orchestration by selecting audio tracks and the next song segment. The app was presented similarly to a DAW interface. Iklax produced a multi-track player[5] which allowed the listener to add or remove instruments of a track for example, with Michael Jackson's 'Billy Jean' the listener was allowed to mute or unmute the bass, vocals, drums and guitar etc. Both companies no longer operate.

In 2015, Native Instruments released a new format called *Stems* aimed at DJs offering new innovative ways to mix music. The stems format consists of four stems. "Typically drums, bass, vocals and percussion/synths". (McQuaid, 2018) Stems require Native Instruments software to use. Traktor Pro 2 provides a controller for each stem track. The volume and effects can be controlled separately. (NativeInstruments, 2015) Many major dance labels are releasing stem formats of their artists' music as well as MP3 versions. A more detailed overview of the Stem format is discussed in Chapter 3.

2.8 Audio Software

Digital Audio Workstations (DAW) software has changed the production and composition processes of recorded music, just as Audio Middleware software has changed the processes and composition of game audio.

There are currently solutions that offer interactivity within a DAW package. For example, Max for Live patches can be developed and integrated into Ableton Live. Ableton Live is perhaps leading the way in this domain with its acquisition of Cycling74, the manufacturers of Max and Max for Live. "Max for Live can completely change how Live interacts with all things external. Reconfigure connections to hardware controllers and synthesizers. Route audio to multiple sets of speakers from your Live project. Use Live to control physical objects like motors and lights using Arduino, OSC and other technologies there are infinite possibilities for connection and control between Live and the world surrounding it." (Ablelton, 2018) Max for Live can be combined with Max 7 or 8, a powerful interactive media programming software.

> "As a result of this integration, almost any parameter accessible through the GUI of Ableton Live can be remote controlled from a MaxMSP patch, including device parameters (devices include audio effects and virtual instruments),

[5] Iklax example https://www.youtube.com/watch?v=sMpUxupyeq0

> mixer controls and clips (clips are chunks of musical content, either MIDI or audio, that can be triggered for playback in live performance or sequenced in a time-line to create a composition." (Bown and Britton, 2013)

Brinkman's book, Making Musical Apps offered musicians with experience in coding and developers the knowledge of how to create innovative music apps. This important book showcased some exciting new software including RjDj and how to embed Pure Data (Pd) with libpd. (Brinkmann, 2012)

Pd is an object orientated programming language for digital audio and multimedia. PD has been around since the 1990s and is very similar to Max. It is open source and is still under active development. It was written by Miller Puckette. (Brinkmann, 2012) Pd is important in computer music and with the help of libpd, a "thin layer on top Pd... turns Pd into an embeddable audio library." (Brinkmann, 2012) The combination of Pd and libpd have offered developers and musicians an advanced and powerful audio engine for procedural audio, powerful processing and synthesis.

Pd has opened up audio design based on interactivity. With the help of software like libPd and Heavy, Pd patches can be integrated into other applications, including gaming middleware audio. Plans, 2017 predicts new:

> "DSP programming languages such as AudioKit, which have been designed specifically to work as embedded frameworks within mobile operating systems ... will possibly replace older frameworks such as Pd and super collider, which were built in the 1980s and 1990s to work in standalone computing devices, themselves evolutions of earlier computer music languages such as Max" (Plans, 2017)

AudioKit's website describes it as "powerful audio synthesis, processing, and analysis, without the steep learning curve." (Plans, 2017)

Young 2013, describes a shift that audio middleware has made "to cater more for composers and sound designers than audio programmers." (Young, 2013) Audio middleware software is not only allowing more artistic control of audio integration but is also beginning to become more uniform in its overall approaches and capabilities. (Young, 2013) Young comments about DAW software also seeing this trend "where certain layouts, key commands, and logic flows became consistently simple through popular demand."(Young 2013). Audio middleware software developers are integrating more production orientated tools. Young highlights how the layout of FMOD is very similar to Ableton Live. (Young, 2013)

The Group Report: Interactive Music Creation and Adoption listed a number of barriers in the creation of interactive music. These included; inaccessible tools, rock/pop artists may not be aware of tools, algorithmic tools not offering satisfying sounds, and non-recording features of DAWs were described as too techy. (Brown et al., 2014) As part of a small feasibility example the group worked on an interactive / algorithmic rock song and recommended improvements in the usability of tools and new steps added to workflow. (Brown et al., 2014) The process highlighted the need to expand on tools currently offered in DAWs and audio middleware software.

Figure 2.4: Image of Fmod Audio Middleware reprinted from (fmod n.d)

Audio software plugins are now also being developed for audio middleware software as well as DAW software. Young highlights company iZotope, who primarily manufactured "traditional linear mixing, mastering" plugins (Young, 2013) and have now partnered with Audio Kinnect, makers of Wwise middleware software.

> "We are beginning to enter an era where complex audio effects will not necessarily have to be 'baked' directly into audio files. Rather, one audio file will be able to be processed in real time in a myriad of different ways, increasing flexibility and decreasing storage needs." (Young, 2013)

Furthermore, Young predicts that:

> "DAW developers and virtual instrument companies will enter the fray as well, and more musical tools will be built into existing audio middleware and game audio engines. The potential for support of VST and/or other plugins in these engines may not be far off either." (Young, 2013)

If what Young predicts comes to fruition, music production could be totally transformed, allowing for flexible composition and production processes that results in music that can change and adapt to data incorporating procedural, generative and AI processes. As artists and producers begin to learn these new tools, the idea of music fixed in time may eventually be a thing of the past.

In an interview, acclaimed game audio composer Guy Whitmore states:

> "there's a general lack of awareness of adaptive techniques both in big and small game companies, but I don't think there's a lack of interest. The problem is that even audio directors, who are the ones who call the shots on the music side of things, aren't aware of the potential of adaptive music. Again, there's a lot of educating to do at the level of the audio directors, producers and composers to show them how adaptive music can improve the game experience." (Velardo, 2017)

This lack of awareness may be due to the complexity of adaptive and interactive music development which has been discussed throughout this chapter. If video game developers still don't fully understand the potential for adaptive music in gaming, it may be some time before the music and recording industry can understand the potential for interactive music forms in popular culture and future music products.

2.9 Conclusion

We are now in a situation where there are many new approaches and expert skills required to make future music products. This creates a huge problem for musicians and the music industry wanting to embrace these changes in technology and communication.

Another important issue emphasised by some of the examples in this chapter pertains to the costs of developing playback systems. Continual platform updates for iOS, Android, OS and windows necessitates constant updating of their systems. Many works that have been important in developing key themes in this research are no longer accessible, including CD-ROMs, but also some mobile apps that are not even five years old. With advances in software like Pd and libpd and start-ups supporting the open development of apps as artworks (RjDj), the field is beginning to get some traction. However, as discussed, many of the start-ups in this area over the past 10 years are no longer operating.

The two issues discussed over the past two chapters have been identified as;

1. the relationship between fixed song forms and dynamic composition; and
2. the need for a criteria to embrace this relationship between static and mobile song forms.

They identify a gap in the production and composition processes of creating music products and works based on interactive principals.

The next chapter addresses these issues by examining and reviewing relevant debates, including a review of existing platforms/creative works that are pushing boundaries and literature around the debates of key terms and standardization.

Chapter 3

Literature and Contextual Review: Part 1

Chapters 1 and 2 introduce and discuss two interconnected problems for musicians and those in the music industry who want to embrace changes in technology and communication:

- the relationship between fixed song forms and dynamic composition; and
- the need for a criteria that encompass the relationship between static and fluid song forms.

This chapter discusses literature and works that focus on the nexus between popular music, interactive music forms and data sonification.

There is a large body of literature surrounding approaches and techniques for the composition and production of interactive music across a range of academic fields including computer music, data sonification, media art, and sound art (Bongers, 2000; Chadabe, 1984; Drummond, 2009b; Paine, 2002; Rowe, 1992; Winkler, 1995); video game audio (Collins, 2007, 2008b; Kaae, 2008; Pichlmair and Kayali, 2007; Sweet, 2015; Wooller et al., 2005; Young, 2010); and music interaction (Holland et al., 2013a), a sub field of human computing interaction. This chapter will not attempt to review all the work in these fields, which has been thoroughly captured by Chadeby (1984), Rowe (1992), Winkler (1995), Drummond (2009), Bonger (2000), Paine (2002), Collins (2007, 2008), and Kaye (2008). It will instead, focus on interactive music production and forms within popular music context. Identifying key works that support this context. It should be acknowledged, however, that interactive popular music has been built on the innovative principles in these research fields. As well as audience and technology demand as discussed in Chapter 1.

In order to showcase the diverse new work popular musicians are producing, a selection of important works are reviewed and discussed over the next two chapters. A short summary of the work is provided, highlighting artistic concepts, musical content, interactive approaches and distribution methods. The works have been organised into six categories.

1. Concept Albums, EPs or Singles, Album Apps, Generative and Locative works
2. Artificial Intelligence

3. Data Sonification
4. Standardisation
5. Systems and Formats

The chapter also discusses important themes for each category including software, standardisation formats, audio systems to control and map data and the confusion of descriptive terms across fields of music.

3.1 Concept Albums, Eps or Singles, Album Apps, Generative and Locative works

3.1.1 Album Apps

Dredge (2016) provides an interesting history of the album app since the first releases in 2009. This collection of music apps shows a growing number of artists experimenting with mobile technologies. The works presented differ in what they offer audiences and how they are presented. Most of the apps discussed contain interactive elements, however many feature music that is static or fixed in form.

There is no specific format for what is to be included in a work for it to be described as an album app. Some examples like in 2011's *Sting 25* is presented as an "umbrella app for Sting's entire back catalogue" (Dredge, 2016) while Kim Gun Mo released a karaoke app. The Little Boots release was considered an album app even though it only contained four tracks. The loose term album app is used as a way for audiences to associate it with a traditional album even if in actuality it is nothing like an album. Toulson, Paterson et al (2016) provide a good definition of the album app. "The album app format is valuable since it allows unique artistic and interactive content to be distributed alongside a collation of audio, supporting the notion that an album is more than just a collection of songs, but potentially a representation of artistic vision which may include artwork, photography, lyrics, video, animation, gaming, social networking and crucially - interaction" (Toulson et al., 2016). With this definition many of the works discussed herein might be considered album apps.

Over this timeline more apps are being developed that involve some kind of transformation of the actual music itself. RjDj were heavily influential because of their first popular music release in 2009, Little Boots. Scott Snibbe, Björk's collaborator on the *Biophillia* app was also influential, producing some interesting and cutting-edge album apps, *Metric Synthetica* and the Philip Glass album, *Rework*. *Piano Ombre* By Francois and the Atlas Mountains is an interesting album app discussed in detail by Shakhovskoy and Toulson (2015). Interestingly, it was the first app that was eligible to chart. (Shakhovskoy and Toulson, 2015) The app was "designed to provide a digital music album experience that maintains the rich visual media and additional artistic content that would be expected in an analogue sleeve, and much more as well. The listener can play the album while browsing song lyrics, production credits, photographs, biographies, artwork, animations, and can also access exclusive studio outtakes and B-side tracks." (Shakhovskoy and Toulson, 2015) The music presented, however, remained the same as a static album. The important album apps which involve a change to the actual music itself are discussed below.

3.1.2 Little Boots Reactive Remixer

The Little Boots app[1] was released in 2009. (Boots 2009) The app included two interactive tracks or remixes as well as marketing information, a social area and updates about touring and content for Little Boots fans. The audio system was built using RjDj and Pd. Audio recording of the listeners' environment (microphone), the listeners' movement (accelerometer) were used to influence the tracks. The audio added was selectively recorded by listeners' phones. The composition also included musical layering such as percussive elements being added or removed based on the movement of the listener. The app was available in the iTunes store for $2.99 with links to iTunes to purchase tracks. The app included demos, previews of album tracks, news and blog feed, artist videos and a share space where the user could upload different things they had recorded.

Figure 3.1: Screen shot Little Boots App, Reactive Remixer

> "The phone's microphone picks up sounds from your environment while the accelerometer takes in the movement of your phone. RjDj's app recently launched at this time could incorporate both into the track, making each time you play a song entirely unique. With the Little Boots collaboration, RjDj took three tracks from her already released album and turned them into a $2.99 app allowing

[1]https://www.youtube.com/watch?v=f1LuxWeo11w

the listener to apply effects to each song. One track focuses on accelerometer movement which can sound more agitated depending on how fast you're walking or how much you're shaking the phone. Another track takes in sounds from your environment, like chatter from people around you in a cafe, and infuses them into the song. The effects range from being almost undetectable on some tracks to being completely transformative on others." (Cutler, 2009)

Robert Thomas, who was the adaptive music producer on this project, was part of the start-up RjDj, which is discussed later in the interactive systems and formats section.

3.1.3 Love by AIR

Love was a concept single released in 2010 by the electronic pop duo AIR. The project was also developed in collaboration with RjDj. It provided listeners with a new and immersive opportunity to experience the song with five different "soundscapes". The listener could also transform the track by adding their own voice and sounds, these were sampled and processed into ambient sounds in real-time. Users had the option to record their unique creations and share them amongst their social networks. (Floyd, 2010)

The app was designed to function like a real-time sound studio. The music is "presented as five different pages, or "soundscapes," that the listener can swipe between to shape their experience (Floyd 2010) The five soundscapes include:

- "Chanter - puts your voice in the music, letting you sing, speak or add your own sounds into the mix
- Harmonie - vocodes sounds in real-time and makes them harmonize with the music
- Papillon - samples tiny segments of sounds and creates audio butterflies from them, flying around inside the music
- Voler - creates a rising texture of sound by sampling reality and layering and/or filtering them in the music
- Voyage - takes you on a musical journey through all of the soundscapes" (Floyd 2010)

3.1.4 1000 variations

1000 variations is a work produced by Oliver Bown and Sam Britton. They refer to Jacques Attali and Luciano Floridi's work as a philosophical backing. "These both privilege the idea of interaction and share the view that some critical identification with difference or variance in the broadest sense is a key component for the future of music." (Attali, 1985)

Interestingly, Bown and Britton "define parametric composition as the composition of musical elements that contain one or more controllable parameters with which specific instances of the music can be specified." (Britton and Sam, 2014) "Borrowing from programming terminology, such a product can be thought of as a 'singleton', an object of which there is only one real instance, no matter how many times it is referenced. While some pieces of music exist in many manifestations, a large number effectively have a definitive form, the album version." (Britton and Sam, 2014)

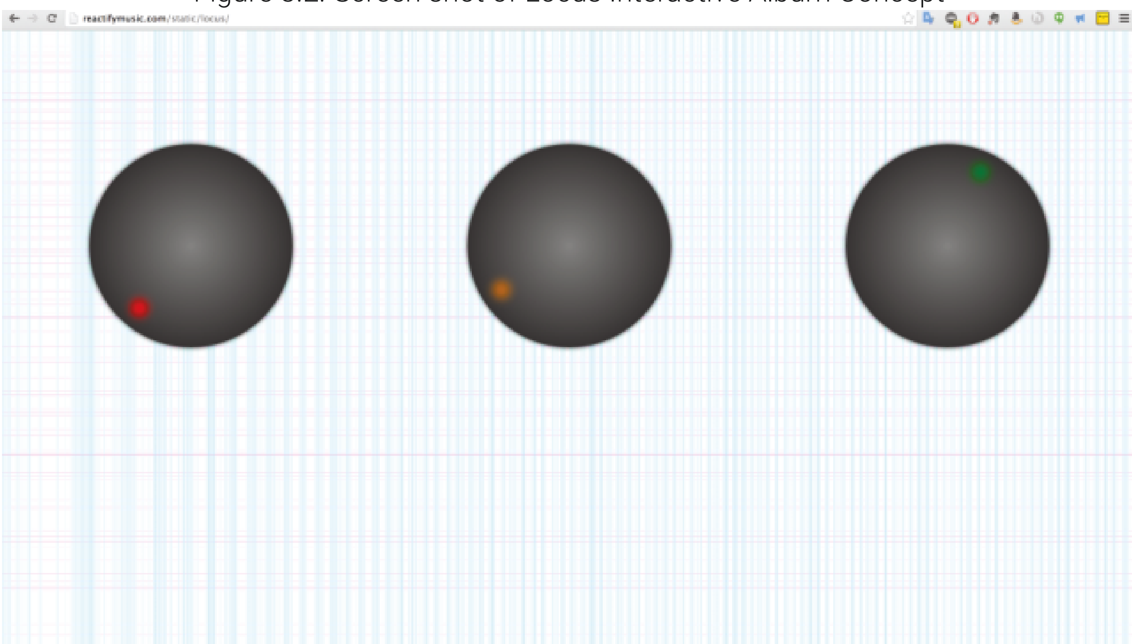
The concept of the interactive album is not new to the popular music industry and many album apps have been released over the past 10 years. However this is a unique approach as it demonstrates important new approaches in composition and production methods.

3.1.5 Locus Interactive Album Concept

Locus Interactive Album Concept [2] was published in 2015.

> "Locus is a concept for a new way of creating and distributing an album, where songs are presented not as individual tracks, but as one continuous body of music, or as a multi-dimensional 'music space' that can be explored non-linearly. Presented with a minimal interface of three parameters on the screen, the listener can change these parameters to change the characteristics of the music. This current demo contains three 'tracks', with 'Speed' (the far-left circle) being the main differentiator between them. The other two circles control the 'Intensity' and 'Spaciness'. Certain musical elements, such as the lead vocals, will only occur when the parameters are at the correct values. This means that 'tracks' can be thought of as different configurations of the parameters' values." (Levtov and Adenot, 2015)

Figure 3.2: Screen shot of Locus Interactive Album Concept



The audio system is built using Pd, Web Audio and Java. By using the mouse, the user can change the intensity and spaciness. The system is browser based and available on Sony android.

[2] http://reactifymusic.com/static/locus/

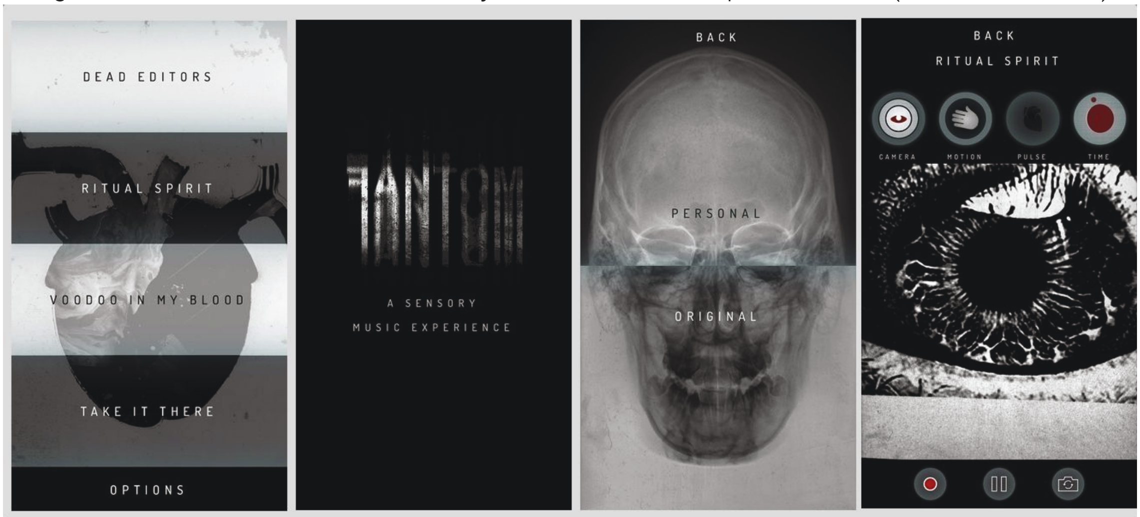
> "The music has been composed with a mixture of traditional DAWs and Pd. Certain elements of the music, such as the drums and vocals, are sample-based, whereas the bass, synths and effects are all generated in the browser. This also allows a great degree of flexibility with the melodies and chords being generated in real-time. The Pd patch is then compiled using a Pd-to-C compiler, Heavy, which converts the C to JavaScript using Emscripten, allowing us to run it in the browser with the Web Audio API." (Levtov and Adenot, 2015)

The project was developed by Reactive Music Producer, Yuli Levtov, who was involved with the RjDj project and has developed a number of the reactive music projects surveyed in this review. Its concept combines parametric and generative composition to produce an ever-changing piece of music.

3.1.6 Fantom

Massive Attack released *Fantom* in 2016. *Fantom* is promoted as a sensory experience and uses the listener's mobile phone's camera, location and heart rate from an Apple watch. The app was described in the band's press release as "a sensory music player that remixes and reforms songs uniquely using a variety of environmental variables including location, movement, time of day, heartbeat and the integral moving image camera." (Monroe, 2016)

Figure 3.3: Screen shot of *Fantom* by Massive Attack reprinted from (Ask Audio, 2016)



The audio system was developed using a combination of Pd and custom software. The system utilises the listener's location, time of day, video camera and real-time recording of audio, movement via the accelerometer, and heartbeat via the apple watch. There is a wash and filter on the video which creates a slightly dark and interesting treatment to the resulting video recorded by the phone. The audio changes based on the location of the phone and the listener's movement, also the time of day is said to affect the music. How it effects the musical output, however, is unclear. If you have an apple watch it also responds to your heartrate. The user can record their video and supporting unique music mix from one of four Massive Attack tracks and share it with their social networks. *Fantom* is available as an App from the iTunes store. It is free to download and contains in-app purchases of mp3s from the EP. [3]

Aesthetically the app is dark and enigmatic. When originally released in Jan 2016 there were four tracks. Since then three more tracks have been added. All tracks use the same video interface and filter. In an interview in Motherboard, Massive Attack's Robert Del Naja and collaborator Robert Thomas (Adaptive Audio Composer) discuss the details of creating the app and their approaches. Del Naja explained that originally he thought, "Why would we put a premixed album out when there's algorithms that'll mix this for you?" (Fenwick, 2016) He was then introduced to Robert Thomas. Thomas had a decade-long history working with interactive and adaptive music tech as the CEO of RjDj. "I think of it as quantum composing," he explained from his studio in Hackney.

> "You're thinking about all of these different universes the music could exist in and have to design for every eventuality." (Fenwick, 2016)

The audio used in the app was recontextualised using the masters to Massive Attack's new album. These masters were then minimised to create shorter audio segments. So essentially the app is a system that creates remixes using the user's phone data including video, motion, time of day and heart rate. The article discusses that Thomas sees this process as "striking a balance between nonlinear composition and the formality of conventional music." The article quotes him as saying:

> "I think the mistake that people make when they think about this kind of work is that it's all randomly thrown together, but the way to make this stuff well is to build rules into the system," he says. "We have to make sure it makes sense melodically: so a piece from the chorus will never appear alongside a verse, which means the behaviour of the system can change, but it will always change in a musical way." Robert Thomas via (Fenwick, 2016)

Robert Thomas has worked with many successful and established bands on interactive and adaptive works. His role as an adaptive music producer is a creative role working alongside the music artist to realise a new work.

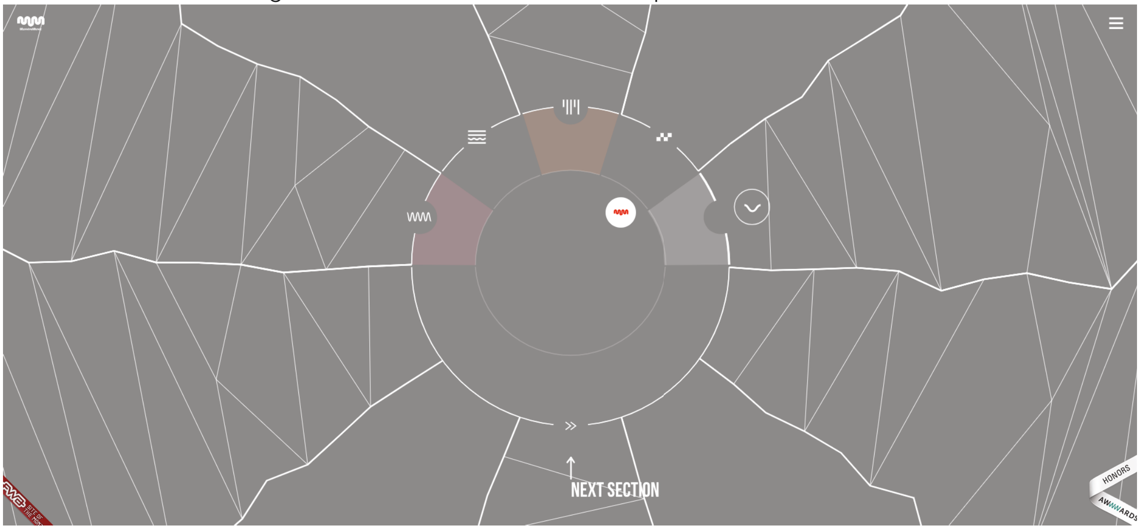
Interestingly the app hasn't had enough ratings to display a summary in the app store. This makes it difficult to determine if the app was popular with fans. At the time of writing there were 353 public posts on Instagram, however the amount of private posts cannot be ascertained. It is, therefore, difficult to measure the success of the app given its obvious goal of creating an experience for its audience.

3.1.7 Mmorph

Mmorph [4] was released in 2016. *Morph* is a browser-based interactive music experience. The user can interact with a mouse or set up their mobile phone as a pointer via a code then calibrate it via a few instructions. The experience is available in HD or SD. There are five different scenes or song sections:

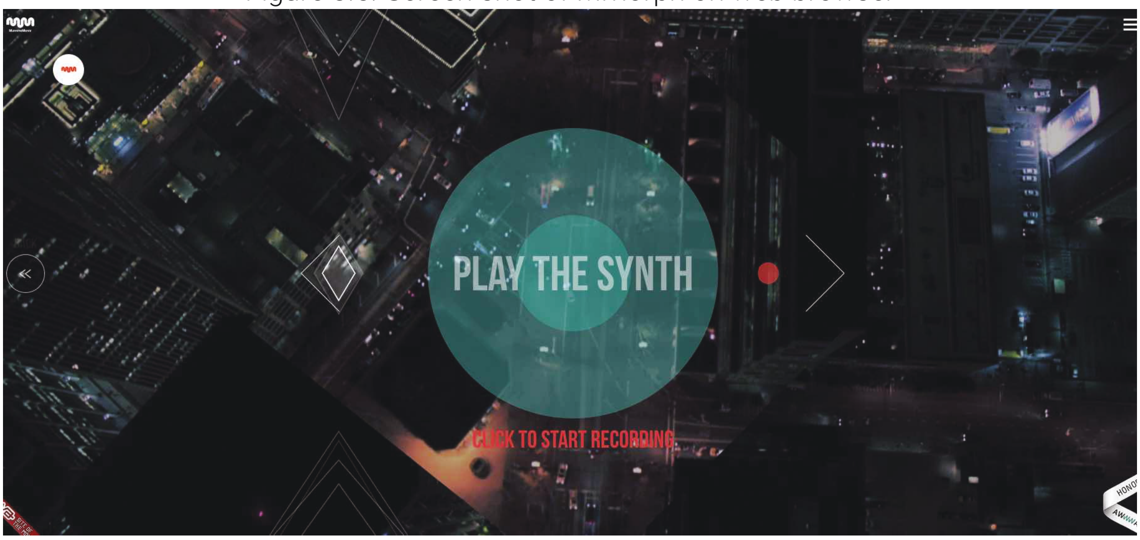
[3]An EP (Extended Play) is recorded music product usually containing 4 to 5 tracks.
[4]http://mmorph.massivemusic.com/

Figure 3.4: Screen shot of Mmorph on web browser



1. The user can select a combination of loops including bass, drums, synth, vocals and Ukulele. When ready, the user can select next section, see figure 3.4;
2. This section requires the user to shake either the mouse or phone and produces a filter 'build' effect that cuts out the music before taking the user to an effects section.
3. Here the user can interact with a filter, delay and other effects by twisting the phone.
4. The next section is 'play the synth' where the user can move the mouse or phone to change the note of the synth. A record button comes up after a few seconds and if the user hits record, it records a short sample, see figure 3.5;
5. Finally, there is another 'build' filter section. The user can gently shake the phone or move the mouse to build. The final page is the outro of the track an consists of with falling shapes.

Figure 3.5: Screen shot of Mmorph on web browser



The user can go back into sections and the audio slows down to start again. A high internet speed is required. If high speeds are not available the track will not transition smoothly, it appears jerky and gets stuck, and it is hard to experience the app the way it was intended.

The experience is aimed at gamers and interactive audio enthusiasts. The audio system was developed in Pd utilising Heavy [5] to integrate the system into web audio API. It is browser based, the user can interact with the system using their mobile phone or a mouse click. They can affect the tracks parameters and structure via filter, delay, song sections, loops and instruments, transitions and builds. This project features in the Reactify (company owned by Yuli Levtov) portfolio of works and was developed in collaboration with Massive Music and Owen Hindley.

3.1.8 VW and Underworld Play the Road

VW & Underworld: Play the Road [6] was released in 2013. The project was created in support of the new Golf GTI.

Play the Road is a "completely reactive piece of music, specially tailored to be driven, not just listened to." (Reactify, 2013)

The music was composed by "UK electronica pioneers Underworld, with extra help from Nick Ryan." (Reactify, 2013) Reactify's contribution involved programming a system to map Underworld's music to data received from the car. The audio system was developed using Pd and is a combination of audio stems and Pd programming.

Real-time data is received from the car's steering and acceleration processes. The location data is calculated from a combination of the iPhone's accelerometer, gyroscope and GPS receiver speed and RPM information from the GTI's on-board computer. The car's computer provides data on the speed and RPM, whilst the GPS, accelerometer and gyroscope data are provided by the user's iPhone. Filtered data is used in Pd to produce audio. This product is not available commercially and is a stand-alone app available only with new VW Golf.

> "I think we all felt from the beginning that if it was just an experiment that produced an experimental result and that was it then it was going to be a failure. It needed to arouse emotions, as music does." Rick Smith(Underworld) (Volkswagen, 2013)

> "Using the musical program language Pd, the music and data were brought together. Different musical motifs were attached to different data streams, so the car's movements or locations would trigger and effect the music live. The only way to refine the composition was to drive it, over and over, allowing the team to identify locations in the soundscape where the composition and Pd patch could be tightened. The GTI became an office for Underworld, Nick, Yuli and the precision driver Steve Gault, until the final composition was finished." (Volkswagen, 2013)

[5] https://enzienaudio.com/

[6] http://reactifymusic.com/portfolio/vw-underworld-play-the-road/

> "Responsive music presents the musician with completely new freedoms of expression. It allows them to design 'experiences' for listeners, which are contextual to the listener's environment, their activity and their behaviour." Nick Ryan (Volkswagen, 2013)

> "We want to listen to this bit of data here, but then we want to stop listening to it here and listen to this completely different bit of data here. How they all interweave, that's where the complication of the project starts to multiply." Yuli Levtov - Reactive Music Producer (Volkswagen, 2013)

The *Play the Road* project with Underworld showcased some very interesting approaches to composition based on data, however the project was used to promote the release of a car and is not available as a music product.

3.1.9 Bluebrain - The National Mall

Bluebrain released an important work in 2011, the first location-based app (for iPhone). The duo is based in Washington DC and the music responds to the listener's location in The National Mall a large parkland area in down-town Washington. Bluebrain have gone on to produce other location aware albums since.

The app tracks the user's location via their mobile phone's GPS. "Hundreds of zones within the Mall are tagged and alter the sound based on where the listener is located in proximity to them. Zones overlap and interact in dynamic ways that, while far from random, will yield a unique experience with each listen." (Bluebrain, 2011) The path the user takes can add variation to the melody, rhythm, instrumentation and pace of the music.

Bluebrain explained the concept in more detail: it

> "is not an augmented reality application in that it does not respond to input from the listener. It is not a toy or game that allows users to input or experiment with limitless possibilities to alter what they're hearing. Each position on the map has been carefully considered, the music composed and recorded to be heard in their specific place in the same way you would hear a piece of music on a physical record. However, because each listener will explore the Mall in a different way and at a different pace, experiences with the album will be unique in sequencing and in arrangement." (Bluebrain, 2011)

The work is composed in a way that different songs, melodies, rhythms etc are experienced at different locations. The musical output is fixed for different locations.

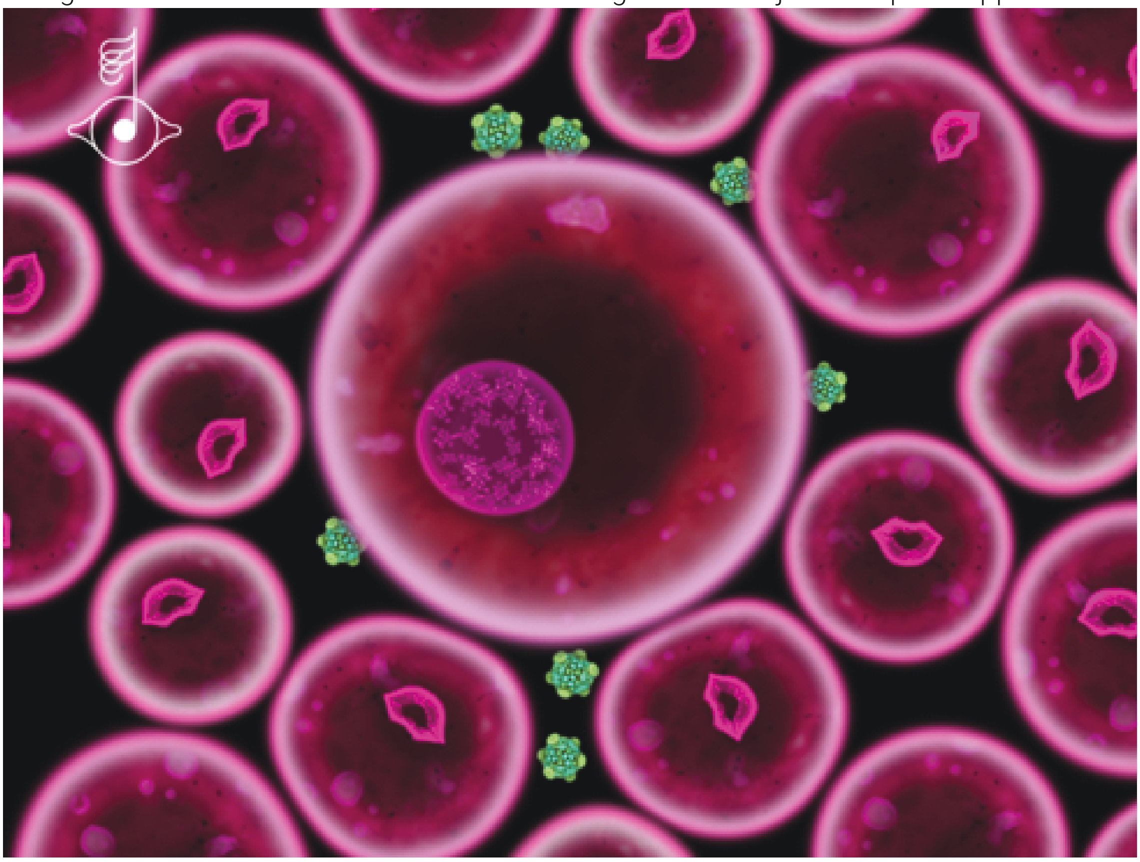
> "What you hear standing twenty feet south of and staring up at the Washington Monument will be there when you return to it one year or 10 years later. The landscape is simply the way to discover and interact with the music that's been composed and carefully placed throughout." (Bluebrain, 2011)

This project showcased a unique compositional approach, where the work was composed specifically to be experienced at a location. Whereas recorded music can be experienced anytime anywhere, this music was composed to be experienced with a particular visual experience, just as film music is composed to support the video being watched.

3.1.10 Biophillia, 2011

Biophillia is a unique and innovative work which has had a huge impact on the music industry and audiences. *Biophillia* is a multimedia project by Björk and consists of a "studio album, a suite of apps for mobile devices, live shows, residencies with pop-up music schools and a variety of other activities and artefacts." (Dibben, 2014) The app was "unique in being a suite of apps structured as an album and released in synchrony with the physical and digital album." (Dibben, 2014) The album consisted of 10 tracks of which are presented as unique apps in their own right. The 10 apps are encased in a 'mother app' designed by M/M Paris, which was a 3D virtual environment that visualised the music work 'Cosmogony'. It is presented as a "star field interface, stars corresponding to the song apps glow and pulse; each song increases and decreases in volume as the user approaches them in the 3D space by pinching the screen and zooming nearer and farther away; even song names in the track listing screen move and bob as if suspended in space." (Dibben, 2014)

Figure 3.6: Screenshot from iPad of the Virus game from Björk's Biophilia application



Dibben produced an in-depth essay on *Biophillia*, "Visualising the App Album with Björk's *Biophillia*" which consists of interviews with Björk and consumers. The essay offers insight into the possibilities for the album app format and a thorough review of the work.

Each track from the album takes on a new form in the app version, with each app being created based on each song's concept. All the apps provide a linear version of the track and most enable the user to create their own versions of the work in some way. Dibben, notes that two apps, 'Cosmogony' and 'Hollow', "do not exist in fixed versions". (Dibben 2014)

'Thunderbolt' offers users the ability to improvise the bassline of the track. 'Crystaline' allows users to change the song structure by changing roots within a virtual tunnel. In 'Virus' the user can delay the song progression. 'Sacrifice' allows users to write music notation. In 'Moon', 'Solstice', 'Hollow' and 'Dark Matter' the user can compose musical sequences. (Dibben, 2014) Importantly Dibben notes that "within this context, the song becomes process rather than a fixed, single object that is remade in different performances according to available resources: not only are the versions of songs on the app suite and music album different, the versions on the song app, score, and animation also differ." (Dibben, 2014)

In a discussion Björk showed Dibben that she based the app album concept on educational apps including *The Elements* and *Solarwalk* and music apps including *Bloom*, *Sound Drop* and *Bubbleharp*. (Dibben, 2014)

> "Björk had noted that whereas people can grab a guitar and sing rock songs together, they couldn't do that as easily with electronic music." (Dibben, 2014)

This quote puts into context much of how music has changed with digitisation. Interfaces open up not only the possibility to create new multimedia experiences but also to play with and experience electronic music in new ways either as an instrument, creative tool or listening experience. Dibben (2014) highlights the potential of the interface and touch screen devices which offer users an extra level of experience. Cultural products can be touched and manipulated. (Dibben, 2014)

Biophillia does in some ways blur the boundaries of gaming and music. Scott Snibb, developer of the *Biophillia* app, when discussing past projects states, "we were trying to find creative, open-ended ways to interact with music that weren't turning it into a game. Guitar Hero pigeon-holed music into the same idiom as a normal game, trying to get a score. You don't get a score using Pro Tools, right?" (Dredge, 2011) In Dibben's research she notes

> "In the context of gaming, the apps extend the notion of music games in that they also allows users to create and perform music, but focus on musical structures and processes through metaphors of natural phenomena; as one informant noted, comparing the *Biophillia* app to the status of music within computer games: "you're coming from music and you're sort of bringing in, you're game-ifying the album" (male computer technician, aged thirty)." (Dibben, 2014)

3.1.11 Red Planet

The *Red Planet* app by Daisy and the Dark was funded through the Arts and Humanities Research Council (AHRC) "The project investigates the app as a potential album-release format of the future in an initiative to lure the consumer away from the 'single track download' mentality" (Toulson et al., 2016)

Figure 3.7: Screen shot from iPhone Red Planet App

The app includes four tracks which can also be experienced interactively.

1. *Red Planet* was based around a circular image which allows the listener to mix between different versions of the title track. In the centre of the circle is the radio edit of the track. By selecting different areas of the circle, users can hear different versions of the song including acoustic, EDM (electronic dance music), dub and choral interpretations. The vocals can be muted by tapping the circle.

2. 'Circus' is presented as a matrix containing 25 mixes. The user taps or drags the matrix interface. The radio edit version is in the centre. "Each matrix cell plays a subtly different mix, and when a new mix is selected, a unique crossfade algorithm smoothly transitions the music from one mix to another" (Daisy and the Dark, 2016) Another

feature of the work is called variplay. When the user activates one of four buttons below the matrix, a quadrant lights up and the music is controlled by an algorithm selecting different mixes throughout the track.

3. ’Waltzing’ consists of a series of buttons which mute and unmute instruments allowing the user to create unique mixes of the track.

4. ’Ghost’ uses a triangle crossfade mixer. The track include three mixes that can be crossfaded and blended together. (Daisy and the Dark, 2016)

The project also aimed to create a template or standard for album apps by combining multi-track mixing with an interactive album experience. This also included other media like video, images, lyrical content. This project introduced important research outcomes discussed in more detail in section 3.4.

3.1.12 PolyFauna by Radiohead

PolyFauna was released in 2013 by Radiohead. It is a collaboration between Radiohead, Nigel Godrich, Stanley Donwood and Universal Everything. It was designed to be an audio-visual experience based on the studio sessions from the King of Limbs album. Plans, 2017, provides a good overview of the app, which "uses the sensors on the phone to capture data on the phone’s position, and reacts visually to the position of the sun and moon to vary the generated visual landscapes." (Plans, 2017) The experience is dynamic and changes on every listen.

3.1.13 Bloom

Generative based music apps are also growing in popularity. *Bloom*[7] was published by Brian Eno and Peter Chilvers in 2008 with an update released in 2017.

> "Generative music is music which is not specified by a score, but by an algorithm, a set of rules, a set of processes, a mapping from randomness, or some other such method." (McDermott et al., 2013)

Bloom is an interactive, generative music experience. It is a hybrid of an instrument, app, visualizer and generative music device. It has three different modes: classic - original sounds and functionality; Infinite - infinite patterns and shuffled music parameters; and freestyle - all settings are available to the user to manipulate and organise. The music is ambient and includes visualisations of coloured circles (like the effect of droplets on calm water) against a coloured background. It produces a hypnotic, immersive and relaxing affect.

The app is aimed at fans of Brian Eno, and ambient and relaxation music in general. The system is built using Xcode and Objective C. There are three categories of sounds and 12 moods. Each of the 12 moods changes the colour and scale used as well as the background

[7] http://www.generativemusic.com/bloom.html

drone's audio. The audio is made up completely of audio samples from Brian Eno's library. Parameters that change include delay and echo.

The app gives the listener limited control. This consists of a sleep timer, touch screen and button selection. The app is available in the Apple app store for $5.99.

> "*Bloom* is entirely sample based. Brian has a huge library of sounds he's created, which I was curating while we were working on the Spore soundtrack and other projects. It's funny, but the ones I picked were just the first I came across that I thought would suit *Bloom*. We later went through a large number of alternatives, but those remained the best choices. The version of *Bloom* that's currently live uses fixed stereo samples, but an update we're releasing soon applies some panning to the sounds depending on the position of each 'bloom' on screen. It's a subtle effect, but it works rather well." Peter Chilvers via (Milani, 2008)

3.1.14 Discussion of Albums, EPs or Singles, Apps and Locative works

This review is concerned with apps that involve transformation of the actual music through some type of data input. RjDj were heavily influential with their first popular music release in 2009, Little Boots, which was produced by Robert Thomas as well as *Love* by Air. Robert Thomas, Yuli Levtov and others have been shown to be pioneering a new direction in popular music at a professional standard. Scott Snibbe, Björk's collaborator on the *Biophillia* app has also been influential, producing some interesting and cutting-edge album apps such as *Metric Synthetica* and *Rework*, Phillip Glass. More recent releases include *Red Planet*, Daisy in the Dark and the browser-based experience *Morph* in 2016

Other approaches can demonstrate how music can be produced in an album like form without being fixed in form. Examples discussed include Album with *1000 variations* and the *Locus Interactive Album Concept*.

Context-based works like *The National Mall* (Bluebrain 2011), *Fantom*, Massive Attack 2016 and VW and Underworld's *Play the Road* (2013) in collaboration are also examples of how popular music forms are adapting to interactive technologies, whether or not it be via the listener's contextual data.

The examples used to promote popular musicians like Little boots, Massive Attack and AIR offered fans new experiences. However, they were often used to aid in the sale of the static album or single. As highlighted in the *Fantom* review it is difficult to measure the success of these apps given they are not included in traditional chart and sales figures in the music industry. Also many of these apps are no longer available in the app store due to operating system and platform updates.

Dredge (2016) highlights some of the issues surrounding the album and music apps. Firstly, these apps he discusses were mostly funded by the marketing budgets for specific albums. There were no allowances in these budgets for updates like regular OS system updates for Apple and Google. This has led to most of these apps becoming unavailable from app stores and not being compatible with most smart phones. He writes that it's "a shame that, as a part of this industry's history, album apps are disappearing in a way that, say, videos from MTV's heyday are not." (Dredge, 2016) Unfortunately this is also the case for most of the historical overview of those works on CD-ROM and Flash featured in Chapter 2.

"The album-apps that stick in our brain for their creativity tend to be the ones that were artistic works in their own right, by the artists, rather than marketing campaigns. Björk's *Biophilia*; Bluebrain's location-based albums; Gruff Rhys' *American Interior* and now *flux* by Adrian Belew - these were creative works in their own right that made sense as apps." (Dredge, 2016)

Dredge (2016) highlights the lack of evidence for large financial returns from the album app. He lists experimentation with pricing between 5-15 GBP per app, as well as a free app with in-app purchasing. Another reason album apps may not have been financially successful may be due to limitations made by app platforms. "At one point in time, Apple's rules were a challenge too: buying an app with the music didn't mean you got the tracks as separate audio downloads, and developers were barred from giving you a code to get those downloads directly. Even Björk's keenest fans may have balked at buying Biophilia twice - once in app form and once in album form." (Dredge, 2016)

Dredge (2016) doesn't see all doom and gloom in the future of album apps and highlights some ideas he believes may be worth exploring further. "Bluebrain's location-based music could find another wave of interest post-pokemon go." (Dredge, 2016)

Album Apps provide artists with a new type of control over how audiences can experience their work. At this time most popular music artists are releasing apps to co-inside with a fixed form album, single or EP. The fixed form represents the idea of an 'original work' from a copyright perspective. Like the story from a book being made into a movie. Where as apps like Bluebrain's *National Mall* the app is the original work in its own right there is not fixed version of the artwork. As music technology grows and develops there might be a time when we start to see more artists producing apps without a fixed form version (or so-called original version) of the work.

Software and new integrations for software like Wotja, [8] Max for Live, Pd and web audio are fostering the way for more musicians to work with generative and dynamic audio concepts.

3.2 Artificial Intelligence

As AI becomes more ingrained in society, possibilities for using it in music will continue to develop. At this time the Bronze Format (see section 4.1.7) is a good example of how AI technology can be used in popular music making. The Bronze format uses algorithms to create a music work which will never be the same. It is a music format and is not attributed to just one music work and is therefore reviewed in the systems section in Chapter 4.

When games composer, Guy Whitmore was asked what he sees as the future of adaptive music and whether he thought the paradigm in which people engage with music will fundamentally change," he stated:

[8] https://intermorphic.com/apps/

> "Mechanically, I see a trajectory that seems pretty obvious. AI is affecting any aspect of technology and music is no exception. The use of AI in music making seems inevitable. To me, as a human, I am particularly interested in the question: how do I interact with those AI systems? There's a world where you press a button and there's a producer that comes out with a piece of music and I can tweak the knobs. That will happen as it is an extension of what's already happening with the use of music libraries. There's another - more sophisticated - world where you don't get complete tracks, but different stems that you can stitch together. The next step is an algorithm that does the stitching for you. I see this happening and controversies coming up around this innovation! Ultimately, I'm interested in keeping humans in the equation by working with these machines to create wonderful musical experiences for the players. Rather than becoming an audio director who curates the different tracks provided by the AI, I want to remain a composer and collaborate with these systems and influence them. So, there's a broad spectrum here: the AI does everything, you can work with it to a degree, and then you can compose with just a little bit of AI." Guy Whitmore via (Velardo, 2017)

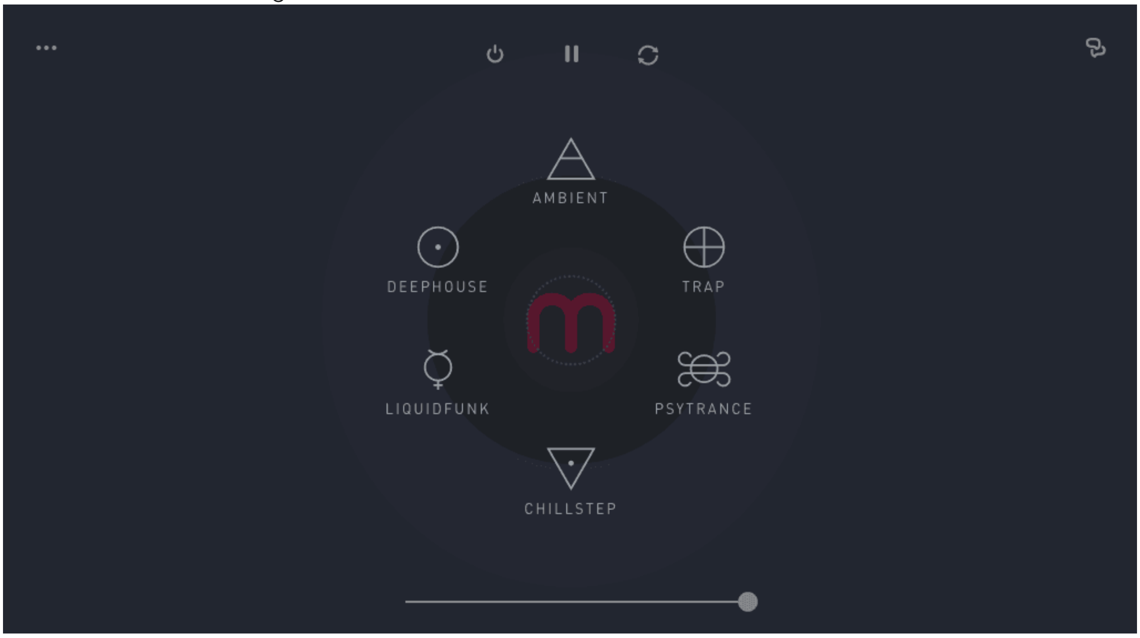
His answer highlights how AI is changing the landscape for adaptive game music. These themes cross over to popular music products. The following projects highlight a number of approaches of how AI is being utilised within popular music making

3.2.1 Mubert

Mubert was published in 2016 online with the tagline "Enjoy AI music created by worldwide producers." (Mubert, 2019) *Mubert* is a Generative Music App, it creates and composes music in real-time from a mix of loops. Its website claims its audio stream is infinite and works seamlessly. Businesses who might use it include public places, game development, videos and advertisements. It's also a platform where music makers, djs, labels and experts can create and monetize generative music.

The music system uses algorithmic processes and consists of a large library of audio loops. The system uses algorithms to combine and organise the loop library. The track is different every time it's played back. The browser-based system `http://play.mubert.com/en/` plays a variety of electronic music styles including ambient, deep house, chill step, liquid funk, trap and Psytrance. The app version has options including relax, focus and work on the iOS app. This newer system is also on a player of the promotional website for *Mubert*. There also seem to be hashtag descriptions set up as well including #drone, #nature #ambient. It is unclear exactly how the audio system works. There are two other systems that support *Mubert* including a musician's platform and licence management based on blockchain technology.

Figure 3.8: Screen shot from web browser - Mubert



3.2.2 Magenta - Google

The research project *Magenta* was started by 'Google Brain Team' engineers and researchers. This exciting project explores "the role of machine learning in the process of creating art and music." (Magenta, 2018) It aims to provide artists and musicians with tools to extend their processes.

The website offers code via Github, publications, demos, a public discussion forum and a blog. There are also a set of Max for Live MIDI plugins which provide a set of AI based tools from the Magenta Studio including continue, groove, generate, drumify, and interpolate.

The Magenta demos provide a demonstration and the code to exciting musical processes that could be incorporated into future music products. Beat Blender is a rhythm slicing demo: "You can use it to generate two dimensional palettes of drum beats and draw paths through the latent space to create evolving beats. The four corners can be edited manually, replaced with presets, or sampled from the latent space to regenerate the palette." (Magenta, 2018)

3.2.3 Daddy's Car

In 2017 Flow Machine composed its first pop song *'Daddy's Car'*[9] which was stylised on The Beatles. The work received some help from French composer Benoît Carré who wrote the lyrics and arranged segments of music, generated by the systems AI or deep learning. Flow machines is a joint research project between Sony Computer Science Laboratories and Pierre and Marie Curie University (UPMC).

The project researches future authoring tools for composition with the goal of boasting creativity and to assist people finding their own style. (Sony, 2018)

[9]https://youtu.be/LSHZ_b05W7o

> "The goal of Flow Machines is to research and develop Artificial Intelligence systems able to generate music autonomously or in collaboration with human artists. We do so by turning music style into a computational object. Musical style can come from individual composers, for example Bach or The Beatles, or a set of different artists, or, of course, the style of the musician who is using the system" (Sony, 2018).

The system analyses styles using the Markov Chain, then can assimilate that style into others.

3.2.4 Digital Love

Digital Love [10] released in early 2018 was produced in collaboration with Jukedeck and the South Korean based company Enterarts. Enterarts specialises in AI music production and artist management. Jukedeck is a startup launched in London in 2014. Jukedeck is developing a technology that "brings artificial intelligence to music composition and production." (Jukedeck, 2018) This is achieved by training "deep neural networks to understand music composition at a granular level" with the hope of building tools to aid with creativity. They use their technology to create a digital representation of a composer's brain which is then used to create new original tracks. (Featherstone, 2017)

Jukedeck started its journey with the idea of composing background tracks for user-generated videos. However, this collaboration extended the startup's vision. K-pop stars including Kim Bo-hyung and Highteen produced the song *Digital Love* using deep neural networks.

> "The AI predicts note sequences to compose brand new songs. After users select parameters such as mood, genre, and beats per minute, the AI cranks out a track that artists can embellish." (Jancer, 2018)

The way AI is developed as a component in music composition is quite different from the Flow Machine (used in Daddy's Car), which focuses on style. JukeDeck is developing its technology based on mood and the compositional process.

3.2.5 I Am AI, Taryn Southern

I Am AI is the first popular music album to be composed using AI technology and was released in September 2018. (Johnson, 2018) The first single 'Break Free' [11] from the album was released in 2017. It was composed using the AI based technology, Amper. "Amper is an artificially intelligent music composer, producer, and performer. The AI was developed by a team of professional musicians and technology experts, and it's the very first AI to compose and produce an entire music album." (Galeon, 2017)

The project is described as more of a collaboration with artist Southern and Amper. Southern describes the process of feeding sounds, notes, or instruments she liked into

[10] https://youtu.be/NI4t3TEsxnQ
[11] https://youtu.be/XUs6CznN8pw

the system. The Amper software provided either a stem, or audio segment matching that criteria. This music was then tweaked and stitched together to create a track. (Johnson, 2018)

This approach differs from Flow Machine, however there are similarities with Jukedeck's system. This system, however, uses the deep learning of specifically selected musical parameters to compose something.

3.2.6 AI Software for Music Production

A number of music production software and plugins are also beginning to enter the market, including AI and algorithmic mastering service *Landr*. The service automatically generates a mastered copy of an uploaded track. It has been popular within the STEM format when a number of stems need to be mastered instead of one audio track.

The drum plugin *Atlas* uses AI technology to organise large sample libraries into an easy to use interface. The user can randomly create a drum track by letting the software know which sounds they like. Then the software will try and select drum sounds it thinks you will like. Another example of a recently released AI based plugin is *Quantakor*.

3.2.7 Summary of Artificial Intelligence

There is a large number of AI based music companies and start-ups entering the popular music industry in addition to Flow Machines, Magenta, Jukedeck and Amper. They include Popgun, IBM Watson Beat, Melodrive, Spotify's Creator Technology Research Lab, and NSynth Super.

> "Most of these systems work by using deep learning networks, a type of AI that's reliant on analyzing large amounts of data. Basically, you feed the software tons of source material, from dance hits to disco classics, which it then analyzes to find patterns. It picks up on things like chords, tempo, length, and how notes relate to one another, learning from all the input so it can write its own melodies. There are differences between platforms: some deliver MIDI while others deliver audio. Some learn purely by examining data, while others rely on hard-coded rules based on musical theory to guide their output." (Deahl, 2018)

The excitement around AI and popular music is also bringing a number of issues to the fore including hype around current limitations of AI, debate over the future need for musicians and the potential copyright models for machine composed music.

3.3 Standardisation

Toulson, Paterson et al (2016) provides an important overview interactive /album app releases and multi-track formats within the popular music context, (as discussed in section 3.1.12) Their "research looks at the emergent format of the album app and extends existing paradigms of interactive music playback." (Toulson et al., 2016) That chapter focuses on the implementation of mix-stems into an album app structure, it hopes to offer a model for future formats as the area evolves. The research investigates opportunities for artists based on the capabilities of new technologies and audience responses to their approach. (Toulson et al., 2016) These opportunities are focused on a mix-stem playback with the addition of other artist media like video, images, lyrical content etc, thereby offering an alternative to fixed playback formats like CDs and vinyl. It is out of the scope of their research to offer insights into the authorship of the stems and how this process in itself could offer a richer music form from the artists' and audiences' perspectives.

Toulson et al. (2016) conclude that due to the limited number of album app releases "a unifying format for the future could hold potential benefit before too many variants emerge. (Toulson et al., 2016) However, as with other attempts at standardising interactive music playback like the MXP4 and IM AF, it could potentially limit the scope for artists to experiment with the concepts of Dynamic Music production discussed in this research. The reviews in this chapter showcase the cutting edge approaches available to artists. Perhaps more variants need to emerge as artists experiment with the principles of interactive technologies. As discussed in a previous paper (Redhead, 2015a), there is no reason at this time that there be a standard interactive format for popular music in its musical material and interface design. Developers:

> "seem to be approaching the development from a 'design first and add content later' model. The interface is designed first and then musicians create music for the interface. . . This model and way of thinking needs to be reassessed. A new framework for composing, arranging, producing and recording a work needs to be developed with the output being an amorphous artwork that has many dimensions and ways of being heard. . . Instead of the development evolving from an industry and software engineering perspective it needs to work concurrently with how artists perceive their music within a fluid format." (Redhead, 2015a)

Stewart, Kudumakis and Sandler (2011) reviewed potential formats that could help standardise music embedded with interactivity.

> "Music is now consumed in interactive applications that allow for the user to directly influence the musical performance. These applications are distributed as games for gaming consoles and applications for mobile devices that currently use proprietary file formats, but standardization organizations have been working to develop an interchangeable format." (Stewart et al., 2011).

This review is based on karaoke-style applications requirements. Since these concepts have developed the requirements have also expanded.

The IM AF (Interactive Music Application Format) "integrates multiple audio tracks with appropriate additional information, enabling users to experience various preset mixes and to make their own mixes complying with the interactivity rules imposed by the music composers with the aim of fitting their artistic creation." (Inseon et al., 2011)

Some kind of standardisation may be required for music based in interactivity to reach its potential. The standardisation of the MIDI and OSC protocols highlight the possibilities when all software can work together. Before MIDI was standardised, electronic instruments all used different protocols that didn't work together. However, before MIDI became the standard there was much development and experimentation in the field. The IM AF format is based on multi-track recordings that offer artists extended formats to realise new works that include artwork and interactive capabilities based on the current form of popular music. However, this thesis is concerned with how the form of popular music could change and a standard like this would need to grow with the needs of artists to be totally flexible in order for the diverse approaches and new forms of popular music being undertaken. Standards being developed in the gaming industry may extend the possibilities for popular music artists.

In 2007 the Interactive Audio Special Interest Group (IASIG) released the iXMF format which is used in video games. iXMF is an extension of XML. "For at least forty centuries in all cultures, music has used symbols to represent its contents and give hints for its performance, thus this standard is the continuation of this tradition with its use of human and machine-readable symbols using the XML language." (Baggi and Haus, 2007) Many authors would like to see this become the standard for all music in video games. "The goal of the IASIG in designing this format is to put artistic control into the hands of the artists, to keep programmers from having to make artistic decisions, to eliminate rework for porting to new platforms, and to reduce production time, cost and stress." (Guerraz and Lemordant, 2008)

Gruerraz and Lemordant (2008) provide an overview of standard formats for game audio and mobile gaming. They define iXMF as "a public standard structured audio file format that supports cross-platform interchange of advanced interactive audio soundtracks." (Guerraz and Lemordant, 2008)

The iXMF format consists of cue, cue request and media chunk.

1. Media Chunk is an audio or MIDI file. It can be the entire file or a defined continuous region. "The continuous soundtrack is built by stringing media chunks together, and sometimes by layering them." (Guerraz and Lemordant, 2008)

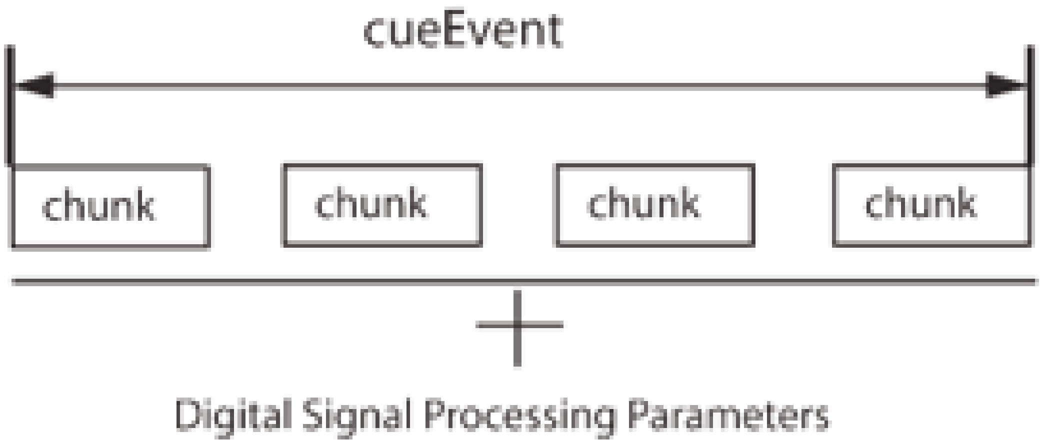
2. Cue Request "is an event that the game signals to the soundtrack manager, and to which the soundtrack manager responds with a cue which is an action designed by the audio artist at the time of authoring." (Guerraz and Lemordant, 2008)

3. - "a cue can contain any combination of services or operations that the soundtrack manager can perform." This includes actions other than audio like setting a variable, loading media etc. (Guerraz and Lemordant, 2008)

Young (2013) predicts that:

> "The day may not be far off where a composer could take a musical score's DAW multi-track session, complete with group-bussed stem mixes, individual tracks, effects inserts, automation and dozens of different audio regions, export the session into a single file in the IXMF/Interop format (or equivalent), and then open that file in any given audio middleware and have all the files , tracks, automation and meta-data transfer and open flawlessly" (Young 2013)

Figure 3.9: iXMF model reprinted from (Guerraz and Lemordant, 2008)



Traditional music production and game audio software are also showing signs of possible future integration or even convergence of their technical capabilities. This process and outcome could not only dramatically assist with standardisation formats, it could also provide a completely new set of composition and production tools for music that are based in interactive technologies.

3.3.1 Chapter Summary

This review demonstrates the types of approaches emerging in the popular music field. Many artists and the music industry still approach producing and composing recorded music for a fixed playback and expect this form to be adjusted into a non-linear or fluid playback. This may be via remixing or recontextualisation. There is a lack of understanding in how to approach a new form of popular music that will work with interactive technologies. This may be due to the complexity of how popular music can be presented within non-linear playback. There are a large number of artists and industry approaching interactive music as a way to engage audiences to buy fixed versions of their music instead of creating new experiences to sell. The industry is very much stuck in a value chain based on fixed playback forms that require charts and awards to help gain momentum and increase audiences.

These works demonstrate important new approaches in composition and production methods within a popular music context. However, there is little information available with regards to the musical process and composition techniques used in these works. Many examples involve a producer recontextualising audio by the collaborating music artist.

The following chapter presents a series of Interactive Systems and formats which can also be works in their own right.

Work	Authors	Year	Audio Systems	Playback
Little Boots Reactive Remixer	Little Boots	2009	Interactive/Reactive	Mobile App
Love	Air	2010	Interactive/Reactive	Mobile App
One Drop	Tracy Redhead	2011	Interactive	App
1000 variations	Oliver Bown/Sam Britton	2014	Autonomous	Digital Download
Locus Interactive Album Concept	Levtov,Y/Adenot,P	2015	Interactive	Web App
Fantom	Massive Attack	2016	Interactive/Contextual	Mobile App
Mmorph	Massive Music	2016	Interactive	Web App
VW & Underworld Play the Road	Underworld	2013	Reactive/Contextual	Custom
The National Mall	Bluebrain	2011	Contextual	app
Biophillia	Björk	2011	Interactive	Mobile App
Red Planet	Daisy and the Dark	2016	Interactive	Mobile App
Polyfauna	Radiohead	2013	Autonomous/Contextual	Web App
Bloom	Brian Eno/Peter Chilvers	2008	Generative/Interactive	Mobile App
Air	Brian Eno/Peter Chilvers	2009	Generative	Mobile App
Mubert	Mubert	2016	Autonomous/Algorithmic	Web/Mobile App
Magenta	Machine	2018	AI/Static	Single/Video
Daddy's Car	Benoit Carre/FLow Machines	2017	AI/Static	Single/Video
Digital Love	Kim Bo-hyung/Highteen/Machine	2018	AI/Static	Single/Video
I am AI	Taryn Southern/Machine	2018	AI/Static	Album/Video

Table 3.1: List of Works.

Chapter 4

Literature and Contextual Review: Part 2

4.1 Systems and Formats

The development of interactive, contextual, reactive, adaptive, algorithmic, generative and autonomous music forms brings the rise of new formats for playback and distribution. Static music has well established playback and distribution models which include formats like CD, Mp3, vinyl, tape and platforms like radio, streaming services and other broadcast services. This section provides an overview of important new systems within popular music. This is not an exhaustive list and is used to highlight important developments in which the music can change in some way on playback.

4.1.1 WEAV

Weav[1] is a new music format released in 2015. It consists of software for: producing tracks called the *Weav* Mixer; and a playback Software Development Kit (SDK) which can be embedded into third party apps. *Weav* "allows artists endless possibility in designing how a song should sound, feel, and respond to a listener's movements." (Weav, 2018)

The technology claims to adapt the tempo of a song between 100-240 bpm "without lessening the quality of the song." (Weav, 2018)

> "For listeners, imagine dancing to your favourite song, and keeping things down-tempo, or grooving into double (or triple) time, then effortlessly transition back and forth. It's music in the palm of your moves. Simply put? Recorded music has always been static. We're bringing it to life." (Weav, 2018)

The software was developed by *Weav* to assist in the composition and production of tracks that can adapt in tempo. Unlike the track view on a DAW, where tracks are presented horizontally, in *Weav* tracks are presented vertically as shown in figure 4.1. Stems are placed at different tempos so the composer can have a group of stems at say 80bpm, another

[1]https://www.weav.io/

Figure 4.1: Weav Production Software reprinted from (Weav, 2018)

group at 120 and another at 160. This allows a composer to visualise, record and create a work for different tempos. *Weav* time stretches stems between three different bpm values chosen by the artist. The time stretching is of high quality and doesn't affect the pitch.

The system is similar to the concept behind *Spotify Running* which was launched around the same time as *Weav*. *Spotify Running* uses mobile sensors to detect the pace of a runner and plays a song at that BPM.

Lars Rasmussen, *Weav* and google maps creator told Billboard magazine

> "*Spotify's running* app is a great example of the kind of app we think could benefit from interactive music the most. We believe that as our lives become increasingly digital, and as our increasingly powerful mobile devices play greater and greater roles in our lives, having a song that can change and adapt - in real time - to what you are doing will become increasingly important. And delightful. This is why we built *Weav*." (Pham, 2015)

4.1.2 Spotify Running

Spotify Running was a feature released as part of the Spotify mobile app in 2015. However, as of February 2018, the feature has been removed. Spotify gave no clear indication as to why it has been removed and there are many discussions in forums from users upset with its disappearance. The *Spotify Running* app could detect a user's running speed using smart phone sensors and then match a song to that bpm. Along with the app, Spotify also "introduced a new track format that allows creators to compose elastically, giving music made specifically for the purpose to adjust as a runner's pace does. " (Flanagan, 2015)

The service received mixed reviews, Mitroff, 2015 argued in a CNet article that the tempo detection function didn't work well and could not pick up a walking or power-walking tempo, and sometimes had trouble adjusting tempo. "Once the tempo was set, I encountered two new issues. First, the song selection wasn't always spot-on, leaving me with tracks that sounded slower than my pace. In the pop-focused 'Upbeat Run' playlist, I got Katy Perry's 'Wide Awake' which is around 80bpm, even though my tempo was set to twice that at 160 steps per minute. I did get some well-matched songs in the playlist, though it often went off-theme with a few unwelcome country and slower alternative tracks." (Flanagan, 2015)

Another issue she listed was that after the tempo was set, there wasn't the ability to change for warm up or cool downs, meaning fussing about with the app if you wanted to change the pace of your workout. (Mitroff, 2015)

> "These [streaming] services cannot be utilities, it's not enough. They have to be - they almost have to make music a verb - it has to just move." Jimmy Iovine, Apple via (Potts, 2017)

Spotify running had many positive features amongst the bugs and teething problems. Perhaps the feature will return bigger and better than ever. It is an interesting space to watch as Spotify and other streaming services have huge potential for playing context-based and interactive music. Streaming services may well become the most important platform for audiences realising and experiencing Dynamic Music works.

4.1.3 Ninja Jamm

Ninja Jamm app was released in 2012 and had reached 400,000 downloads at the beginning of 2017. *Ninja Jamm* was produced by Coldcut in collaboration with Seeper and is a music making and remix app available for Android and iOS. It was inspired by My Little Funkit and Playtime which were available on Coldcut's CD-ROMS, which offered unique interactivity at the time. My Little Funkit and Playtime are said to be the prototypes for *Ninja Jamm*, which was "designed and launched 16 years later." (Wikipedia, 2018)

The app is aimed at fans of artists released through the Ninja Tune label like Coldcut, Bonobo and Starkey, as well as Djs and music producers. The app allows the user to remix over 40 artists' tracks. It is free to download and comes with a variety of free tune packs. More tune packs are available for download for a fee and consist of specific artists and track audio loops.

> "These tunepacks are tracks broken apart into a 4x8 matrix of clips, 8 each for drums, bass, and two more (melody, keys, vox, FX) depending on the tune. Most clips come from the original tunes, but some extras have been added to round out the bill. Users can turn instruments on and off, swap between clips, glitch them out, add effects like reverb and crush in a number of different ways, trigger the 'Coldcutter' for beat-repeat action, trigger and pitch-bend stabs and one-off

> samples, and even change the tempo of the track. 'Jammers' can record what they're doing as they mix and instantly upload the whole thing to SoundCloud when they're done." (CDM, 2013)

Figure 4.2: Screen shot from iphone - Ninja Jamm

Ninja Jamm was developed in Pd and uses custom build Pd patches like Coldcutter to synthesize the music. LibPd was then used to integrate Pd into an app. This is an innovative app due to the custom built DSP functionality developed to create unique remixing tools. It is hard to gauge the success of the *Ninja Jamm* app like all examples discussed in this chapter. This is another example of how labels are innovating when it comes to their release strategies and products.

4.1.4 Yellofier

Yellofier was released in the app store in 2013. The app was developed by Hakan Lidbo and Boris Blank from the band Yello.

Users can record sounds and turn them into music. Each recording is represented as a cut-up sound wave (see figure 4.3), with each individual sound being attributed to a coloured block. These blocks can be used within a 16-block matrix to create a loop. Effects and volume changes can be made easily (figure 4.4). Each loop block then becomes part of an overall track structure (figure 4.5).

> "The *Yellofier* transforms any sounds into funky music in literary one second. The app can be used as a professional production tool or as an amusing toy. The app had 100,000 downloads within four weeks after the release on AppStore and has been no#1 music app (iPad) in eight countries and was App Of The week at the Game Developers Conference." (Lidbo, 2018)

Figure 4.3: Screen shot from iPhone - Yellofier

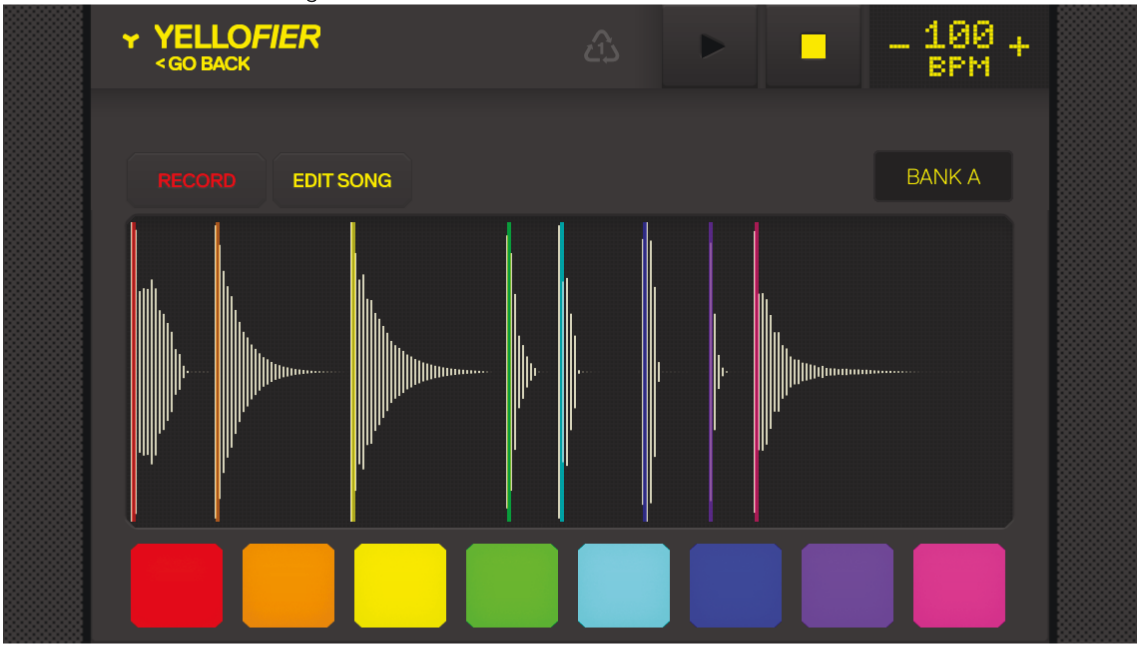
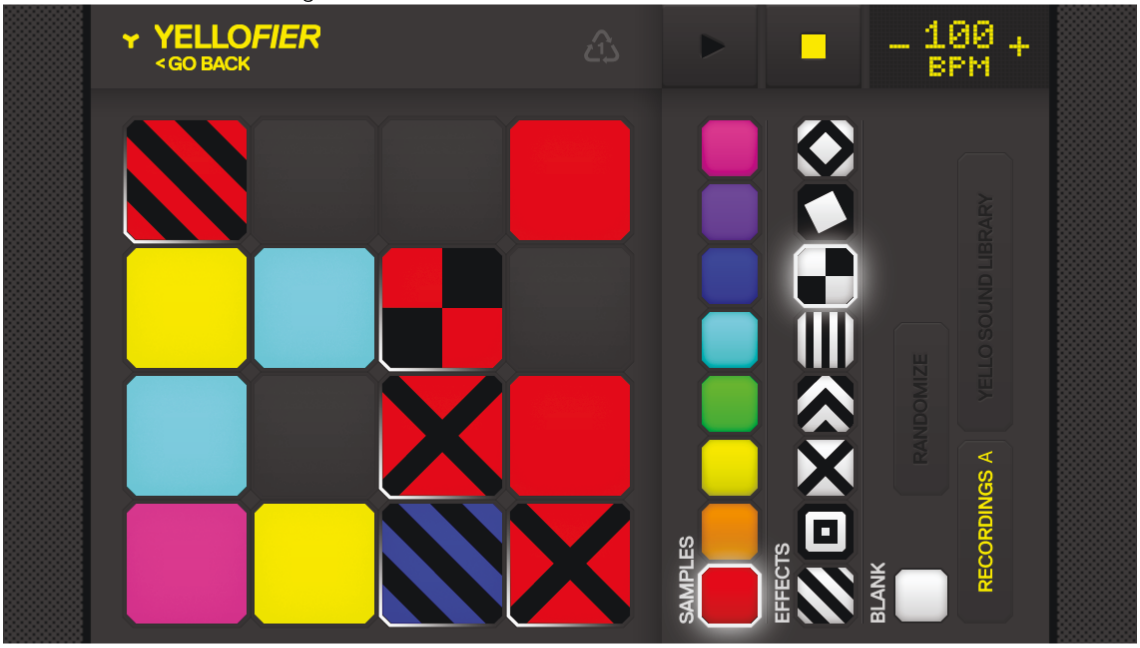


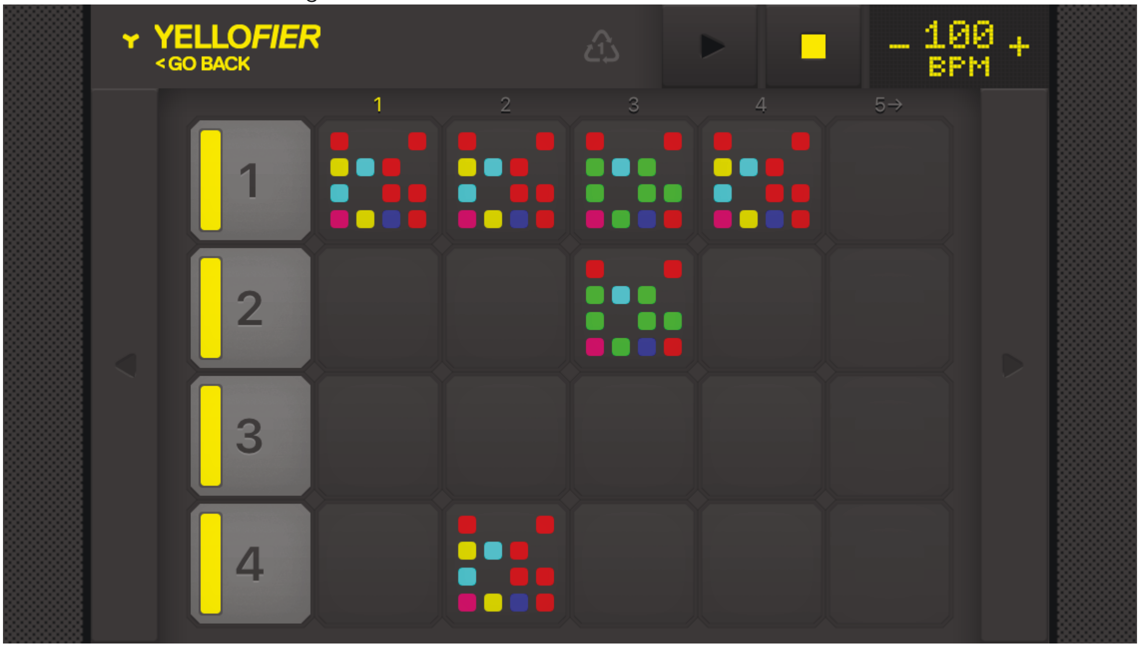
Figure 4.4: Screen shot from iPhone - Yellofier



Yellofier was produced in collaboration with T-mobile/Electronic Beats Media with sound and song contributions by artists including Carl Craig, The Orb, Trentemoller, Booka Shade, Henrik Schwarz, Steve Bug, Orbital, The The, Charles Webster and Thomas Fehlmann. "All songs can easily be re-arranged by the Yellofier user." (Lidbo, 2018)

This is another example of a system build for novel and new ways of experiencing and playing with sound and music.

Figure 4.5: Screen shot from iPhone - Yellofier



4.1.5 Horizons VR

Horizons VR was released in 2017. It uses Daydream, Google's VR platform, to create "interactive musical journeys" (Reactify, 2016)

Audio-visual experiences are utilised to create unique scenes where users can explore and interact in virtual reality. The three scenes in the app include

1. *Outlier* including music from Bonobo
2. *Reach* including the music of Reuben Cainer, and
3. *Empyrean* including music from My Panda Shall Fly.

> "*Outlier* sees you flying through surreal landscapes and terrains, over mountains and deep into oceans, as you manipulate the music by directing flocks of birds with the Daydream controller and progressing through the various stages of the track via your own movements and actions. *Reach* has you tilting and touching the Daydream controller to add sonic and visual effects, and constantly building tension in the music to progress the track to the next section, whereas *Empyrean* is more relaxing and explorative, guiding you to slowly illuminate a psychedelic forest with musical phrases." (Reactify, 2016)

The project is aimed at VR and music fans. It uses Unity as its core system and utilises a VR handset and vision interactions. It is available from the Google Play store as well as a brower-based experience. It contains no premium content. Horizons is the platform and the artists' tracks are played on that platform. "Unlike most other music VR experiences out at the moment, every scene in Horizons has been imagined with musical interaction as a core principle", says Horizons Studio co-founder Yuli Levtov in a statement.

> "Much like a music video director creates a visual story that fits the music, we create layers of interactivity that allow people to make their own path through the music. The track becomes more like an explorable playground that you actively engage with, rather than something with a set length that you're just watching." (Graham, 2017)

4.1.6 NI STEM

In 2015, Native Instruments (NI) released a new format called *Stems* aimed at offering DJ's new, innovative ways to mix music. The *Stems* format usually consist of four stems: drums; bass; vocals; and percussion/synths. *Stems* can be played using Native Instrument's *Traktor Pro 2*, which provides a controller for each stem track. The volume and effects can be controlled separately. (NI, 2018) Many major dance labels are releasing stem formats of their artists as well as MP3 versions.

> "Stems allows DJs and producers to make instant edits, remixes, and more, by separating the elements of a track to play with live. Imagine being able to split each stem of a track, when vocals, drums, melody, and bass line all become tangible elements to experiment with more freely". (Leonard, 2016)

As outlined in section 2.1.7, this concept came about in the mid 2000s, when popular music artists began to release stems. Remix competitions using stems from artists were also popular. (Redhead, 2015a)

> "Yet whereas in the past, only someone with a studio could alter recorded music ... with digitally recorded music and with inexpensive software or even free internet websites, it is now possible for music fans to remake and remix someone else's music" (Taylor, 2001)

Since the release of the NI *Stems* format there has been a slow but steady growth and adoption of the product. (Capelluto, 2017) Still in its evolving stages, the Stem format's success will depend on the up take of both artists producing tracks as well as the DJs embracing them. At the moment there is a lack of tracks, only around 10,000 are available (Capelluto, 2017). For the format to evolve, more content from a wide range of genres and artists needs to be created. "At the moment there's only about 10-20 tracks in the stems format available that I'd conceivably want to play." (McQuaid, 2015) Capelluto highlights the need for the format to be integrated into other software and DJ hardware. "Look at how quickly the *Ableton Link* technology was adopted and integrated in *Serato*, *Traktor*, and others - why not the same with Stems?" (Capelluto, 2017). Another drawback mentioned by McQuaid, is that not all tracks work well when they are stripped down to four stems. This final point highlights a gap of knowledge for Dynamic Music production. Music being produced for the Stem format is still being produced for a fixed form as MP3's are remixed into the Stem format. There is a lack of information about how to produce music that works well in this format. The mindset of music produced for a fixed format remains primary even though the Stem format is a form of Dynamic Music.

The *Stem's* website offers tutorials on creating stems and mastering techniques and also offers the *Stem Creator* software. The MP4 can be played back as a stereo file on any media player. To access the four separate stems, you need to use Stem compatible software which currently is only available via Native Instruments software and hardware. Interestingly, NI have teamed up with LANDR, an algorithmic master service software that can digitally master tracks uploaded via their website. The service now masters the Stems format which will make it easier for artists to produce music for this format. This shows promise, as mastering Dynamic Music is a great challenge conceptually for many engineers. There is a lack of academic literature on the mixing and mastering techniques for Dynamic Music production.

The Stem format is generally more expensive to purchase than an MP3. "If I'm an artist and I normally sell a song on Beatport for 99 cents, I could sell a Stems version of my track for, say, $5 because it lets people do more with my music." (Ramley, 2015) The NI website states "music in Stem format can be sold for a premium price, encouraging new income and increased label exposure." (NI, 2018) Currently the format is available for sale at online stores including Beatport, Juno, Traxsource, whatpeopleplay and Wasabeat.

4.1.7 Bronze Format

The *Bronze* format utilises AI based algorithms, which use stems to generate infinite versions of a song. It requires no external data so it is an autonomous system. This results in a song with endless ways of being heard. The song changes based on an algorithm so doesn't require any contextual or interactive data from its listener. The *Bronze* format was a collaboration between Gwilym Gold, producer Lexxx and Dr Mick Grierson at Goldsmiths University. Gold describes *Bronze* as "a new format for recorded music, in which the recorded material is transfigured to produce a unique version on each listening." (Snapes, 2011) The first work released was 'Flesh Freeze' by Gwilym Gold in 2011.

> "The software is intelligent and will learn from itself, figuring out the most interesting, satisfying path through the waves. Essentially it performs for you, and according to Gwilym, the chances of winning the lottery versus the chances of hearing the same version of the song twice don't even compare." (Snapes, 2011)

In his blog from Goldsmiths University, Prof. Mick Grierson explains, "it's not really similar to generative music approaches that have been tried before by the likes of Brian Eno, and other computer music researchers. Instead, it's been designed as a commercial music format, and so can't be a software program that creates random mixes of songs - it's not at all random, as this isn't really what the musicians and producers we work with want." (Grierson, 2012)

"It's aimed at producers and composers who want to make any kind of music, including very organised, highly structured music, that is at a professional level equal to that which you can achieve with professional authoring tools, but that is capable of being different each time, whilst still sounding like the same track - retaining the quality and balance of the original mixes, and the words/music in all the right places." (Grierson, 2012)

In an interview on Audio News Room, Grierson stated that the *Bronze* format "is basically a new way of both making and playing back music that allows the finished piece not to have to exist in a 'static' form. It puts the music into a constant state of regeneration." (Fab, 2016)

In 2016 the *Bronze* format was utilised by Sigur Ros for a 24-hour live streaming event on Youtube called 'Route One'. The song 'Oveour' was integrated into *Bronze* to produce an evolving song as the band drove "a 1332km journey the whole way round Iceland's coastal ring road." (Fab, 2016)

Grierson is currently working on a new research project MIMIC: Musically Intelligent Machines Interacting Creatively, funded by the AHRC. By utilising AI and machine learning technology the project will "develop and disseminate creative systems that can be used by musicians and artists in the creation of entirely new music and sound." (NA, 2018)

The calibre of popular music artists using this software and the current research project highlight that popular music artists are interested in creating new works that are not fixed in their playback. *Bronze* is a good example of how a popular music work can be amorphous and still produce something in which artists have control over the quality of their work.

4.1.8 Nagual Sense

Nagual Sense[2] is a mobile app that lets its user compose music by dancing with a mobile phone. The app utilises data produced via the user's movement around the X, Y, Z axis and by shaking their mobile phone, via the phone gyroscope and accelerometer sensors. Rotating the X axis of the phone controls the lead instrument; the y axis controls the chords or harmony; and the Z axis controls the bass. Finally, by shaking the phone, the user can control the percussion.

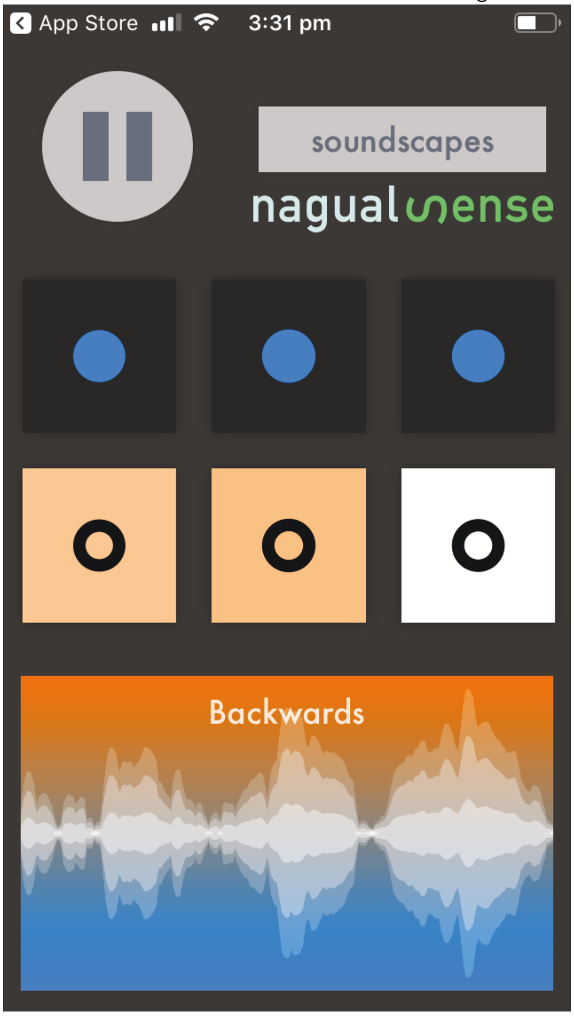
Mark Moebius, developer of *Nagual Sense*, is exploring methods for interactive composition. The website of the app states that they have developed a compositional interface which is designed to assist composers and producers with the organisation and mapping of their loops and stems, based on the control data being received from a mobile phone.

The app is similar to Ninja Jamm in the sense that it has tried to monetise itself. There are music packs that are available for in-app purchase with a couple of tracks free to access. Their music for purchase is not by any specific artist. This could be of some benefit for the app's success in the future. The music interaction is playful and fun and could create a desire for users to explore more tracks.

> "We have developed a totally unique method to convert data streams in real-time into tonal music! Just like a jazz pianist uses scales and chords for the interpretation of an existing song, a computer can do the same using the appropriate software. Through the software engine developed by us, input data can be used as a tool to personalize pieces of music, in order to create individual interpretations of a piece of music in real time. Through this technology, music is vividly and intuitively controllable. This method can be used with all available

[2]https://www.nagualsense.com/

Figure 4.6: Screen shot from iPhone - Nagual Sense



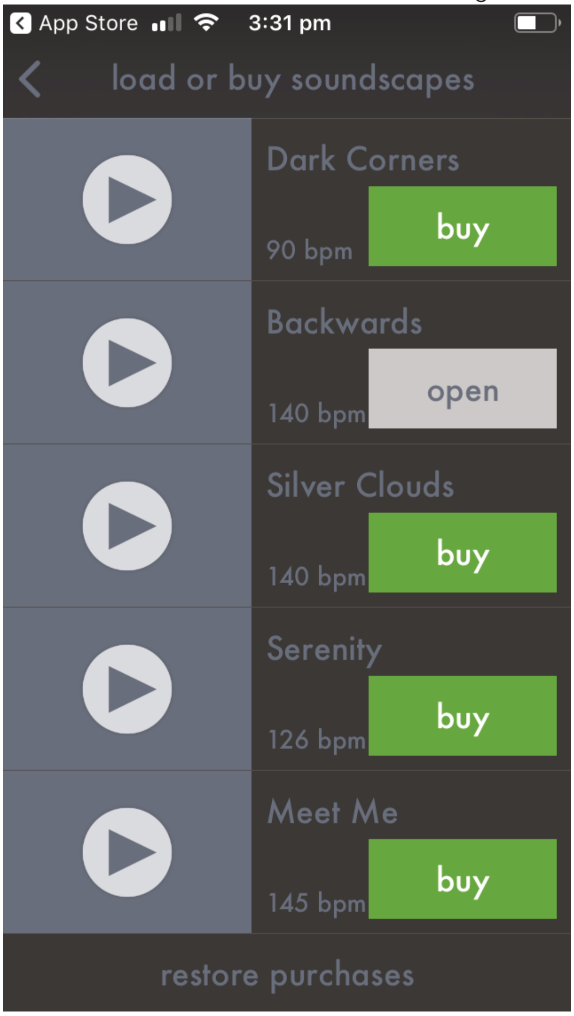
> kinds of sensor data, and since we are in constant contact with sensors, this technology has a great number of applications." (Nagual Sounds, 2018)

Before developing the app the creators first developed a similar product based on dance, using kinect and 3D Cameras.

> "The first commercial product we are developing using this new technology is an entertainment software called *Nagual Dance*, which translates body movement captured by a 3D camera into music - in real time! *Nagual Dance* assigns specific sound elements or instruments to the arms and legs. The user can combine these sounds in endless variations, and what they create from this is totally up to them. This software offers the user the ability to create individual and unique music pieces just from their movement." (Nagual Sounds, 2018)

In a way this app could be seen as an instrument where musicians have the ability to adapt their music and integrate it within the system.

Figure 4.7: Screen shot from iPhone - Nagual Sense



4.1.9 Summary of Systems and Formats

The overview of these systems developed for popular music since 2011 highlights a growing trend in digital music production and distribution. Unfortunately, it is hard to gauge the success of these systems and formats. As discussed, there is huge potential in the future for music streaming services to begin to integrate new types of music experiences. As discussed in Section 1.1, Wikstrom (2012) predicts the next phase of music will be context-based music. (Wikström, 2012)

As production software and tools develop with;

1. new machine and deep learning capabilities
2. more flexible music making capabilities, like the vertical tracking in the WEAV system
3. the integration of audio middleware and DAW software

there will be a growing demand for music players and playback systems to playback music in ever-changing, reactive or interactive designs. There may also be new business opportunities to produce some kind of broadcast systems that allow audiences to experience these new works.

Throughout this review there is a clear gap between methods and knowledge of how to produce and compose music that can change and adapt with data or algorithms. Music being produced for the NI *Stems* format still appears to be produced for a static Mp3. Whereas producing music for the *Weav* system requires new approaches. *Ninja Jamm* also require artists to create loops from their recording and recontextualise the music to work for the system or create a new work of loops. Composing for the *Bronze* format also challenges traditional forms of producing and composing and utilises a team of computer scientists and producers to work with artists. *Nagual Sense* is production software that creates interactive compositions in support of its system. All these new systems require new skills and approaches in popular music making. Producing music that can be experienced in many variables is complex in design and production. It also requires the development of an interactive system, which is outlined in the next section.

System	Audio System	Year	Audio Source	Playback
WEAV	Contextual	2015	Stems	Mobile App and Audio software
Spotify Running	Contextual	2015	Audio Tracks	Mobile App
Ninja Jamm	Interactive	2012	Loops	Mobile and Tablet App
Yellofier	Interactive	2013	loops and new recordings	Mobile and tablet App
Horizons VR	Interactive	2017	Loops and Stems	VR System
NI STEMs Format	interactive	2015	Stems	Mp3 multi-track
Bronze Format	Autonomous	2011	stems	bronze format via iTunes
Nagaul Sense	Interactive	2016	loops	Mobile App

Table 4.1: List of Systems.

4.2 Interactive Systems

> "The key aspect of audio is that when it is digitized it can be manipulated. To do this one needs to stop regarding audio as sound and see it for what it really is: data that can be manipulated." (Pfeiffer and Green, 2015)

Interactive technologies are vastly different except for the fact that they all produce data or a control input. This data can be mapped onto some kind of audio or sound synthesis parameter. Data could be produced from a variety of sources and interactions including but not limited to;

- Gestures and dancing
- Mobile phone data from accelerometers or geo-location
- Body data from one's heartbeat or jogging tempo
- Social media interaction
- Camera or video
- Visual interactions within virtual reality

- Body sensors
- Mouse events
- Touch screen
- Autonomous systems
- Data sets - for example scientific data including weather, satellite, biological, space etc
- Emotions like excitement or concentration via a brain interface

All of these types of technologies require the manipulation of data to control a set of mapped parameters. A music system is developed to map this data and transform the music. Hence, data mapping becomes central to popular music making or, more precisely, the song writing and production process.

The mapping of data, the development of the system and approaches to production and composition present a big challenge to popular music makers. Complex data analysis produced by interactive technologies needs to be classified and analysed based on users' interactions or contexts before the music mapping design can be achieved. New developments in machine learning software like *Wekinator*, AI technology, *Gesture Follower*, custom APIs, as well *libPd* and *Heavy* for Pd integration, give artists new approaches for dealing with and classifying complex data sets.

Based on these new technologies, works continue to be released and prototyped by popular music artists utilising mobile apps, virtual reality (VR), augmented reality (AR), 360 videos and wearables like brain interface controllers and gesture-based products. However, as Holland et al (2013) explain, developing interactive music products involves the expertise of musicians, interaction designers and researchers and that these individual collaborators often play more than one role. (Holland et al., 2013a) The Interactive Audio Special Interest Group (IASIG) [3] also discusses the requirements of developing interactive audio, "the creation and delivery of Interactive Audio involves specialized skills and tools, and the close cooperation of composers, musicians, sound designers, programmers, educators, and software/hardware developers." (IASIG, 2018) Many artworks or products outside of the gaming industry utilising interactive data must also develop an interactive software system (Drummond, 2009a) which requires the expertise of a programmer or computer scientist. There are many approaches and techniques to consider when designing a system created to map data to a musical output.

Bajakian, Battino et al (2003) define Interactive Audio as "sound produced by an Interactive Audio System" (Bajakian et al., 2003) defining an Interactive Audio System as an "audio system that is designed to have its pre-determined sonic behaviour influenced in response to real-time events, and is comprised of an Interactive Audio Engine and Interactive Audio Data." (Bajakian et al., 2003) They describe interactive data as, "data that may

[3] "The IASIG is an organization that brings together experts to share their knowledge and help improve the state of the art in audio for games, websites, VR content, and other interactive performances." (IASIG, 2018)

include parameters and/or instructions interpreted by the interactive audio engine to control audio behaviour. All types of audio, including music, dialog, and sound effects, can be classified as interactive audio data." (Bajakian et al., 2003) An Interactive Engine is "a set of software and/or hardware algorithms that process interactive data based on the input stimuli to render a unique audio output." (Bajakian et al., 2003)

IASIG defines Interactive Audio "as audio for interactive media such as video games, AR/VR environments, and websites... anywhere the audio changes according to listener input. The term 'interactive' is used to distinguish it from 'linear' forms of audio (such as in films and in cut scenes in games) where the audio is decided in advance and always is the same no matter who is listening. (IASIG, 2018)

Bajakian, Battino et al (2003) discuss direct and indirect categories of input stimuli or data within an interactive audio system. "In the direct case, the user is consciously controlling the audio; in the indirect case, the user is controlling some other parameter that in turn affects the audio." (Bajakian et al., 2003) Not all systems that respond to input stimuli can be defined as interactive audio systems. An interactive system allows changes in input behaviour to modify the audio behaviour, whereas a reactive system simply plays back static audio events without any adaptation to the user stimulus." (Bajakian et al., 2003) This highlights another confusion of terms, contextual music which incorporates locational music is similar to the game audio definition of adaptive music or Bajakian, Battino et al's 2003 definition of reactive music.

Bauer and Waldner (2013) define reactive music as non-linear music which reacts to the listener and/or their environment in real-time. "Instead of distributing linear sound files to the listener, reactive music is software that uses input data and transforms it into audible formats for the listener. This mechanism allows the generated music to adapt to the listener and her or his environment by using, for instance, the built-in sensors (e.g. camera, microphone, accelerometer) of mobile devices." (Bauer and Waldner, 2013) They provide examples of what they define as "adaptive music players" that "select predefined linear songs from a database based on the user's behaviour (e.g. pace) and/or adjusts the bpm (as far as technically possible such that the song is still okay to listen to). Instead, reactive music is generated in real-time." They cite Andie Nordgren, who defines reactive music in context with the RjDj player "RjDj is a player for reactive music that lets you be a reality jockey - influencing and creating sound in collaboration with pre-written audio scenes that react to the environment in different ways." (Barnard et al., 2009)

There are many examples of location-based apps, context-based apps and reactive apps. It seems they all utilise the user's contextual information to influence the music experience, however there is increasing confusion as to the terminology. Levtov (2018), who is an innovator of reactive music, describes the three types of algorithmic music for mass distribution as generative, reactive and interactive. (Levtov, 2018)

Plans (2017) writes about procedural music. "Procedural Music encompasses a body of music(s) that are composed through algorithmic processes, rather than through the conventional, manual methods of score-composed music. These music(s) evolve through processes that can be either predetermined rules of themselves evolving (through functions that generate rules)." (Plans, 2017) Collins defines procedural music as a "composition that evolves in real-time according to a specific set of rules or control logics." This is different to adaptive music as adaptive music is cued by context and the actions of the player in a video game. (Collins, 2009)

Demand for music influenced by data is developing across all areas of music. As highlighted throughout Chapters 3 and 4, this might involve data produced in real-time, some kind of interactive control data or even an autonomous algorithm, machine based in AI or a set of data. All of these types of music works are being created and released at a professional standard.

Given the confusion across music fields as well as artists' description of terms used to describe music based on data and interactive technologies, a generalised term could help provide some clarity. This is not to say that any term discussed is not correct, however it can be a confusing area moving forward.

Instead of keeping to terminology used across fields, this thesis investigates the entirety of fields representing music produced by data and suggests the term Dynamic Music to describe music that changes or is influenced by data. In 2008 Collins refers to an emerging field called Dynamic Music within the game audio field: "Dynamic Music is becoming more of a requirement for games as production values increase and players tire of the typical looping playback model of older games' music. Looping is generally frowned upon as an ineffective way of using music in games" (Collins, 2008b) In the digital domain this demand has been bought about by developments in computing, videogames and the internet as highlighted so far in this thesis. It would appear that technology has created ways for digital music to be more flexible. It is also able to realise organic interactions within music in the realm of recorded music, which traditionally has been associated with fixed playback. (Tanaka, 2006)

4.3 Summary

Given the established mindset that popular music making operates in a fixed format while at the same time popular music is inextricably dependent on new technologies, **this thesis believes there is a gap emerging between state-of-the-art interactive technologies and current popular music making.**

There is also quite a confusion of terms with works being described as interactive, reactive, contextual, location-based, generative, algorithmic, responsive, dynamic and more. It may help if these terms were defined across all music fields.

Throughout these two Chapters it can be shown that music is changing along with the tools used to produce it. The current forms of popular music making will not only hold back innovation but risk becoming dated. Song-writing and production processes need to adapt to Dynamic Music forms for popular music to realise its potential for embracing interactive technologies and beyond. As artists' tools continue to develop standard approaches to Dynamic Music production, artists will have endless opportunity to explore new music forms. The review of works and discussions unpack the complexities of developing music systems, integrating these music systems into interactive systems, the mapping of data, and composing in a dynamic setting.

To restate the research question from Chapter 1 this thesis asks, how can interactive technologies be used to develop new forms of popular music?

Chapter 5

Methodology Part 1: Towards an Aesthetic of Dynamic Music

> "It should be evident that the medieval attitude toward music differed considerably from ours. Neither theorists, composers, nor performers regarded a piece of music as fixed and unchangeable, something to be preserved and always presented in exactly the form given it by its first creator." (Hoppin, 1978)

5.1 Introduction

Although the above quote highlights the perception of music in medieval times it is still relevant today at a time when game music and interactivity are prominent. New technologies provide opportunities to create recorded music which can be as dynamic and changeable as live performance and improvisation.

Chapters 3 and 4 provided an overview of the diverse approaches to composition, sound design, system and software development, programming, interaction design and playback options. These approaches highlight the complexities involved in creating popular music products utilising interactive technologies. At the conclusion of Chapter 4, the term Dynamic Music was introduced to embrace the complexities of music that adapts, responds and interacts with data. Informed by Chapters 3 and 4, the methodology combines practice-based research with inductive techniques used in grounded theory. This involves the development and testing of a framework for Dynamic Music that has been informed by existing perspectives on Dynamic Music and the development of criteria for evaluation applied to my creative work. The methodological framework is presented in Chapters 5, 6 and 7 with Chapter 8 functioning as a proof of concept.

Chapter 5 discusses form, structure, process and time in Dynamic Music and provides definitions in the field of Dynamic Music. Chapter 6 provides an overview of the components of music design in Dynamic Music. Chapter 7 introduces a set of criteria to evaluate the key concepts and approaches of Dynamic Music. Chapter 8 demonstrates the robustness of the framework with discussion, analyses and evaluations of a portfolio of Dynamic Music compositions using the criteria developed in Chapter 7.

The evaluative framework and its epistemology discussed in Chapters 5, 6 and 7 propose new approaches to forms in popular music fusing interactive technologies. Chapter 1 argues that the form of popular music needs to evolve to work with interactive technologies. Given the range of approaches and technologies currently being used and experimented within the field (as outlined in Chapters 3 and 4), this thesis uses the term Dynamic Music as an overarching term. The term Dynamic Music describes the different composition and system approaches of all music that changes with data.

While Dynamic Music is an emerging industry term (Collins, 2008b; Thalmann et al., 2016) used by composers working in interactive composition and game music, Chapters 5, 6 and 7 extend current understandings of the term to embrace a wider context by encompassing all forms of music that react, adapt and respond to input or control data. This includes music which is adaptive, interactive, autonomous, algorithmic, reactive, responsive, generative, procedural and contextual. The purpose of Chapter 7's purpose is to show how the concepts in Chapters 5 and 6 can be used and referred to by the industry so that vagaries and contradictions are avoided. This emerging term and field provide a solution to the problem discussed in Chapter 1 regarding popular music and new music technologies.

5.2 Dynamic Music

Dynamic Music is an overarching term that describes all forms of music which react, adapt and respond to data; whether it be input, control or autonomous data. Given music is and always has been dynamic when performed, the thesis uses the term Dynamic Music within the context of recorded and digitised music associated with a software system. Dynamic Music can be understood as one branch of popular music. Collins defines "dynamic audio as audio that is changeable". (Collins, 2008b) Thalmann et al describe a Dynamic Music Object (DYMO) as:

> "an amalgamation of audio files, structural and analytical information extracted from the audio, and information about how it should be rendered in realtime... We think of Dynamic Music Objects as Digital Music Objects aimed at consumers and intermediary music professionals. In contrast to the broader Digital Music Objects, they are designed to be flexible and modifiable within degrees of freedom and constraints that are given by the producers and composers. They are meant to be played back directly based on this information, rather than remixed or reused in a more general sense. Within these constraints, DYMOs typically sound different every time they are listened to." (Thalmann et al., 2016)

Kaae defines Dynamic Music as "music which is in some way able to react to game-play, and or is in some way composed or put together in real time by the computer." (Kaae, 2008) This all-encompassing term simply describes all types of music which are changed or influenced by data. This term unites music from all fields including: game audio; interactive art; computer music; and generative music. Control/Input data (or for that matter any type of data) is used to transform the form, structure, organisation of sound and music material, creation of sound and music material and/or the overall mix of the work. This data hence becomes central to the composition and/or production of the work.

In a game audio context, Dynamic Music has been defined as "a broad concept that encompasses both interactive and adaptive audio. It is audio that reacts both to changes in the gameplay environment and/or in response to the player." (Collins, 2008a) Renowned game composer of the Super Mario series, Koji Kondo's four components of composing Dynamic Music are highlight by Collins (2008a)

1. the ability to create music that changes with each play-through;
2. the ability to create a multi-coloured production by transforming themes in the same composition;
3. the ability to add new surprises and increase game-play enjoyment; and
4. the ability to add musical elements as game-play features." (Kondo, 2007)

In order to extend the term Dynamic Music to include all fields of music the four components outlined above by Kondo require significant broadening. And, in order to extend the term Dynamic Music as an all-encompassing musical term, many of the correlations between music and with the interactive technologies referred to in Chapters 3 and 4 need to be further discussed. This is due to the confusion of terms as highlighted in Chapter 4.

The terms interactive, reactive, generative, algorithmic and contextual have all been used in a popular music context without no clear and finite definitions. The music industry uses buzz words like interactive and dynamic in the marketing of music products and when referring to streaming services like Spotify or Youtube. However, the music itself is not interactive or dynamic. For example, an artist may release an interactive app which doesn't include any type of Dynamic Music. Another example could be the term 'dynamic album', which was used by IFPI (2016) to describe an album whereby new tracks are introduced over a time span such as a new track every week, yet the music itself is still presented in a fixed format. (IFPI, 2016)

Toulson et al. (2016) define interactive music within a popular music context "as music in which it is the user's intention to change the nature of the audio, whereas variation in Dynamic Music is primarily a function of some other variable or state, for instance user-engagement with a video game."(Toulson et al., 2016) In contrast, Collins defines the term dynamic audio as a category of music encompassing both adaptive audio and interactive audio in the video game music field. (Collins, 2008a) She defines interactive audio as a direct action by the player which produces sound or music, giving the example of a player swinging a sword on screen, with the sword makes a 'swooshing' noise. If the player presses the button again the sound will reoccur. She defines adaptive music as music that adapts to the player's environment, for example the music may be a steady tempo in a game, then as the time begins to run out the tempo speeds up. (Collins, 2007) Here, both definitions for interactive music are similar: interactive music involves a direct action from the user/listener.

Chapters 3 and 4 accentuate the different terms artists and scholars use to describe their work. It is for this reason the term Dynamic Music is used as an attempt to simplify and unite the field. Dynamic Music is music that can change and adapt to data. Dynamic Music creates an experience beyond a static form for its listeners. It involves a direct or indirect action made by a human or machine interaction. There are similarities in how data effects the form, process, structure and experience of the music. Given all these works react to data in some way; a united approach gives all fields of music a foundation to build upon. Key terms based on the form, structure, process and time of Dynamic Music are defined below so that a robust methodology can be developed.

5.3 Form, Structure, Process and Time in Dynamic Music

5.3.1 Form

Form in music is a complex area which can be understood in different ways with relation to the musical material, genre, style and era. Form can be defined as the perceived relationship between events in time. It is beyond the scope of this thesis to discuss the history of musical form and its relationship to structure and style. The following brief discussion provides an overview to help set the context for a discussion of Dynamic Music as a form.

Many understandings of form in western music centre around the relationship between form and structure. One approach to form has been understood as a pre-defined shape within which music is composed to fit, like a mould. Fixed forms have been used as a tool to emulate composers by providing a template per say of the movements and themes within a work. For example, the sonata form was defined by Adolph Bernhard Marx (1795-1866) in 1845 after many years devoted to the theorist's analyses of the works of Mozart, Beethoven and Hayden. The sonata form as a theoretical construct did not exist when the compositions were originally composed. Marx observed that the practices of composers at that time adopted particular strategies to generate their musical forms. (Christensen, 2006)

In music from the classical era, form is partitioned into sections and defined by the movement of key areas with a tonal framework. Similarly, popular music forms are mostly segmental and generally utilise static structures including strophic, 12 bar blues and forms using combinations of verse, chorus and bridge. With the gradual breakdown of tonality in 19th century western art music and the ever-increasing use of chromaticism to the point of harmonic ambiguity, approaches to form in the late Romantic period became less partitioned. In reaction to this ambiguity, some composers such as Brahms used neoclassical forms to generate large-scale works. Schoenberg, despite his use of neoclassical forms in his twelve-tone system, saw form as evolutionary: "Form means that a piece is organised; i.e. that it consists of elements functioning like those of a living organism" (Schoenberg et al., 1967)

This organic approach to form combined with the removal of tonality as a defining force for organisation laid the foundations for much 20th century western art music in which a form became unique to each work. Picking up from Schoenberg's twelve-tone method and post WW2 serialism, the many musical forms adopted by mid-20th century experimental, avant-garde and computer music works were the result of a process generated by algorithms, procedures, chance, directions or randomness.

5.3.2 Form and structure

With respect to popular music forms, the above very brief discussion on form in western art music and its relationship to tonality remains relevant. Popular music generally utilises common forms based on tonal or modal harmonic organisation linked to sectional organisation such as verse, bridge and chorus combinations, strophic sequences or the 12-bar blues. They are the opposite to Schoenberg's organic conception of form. These enclosed, static forms present a challenge when composing Dynamic Music. In order to address this challenge and its relevance to Dynamic Music composition and at the same time deal with the conundrum of defining musical form, the ideas of three composers are discussed. They are Edgard Varèse (1883 - 1965), James Tenney (1934 - 2006) and Curtis Roads (born 1951). Of particular note is their views on the relationship between form and structure.

Every event has a structure. The event can be a texture, melodic line, rhythmic pattern, sound envelope, or sonic object. Depending on the type of music, form and structure are either the same or are complementary. In either case they coexist. A discussion on structure will depend on the parameter under investigation and its relation to the form. Structure tells us how the parts are put together. For example: in order to discuss a texture, one has to talk about the texture's structure (multi-layered, melody & accompaniment, sound mass, etc).

> "Classical music, like classical architecture, like many other classical forms, specifies an entity in advance and then builds it. Generative music doesn't do that, it specifies a set of rules and then lets them make the thing." (Eno, 1996)

Eno's quote highlights new approaches in music form, which are entirely reliant on structure. With the classical, early romantic eras and with many popular songs, form and structure are not always inextricably combined, Varèse, Tenney and Roads have revitalised the discussion as to whether form is defined by or is dependent on structure. Early parallels to this approach can be seen in the Baroque fugue or the medieval palindromic form.

For Varèse, form is the result of a process. Process is essentially the way the music is generated.

> "The misunderstanding has come from thinking of form as a point of departure, a pattern to be followed, a mould to be filled. Form is a result - the result of a process. Each of my works discovers its own form." (Varèse, 1967)

Varèse (1967) provides an analogy of the crystal form to describe his understanding of music form, which is worth citing in full.

> "Conceiving musical form as a resultant - the result of a process - I was struck by what seemed to me an analogy between the formation of my compositions

> and the phenomenon of crystallization... The crystal is characterized by both a definite external form and a definite internal structure. The internal structure is based on the unit of crystal which is the smallest grouping of the atoms that has the order and the composition of the substance. The extension of the unit into space forms the whole crystal. But in spite of the relatively limited variety of internal structures, the external forms of crystals are limitless... Crystal form itself is a resultant [the very word I have always used in reference to musical form] rather than a primary attribute. Crystal form is the consequence of the interaction of attractive and repulsive forces and the ordered packing of the atom.
>
> This, I believe, suggests, better than any explanation I could give, the way my works are formed. There is an idea, the basis of an internal structure, expanded and split into different shapes or groups of sound constantly changing in shape, direction, and speed, attracted and repulsed by various forces. The form of the work is the consequence of this interaction."(Varèse, 1967)

The resulting process involves the organisation of sounds and parts in time and space. Similar to Schoenberg's evolutionary form, Varèse uses these definitions of form to describe their process within non-tonal music and music based on rhythm or timbre.

James Tenney's work on form specifically Meta/Hodos 1961 and Hodos and META meta, 1977 uses the term temporal gestalt to describe the hierarchical levels within music and their relationships between lower and higher levels or micro and macro. (Tenney et al., 1977) This definition of form is a gestalt definition dealing with all attributes contributing to the whole as it refers to structure.

The theories of Varèse and Tenney lay the foundations for a definition of a music form that is applicable to Dynamic Music. **This thesis defines form in Dynamic Music as the organisation/generation of a musical composition and its relationship to time.**

The form is a resultant of a music work that can include;

- Fixed forms - sonata form, ternary, binary, strophic, etc.
- Process - the way in which a work is generated, the compositional process.
- Gestalt - Form as a totality made up of components.
- Open form - the placement of components/units are not fixed, do not observe a fixed order, and can have unlimited possibilities.

Varèse's crystal analogy can help one to visualise the complexity of Dynamic Music form. Because Dynamic Music changes and adapts, it requires new understandings of the potential of musical design. Tenney's understanding of form as a gestalt helps to separate the hierarchical levels of music, thus providing a more in-depth understanding of the potential for data to transform the musical form.

Tenney's understands form, essentially, as the structure of a work. This understanding is necessary for algorithmic, indeterminate, free and stochastic music. Structure in

Dynamic Music is the relationship of the musical attributes across timescales and their contribution to the total. The term formal structure is often used to describe the organisation of sections which make up the overall form. The structure of a work is part of the overall form of the work like the structure of a crystal creates its overall form.

Therefore, form is the resulting organisation of material in a set format in which sections (material) can be: repeated; juxtaposed; episodic; continually evolving; or individually unique.

Tenney et al. (1977) describes the three basic types of structure as statistical structure, morphological structure and cascaded structure. Each refers to the relationship between lower hierarchical level states, shapes and structures respectively.

- state - A description of the shape (or sometimes the structure) of a formal unit at one of these hierarchical levels frequently involves certain statistical characteristics of the formal units at the next lower level - e.g. the average value and range of each important parameter. It "refers to all the parts that make up the form and the range of each of its musical and acoustic parameters, its duration and if it is dynamic or static.

- shape - "Contour, the variation of some attribute of a thing in space and time" or the different parameters, essentially their envelopes of each element or part.

- structure - "the disposition of parts, relations of part to part, and of part to whole element."(Tenney et al., 1977)

Tenney (2014) summarizes by stating

> "we thus have three aspects of form to consider, at each hierarchical level: the structural (internal relations), the morphological (shape), and the statistical (state, condition)."(Tenney, 2014)

These three aspects of form are interrelated at different hierarchical levels, from the most elementary constituent ’formlet’ to the overall form.

5.3.3 Structure, Time Scales and Temporal Gestalt

De Bievre (2012) further discusses that Tenney "sees a work of music as a succession of what he calls "temporal gestalt units"(De Bievre, 2012) or more simply "time-based forms". Gestalt is defined as "an organized whole that is perceived as more than the sum of its parts."[1] De Bievre (2012) writes that Tenney envisions "the total form of a piece of music consists of a succession of smaller forms, each in turn consisting of even smaller forms, etc, all the way down to the elementary clang, an indivisible unit." (De Bievre, 2012)

Tenney’s hierachical levels of time-based form are made of up the following;

- Sound Elements - the smallest level where an element of sound exists or a sound unit. "a Temporal Gestalt that is not temporally divisible, in perception, into smaller Temporal Gestalts." or invisible sound units

[1] Oxford Dictionary

- Clangs - is "at the next higher level, consisting of a succession of two or more elements." It can also be understood as a motif or phrase
- Sequences - "A succession of two or more clangs, heard as a Temporal Gestalt at the next higher level constitutes a sequence."
- Higher level Temporal gestalts are segment, section and finally the piece itself. (Tenney et al., 1977)

Tenney et al. (1977) notes that some "situations are certainly conceivable where still larger gestalt-units might be of interest e.g., the series of pieces in a concert, or the set of all pieces by a particular composer." It should be noted that there is no finite definition of these hierarchical levels as they are both objective and subjective

Roads (2001) outlines nine 'time scales' of music from the largest to the smallest.

"Music theory has long recognized a temporal hierarchy of structure in music compositions. A central task of composition has always been the management of the interaction amongst structures on different time scales. Starting from the topmost layer and descending, one can dissect layers of structure, arriving at the bottom layer of individual notes." (Roads, 2001)

This temporal time scale in music described by Roads can be traced back to Tenney's temporal gestalts. "This somehow quite complex approach allows us to zoom in onto details or specific elements 'granted freedom' by the composer." (De Bievre, 2012)

Tenney's levels were based on a philosophical ontology which has been built on by Roads to include a larger spectrum of hierarchical levels based on the physics of music and sound. This framework provides a sample, sub sample and infinitesimal model that may be required by Dynamic Music Systems based on highly complex algorithmic approaches.

Roads (2001) outlines nine 'time scales' of music from the largest to the smallest.

1. "Infinite - The ideal time span of mathematical durations such as the infinite sine waves of classical Fourier analysis.
2. Supra - A timescale beyond that of an individual composition and extending into months, years, decades, and centuries.
3. Macro - The time scale of overall musical architecture or form, measured in minutes or hours, or in extreme cases, days.
4. Meso - Divisions of form. Groupings of sound objects into hierarchies of phrase structures of various sizes, measured in minutes or seconds.
5. Soundobject - A basic unit of musical structure, generalizing the traditional concept of note to include complex and mutating sound events on a time scale ranging from a fraction of a second to several seconds.
6. Micro - Sound particles on a time scale that extends down to the threshold of auditory perception (measured in thousandths of a second or milliseconds).

7. Sample - The atomic level of digital audio systems: individual binary samples or numerical amplitude values, one following another at a fixed time interval. The period between samples is measured in millionths of a second (microseconds).

8. Subsample - Fluctuations on a time scale too brief to be properly recorded or perceived, measured in billionths of a second (nanoseconds) or less.

9. Infinitesimal - The ideal time span of mathematical durations such as the infinitely brief delta functions." (Roads, 2001)

The quote below by the Argentinian author Jorge Luis Borges (1899 - 1986) provides an excellent analogy for understanding the infinite potential of the micro to macro time scales.

> "The line is made up of an infinite number of points; the plane of an infinite number of lines; the volume of an infinite number of planes; the hypervolume of an infinite number of volumes." (Borges et al., 2004)

Roads describes approaches to composition at the macro level as either top down or bottom up. "A strict top-down approach considers macro structure as a preconceived global plan or template whose details are filled in by later stages of composition." (Roads, 2001) Alternatively, "a strict bottom-up approach conceives of form as the result of a process of internal development provoked by interactions on lower levels of musical structure."(Roads, 2001) In summary a top-down approach to form describes a mould that the music is composed to fit into, where a bottom-up approach fits with Varèse's description of form as the result of a process.

Spiegel (2000), renowned composer and music technologist states that "[m]uch of the new music we hear today is not organized along hierarchical lines at all. It may be built by progressive layering of unrelated elements, or extrapolation or permutation." She says: "The likes of such standard multilevel forms as sonata and rondo are no longer used nor are comparable new forms being invented." However, she notes that although comparable new music forms are not being invented, new standard processes are. (Spiegel, 2000) "It is already common that musical movement is built within a single complex sound or texture, by variation of amplitudes or harmonic spectra. Use of the concept of the 'note' is now an option, rather than a necessity, for music making." (Spiegel, 2000)

To summarise the discussion on structure and its relationship to Dynamic Music thus far, the structure of the work is based on some type of variability within the hierarchical levels effected by data. This can range from the infinitesimal to the infinite. Anything can change in Dynamic Music. The form is open to change on any level of the hierarchy, be it at the micro or macro level. Form is not fixed in time any more but open to reinvention, reinterpretation, variation, and disruption. This raises challenges for Dynamic Music composers working with popular music forms due to popular music being reliant on fixed repeating forms such as verses, bridges and choruses. One solution to this challenge is to slowly change forms as can be found in music compositions based on process.

5.3.4 Process

One of the most important differences between Dynamic Music and compositions fixed in time is that they change, thereby creating new ways of experiencing music. Whether this is via interaction, immersion, play or another process, experience or specifically designing an experience is an essential component to be addressed. It not only allows for new ways of experiencing music but also provides a new set of factors for consideration in the composition and production of Dynamic Music. One important factor is process. A process involves a series of actions that change in some natural or orderly way in order to achieve a result. Nyman (2000) outlines various approaches to process in the composition of experiential music which are not concerned with a form that is predetermined or fixed. Similar to Varèse's definition of form, experimental composers were more concerned with process than form.

> "Experimental composers are by and large not concerned with prescribing a defined time-object whose materials, structuring and relationships are calculated and arranged in advance, but are more excited by the prospect of outlining a situation in which sounds may occur, a process of generating action (sounding or otherwise), a field delineated by certain compositional rules" (Nyman, 2000)

If the composers referred to by Nyman approach music form as the result of process, the differences between composing a static popular music and a Dynamic Music work based on popular music forms can be clarified as such. When creating any musical work, the composer must decide on a process for the organisation of their musical material. With popular music this process of organisation is based on developing a musical theme, harmony, rhythm, the option of using verses, bridge and chorus and melodic structure. This is composed on a time-line (a fixed sequence of events), which may have a specific duration. For example, in the three-minute pop song, the work is refined to include emotional dynamics, continuity and an overall formal structure. When composing a dynamic work, the composer is using a process to organise the way the music may work within a musical design. The process creates a system or set of rules and instructions as to how the musical material should be organised in real-time. Instead of the work being composed on a fixed timeline the work is built on processes, events and transitions which can be ordered or occur in a variety of ways depending on the system driving the music.

These types of processes highlight some of the approaches that can be utilised by composers working in Dynamic Music to develop a control system. "The importance of Cage's chance methods of the early 50s, according to Dick Higgins, lay in the placing of the material at one remove from the composer by allowing it to be determined by a system he determined. And the real innovation lies in the emphasis on the creation of a system (or process)." (Nyman, 2000)

It is very interesting that experimental composers in the mid 20th century were using, exploring and creating tools and techniques for composing music which are now able to provide a fundamental framework for music utilising interactive technologies and beyond.

Bringing it all together, process in Dynamic Music refers to both the creation of the musical content and the programming of change within a system. This change can be initiated by chance, musical techniques (for example repetition), human intervention, context, algorithmic or generative process, or any other predefined intervention to trigger change.

5.4 Time and Dynamic Music

The perception of music depends "on the ability to associate what is happening in the present with what has happened in the past and with what one expects will happen in the future. The frustration or fulfillment of such expectations and the resulting tensions and releases are basic to most musical works." (Kirby, 2016)

The above discussion on form and process and their impact on time can now be discussed. Music is a time-based artform, music creates its own time, but is also experienced in time. Because of its ability to change at any moment in time, time is an important conceptual issue at the heart of producing and experiencing Dynamic Music. Two concepts of time are discussed: time line and time stream. A time line is a sequential series of events or points that follow a logical order such as past present and future. Music is often represented on a timeline in notation, software environments and in gaming composition with analogies like horizontal and vertical changes. Taken from science fiction, a time stream(Kaae, 2008) is metaphor for a non-linear presentation of events which can occur in any order such as backflashes or future flashes in a film.

Section 5.3.1 discussed fixed forms in which events happened in a specific order and never change with any rendition of that performance. That fixed order of events is based on a time line. The time line is linear and the music is ordered in a particular way to achieve a certain emotional or conceptual impact. It has a structure and form composed to be experienced from start to finish over a specific duration.

A time stream occurs when events can occur in any order based on some conditional operation. The events are not fixed to a specific time line. The moment forms of Stockhausen, or the indeterminate works work of John Cage and Earl Brown exemplify a musical time stream. Dynamic Music can be understood as being within a time stream. All aspects of the music are not fixed to a timeline as such. Instead dynamic time could be understood as events and processes that can occur in a time stream, which change with data. The set of rules or a control system designed by the composer enables events to respond to other events which can be triggered by people, a machine or external factors. Dynamic Music provides composers with the opportunity to explore multiplicities of time.

Dynamic and fixed form music can intersect on many levels. Fixed music forms can be presented using notation and charts whilst Dynamic Music can be difficult to represent visually as it may be ever changing, open in form or controlled via a control system. The form of the work is often continually being created through the processes designed by the composer. In order for Dynamic Music to be experienced a system is required.

5.4.1 Definitions of a Dynamic Music System

After the above discussion of form, structure and time this next section discusses how these concepts can be integrated into a system. A Dynamic Music System transforms data and maps that data to control musical parameters to produce a rendered musical output. The system can create the content and/or form of the work depending on the design.

A system is required for Dynamic Music to be experienced so it not only works as the control and organisation system for the composition but is also the playback media. The system may be

- created simultaneously with the musical design. The sound material and control system are customised and created to realise a dynamic rendered musical output
- designed based on a pre-composed music work. A work composed to have many musical options that require a system to realise a rendered musical output.
- actually be composed to produce the musical design. The system creates, synthesises and/or composes the sound material and organises into musical form.
- a standardised pre-designed system to play forms of Dynamic Music. The system is designed and music is composed to fit within the Dynamic Music design.

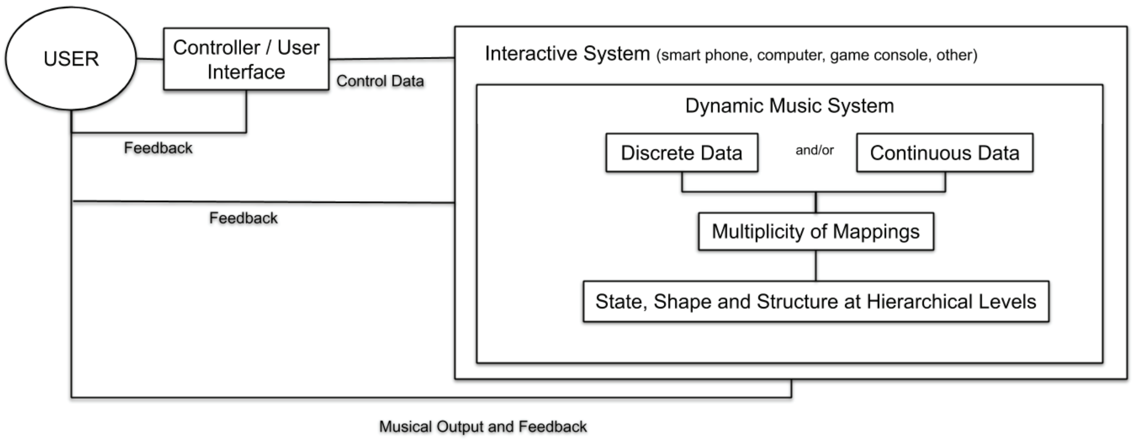
As an illustration, a Dynamic Music form can be composed as sound material that is realised within a dynamic system via the system organising or manipulating the sound material at any desired timescale. Alternatively, the system can be composed to create its own sound material and organise this material via each timescale into its final form.

Dynamic Music System is an over-arching term describing the many systems developed utilising different approaches to process, structure, data and interaction. This includes and is not limited to interactive, adaptive, reactive, contextual, autonomous, generative, and algorithmic systems. There are similarities across all these systems in respect to their approaches to music design. Essentially, a control system is designed which maps data to change and or organise the music. These changes might be the state, structure or shape of music parameters across one or all hierarchical levels producing a rendered music output.

To provide context it is important to show how a Dynamic Music System fits within the context of a product or work. Figure 5-1 shows the work flow that a dynamic system fits within. A list of definitions is provided.

- **User** - The audience, performer or individual listening and interacting with the music product.
- **Controller** - The user engages with a controller to interact with the music work. This controller provides input data into an interactive system. A controller could be a user interface like a touch screen, joystick, game controller, gesture sensor, brain interface or wearable. Controls may be as limited as a start button and may not require any interaction from the user. The level and type of control on offer is dependent on the vision and requirements of the work.

Figure 5.1: Dynamic Music System Diagram



- **User Interface** - Is a graphical interface which enables interactions between humans and machines, basically like a control panel. A GUI or graphical interface could also be a controller in a touchscreen scenario.
- **Control Data or Data** - is the data is that is produced by the controller or interface. This data can be generated by a direct action of the user and/or contextual data. The term encapsulates control data and other data produced by a machine. This might include twitter feed data, weather data, research data or any type of data. This data is then treated, organised, classified and mapped to a musical parameter.
- **Feedback** - Feedback is provided to the user by the system. This may be tactile, haptic, or via a user interface. The feedback system should be designed to aid the user in understanding their interaction with the system. For example, if the user presses a button on a GUI (Graphic User Interface) the colour of the button could change, the button could then create an event in the musical output. The feedback is used to assist the user in understanding that their action has an effect.
- **Interactive System** - This is the playback system for a work. Examples include mobile phones, computers, tablets or game consoles. An interactive system may also include software used as part of that system like a web browser, platform or custom-built system.
- **Rendered Musical Output** - A Dynamic Music System renders a musical output by compiling a set of instructions and control information and mapping it to musical parameters. The result of the process in a Dynamic Music System is the rendered musical output.
- **Dynamic Music System** - This a system that controls multiplicity, mapping data to musical parameters at hierarchical levels to create a rendered musical output. This

system may be part of an interactive system, for example when a game is played on a game console and the game itself contains the Dynamic Music System that is experienced through a game console (interactive system).

A Dynamic Music System is designed congruently with the musical design of the work. The system transforms data, mapping it to musical parameters. In order to understand how a Dynamic Music System works we must first understand how to design a composition as a musical system.

5.5 Summary

In summary Dynamic Music is an overarching term used to describe any music that can change and adapt with data. Creating an overarching field allows a formalised and unified approach to the musical design of music which can change and adapt to data. It is hoped this will provide a framework addressing some of the complexities discussed for composers and producers working within this field.

In order to understand approaches to form, structure and time in Dynamic Music the thesis has discussed the ideas of five composers; Edgard Varèse (1883 - 1965), James Tenney (1934 - 2006), Brian Eno (1948), Laurie Spiegal (1945) and Curtis Roads (born 1951). Defining form as the organisation/generation of a musical composition and its relationship to time. Varèse describes form as the result of a process instead of a mould to fill. This understanding may enable the composition of dynamic forms in popular music to become flexible.

Understanding of form as a gestalt (Tenney et al., 1977) helps to separate the hierarchical levels of music and thus provides a more in-depth understanding of the potential for data to transform the musical form. Tenney's understanding of form as structure is necessary for algorithmic, indeterminate, free and stochastic music. Structure in Dynamic Music is the relationship of the musical attributes across timescales and their contribution to the total. Tenney's three basic forms of structure are statistical structure, morphological structure and cascaded structure. Based on the hierarchical levels outlined by Tenney; sound elements, clangs, sequences and higher-level temporal gestalts, Roads (2001) provides nine timescales based on the physics of music and sound. (Roads, 2001)

Dynamic Music also challenges perceptions of time. Fixed forms of music can be understood as being rolled out over a timeline and Dynamic Music can be understood using the metaphor of a timestream.

Dynamic Music involves variability in its composition given it can change and adjust with data. It also requires some kind of system to map data to musical parameters and render a musical output. A Dynamic Music System can support Dynamic Music in a number of ways, it can be

- created simultaneously with the musical design.
- designed based on a pre-composed music work.

- composed to produce the musical design.
- a standardised pre-designed system to play forms of Dynamic Music.

A Dynamic Music System is very much part of Dynamic Music, given it is required for Dynamic Music to realise its form. In order to understand how Dynamic Music and a system can be composed, Chapter 6 discusses the musical design and the essential components of Dynamic Music in detail.

Chapter 6

Methodology Part 2: Designing a Dynamic Music System

Chapter 6 is in two sections. Section A discusses the components needed in the musical design of a Dynamic Music system. Section B discusses factors impacting on the musical design of a Dynamic Music composition.

Section A

6.1 The Components in the Musical Design Model for a Dynamic Music System

Chapter 5 lays the theoretical foundations for Dynamic Music with reference to some key writers on form and structure. Based on the theoretical foundations from Chapter 5, Chapter 6 discusses the technical requirements needed for the musical design of a Dynamic Music system. It brings together research from related areas in electronic music composition, interactive systems, generative and algorithmic composition, music theory and game music. Composing Dynamic Music requires the composer to not only design a song (as in static music) but to essentially design a song system. A system is defined as;

> "A set of things working together as parts of a mechanism or an interconnecting network; a complex whole."
>
> "A set of principles or procedures according to which something is done; an organized scheme or method." [1]

There are many types of systems used in Dynamic Music. A Dynamic Music system can create, change, organise and playback music. It is built on the following four components;

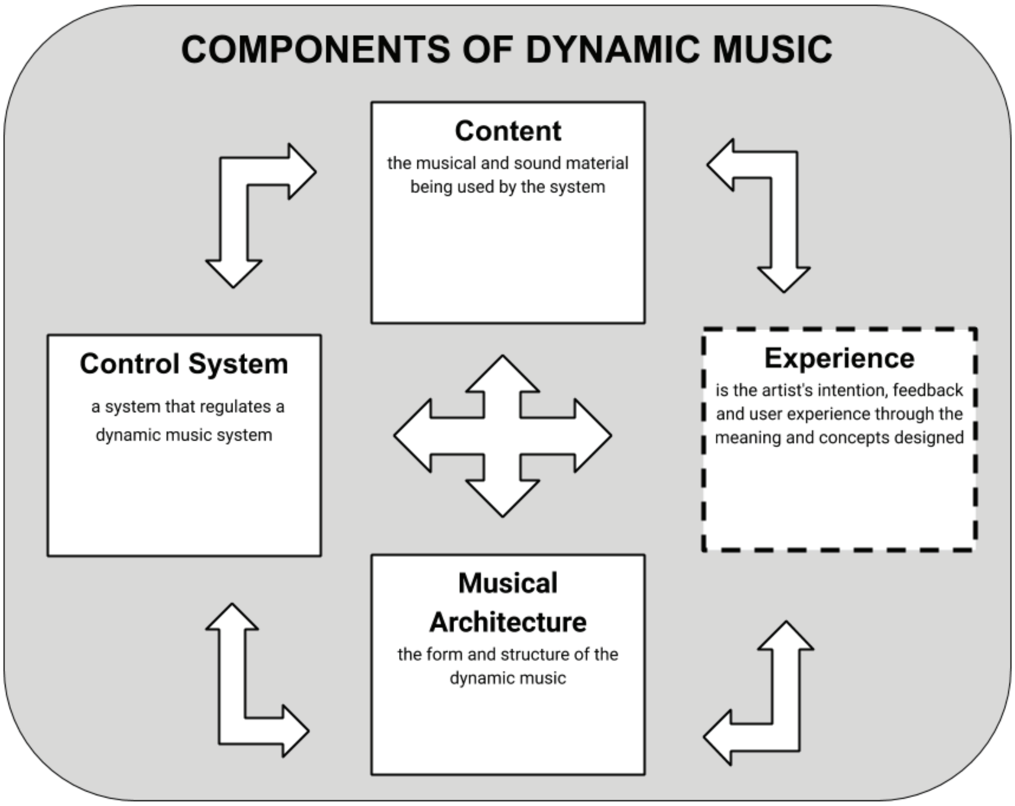
- **Content:** the material being used by the system. This can include music, sound, image, video, animation etc.

[1]Oxford Dictionary - https://www.lexico.com/en/definition/system

- **Musical Architecture:** the form and structure of a music work.
- **Control system:** a system that regulates another system.
- **Experience:** "the process of getting knowledge or skill from doing, seeing, or feeling things" or "something that happens to you that affects how you feel" [2] Musical Experience is a relationship between the composer/performer and the audience.

Figure 6.1 schematises the complex interactive relationships between all the components of a Dynamic Music system. Throughout Chapter 6 these four components are discussed in relation to the musical design of a Dynamic Music composition.

Figure 6.1: The Components of a Dynamic Music System



6.2 Designing Experience in Dynamic Music

Experience within a Dynamic Music work is multifaceted. Experience can be understood from composers' and listeners' perspectives. The listener's perspective is a large and complex area involving cognition, perception and emotional states. Spiegel (2000) states:

> "[a]s more is learned about the way we ingest, parse, and experience sounds, the technical rubric on which our creative concepts take form would be designed for optimal plug-in compatibility with our music's intended destination, the receiving processor, the ear and mind." (Spiegel, 2000)

[2]Cambridge Dictionary - https://dictionary.cambridge.org/dictionary/english/experience

She concludes with the statement:

> "As calculus introduced to mathematics in the 17th century a previously unimagined way to study motion and change, music deserves, and may finally obtain, a representation and conceptual model designed for the structure of how music is experienced, not just how its components are manufactured." (Spiegel, 2000)

Dynamic Music requires music to be experienced in new ways. However, it is beyond the scope of this thesis to discuss concepts of the listener's perspective in detail, even if this area is significant and can impact upon the overall design process. As Dynamic Music composition and software tools develop, a "conceptual model designed for the structure of how music is experienced" (Spiegel, 2000) may well become as important as the compositional processes discussed in this thesis. Evaluating user experience has foundations in the Human Computer Interaction (HCI) and Music Interaction fields and is important in the later stages of design (see Section 7.2). This methodology is concerned with how popular music forms can change to work with interactive technologies. It articulates the components of a musical design required to create a compositional model of Dynamic Music. Therefore, experience in this context relates to the artist's intention through the meaning and concepts they design for the audience to experience. Figure 6.1 represents experience with a dotted line to highlight that experience is only partially represented in this context and requires further research in the future.

When producing a Dynamic Music work, it is crucial to understand the design of the desired musical experience. This depends on the overall concept and the intent of the artist. The perception of music is not something that can be controlled or easily understood. It relates not only to the ways the audience, performer, user and/or listener experience the work, but also the ways they might potentially understand the musical changes and feedback.

A Dynamic Music work must be designed to provide an experience beyond a static form. This will include designing the ability for the work to produce some level of variability in its playback and feedback so that changes in the music can be acknowledged. The discussion of musical design throughout this chapter constitutes a palette of approaches for artists to create these new immersive experiences.

6.2.1 Experience Design Considerations

Due to the vast options available for designing experience in Dynamic Music some considerations in relation to experience design can be:

- the length the listener is expected to engage with the work;
- the time it takes to experience the story or narrative;
- the amount of people using or listening to the work at the same time: multiple users or listeners;
- whether the experience will be different each time;

- how will the music change and/or adapt and how much control will the listener have over the music;
- how much music needs to be composed with regard to the length of experience;
- creative direction and musical style/s;
- how obvious will the musical changes be;
- other media available to provide feedback about changes in the music: visual, haptic;
- the content that will be used, music and sound material, and any digital instruments required and/or production tools that can be used;
- system limitations and requirements for example memory issues, content limitations;
- other media involved in the work e.g. audio-visual work;
- game-like or goal-orientated interaction design;
- the amount of variability the composition might need to keep the listener engaged;
- the number of times the listener is expected to want to experience the work, a one-off experience or repeated listening;
- does the music transition smoothly to new parts or sections.

This list of considerations highlights the experience design attributes. Some of these considerations may require user experience evaluation to help provide better experiences and assist the artist in making sure their work can be understood. Providing some kind of feedback to the listener, user or performer is an excellent tool available to composers.

6.2.2 Feedback

Feedback activates engagement and a deeper understanding of the work. Feedback may be "visual, auditory, tactile or kinesthetic." (Wanderley and Depalle, 2004) Designing feedback is an essential part of the experience design. Dynamic Music offers an experience beyond a static form. The listener, user and/or performer need to understand how their actions or data are affecting the musical output. Wanderley and Depalle (2004), examines four types of feedback based on the following characteristics;

- Primary feedback includes visual, auditory and tactile or kinesthetic.
- Secondary feedback is the sound produced by the instrument.
- Passive feedback is "provided through physical characteristics of the system (a switch noise, for instance)"
- Active feedback is a response to a certain user action. This is produced by the system" (Wanderley and Depalle, 2004)

Evaluating feedback from a system as a whole can be achieved through Music Interaction methodologies. However, feedback also becomes part of the musical design. Producing Dynamic Music requires designing all possible actions and interactions and their effect on the musical architecture. Producers must consider how they can keep their listeners and/or performers engaged and involved in the work from a musical standpoint. This also means to compose music that has obvious changes. Changing the lead vocal/melody or dramatically changing the tempo/genre are examples of obvious changes for audiences who may not notice more subtle musical changes.

Feedback can also be used to guide a listener and engage them to take action. For example, the work could resolve to the tonic once the user performs an action. If the work involves multiple mediums, the feedback may also include visual and haptic experiences. A button flashes in colour indicating it wants to be pressed. Every time the user presses that button, a slight vibration is felt to indicate that an action has been produced. Studies highlight the importance of providing feedback to individuals in order to create meaningful experience and to avoid frustration. (Hodl et al., 2014; Lee and Freeman, 2013)

6.2.3 Summary of Experience

Designing the experience of a dynamic work consists of a number of considerations including feedback and control. Each work is designed to be based on the artist's vision which should stipulate the amount of control required by the user, machine, performer and/or audience. In order to avoid frustration and confusion, the experience must be designed with the aim of engaging and immersing the listener.

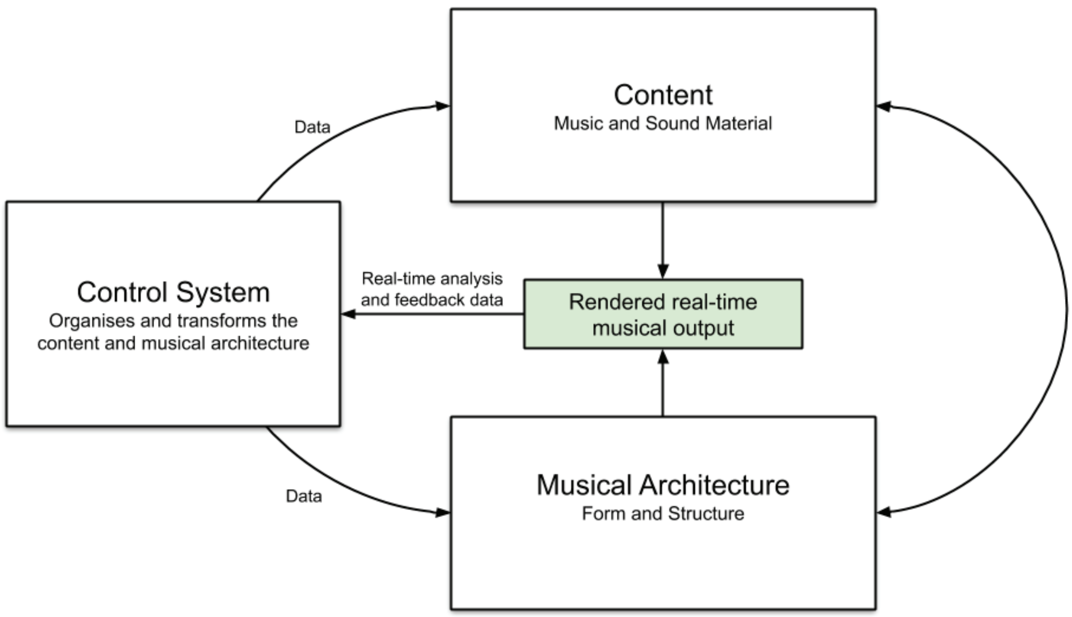
6.3 Musical Design of a Dynamic Music System

A Dynamic Music system involves designing a system to create and change music. This requires the development of a unique hierarchical compositional model. This is because of the many types of processes and control systems that are incorporated by the term Dynamic Music. The compositional model is the composer's model of the musical design for the work. The Italian composer Agostino Di Scipio defined a compositional model "as the composer's instantiation of a procedural description for the musical structure." (Di Scipio, 1994) As a point of departure from Di Scipio, composer/producer Greg White presents a model of musical design which "uses a control system to organise sound material into a musical architecture." (White, 2015) He argues that software environments enable the performance, composition and production to happen simultaneously in real-time, which he describes as convergence. This is very relevant to Dynamic Music, given it too is performed, composed and mixed in real-time.

> "Musical design is both the process of creating a plan for music making and the plan itself." (White, 2015)

Building on White's model for the music design, an abstract model for the musical design of Dynamic Music is provided in Figure 6.2. The term “sound material” has been changed to 'content' to cover a broader range of material. The control system organises and transforms the content and musical architecture to produce Dynamic Music. This model aims to provide the technical considerations required for the design of a compositional model for a Dynamic Music system.

Figure 6.2: Components in the Musical Design Model for a Dynamic Music System



In this model the four definitions provided above are explained further in terms of their role and purpose:

- **Content:** refers to the various types of digital media that are created, manipulated or reconfigured in the work. The content can be sound, music, animation, video, images or texts.
- **Musical Architecture:** is the development and invention of music and sound at each hierarchical structural level and includes the resulting form.
- **Control system:** organises, transforms, programs, synthesises and or analyses sound material and musical architecture into a rendered musical output.

Within this model, **experience** is implicit in the design of the control system, content and musical architecture. Experience is the artist's intention, the feedback and the user's experiences of the meaning and concepts designed.

6.4 Content

Content is the material or media that is deployed within the system. Content can include two categories; composing with existing material or composing material via the control system.

This can be any material including music, sound, image, video, visuals and animation etc. Given the scope of this thesis, only music and sound content are discussed in any detail. Within a Dynamic Music system, the content is selected, organised, transformed, created, shaped and/or integrated by the control system. This section discusses the types of content that are used and altered and how they can be organised within a Dynamic Music system.

At this time, it is important to note that the musical and sound content used in a Dynamic Music system also has a musical architecture. Referring to Roads (2001) time scales (Section 5.3.3), musical architecture in the age of computer music, digitisation and software environments extends music design processes to micro, sample and even infinitesimal levels. Given the extension of design levels needed to create sound, the design of musical architecture can be separated into a two-step process:

1. composing the sound and;
2. composing with sounds. (Di Scipio, 1994)

Here composing the sound refers to making the sound, whereas composing with sounds refers to organising or manipulating sounds to form a structural relationship. Electronic music production in many ways exemplifies this two-step approach by composing samples and short musical segments such as MIDI or audio loops into higher structures. Separating composing the sound and composing with sounds can assist in understanding the complex role that music and sound content plays within the overall Dynamic Music system.

In order to create the most effective Dynamic Music system intended by the composer, there are times when music and sound material needs to be designed to optimize memory and system requirements.

The music and sound content may consist of one or a hybrid of the following approaches to sound and music making; audio, MIDI, DSP, digital instruments, plugins, patches, sound libraries; and procedural sound [3]. The music and sound content are organised by the control system to create the musical architecture.

6.4.1 Organising the Music and Sound Content

Dynamic Music at all times is structured hierarchically. The music and sound material needs to be organised within a hierarchical structure depending on its state. This may include labelling audio or creating hierarchical filing systems. Game Audio composition has established techniques for the organisation of music and sound material so it can be integrated into a musical architecture. Terms like vertical (layering and blending) and horizontal

[3] There are many approaches to the creation of procedural sound including generative, stochastic and algorithmic music, and sound produced by Artificial Intelligence (AI).

(song/formal structure) sequencing are used. These terms describe music represented as a timeline such as a musical manuscript or by tracks used in DAW software.

However, as the following examples will show, new groups and relationships can be created beyond these metaphors of the vertical and horizontal. Dynamic Music is a multiplicity of relationships across different hierarchical levels and the ability for them to be fluid. Afterall, the options of a timestream are infinite.

Musical content can be organised in many different ways: by genre; song structure or formal structure; or features such as tempo, high or low frequencies, key signatures and scales. The system Ninja Jamm, reviewed in Section 4.1.3, uses music packs as its content. Figure 6.3 shows the four tracks playing one of eight loops. Once the loops are selected, the user can arrange a song structure and process the sound and loops through four windows which offer different DSP and effects.

Figure 6.3: Ninja Jamm App. Screen shot from iphone.

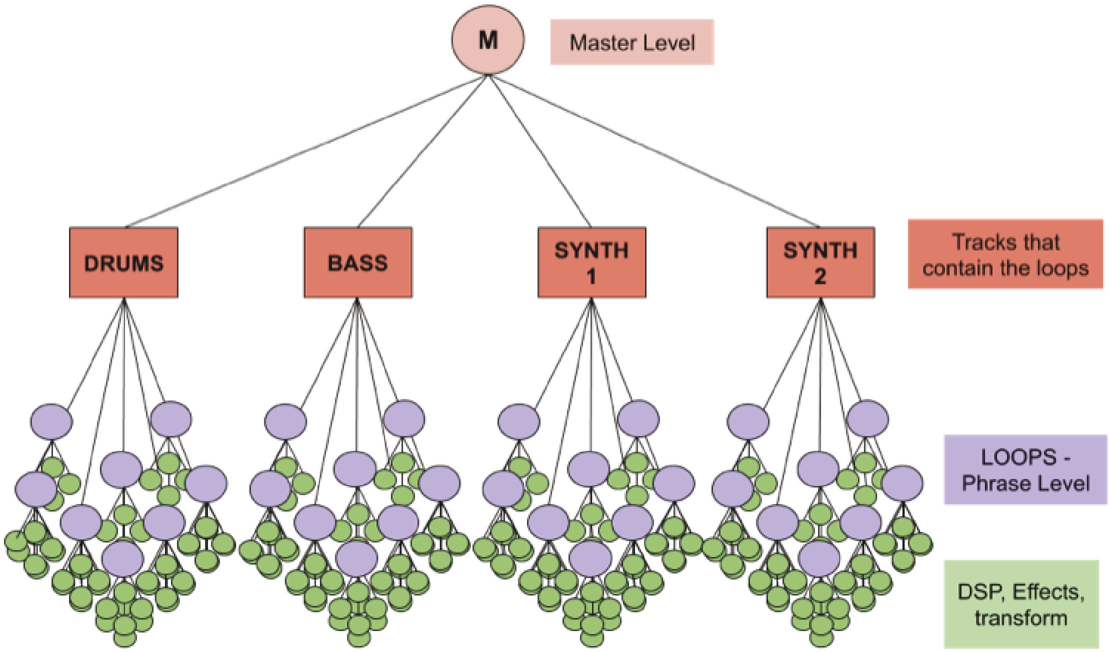
These music packs consist of four groups of eight loops and one group of samples (which can be triggered in the app). These groups or folders of loops separate the kinds of audio such as drums, bass, synth1, synth2. Music packs are created and customised by artists on the Ninja Tune label. The loop group title and its organisation depend on the Ninja Tune artist and their use of content and material. Figure 6.4 shows the organisation of the content in the Dynamic Music system.

For more complex systems, Thalmann et al. (2016) introduce the Mobile Audio Ontology MAO[4] to define Dynamic Music Objects (DYMO's)[5] This offers another way to organise and group relationships for Dynamic Music. It also visually provides a method which enables a

[4]MAO is "a Semantic Web framework that investigates new ways in which music can be experienced on mobile devices." (Thalmann et al., 2016)

[5]"Dymos are playable semantic web graphs. They are multi-hierarchical structures and constraints" (Thalmann et al., 2016)

Figure 6.4: Ninja Jamm content organisation schematic.



more flexible musical design. "Hence the music form could be viewed as a multiplicity of relationships which is hard to represent visually." (Thalmann et al., 2016)

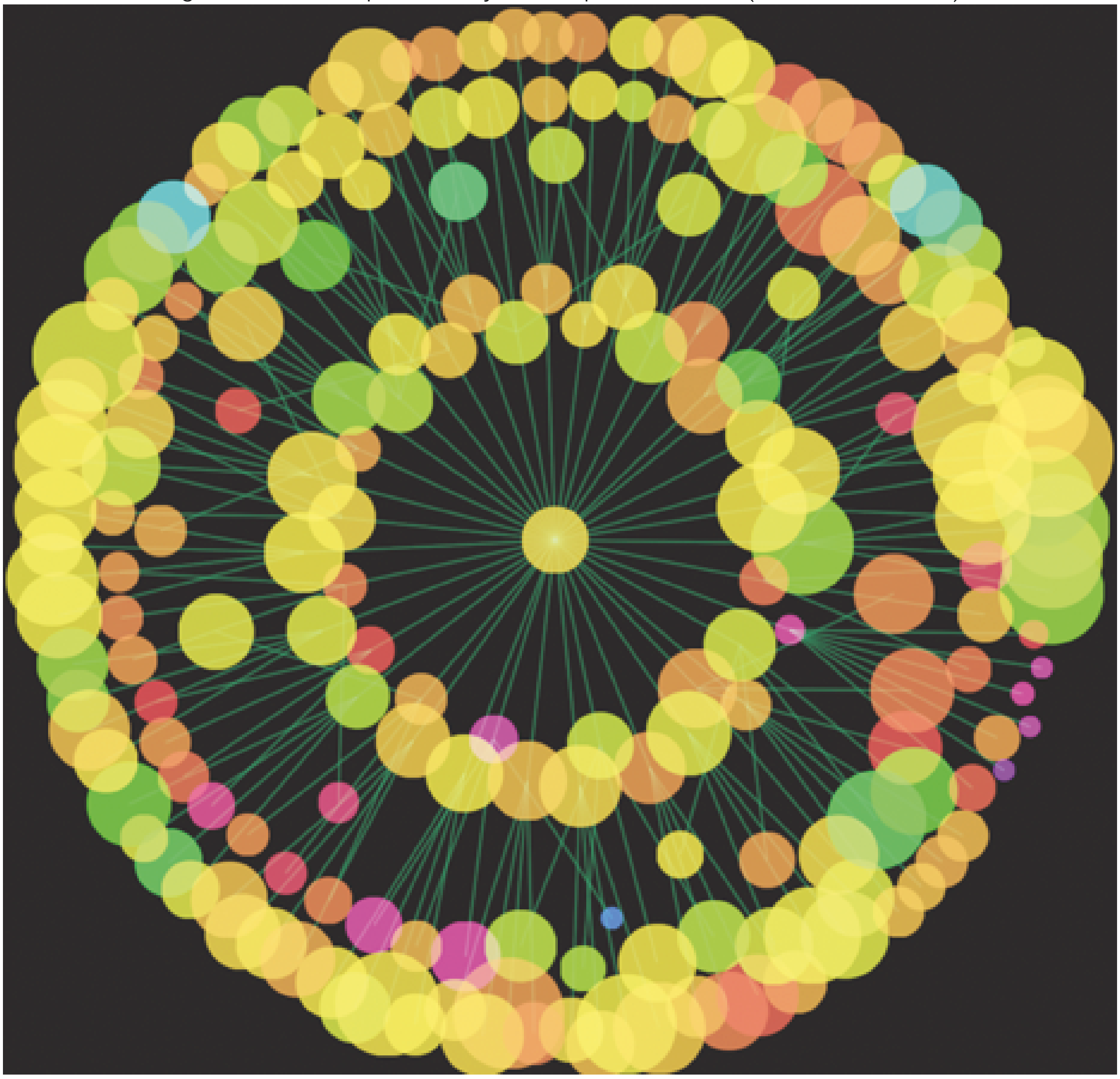
The mobile ontology represents these relationships using a semantic web graph. Figure 6.5 represents a dynamic song including all its relationships at different time scales. This image is presented in 2D, however a 3D structure would be easier to understand. The outer layer of the diagram is where the music is played back, like a record. Thalmann et al. (2016)

Other ways of organising sound material are created by a customised hierarchical filing system which contain audio elements grouped together or tables/matrices of audio. In game audio composers will build their own custom musical hierarchy. In Wwise, the Audio middleware software used in game audio composition, the levels are 'work unit', 'containers', 'segments', 'tracks' and the 'audio file'. These can be organised and designed according to vertical and horizontal aspects.

- The Work Unit is the master level.
- Containers can be multiple containers or containers within containers. Each container controls how its lower level containers or segments will behave. A container can be a switch or a playlist. It can randomly play a particular container or choose to play a container based on some control data.
- Segments contain and organise music tracks.
- Music Tracks contain and organise the audio files being used.

There can be multiple audio files in a music track, depending on the musical design and organisation of the material.

Figure 6.5: Example of a Dymos reprinted from (Thalmann, 2018)



6.4.2 Summary of Content

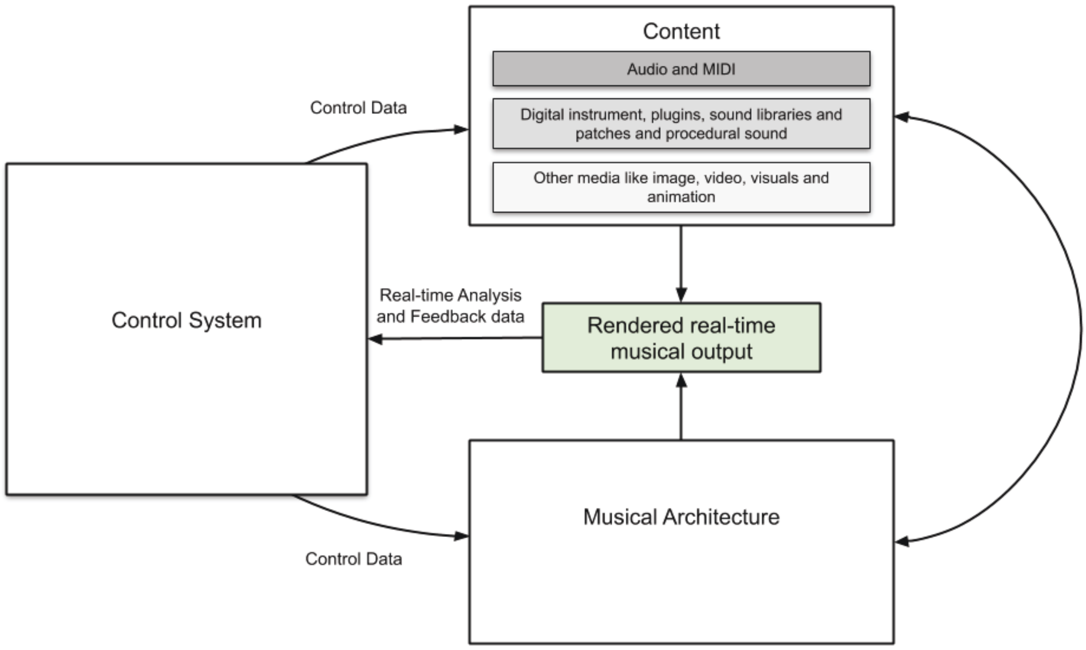
The content is the material that is used by the system.

Specifically, in this model it is the music and sound material that is used in the Dynamic Music system. Other content can also include images, video, and animation. Audio content is the music or sound material used or created within a Dynamic Music system and includes: digital instruments; audio; MIDI; plugins; patches; sound libraries; and procedural music. Figure 6.6 highlights types of content that can be utilised in a Dynamic Music system. The organisation of the music and sound material depends on the design of the control system and musical architecture.

6.5 Musical Architecture

Designing the musical architecture (i.e. the form and structure) for Dynamic Music can be understood as "composing with sound" (Di Scipio, 1994). The musical architecture is the

Figure 6.6: Musical Design of Dynamic Music – Content



musical or sound content, and how it is shaped, transformed, organised into a sequence, balanced and/or mixed, to produce a rendered musical output.

The overall musical design defines how the control system creates and alters the content and musical architecture on different hierarchical levels. This requires the composer to view the composition process in a new way. There is no set form: the design is completely dependent on the vision of the composer and the limitations of the system design and interactive technologies being utilised. Musical architecture exists within the music and sound material (the content), the control system and or the realised form of the work.

Music can be dissected into smaller pieces, for example, a song can be split into sections like a verse or a chorus. Sections can be split into phrases or organised by layers, bars etc. As Section 5.5.1 discusses, time scales or the hierarchical levels of musical form provide the basis for composing Dynamic Music. A system is composed whereby data can change the musical architecture and content. The musical design of Dynamic Music includes the amount of change the data can have on the musical form.

Designing the musical architecture consists of the creation of a plan or set of instructions. This could refer to how the content is being used or created in the system. It can also refer to how the music is structured into a macro form. Roads outlines multi-scale composition consisting of three levels: the Macro form (the duration of the work); its substructures; and the sound material. Macro can be used synonymously with the term master level. Substructures (Meso Level) are "divisions of form.

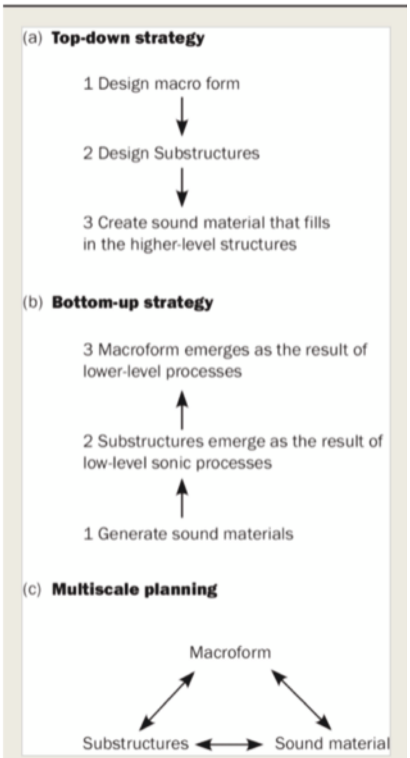
Groupings of sound objects into hierarchies of phrase structures of various sizes." (Roads, 2001) A brief overview of Roads' levels of form is discussed in the next section in the context of its relevance to the musical design of Dynamic Music.

6.5.1 Macro Form

"The macro timescale covers the overall form of a composition. It is one thing to create an interesting sound or a clever phrase; it is quite another to design an original and convincing form. The test of composing is the delicate and dangerous business of piecing together a series of major sections that result in a form." (Roads, 2001)

The macroform is the result of a compositional design or plan. Roads divides this compositional design or plan into three basic approaches: top-down, bottom-up, and multiscale, as shown in Figure 6.7 (Roads, 2015)

Figure 6.7: Compositional Approaches reprinted from (Roads, 2015)



A bottom-up approach to musical design means designing from the lower hierarchical levels up. This may include a system whereby through interaction a user can create substructures with the sound material in open form.

If there are no substructures organised in the work, the work may be perceived as an instrument. Substructures may be organised through a set of rules or instructions or within the musical and content.That is, if the work involves creating and transforming at the sound object level only, it is similar in functionality to an instrument which requires the performer to create the substructures by playing notes or sounds. A Dynamic Music work would include some kind of organisation to the substructures of the musical architecture.

Top-down is more like designing music for a mould where the composer starts with the design of a formal structure. Then the lower levels are designed to fit within this mould. Top-down approaches are required when composing music for an existing Dynamic Music system which has a pre-designed control system and requires content in a particular form, like Ninja Jamm, Nagual Sense and Weav.

Roads also presents a multiscale approach to composition. He states that a multiscale approach represents the reality of how many compositions within electronic music come together on multiple levels and in multiple stages. (Roads, 2015)

> "To work in the widest possible zone of creativity, the composer wants to navigate freely across timescale boundaries, to re-evaluate and modify strategy at any stage. This means not only making corrections but also opportunistically taking advantage of insights gained in the re-evaluation, perhaps elaborating on an idea that appeared in the initial process. All timescales can be planned and organized, but these plans need not be rigid; we can adapt as the terrain of composition shifts, as it inevitably does during the course of any realization. To generate, delete, rearrange, and transform sounds on any timescale at any step, this is the multiscale approach to composition." (Roads, 2015)

This multiscale approach to composing can be expanded within a Dynamic Music design. When composing on a static timeline, many ideas and concepts are lost or not explored due to the limitations of the formal structure. Dynamic Music works can include multiple sections, lyrical ideas and changes in tempo. In fact, the musical design becomes boundless giving composers the freedom to explore multiple ideas, themes and concepts within the same work.

Multi-scale composition is an important approach given the musical design of Dynamic Music is designed to be altered and transformed across all hierarchical levels.

6.5.2 Sub-structures

In further deconstructing the macro form, there may be multiple substructures, such as a motif, phrase, section and or a segment, at the meso level. The levels of hierarchy will depend on the musical design of the work.

Roads outlines common mesostructures including;

1. Repetitions—the most basic musical structure: iterations of a single sound or group of sounds. If the iteration is regular, it forms a pulse or loop.

2. Melodies—sequential strings of varying sound objects forming melodies, not just of pitch, but also of timbre, amplitude, duration, or spatial position.

3. Variations—iterations of figure groups under various transformations, so that subsequent iterations vary.

4. Polyphonies—parallel sequences, where the interplay between the sequences is either closely correlated (as in harmony), loosely correlated (as in counterpoint), or independent; the sequences can articulate pitch, timbre, amplitude, duration, or spatial position." (Roads, 2015)

6.5.3 Sound Material (Sound Object Level)

The sound object time scale includes events of a duration that are associated with the fundamental unit of composition: the note as well as any individual sound from any source. (Roads, 2015) The note is the key unit of conventional music architecture and consists of four properties:

- Pitch – generally one of 12 equal-tempered pitch classes
- Timbre – generally one of about 20 different instruments for a full orchestra, with two or three different attack types for each instrument
- Dynamic marking – generally one of about 10 different relative levels
- Duration – generally between d100 ms (slightly less than a thirty-second note at a tempo of 60bpm) to 8 seconds (for two tied whole notes) (Roads, 2015)

Within a sound object, the components of a sound can include "multiple time-varying envelopes for pitch, amplitude, spatial position, and multiple determinants of timbre. These variations may take place over time scales much longer than those associated with conventional notes." (Roads, 2015)

6.5.4 Hierarchical Levels in Popular Music

It must be stated that the terminology for temporal gestalts (see Section 5.3.3) in modern popular music making is slightly different. Terms such as master, duration, sections, phrases, loops, samples, soundbites, notes, builds, hooks, drops, breakdowns and riffs can be introduced depending on how the composer intends to organise the formal structure. To expand the substructures of musical design into popular music terminology the following hierarchical levels are made as a suggestion.

However, the levels will be created based on the overall requirements of the musical design. Hence the following is presented as a guide only.

1. Master Level (macro level) – This is the duration of the work and the overall form. It can be measured in minutes, hours, days, months or years depending on the musical design. In a recording context it is also the master mix level. Changes at this level effect all levels within.

2. Section Level – A section of a track refers to one of the sections in a song structure, for example verse (A), chorus (B), bridge, hook, breakdown, drop. Sections consist of two or more phrases. A section can be measured in seconds or minutes.

Macro Level	Master Level
Meso Level(substructures)	Section Level, Phrase Level
Sound Object	Sound Object

Table 6.1: Time Scales Comparison

3. Phrase Level - When two or more sound objects are combined to form an identifiable unit. It is also referred to as a motif. For example a loop, audio file, a small phrase of notes or a short melodic, harmonic or rhythmic motif. A phrase is measured in seconds.

4. Sound Level – this is a note that has pitch, duration, timbre, sound envelopes, wave form, amplitude, time, filters and MIDI parameters.

5. Micro level – "Sound particles on a time scale that extends down to the threshold of auditory perception (measured in thousandths of a second or milli-seconds)." (Roads, 2001)

With respect to Roads time scales provided in Section 5.3.3, Table 6.1 shows the relationship of the above hierarchical level.

The micro level may not be required in most popular music Dynamic Music systems. The micro level may be required, however, if the system utilises time granulators and analysis-resynthesis software.

6.5.5 Summary of Musical Architecture

The Musical Architecture is the form and structure within a Dynamic Music System. It can be understood as “composing the sound” and “composing with sound” (Di Scipio, 1994). The overall musical design defines how the control system creates and transmutes the content and musical architecture on the different hierarchical levels as shown in Figure 6.8.

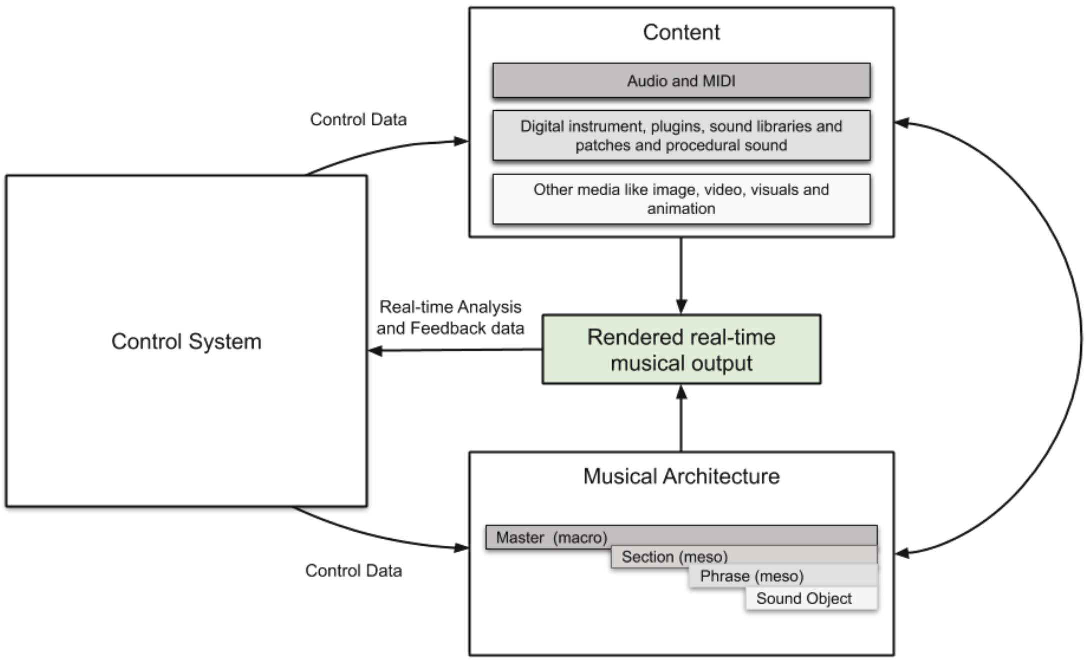
The hierarchical levels include the macro, meso and sound object levels (Roads, 2015). These also relate to the macro, substructures and sound material in multiscale composition.

6.6 Control System

The control system can be an aid, support or part of the compositional processes of Dynamic Music. The control system is required to regulate the rendering of a Dynamic Music system’s musical output. This control system can be custom built for the work, a software environment or can exist as a predefined system. The following requirements are fundamental to the design of the control system:

- the type of data used and how it needs to be transformed
- the type and use of musical and data analysis within the system

Figure 6.8: Musical Design of Dynamic Music - Musical Architecture



- how that data is mapped within system
- the processes and level of control that the data has in the system
- how data is designed to change and/or create the sound material and/or architecture.

These requirements are discussed for the remainder of this section in order to outline the technical considerations required in the design of a control system to realise a Dynamic Music work.

6.6.1 Data Transformation

Data can be inputted, received or autonomously produced by a system. Data can be in many field types including text, number, large number, rich text, currency, etc. Data can either be discrete or continuous.

- Discrete Data – This includes fixed datasets that may be inserted into the system by the developer. Fixed data sets can be explored to develop sound and musical architecture. "This dataset is then explored as a whole, allowing the development of … auditory expressions that seek to reveal the complexity and inherent structure of the data, namely when spatially or temporally displayed." (Lee and Ribas) In gaming, discrete data is also control data which can be mapped to an 'event' or a cue. An 'event' is a musical event and has a start and finish time. It could also be a note or an instruction. Events can be static or dynamic in music. A score contains static music events where as an interactive system may contain dynamic events.

- Continuous Data – This is "..a continuous data stream, whose values are changing in real time, or even chunks of information that gradually update the values. These streams or chunks are usually captured through computational processes and inserted into the system automatically" (Lee and Ribas). Continuous data stream can also be used to control a Dynamic Music system. This could be received as a data set at specific times, for example the weather API updates data every 30 minutes. Another example might be a gesture sensor that has a gyroscope producing a continuous data stream. In gaming a constant data stream of control data is called RPC. [6]. It is used to map to musical parameters that are constantly required to change, for example mixing effects.

Data can be input into the system or produced autonomously. Once data is in the system it undergoes transformation. There are many different technical processes available to transform and utilise data within a Dynamic Music system. The control system is designed based on the complexity and type of data being used as well as the overall system design.

A system can be built around many different types of data. Autonomous processes such as algorithmic composition produce data. Data can also be received by the system from mobile phone sensors, GUI, game controller (Kinect, VR tracking), GPS data, sensors, live datasets, contextual data etc. Many interactive technologies have standardised datasets (mouse events, button events etc) that provide an established set of control data.

These can easily be used to control events and processes within a musical design. However, outside of the gaming field, input data will often need to be transformed and classified to create a more meaningful data-set. There are many processes that can be used to classify data including simple, complex and learning algorithms.

Wooller et al. (2005) look at processes of algorithmic music. They provide some key insights into how data can be transformed and mapped. They write of transformation in two ways.

1. Change in potential size of data.
2. Change in the representation scheme. (Wooller et al., 2005)

The data size can be transformed to reflect a data range required for mapping to MIDI parameters. These require a value between 0-127, Controlling an effect like delay or reverb requires a value of 0-1. Other common transformations involve stochastic processes which can be used to "find basic patterns in a set of observed data" in order to provide "more coherent information about that data." (Wooller et al., 2005)

Wooller et al. (2005) outline three types of algorithmic approaches to the transforming of data for music mapping. They are analytic, transformational and generative algorithms. Learning algorithms are another important approach used to make sense of highly complex or noisy datasets. Fiebrink (2016) provides a detailed overview of how machine-learning

[6] Run-time Parameter Control

algorithms can be utilised in music systems as a creative tool. She explores how machine learning can be mapped to five musical goals that are relevant to many musical systems; recognise, map, track and discover new data representations, and collaborate. (Fiebrink, 2016)

The approach used to transform data will depend on the level of complexity of the data and how it is being used to control musical parameters.

6.6.2 Analysis – Music Information Retrieval and Semantic Audio

A control system can also analyse or process information such as audio and data. Music Information Retrieval (MIR), a subdomain of the Information Retrieval academic field, can be defined simplistically as a way to sort, analyse, retrieve and categorize music. New technologies and research are rapidly expanding this field as methods are developed to extract and analyse music in real-time. MIR is the backbone to many new music distribution methods, interactive music projects and digital music products.

Systems can predict styles of music that a user may like by querying "example songs, excerpts of recorded audio or even hummed melodies" (Lidy and Rauber, 2009). The field provides opportunities for real-time music feedback within a Dynamic Music composition. Music information retrieval includes many approaches for real-time audio analysis including feature-based mixing and composition.

MIR, semantic audio and other musical analysis methods are important areas of this research as they offer techniques and software to aid with advanced methods of Dynamic Music composition and production. For example a highly complex system could be developed combining musical or data analysis methods with learning algorithms to produce a music system that can continually compose new musical content or adapt and customise the music to the personal taste of the listener.

The analysis of audio and data doesn't need to be performed in real-time, which can include large processing requirements. Analysis of audio can also be included in the system design. Feature-based mixing utilises information based on the analysis of the sound material. The system can then be programmed to make design rules and tasks based on the analysis.

6.6.3 The Relationship Between Control and Process

In order to realise the musical design in Dynamic Music, the composer must decide:

1. what controls the way the music changes;
2. what controls the way the content or music is organised;
3. the level of control the user and/or system has to change the rendered playback.

Control in a dynamic system can include one or all options in any combination. This influences the processes used and vice versa. In Section 5.3.4 the processes used by experimental music composers in the mid 20th century are discussed. Many of these processes can be utilised in a Dynamic Music system including chance, people, electronic and context processes. Just like process in experimental music, process in a Dynamic Music system is a set of rules and instructions used to compose. Any type of process can be introduced into a dynamic system. The main types of processes are summarised below.

- **Interactive** – the user controls the interaction, the audio and/or visuals can be controlled in real-time by the direct actions of the user.
- **Adaptive** – mostly used in gaming and is defined as non-linear music. The music is composed to adapt and takes form to support the game-play and actions of the user.
- **Autonomous** – system-led music, works independently of direction. This could include, generative, AI compositions and systems.
- **Reactive** – context based on and reacting to data or the environment in which the data stream is constantly updated. For example driving a car controls the playback like in VW and Underworld's Play the Road (see section 3.1.8).
- **Responsive/Contextual** – adapts music to the user's environment or actions but not through direct actions where the user is in complete control and driving the interaction as in interactive music. Here the user's contextual data, for example location or weather, is used to influence the playback of the music.
- **Generative** – music is created by a system and is ever changing.
- **Algorithmic** – generating music using mathematical approaches including Markov chains, stochastic algorithms, automata and highly complex Fourier analysis
- **AI** – is an area of Algorithmic music, it uses learning, problem solving and or knowledge base algorithms to create music. This includes machine learning and deep learning algorithms.

These are essentially the main processes used in a Dynamic Music system. They can be used to design any part of the musical architecture including the music and sound content. Based on Nyman (2000) categories of process: chance determination; people; repetition; electronic; and context processes, the four controls in Dynamic Music are

- **User control** – the user can directly and indirectly control the rendered playback or other elements.
- **Machine Control** – an autonomous process controls the rendered playback. This includes a system, dataset and/or algorithms that have been developed to control the musical output.
- **Chance Control** – random processes control the rendered playback.
- **Contextual Control** – data controls the rendered playback. Data produced by a user interacting with the system would be classed as user control. Data control includes contextual data or another system which produces data, for example data sonification processes.

6.6.4 Mapping

Mapping is a term used in the computer music field to describe the process of using data to control musical parameters. Dynamic Music can be viewed as a multiplicity of mappings. The data that is mapped can be an event or process. Once the data has been classified and organised it can be mapped to control the musical architecture and/or content, thereby producing the rendered musical output.

Many scholars in computer music discuss mappings and music and have provided models and practices for data-based music mapping. (Bevilacqua et al., 2011; Drummond, 2009a; Hunt and Kirk, 2000; Wanderley and Depalle, 2004) Any data can be mapped in the following fours ways as described by Hunt and Kirk (2000); Wanderley and Depalle (2004) and summarised by Drummond (2009a).

1. One-to-one – an output is mapped to an input "for example a slider mapped to control the pitch of an oscillator" (Drummond, 2009a).
2. One-to-many – an output is mapped to more than one input "for example, a single gestural input can be made to control multiple synthesis parameters at the same time" (Drummond, 2009a).
3. Many-to-one – more than two outputs control a single input "for example a single synthesis parameter under the control of multiple inputs" (Drummond, 2009a).
4. Many-to-many – two or more outputs control more than one input.

Using interactive technologies such as gesture sensors and brain control interfaces involve mapping the data received to control music parameters. Drummond (2009a) explains that "Connecting gestures to processing and processing to response are the mappings of the system." Bevilacqua et al. (2011), discusses:

> "the increase in sophistication of new devices that allow gesture and movement to be translated into computer data holds great promise for interactive composition, dance, and creating responsive music in virtual reality systems. Data describing human motion can produce musically satisfying results by their impact on sound and musical processes." (Bevilacqua et al. 2011)

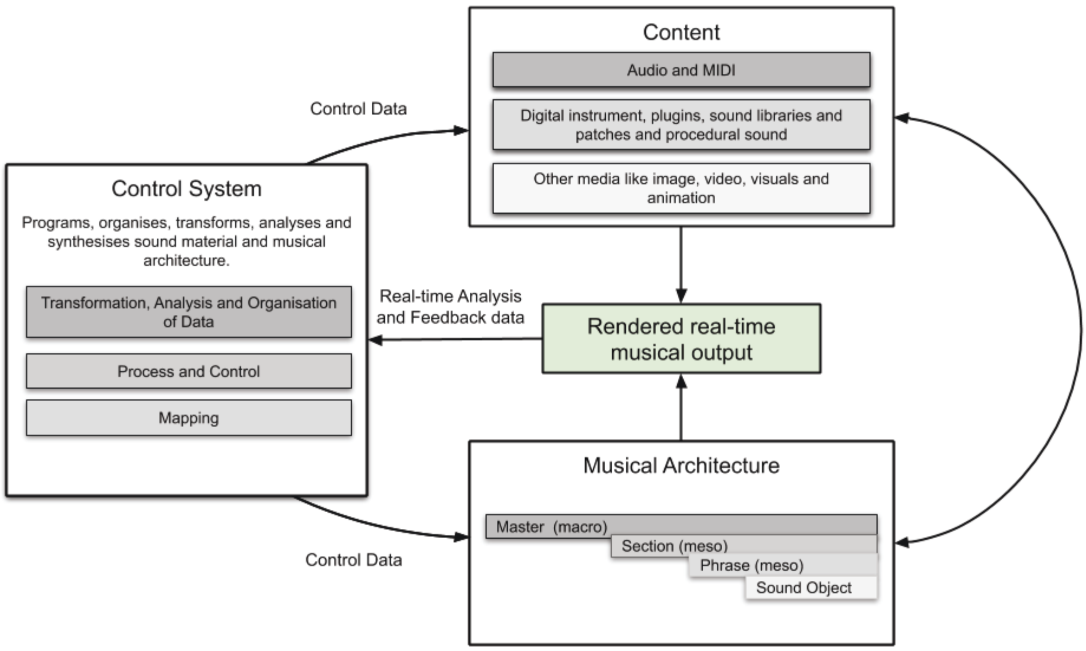
Mappings can be designed by the composer or the system depending on the process being used. Mapping data within a Dynamic Music system drives the music design. More information about mapping within the musical architecture and content is provided in Section 6.3.

6.6.5 Summary of the Control System

The control system is an essential part of Dynamic Music. Without it the music cannot be experienced. The control system, as shown in Figure 6.9, programs, organises, transforms, analyses and/or synthesises the content and musical architecture. The requirements of the control system will depend on the concept of the work, the content being used and the skills of the artist and collaborators. The control system receives data or uses autonomous data, then can transform and organise data, mapping it to musical parameters, processes and or attributes.

This process enables a control system to create and/or alter musical parameters and attributes at any hierarchical level of the music's architecture.

Figure 6.9: Musical Design of Dynamic Music - Control System



6.7 Summary of section A

Dynamic Music consists of four components; a control system, sound material, musical architecture and experience. The musical design of Dynamic Music requires the composition of a song system. This consists of a control system which changes, manipulates and organises the musical architecture and content to produce a rendered music output. Experience is implicit in all aspects of the musical design.

The control system transforms and classifies data. It then maps that data to musical parameters. The control system is designed based on the processes used to create, organise and transmute the music.

In order to show how the presented model for musical design works, a simple Dynamic Music system is used as a proof of concept, see Appendix E. This example is a Dynamic Music web application with a simple control system.

Given data controls musical processes, the form of Dynamic Music is not fixed in time. This can be achieved by designing a control system to change, create, manipulate and organise the musical architecture and content at any hierarchical level.

Section B

6.8 Factors Impacting on the Musical Design of a Dynamic Music Composition.

Section B discusses two key criteria: variability and transmutability. A Dynamic Music system will produce states of change in its rendered musical output through the design of variability and transmutability.

6.9 Variability and Variation

Dynamic Music is fluid; therefore some amount of musical variability will need to be composed so that each time the work is experienced, it changes. It is important to recognise the difference between variation and variability. Variation is an established music term that relates to changes to aspects of the structure or components of a work. As with other musical genres, musical variation is an important technique in the context of Dynamic Music. Variability, however, is the state of being variable, changeable, adaptable, flexible, fluid and or malleable. It applies to all components of a Dynamic Music system.

Variation in music occurs when some aspect of the original is altered to produce a change. There might be melodic variation, harmonic variation, rhythmic variation, for example. Variation is also a music form: examples of forms of variation are theme and variation, elaborations on a cantus firmus, or the Baroque passacaglia. Nelson (1948) outlines the principle of variation.

> "The technique of variation is conventionally thought of as embracing primarily the foregoing alterations or changes which may affect a theme." (Nelson, 1948)

Variation techniques could be changes in harmony, structure, rhythm, timbre, melody, figuration and expression. (Nelson, 1948) He claims that for true variation certain elements of the music must remain constant while others change. However, if all elements were to change and there was no relation to the original it would not be considered variation but contrast. (Nelson, 1948)

Variability hence is a measurement of a Dynamic Music system's fluidity or adaptability. A work with a high degree of variability will sound different for every listening. While variation specifically comes under the architecture and the musical parameters that are manipulated, variability relates to all aspects of the Dynamic Music system. Variability can be composed in the musical architecture, music and sound content, or within a control system.

Collins (2008a) outlines 10 compositional approaches to variability in game music in her 2009 book Game Sound. These approaches are discussed with respect to the hierarchical levels of musical architecture.

1. Variable tempo
2. Variable pitch
3. Variable rhythm/meter
4. Variable volume/dynamics
5. Variable DSP/timbres
6. Variable melodies (algorithmic generation)
7. Variable harmony (chordal arrangements, key or mode)
8. Variable mixing
9. Variable form (open form)
10. Variable form (branching parameter-based music)

Collins discusses how Dynamic Music presents many challenges to the composer including "having to introduce considerable variability into the music." She highlights that the use of variability in game audio "ensures that a composition gets a longer 'shelf life' and can be more responsive to the player and to the narrative/image." (Collins, 2008a)

By creating variability in Dynamic Music beyond gaming, the work will produce a better experience for the audience and result in more variation in the rendered musical output. The design of processes is required for Dynamic Music to change over time with data.

6.9.1 Designing Variability in a Dynamic Music System

> "Processes throw up momentary configurations which have no sooner happened than they are past: the experimental composer is interested not in the uniqueness of permanence but in the uniqueness of the moment." (Nyman, 2000)

The rendered musical output of Dynamic Music represents a moment in time as highlighted by Nyman's quote above. This moment in time is an instance of all the possible combinations that the processes within a Dynamic Music system can offer. For this reason, the rendered musical output is an instance of a Dynamic Music composition's overall form. This creates a contradiction to traditional concepts of a fixed form. As discussed in Chapter 5, a Dynamic Music system becomes the process which results in many instances of form.

Each instance of form or the rendered musical output produced by a Dynamic Music system has a duration and can hence be perceived as static by the listener for that moment. The listener can only hear the resulting rendered musical output that they are experiencing and/or interacting with. It is for this reason that Dynamic Music has a direct relationship to experience.

Dynamic Music offers an extended experience in two ways: using feedback so the listener understands that the music can change; or by the variability of the music each time it is played back.

Some Dynamic Music systems force the listener to become active as in the case of Ninja Jamm. Others demand no interaction from the listener, such as Brian Eno's generative app Reflections. In Dynamic Music systems that do not involve user interaction, it is the variability of playback in the music that provides a new experience for the listener. The music is always unique and unfolding, it does not represent any other moment in time other than the now.

Evaluating feedback in Dynamic Music requires a user study on how audiences might perceive and understand the work. However, in the early stages of development it is possible to evaluate experience on the amount of variability the musical output can provide on playback.

Creating variability in the experience of a Dynamic Music System involves extending the variability of the music each time it is played back. This can be achieved by creating variability in the musical architecture and content and then controlling that variability using the control system.

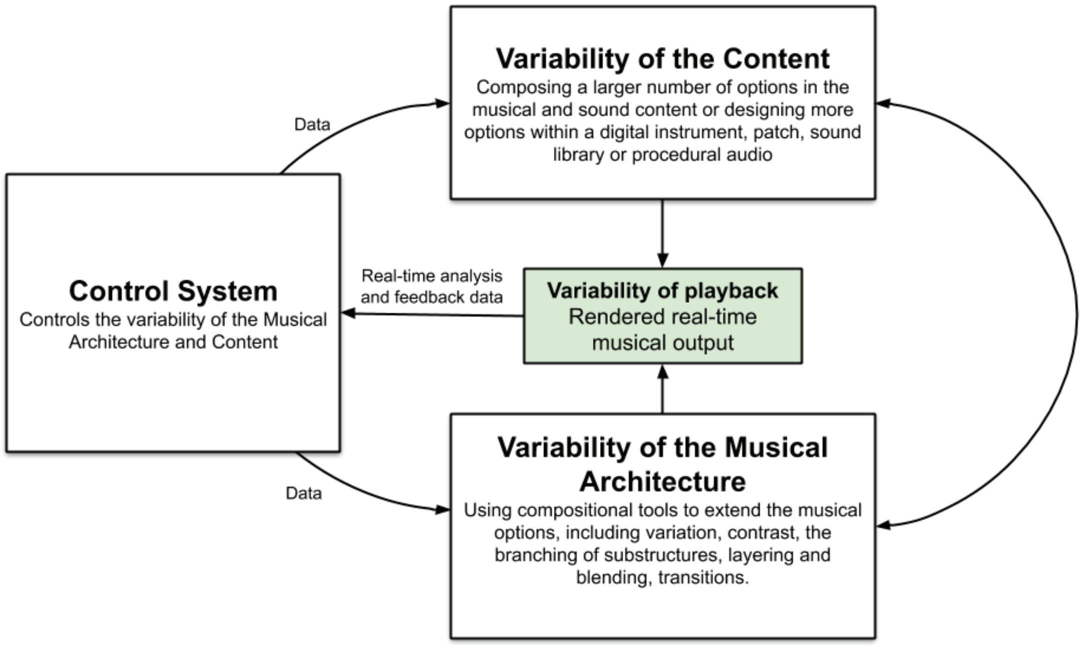
- **Variability in the Musical Architecture** – Using compositional tools to extend the musical options, including variation, contrast, the branching of substructures, layering and blending, transitions.
- **Variability in the Content** – Composing a larger number of options in the musical and sound content or designing more options within a digital instrument, patch, sound library or procedural audio.
- **Variability in within the Control System** – The control system is designed to control the variability options designed in the content and musical architecture.

Figure 6.10 outlines the relationship between the components of Dynamic Music and the design of variability. Variability designed within the content and musical architecture is controlled by the control system to produce the resulting variability of the rendered musical output.

There are limitless compositional tools and approaches for designing variability in the musical architecture of Dynamic Music systems. Approaches to variability can range from the simple to the extremely complex.

Simple variability might consist of variability in the tempo, pitch, volume, or DSP. Variability in the mix of a work can also generate a great deal of variability. Options could include changing the depth of field or spatialisation of the instrumentation, changing the volume of layered tracks or instruments, adding dynamics, or compression, EQ, audio and MIDI effects like delay, reverb, overdrive, filters, modulation etc. Other parameter mapping techniques might include creating options for randomizing the parameters for pitch, structure, tempo and rhythm.

Figure 6.10: Variability within the Musical Design Model for Dynamic Music System



Using MIDI or programming languages [7] can create versatile approaches to variability. MIDI scores, patches and programs can be designed from micro to macro "including tempo shifts, harmonic adaptation, and instrumental rearrangement." (Sweet, 2015) They can also be layered and organised into a formal structure. MIDI and programming also often produce less demand on a system's processing power and memory.

More complex variability includes the use of:

> "algorithms for altering melodies or harmonies, songs structured in layering, 'accumulative form' approaches, variable sequences in open form, or a branching, conditionalized open form." (Collins, 2008a)

Manipulating melodies can include the following options: transposing; re-harmonising; inversion; retrograde; permutation; rhythmic displacement; truncation; expansion; rhythmic alteration; thinning; ornamentation; re-harmonisation and chord mapping. (Sweet, 2015)

The complexity of variability design increases when composing from the bottom up. A song's formal structure can be changed by data mappings controlling the way sub-structures are organised. This includes branching, cross-fading and transitions. The branching of sub-structures in game audio is referred to as horizontal sequencing.

[7] Programming languages include; Java, Python, Chuck, Musimat etc and object orientated programing languages like Pd and Max

> “Horizontal resequencing is a method of interactive composition where the music is dynamically pieced together based on the actions of the player." (Sweet, 2015)

Music is cued to play at an event, for example as a character enters a new space, a new musical sequence is cued to play. In relation to popular music form it may be that a cue is used to trigger a different section of the song for example a chorus or verse or a different version of a chorus or verse.

Changes in formal structure and branching content options can be designed to increase the amount of variability. This includes creating more options for the permutations and the amount of sections and composing variations of those sections. An example is provided of possible content design for branching song sections below. Take a simple AB song structure. The branching song structure options are:

1. ABAB
2. AABA
3. BABA
4. BBAA
5. ...

To increase variability, six variations of musical material are composed for sections A and B as shown below:

- A1, A2, A3, A4, A5, A6
- B1, B2, B3, B4, B5, B6

When combining the section permutation with variation the following outcomes could be rendered. The line numbers below correspond with the line numbers above.

1. A2B3A1B6
2. A5A2B5A1
3. B3A2B1A1
4. B2B2A2A2
5. ...

Overall, there are 20,736 possible playback options, demonstrating a wide range of variability at the form level. This example outlines how designing a simple branching structure with variation can produce a large amount of different rendered output options.

When designing a branching or evolving structure, transitions are important to ensure the music sections and phrases transition smoothly upon playback. This could involve a number of approaches including but not limited to cross fading, transitional parts (for a key or tempo change), a melodic cadence to resolve a melody or introduce a new part and/or skip one or more beats to bring in a new rhythmic section.

The composer will need to compose or program transitions within the musical design. This can be composed within the sound material or within the control system.

Audio middleware software provides excellent transition tools for composers. The most common type of transition is cross-fading; which can be synchronised or unsynchronised to a tempo map. For example, the composer can choose whether the next segment will play immediately or at the next beat or bar. The composer can also select the length of the crossfade for the segment at its end and start. This works well when music segments are similar and will work well together, however, if the segments are too different musically a transitional cue may be needed to join the two segments.

> "This transitional cue can be any length but generally works better if the cue is longer (10 or more seconds), allowing for a better bridge between the two pieces." (Sweet, 2015)

If the compositional design relies on a melodic phase completing before a new segment is introduced, Sweet (2015) recommends 'Branching Scores' where "one musical cue ends, and another begins without using any crossfades." He notes that branching scores work best with shorter segments under 10 seconds and therefore may not work as well with classical style compositions, whereas popular music styles may be a better fit for this technique. (Sweet, 2015)

Layering music is an important part of organising music.

> "Layering is one of the most fundamental means of organising music. For layering to be perceived, each layer must be distinguishable. This is achieved mainly though timbre, differentiation, register allocation and distinctive rhythmic patterns. Other approaches use loudness or the overlaying of identifiable sound shapes." (Vella, 2000)

Combining sounds whether they are melodic, harmonic, rhythmical or noise is an essential compositional technique. The method of layering sounds and building texture is also an effective way to transform and create variability in Dynamic Music. Using simple volume changes on layered tracks and scores can help create emotive content, dynamics and variability of instrumentation.

Instrumentation refers to the choice or selection of instruments within an arrangement. Creating variability can consist in transmuting the timbre of the instrument or changing instruments. For example, a horn part could be replaced by a string part. This transmutation directly affects the sound object level of the work.

The layering of musical parts is referred to as 'vertical' changes in game audio. "Vertical remixing is an interactive composition technique in which layers of music are added or taken away to create levels of intensity and emotion." (Sweet, 2015)

The blending of different parts can also help change the feel of the work. Blending can be understood as the opposite of layering.

> "Blending or fusion is a precarious balance of forces where individual instrument sounds lose their 'identifiability' and when unexpected, striking or otherwise memorable fused sound is in the perpetual foreground." (Erickson, 1975)

> "Layering is like using colours to distinguish one thing from another (for example , using different coloured labels for identifications) whereas blending is like mixing colours to make something new." (Vella, 2000)

Creating a layered approach that can blend when a group of tracks are played together as well as produce interesting layered effects when combined with other parts. This can also be used to create dynamics within the music.

Variability can be created by composing a large amount of material and compositional tools or by using limited material and tools and adding variability to them. Variability in this way can be achieved in a Dynamic Music system through the design of transmutability.

6.10 Transmutability

Transmutability refers to the design of the control system within a Dynamic Music system and how the data received or produced by the system can control and change the music. Transmutability is a measurement of how much control data is required to change the music form.

In discussions about creatively using digital data, transmutability is a growing area. Lee and Ribas acknowledge "the multiplicity of transmutability as a creative concept and practice." (Lee and Ribas) They use the term transmutability as a concept or principle which "relies on the mapping of any input data stream into sounds and images." (Lee and Ribas)

Experimental audio-visual artist Golan Levin identifies that "A significant theme in many audio-visual software artworks is the transmutability of digital data, as expressed by the mapping of some input data stream into sound and graphics. For these works, the premise that any information can be algorithmically sonified or visualized is the starting point for a conceptual transformation and/or aesthetic experience. Such projects may or may not reveal the origin of their input data in an obvious way, and indeed, the actual source of the transformed data may not even matter." (Levin, 2009)

In relation to Levin's quote Lee and Ribas comment that, "the notion appears associated to other concepts that similarly express the inherent mutability of digital data or the potential of mapping any (digitized) physical or sensory phenomenon into new tangible forms. (Lee and Ribas)

Lee and Ribas also discuss the term transmateriality which sees "digital media and computation as material flows (...) transducing anything to anything else" by "sourcing new inputs and/or manifesting new outputs"(Whitelaw, 2008): cited in (Lee and Ribas)

"Therefore, we can say that artefacts that explore this inherent mutability of digital data creatively question the "nature of our now ubiquitous data systems" by making data "explicit" and tangible, while probing its "potential, and significance" (Whitelaw, 2008): cited in

(Lee and Ribas) In this process, different approaches and methods for reconfiguring data may be involved, following mainly analytical or aesthetic purposes." (Lee and Ribas, 2016)

These processes can provide a "new reading or understanding of information" and/ or explore data to "create expressive languages or sensory experiences" (Lee and Ribas). In cultural production discourse, transmutability was coined by Hughes and Lang in 2006. They defined transmutability as "the technical capability to easily change cultural content products that are encoded as digital data" (Hughes and Lang, 2006). As discussed in Section 1.4, changes and demands in the way audiences consume music and cultural products have led to the concept of transmutability. Hughes and Lang provide an important theoretical framework for digital cultural products and transmutability based on the following two tenets:

1. Consumer led digital transmutations; unbundling, re-bundling, portability and distribution, personalization and edit/re-editing.

2. Producer led digital transmutations are classified as re-contextualization, extension, recombination / remixing / sampling.

Web 2.0 and new digital production tools have enabled consumer and producers' roles to merge resulting in more demand for consumers to access producer-led transmutations. (Hughes and Lang, 2006). This has resulted in the gap between consumer and producer becoming increasingly blurred. (Bruns, 2009) This phenomenon has become central to the music industry's approaches to working within the digital domain where the composer can also be the producer.

This framework can be extended into a post-digital environment for cultural products reliant on interactive technologies. Another extension includes the ever-increasing amount of digital data that can be used in processes of music composition.

The thesis qualifies a new transmutation as a data-led digital transmutation. **This new transmutation is classified as a data-controlled process that alters and or creates a music form.** Data can be transformed into music and sound or be used to control and alter existing sound and musical material being used in the system.

6.10.1 Designing Transmutability in a Dynamic Music System

Designing transmutability may include experimenting with data inputs to explore meaningful musical and sound outputs. It can also be used to investigate how data can represent sound and music in a particular context and the development of control systems to support these processes.

A Dynamic Music system is designed-based and dependent on the artist's creative concept and the processes used. These processes will be based on whether the design involves direct or indirect action, human input or autonomous data made by a machine interaction.

As discussed in Section 6.4, the data being used for the architecture within the Dynamic Music system is an essential ingredient in designing transmutability. It is can be discrete, continuous or a complex or simple dataset. Large datasets will need a system designed based on how the data needs to be interpreted. This control system may be custom built for the work, a software environment or may exist as a predefined system. These factors will influence the design of transmutability in the system. Other design factors include:

- the type of data used and how it needs to be transformed;
- the type and use of musical and data analysis within the system;
- the variability options contained in the content and musical architecture; and
- the processes and level of control that the data has in the system.

A control system which has a simple transmutability design might consist of a simple dataset transformation that can be mapped onto simple variability parameters, (for example, mixing parameters). Complex transmutability design would comprise a system that can make decisions, analysis data or audio and/or involve some kind of learning algorithm. A complex transmutability design would include system produced music and sound content. Data can control and create processes including procedural audio and MIDI such as algorithmic, generative or AI. It can also involve the analysis and extraction of existing content to be recontextualised into new material.

Designing the ways data can organise music and sound content into substructures can be controlled by the user, machine or by a set of instructions or rules. The complexity of this process will depend on the system and musical design.

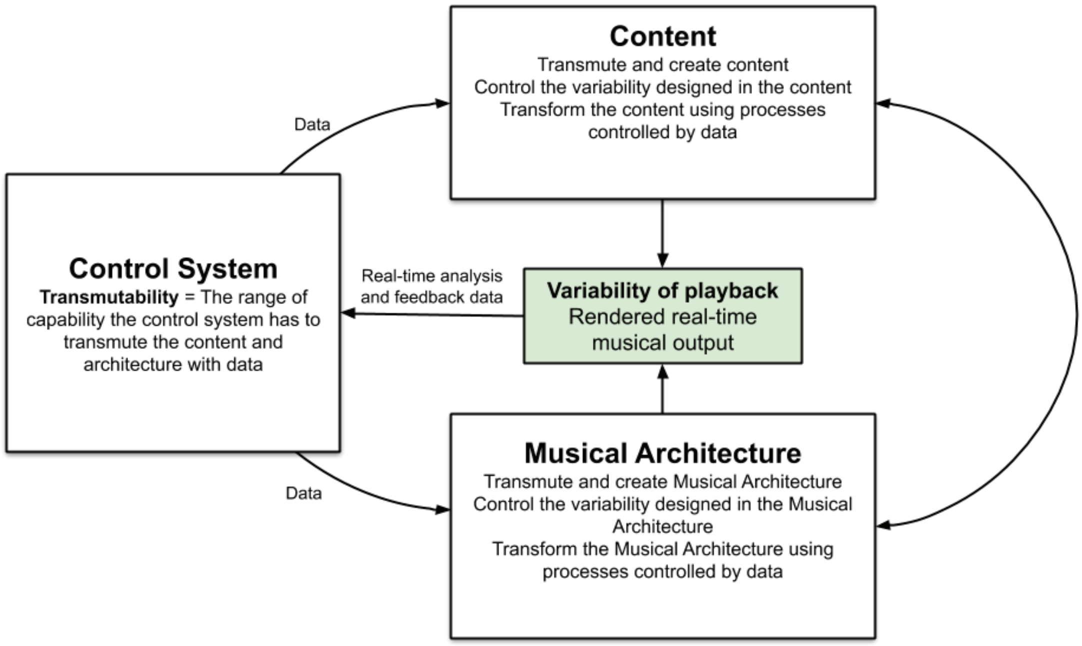
Creating transmutability requires the design of how the data is mapped within the system to produce a rendered musical output. Data can control and create the musical architecture at any hierarchical level. This includes direct, indirect and autonomous data and the way it has been mapped within the musical architecture of the Dynamic Music system.

Creating transmutability in a Dynamic Music system results in extending the variability of the music each time it is played back.

- **Transmutability within the Control System** – The amount and level of control the processes designed within the control system have on the work's form.
- **Transmuting the Musical Architecture** – Data can control the variability designed in the musical architecture and transform and create the structure and form using processes.
- **Transmuting the Content** – Data can control the variability designed in the content and transform and create the content using processes.

As shown in Figure 6.11, transmutability is the range of capability the control system has to transmute and create content and musical architecture. Transmutability can result in variability of musical playback through mapping data to control musical parameters; creating musical or sound content; or by transforming the existing material and recontextualising it through some kind of data-led process.

Figure 6.11: Transmutability within the musical design model for Dynamic Music System



6.11 Summary of Section B

Dynamic Music is music that can change and adapt to data. In order to create an experience beyond a static form, the music needs to provide many different playback options. Variability and Transmutability are two important factors in the design of Dynamic Music.

- **Variability** refers to the options created for the music to be changeable through the musical and sound content and musical architecture of a Dynamic Music system.
- **Transmutability** refers to the range of capability of the control system's use of data to transmute and create content and musical architecture, and how the data received or produced by the system can control and change the music within a Dynamic Music system.

To create variability in the playback of the rendered musical output both variability and transmutability need to be designed across all components of a Dynamic Music system.

There are an unlimited number of compositional tools to create variability in music. These approaches can also be part of the transmutability if data is mapped to the parameter or some process which can control the musical variability.

Both are creative concepts which include the design of compositional tools. Variability is concerned with providing options in the musical architecture, for example composing more content or processes. Transmutability is the process of transforming data into musical and sound outputs. This consists of developing a control system whereby data can be mapped to musical processes and parameters. These two concepts are discussed further in Chapter 7 and are used as a framework to provide a means to evaluate Dynamic Music as a fluid form in comparison to static forms of music.

Chapter 7

Methodology Part 3: Evaluating Dynamic Music

7.1 Practising Researcher Evaluation

The evaluation of a music work is not an easy process due to taste and perception. However one can evaluate the process, creation and experience of a work. Evaluating music works that are based on interactive technologies present even more challenges given their complexity in development and design. However, practising researcher evaluation has been used to support emerging forms of interactive art and music interaction (Candy and Ferguson, 2014; Holland et al., 2013a), whereby the user experience and system can be evaluated in order to develop the work and overall experience. There is an evolving body of work in this area even if not all Dynamic Music products involve the audience actively engaging in the work.

The music itself is generally not evaluated, only the system, user experience, usability and user perception. The proposed framework discussed in this chapter specifically addresses the musical design and how the system supports the work.

Holland et al. (2013a), discuss the interdisciplinarity of Music Interaction.

> "Music Interaction encompasses the design, refinement, evaluation, analysis and use of interactive systems that involve computer technology for any kind of musical activity, and in particular, scientific research on any aspect of this topic." (Holland et al., 2013b)

They state that Music Interaction "typically involves collaboration between researchers, interaction designers and musicians, with individuals often able to play more than one of these roles." (Holland et al., 2013a) Given the many roles required to create Dynamic Music works, it common for individuals to have more than one role.

A complex evaluation method needs to be developed for each role and stage of the design process. O'Modhrain (2011), provides a framework to evaluate Digital Music Instruments (DMI), which bears some similarities with the context of Dynamic Music products.

O'Modhrain (2011), builds on Human-Computer Interaction (HCI) methodologies to offer a role-based evaluation framework, see Figure 7.1. This framework could be adapted to

Figure 7.1: Evaluation Framework for Digital Music Instruments reprinted from (O'Modhrain, 2011)

	Possible Evaluation Goals			
Stakeholder	*Enjoyment*	*Playability*	*Robustness*	*Achievement of Design Specifications*
Audience	critique, reflection, questionnaires, observational studies	experiments concerning mental models		
Performer/ Composer	reflective practice, development of repertoire, long-term engagement (longitudinal study?)	quantitative methods for evaluation of user interface, mapping, etc.	quantitative methods for hardware/ software testing	
Designer	observation, questionnaire, Informal feedback	quantitative methods for user interface evaluation		use cases, feedback regarding stakeholder satisfaction
Manufacturer	market surveys, sales	sales, consumer feedback	quantitative methods for hardware/ software testing, consumer feedback	market penetration (performers, consumers), sales, consumer feedback

work for Dynamic Music works. Given that a Dynamic Music work is a musical work and not just an instrument, the performer and composer evaluation presented could be changed. She describes the DMI evaluation framework as "an attempt to provide some conceptual scaffolding within which both the interests of stakeholders in the design process and possible goals of evaluation might coexist. The goal is to provide a means for those involved in DMI design to understand how these different perspectives contribute to the creation of the final product - an instrument that engages both performer and audience alike." (O'Modhrain, 2011). Roles within the development of Dynamic Music works and products similarly have multiple interests and goals.

In order to develop a good experience for the listener or user, employing methodologies from Music Interaction and HCI is vital. Specifically, Music Interaction which "may be viewed as a sub-discipline of Human-Computer Interaction, just as Human-Computer Interaction may be viewed as a sub-discipline of Computer Science (or just as Computer Science was once viewed as a sub-discipline of Electrical Engineering)." (Holland et al., 2013b) Holland et al. (2013b) discuss that although elements of HCI are the basis of Music Interaction, the actual practice is part of the music community. "After all, what good is an interactive musical system if it is unsatisfactory for musical purposes?" (Holland et al., 2013b) Music Interaction therefore presents challenges, new ideas and new techniques for HCI.

Evaluation methodologies developed in the Music Interaction and DMI fields could be integrated into the development of dynamic products and works to ensure they reach their potential to engage the listener the way they were designed to. McDermott et al. (2013), claim that, "The interfaces used in evolutionary and generative music can be made more effective and more satisfying to use with the influence of the ideas, methods, and findings of human-computer interaction and usability studies." (McDermott et al., 2013) The proposed evaluation framework presented throughout this chapter builds on this important work by presenting a set of practice-based criteria from the perspective of composers and producers working within the Dynamic Music field. As discussed throughout this thesis, it is the creation of the music which requires a change in form and understanding. Therefore, the criteria are an evaluation of the practice which underpins this foundation. It is not an evaluation of how playful a work is but an evaluation of the music form and its design.

The importance of practitioner evaluation is highlighted in the book Interactive Experience in the Digital Age - Evaluating New Art Practice (Candy and Ferguson, 2014), which presents a series of works in which artists and researchers use evaluation for their development of interactive art "and, in doing, so establish a new agenda for art and technology research." (Candy and Ferguson, 2014) The book claims the boundaries of HCI and the digital arts are crossed, moved or removed as interdisciplinary collaborations develop "new forms of interactive art systems and new frameworks and methods for evaluation." (Candy and Ferguson, 2014)

These new frameworks and methods for evaluation are necessary due to HCI and product design generally only taking in account user preferences or experiences and not the impact on creative practice. [Candy,2014] These evaluations push the boundaries of creativity while contributing to "a greater understanding of the nature of interactive experience." (Candy and Ferguson, 2014) "The digital artist in particular is concerned with the affective power of interaction rather than the more utilitarian concerns of interaction designers making products that support tasks in the work place and home." (Candy and Ferguson, 2014)

7.2 Evaluating Dynamic Music

Given the interdisciplinary nature of Dynamic Music the criteria are presented using grounded theory and practicing researcher evaluation. This methodology has been used to support emerging forms of interactive art and music interaction. (Candy and Ferguson, 2014; Holland et al., 2013a)

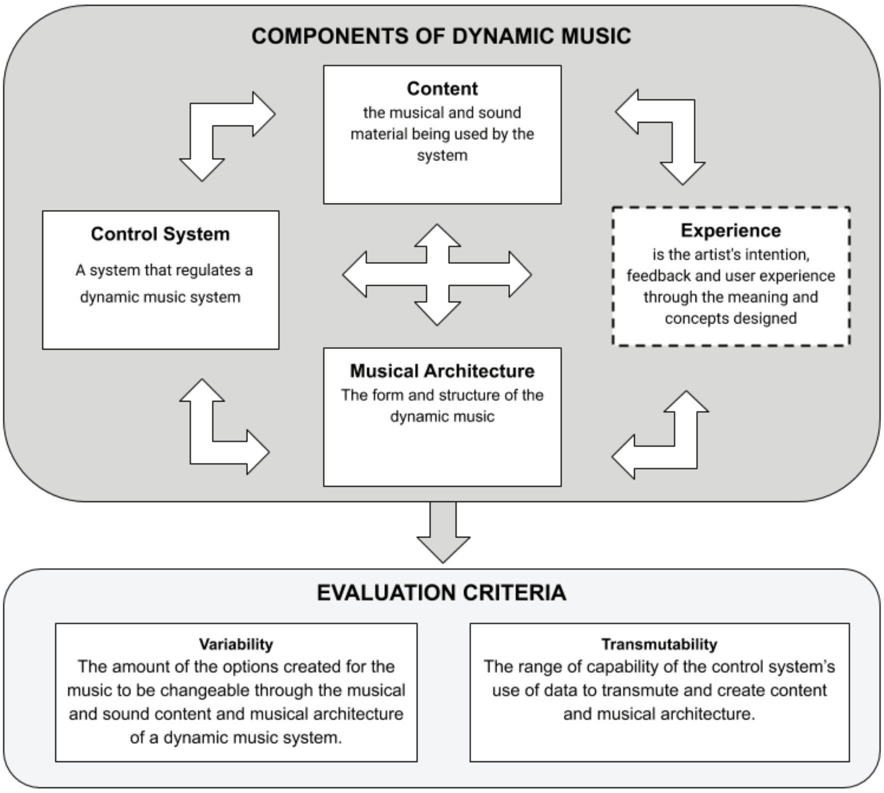
In order to create Dynamic Music that extends the listening experience offered by static music, it must be composed to contain transmutability and variability as part of its architecture and design

Chapter 6 outlined the main components of a model for the musical design of Dynamic Music. The model is based on the following criteria which are discussed throughout the chapter.

The schematic for the musical design of Dynamic Music shown in figure 7.2 involves the composition of a control system, content, experience and musical architecture. Chapter 6 concluded with two definitions that can underpin the evaluation of a Dynamic Music system: transmutability and variability. For the creative process of composing and producing a Dynamic Music system, they are defined as:

- **Variability** refers to the options created for the music to be changeable through the musical and sound content and musical architecture of a Dynamic Music system. The compositional tools used by the composer to create variability.

Figure 7.2: Framework for Dynamic Music Design leading to Evaluation Criteria.



- **Transmutability** refers to the range of capability of the control system's use of data to transmute and create content and musical architecture. The design of the control system within a Dynamic Music system and how the data received or produced by the system can control and change the music.

These criteria provide a solid foundation that stretches beyond popular music's standard approaches to forms.

The evaluation criteria as shown in Figure 7.2 have been developed retrospectively in combination with the contextual review of works discussed in Chapters 3 and 4; the methodology presented in Chapters 5 and 6; and the creative works outlined in Chapter 8. The creative works were conducted to explore approaches in composing and producing Dynamic Music. A range of Dynamic Music approaches were investigated including interactive, adaptive, reactive, contextual, algorithmic and AI processes.

These criteria provide a means for evaluating Dynamic Music as a changing music form in comparison with static forms of music. The criteria include sub criteria, which are summarised below.

Sub Criteria of Variability
1.1 Variability in the musical architecture and content.
1.2 Variability of the resulting form or rendered musical output.

Sub Criteria Transmutability
2.1 The amount of control the transmutability has on the musical architecture.
2.2 The level of control the transmutability has on the musical architecture.
2.3 The design of the control system in relation to control and process.

The sub criteria evaluate the level of complexity in the design of variability and transmutability. As discussed in Chapter 6, variability (Section 6.8) and transmutability (Section 6.9) can be simple, compound and complex in design. These levels are represented by a number value of 1 to 3. If the system doesn't include variability and/or transmutability it is labelled NA and has a value of 0. The levels of complexity consist of the following types:

- NA [value =0]
- Simple [value =1]
- Compound [value =2]
- Complex [value =3]

The levels of complexity for variability and transmutability are evaluated as per the sub criteria are described in the next section.

7.3 The Two Criteria: Variability and Transmutability

As Dynamic Music works are so varied in approach, design, structure and delivery, the criteria are qualitatively measured. All Dynamic Music works will include these criteria to some degree.

7.3.1 Criterion 1 Variability

Criterion 1 refers to the design of variability in the musical architecture and its relationship to time. Dynamic Music is fluid. Therefore, some amount of musical variability will need to be composed so that the musical output changes each time it is experienced. Criterion 1 evaluates the variability of the musical output and the compositional tools used to create that output.

Variability is a measurement of how changeable or fluid the music may be. Criterion 1 relates to the music and sound material (content) and musical architecture within the musical design model for a Dynamic Music system, whereas criterion 2 (transmutability) relates to the control system.

In order to produce variability in the resulting form, variability must be part of the musical design of a Dynamic Music system. There are four components of a Dynamic Music system: sound material, musical architecture, control system and experience. Experience is implicit in the design of the sound material and musical architecture.

In order to produce variability in the resulting form, variability must also be part of the musical design of a Dynamic Music system. Hence variability is evaluated on two levels;

1. Variability in the musical architecture and content
2. Variability of the resulting form or rendered musical output

7.3.2 Sub Criterion 1 - Variability in the Musical Architecture and Content

Sub criterion 1 is evaluated by the compositional tools used by the composer in the musical architecture. Section 6.9.1 discusses in detail the compositional tools to increase variability in the sound material and sub-structure levels. This may result in more sound content and/or processes used to create more variation of existing or new content.

Collins (2008a) discusses how Dynamic Music presents many challenges to the composer including “having to introduce considerable variability into the music.” She discusses that variability may be simple with changes in tempo, pitch, volume, or DSP, or more complex, such as the use of “algorithms for altering melodies or harmonies, songs structured in layering, ‘accumulative form’ approaches, variable sequences in open form, or a branching, conditionalized open form.” (Collins, 2008a)

To increase variability within a Dynamic Music system the options would be to extend the amount of variation in the content and musical architecture. Extending content includes composing options within the work through audio; MIDI; digital music instruments; patch; sound library; plugin; and/or procedural sound/music.

There are a variety of techniques a composer or producer can undertake to further extend a work. Compositional tools and processes can be used to design variability at any hierarchical level. These can include non-linear processes such as branching structures; layering instrumentation; digital instruments designed to offer a variety timbre options; algorithms; generative systems; AI; composing variation of sub-structures; any of the tools discussed throughout Section 6.8.

Variability can be designed at the sound object level to create changes in timbre, pitch, duration etc (see Section 6.4.3). Depending on the form of the content used in the system, it can then be organised intro sub-structures of the musical architecture (see Section 6.4.2). Designing variability within the structure or meso structure to form sections is considered a medium level (compound level) complexity in the design of Dynamic Music. An example of a complex level of variability would be an AI based Dynamic Music system which is able to continually produce new forms of variability in a work.

An important aspect of designing variability is to include musical surprises, obvious musical changes, theme transformations and other tools which may add to the experience. However, although these are an important aspect of designing Dynamic Music, they are difficult to evaluate without user experience evaluation given they relate to perceptions that are out of scope of this research.

- **NA** - The sound material or processes are fixed in form and have been composed for a static medium (master audio file) [value = 0]
- **Simple** - Limited variability, limited changes to sound, music content and/or mixing parameters. [value = 1]

- **Compound** - The content and musical architecture are composed to include variability within the substructure levels (variation in the instrumentation, harmonic, motif, section or phrase structure) [value = 2]
- **Complex** - unlimited variability or everchanging content and/or processes composed for the system. Content is composed to offer a complex level of variability within the sound material and substructures. [value = 3]

7.3.3 Sub Criteria 2 - Variability of the Resulting Form or Musical Output.

This is evaluated by the level of variation the rendered musical output offers each time it is experienced.

Dynamic Music is designed to create unique musical experiences. Depending on the musical design the rendered musical output will change each time the work is played through, i.e. the music always sounds different on playback. The musical output or resulting form may be limited in the number of ways it can be heard or it could provide endless new experiences. It should be noted here that the increasing the changing contexts produced doesn't necessarily equal a better work, that is an aesthetic judgement. It depends on the experience the work is aiming to provide.

In order to evaluate the variability of the musical output, the following criteria can be used.

- **NA** - the musical output is static, it is same on each playback [value = 0]
- **Simple** - the variability is minimal, the structure is the same, musical parameters are preserved, changes are so limited that the output sounds similar each time it is experienced [value = 1]
- **Compound** - some musical attributes are recognisable on each playback - the structure is changed, or some part are changing at relevant hierarchical levels. [value = 2]
- **Complex** - maximum variability - the outcome sounds like a new output, everything is changing contrast [value = 3]

7.3.4 Criterion 2 Transmutability

Criterion 2 refers to the data led digital transmutations afforded by the control system. Data led digital transmutations are classified as data-controlled processes that change and transform a music form. Data is received and/or produced by the control system within a Dynamic Music system. Transmutability is a measurement of how much control the data has to change the music form. It is evaluated by the amount of transmutability offered by a control system and the system's relationship to process.

The processes used by a Dynamic Music system will affect the design of the control system. For example, an interactive approach will require users' actions to be mapped to a reaction in the musical design. An adaptive process will require the music to change to support game play. A generative process will require a system to be produced to generate sound material and organise it into a musical architecture. All processes require a set of rules or instructions as to how data is designed to transmute and, in some cases, create the music architecture.

The processes used by the dynamic system inform the type of data received or produced by the system; how that data is required to be transformed and classified to create a new workable dataset; and how that data is mapped to transmute the musical architecture. Section 6.5 and 6.6 define a model for how a control system can transmute the musical architecture across the shape, state and structure at each hierarchical level. The decision of what processes are used in a Dynamic Music system are part of the overall artistic concept and intent of the work. Hence, it is possible to only evaluate how the control system works and not why it was designed in a particular way. The transmutability of a control system is evaluated by the system's ability to transform the musical architecture, no matter what process it uses to receive and produce data.

To increase the transmutability of a control system the following could be extended:

- processes and types of processes;
- interaction options;
- data sets;
- mapping design;
- reclassification or transformation of the data.

Criterion 2 can be separated into three sub-criteria given the complexity of approaches that a Dynamic Music system can offer:

1. The level of control the control system has on the musical architecture;
2. The amount of control the control system has on the musical architecture;
3. The design of the control system in relation to control and process.

7.3.5 Sub Criterion 2.1 The Level of Control the Transmutability has on the Musical Architecture

Data can control parameters and processes at any hierarchical level of the musical architecture.

A Dynamic Music control system can create, organise and/or transmute music and sound material at any hierarchical level (see Section 5.3.3 and 6.5) depending on the design, including the

- macro level - master level;
- meso level - sub-structures - section and phrase;
- sound object level and below.

If a control system can transmute and/or organise the musical parameters at the macro level the system design will be classified as simple. At the sound object level, the system will require a higher level of complexity but only if the resulting substructures can also be transmuted. The control of mixing parameters is often the simplest for the design of a Dynamic Music system, whereas the control of substructures into sections requires more complexity. If the transmutability is designed to control all and any of the hierarchal levels of the musical architecture, it will be considered complex. The levels of complexity for criteria 2.1 are;

- **NA** - No control of the musical architecture. [value = 0]
- **Simple** - Control only one level of parametric control to transmute the macro level or only simple transmutability including mixing variability. [value = 1]
- **Compound** - Control of two or more levels of parametric control to transmute substructures. [value = 2]
- **Complex** - Control all levels of parametric to transmute the sound object, micro levels and below. [value = 3]
-

7.3.6 Sub Criterion 2.2 The Amount of Control the Transmutability has on the Musical Architecture

Designing the mapping of data to musical parameters requires decisions to be made about the type and number of parameters it can control. If the control system can transmute unlimited musical parameters, it can be considered as a highly complex system. The levels of complexity in the amount of control data can have on the musical architecture consist of the following.

- **NA** - Transmutability of 0 parameter [value = 0]
- **Simple** - Transmutability of 1 parameter [value = 1]
- **Compound** - Transmutability more than 1 parameter [value = 2]
- **Complex** - Transmutability of any parameters [value = 3]

7.3.7 Sub Criterion 2.3 The Design of the Control System in Relation to Control and Process

The third sub-criterion evaluates how complex the system is in the way it transforms and analyses data. The control system may use real-time audio analysis, AI based algorithms or simple algorithmic methods. If a system can make its own decisions through some kind of learning algorithm it is considered a highly complex system. Sub criteria 2.3 is evaluated by the complexity of the control system in relation to process. The levels of complexity include;

- **NA** - The control system doesn't receive or produce data. [value = 0]
- **Simple** - The control system is designed to produce and receive data and to transform and map data to musical parameters of precomposed sound material. [value = 1]
- **Compound** - The control system is also designed to create and reorganise sound material through some kind of process. [value = 2]
- **Complex** - The control system is designed to make decisions or create sound material via musical analysis techniques and/or learning algorithms. [value = 3]

7.4 Relationship between Variability and Transmutability

With the goal of Dynamic Music being to create music that changes, it can be evaluated by the variability in its resultant form or rendered musical output. Variability and transmutability work together to produce this resultant form. The design of transmutability and variability are interdependent within a Dynamic Music system. The design of variability offers more design options for transmutability and vice versa.

Transmutability Options

Transmutability can be designed to produce variability in the resultant form by using data to

1. Control the variability designed in the content and musical architecture
2. Transform and/or create the content and the musical architecture using processes.

Variability Options

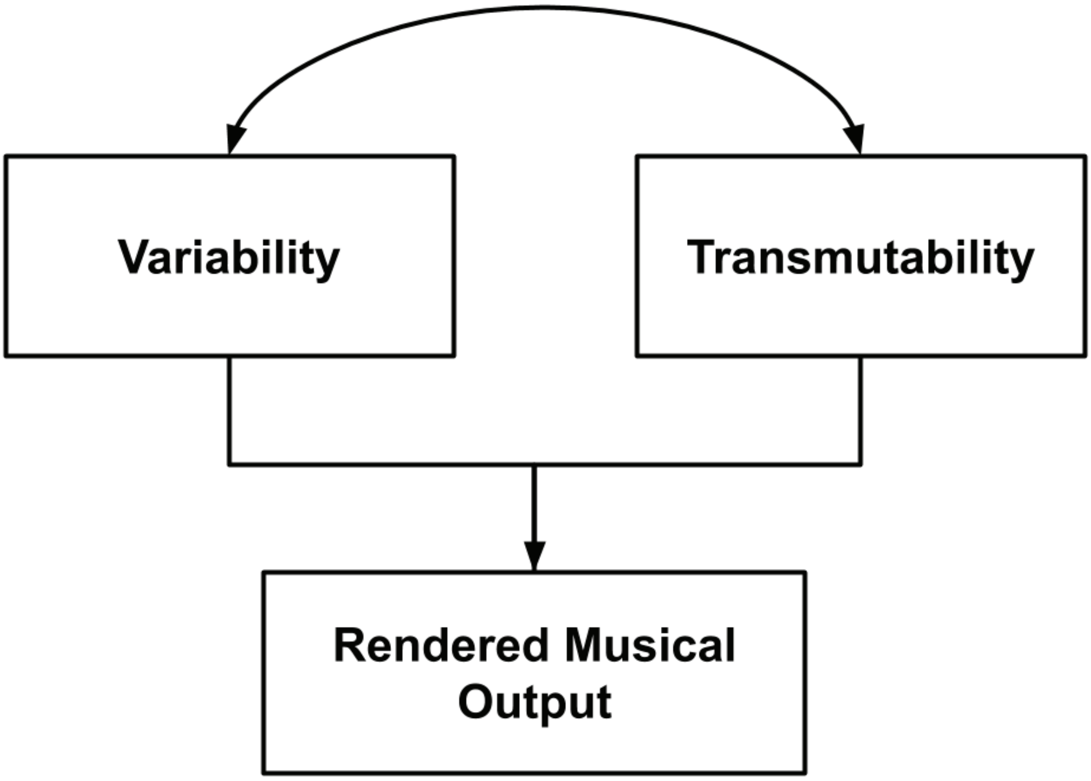
Variability in the resultant form can be designed using two processes

1. Using compositional tools to extend the musical options, including variation, contrast, the branching of substructures, layering and blending, and transitions.
2. Composing a larger number of options in the musical and sound content or designing more options within a digital instrument, patch, sound library or procedural audio.

The interdependency of variability and transmutability to produce a resultant form is shown in Figure 7.3. Without transmutability the variability cannot be experienced. Without variability the control system has nothing to transmute and the work remains static.

Variability composed in the content and musical architecture is controlled by the control system. The amount of variability composed in the system will directly influence the musical parameters that can be mapped to data. Parameters can be controlled across any hierarchical structures contained in the work.

Figure 7.3: The Interdependent Relationship Between Variability and Transmutability.



7.5 The Framework for the Evaluation of Dynamic Music

An evaluation framework has been developed in order to investigate Dynamic Music approaches, processes and forms. Dynamic Music works will be evaluated by the following format.

1. The concept - An overview of the work is discussed along with its goals, objectives and approach.
2. Compositional model - Based on the criteria and sub criteria, a compositional model will be presented for each work which shows the musical design and the relationships between the control system, content and musical architecture.
3. Criteria evaluation - An evaluation is conducted and discussed using qualitative analysis in relation to the three criteria outlined.
4. Summation - A summary of the evaluation

7.5.1 Evaluation Table

The evaluation table is used to summarise the level of complexity of the variability and transmutability in a work's musical design.

Sections 7.7 and 7.8 demonstrate the evaluation framework applied to Radiohead's *A Moon Shaped Pool* (7.7) and *Quarta* by Brett J Gilbert and Peter Chilvers (7.8).

Evaluation of Dynamic Music				
Level of complexity: NA=0, Simple =1, Compound=2, Complex=3	**0**	**1**	**2**	**3**
Sub-Criteria 1.1 Variability in the musical architecture and content				
A brief justification of the level of complexity				
Sub-Criteria 1.2 Variability of the resulting form or rendered musical output				
A brief justification of the level of complexity				
Sub-Criteria 2.1 The amount of control the transmutability has on the musical architecture				
A brief justification of the level of complexity				
Sub-Criteria 2.2 The level of control the transmutability has on the musical architecture				
A brief justification of the level of complexity				
Sub-Criteria 2.3 The design of the control system in relation to control and process				
A brief justification of the level of complexity				

Table 7.1: Evaluation Criteria Table

7.6 Evaluation of Radiohead's A Moon Shaped Pool

A Moon Shaped Pool is an album released by Radiohead. Musically the album is rich in layering and can be experienced many times to discover nuances and layers within the recording. The album is evaluated to highlight an instance of a fixed form album. The choice of artist and album is irrelevant to this evaluation. Any such album format is expected to result in the same evaluation.

7.6.1 Criterion 1 Variability

Sub Criterion 1.1 - variability in the musical design

The work is fixed in form and has been composed for a static medium (master audio file).

Variability in the musical architecture and content	0

Sub Criteria 1.2 - Variability of the Resulting Form or Musical Output.

The processes used in the composition of the work do not transmute the resulting music form. The album could be remixed and recontexualised to work within some kind of Dynamic Music work. However, at this time the composition is fixed and will not work as Dynamic Music. The musical output is static: it is same on each playback.

Variability of the resulting form or musical output	0

7.6.2 Criterion 2 Transmutability

There is no parametric control, only consumer-led transmutability with stop, play and volume controls. Data cannot transmute the musical architecture. The user can only transmute the fixed playback including consumer-led digital transmutations and producer-led digital transmutations. In its current form and musical design no data-led digital transmutations are possible The control system doesn't receive or produce data.

The amount of control the transmutability has on the musical architecture	0
The level of control the transmutability has on the musical architecture	0
The design of the control system in relation to control and process	0

7.6.3 Summation

Evaluation of Radiohead's A Moon Shaped Pool				
Level of complexity: NA=0, Simple =1, Compound=2, Complex=3	**0**	**1**	**2**	**3**
Sub-Criteria 1.1 Variability in the musical architecture and content				
The work is fixed in form and has been composed for a static medium (master audio file)	0			
Sub-Criteria 1.2 Variability of the resulting form or rendered musical output				
The musical output is static: it is same on each playback	0			
Sub-Criteria 2.1 The amount of control the transmutability has on the musical architecture				
No parametric control, only consumer led transmutability with stop, play and volume control	0			
Sub-Criteria 2.2 The level of control the transmutability has on the musical architecture				
Data led transmutability of 0 musical parameters	0			
Sub-Criteria 2.3 The design of the control system in relation to control and process				
There is no control system or interactivity	0			

Table 7.2: Summary Table - Evaluation of Radiohead's A Moon Shaped Pool

This work is not considered Dynamic Music. As shown in the summary table there is no variability and transmutability of its musical design.

7.7 Evaluation of Quarta - Hybrid Game with Generative Soundtrack

The app is a hybrid game with a generative soundtrack developed by game designer Brett J. Gilbert and musician, software designer and *Bloom* co-creator Peter Chilvers. The game involves playing against an AI-based computer player that learns as you play against it, or a multi-player game. This game was chosen to provide an example of a generative music system which is situated in a hybrid context.

7.7.1 Criterion 1 Variability

Sub Criterion 1 - Variability in the Musical Design

There is limited variability in the sound and music content. There are, however, only two instrument sounds.

Variability in the musical architecture and content	1

Sub Criteria 2 - Variability of the Resulting Form or Musical Output.

The composition involves piano notes with an ambient string drone backing. The piano has reverb with a depth to it. It builds and falls and uses spatialization. Although the work is generative and amorphous, its variability is subtle. It starts to sound very similar with some common melodic patterns appearing occasionally between the lower and higher registers. The musical playback is dynamic and produces changing contexts, however its limited change in timbre and orchestration mean the work sounds fairly similar despite this.

The variability is minimal. Many musical parameters are preserved; changes are limited that the output sounds similar each time it is experienced.

Variability of the resulting form or rendered musical output	1

7.7.2 Criterion 2 Transmutability

Without access to the inner workings of the control system of this app, it would appear based on the musical output that data is transmuting the sound material through a generative system. Data can control of two or more levels and parameters. The control system is also designed to create and reorganise sound material through a generative music process. The control system has a compound [value 2] complexity level.

The amount of control the transmutability has on the musical architecture	2
The level of control the transmutability has on the musical architecture	2
The design of the control system in relation to control and process	2

7.7.3 Summation

Evaluation of Quarta				
Level of complexity: NA=0, Simple =1, Compound=2, Complex=3	**0**	**1**	**2**	**3**
Sub-Criteria 1.1 Variability in the Musical Architecture and Content				
There is limited variability in the sound and music content. There are only two instrument sounds		1		
Sub-Criteria 1.2 Variability of the resulting form or rendered musical output				
The variability is minimal many musical parameters are preserved		1		
Sub-Criteria 2.1 The amount of control the transmutability has on the musical architecture				
Control of two or more levels of parametric to transmute (substructures)			2	
Sub-Criteria 2.2 The level of control the transmutability has on the musical architecture				
Data led transmutability on more than one musical parameter			2	
Sub-Criteria 2.3 The design of the control system in relation to control and process				
The control system is designed to create and reorganise sound material through a generative process			2	

Table 7.3: Summary Table - Evaluation of Quarta

The control system is more complex than the variability level in the content and musical architecture. For this work to increase the variability of its resultant form, it would need to introduce more variability to its musical architecture and sound and musical material.

To conclude, this chapter provides an evaluative framework for the design of Dynamic Music based on the criteria of variability and trasmutability. Chapter 8 applies the evaluation framework to a portfolio of creative works which were composed by myself or in collaboration.

Chapter 8

Proof of concept: Creative Work

Three creative works are presented in Chapter 8 to demonstrate the robustness of the framework developed in Chapters 5, 6 and 7. Chapter 5 provided definitions for the field of Dynamic Music and discussed form, structure, process and time in Dynamic Music. The rationale for the research methodology outlined in Chapters 6 and 7 can be located within recent discourses in practice-led research (PLR) in which research findings are demonstrated in the creative work; and research-led practice (RLP) where existing research informs the creative work output (Smith and Dean, 2009). Based on existing literature, Chapter 6 presented a framework for musical design and an overview of the four components of Dynamic Music. Informed by my own creative works and the review of works in Chapters 3 and 4, Chapter 7 introduced a set of criteria to evaluate the key concepts and approaches of Dynamic Music. Chapter 8 discusses, analyses and evaluates the three creative experiments with respect to Chapter 7's evaluation framework. The creative work in this thesis demonstrates both PLR and RLP. **Due to the research methodology being informed by RLP and PLR, the combination of creative work and exegesis is 40 - 45% for the creative work and 55 -60% for the exegesis.**

Each creative work is presented using the format presented in Chapter 7. All works and relevant media discussed throughout the chapter can be viewed within the Appendices media folder. The folder is organised as per the appendix listings.

1. The Concept – An overview of the work is discussed along with its goals, objectives and approach.
2. Compositional Model – Based on the criteria a compositional model will be presented for each work which shows the musical design and the relationships between the control system, sound material and musical architecture.
3. Criteria Evaluation – An evaluation is conducted and discussed using qualitative analysis in relation to the three criteria outlined in Chapter 7.
4. Summation – A summary of the evaluation

As discussed in Chapter 7, the criteria used to evaluate Dynamic Music is based on two terms, variability and transmutability.

- **Variability** refers to the options created for the music to be changeable through the musical and sound content and musical architecture of a Dynamic Music system. The compositional tools used by the composer to create variability.
- **Transmutability** refers to the range of capability of the control system's use of data to transmute and create content and musical architecture. The design of the control system within a Dynamic Music system and how the data received or produced by the system can control and change the music.

The three creative experiments are;

- The Madness of Crowds (2016)
- Gestural-based Interactive Re-mixable Dance-floor (GIRD) (2015)
- Semantic Machine (2018)

All of the works discussed in Chapter 8 involved collaborations with other artists. In each of the projects I[1] did the majority of the composition of music or system design. Each creative experiment focused on a different type of Dynamic Music approach to highlight how the conceptual and evaluative framework can be applied across different types of Dynamic Music systems.

The Madness of Crowds[2] and Semantic Machine[3] involved collaborations with artists who developed the control system for the work. These collaborations enabled me to focus more on the compositional aspects of the work. With the GIRD project I developed the Dynamic Musical control system[4].

8.1 Madness of Crowds - 2016

`https://www.youtube.com/watch?v=RJ6dXnJz6sg`

The Madness of Crowds was a collaborative performance involving technology mediated interaction and improvisation. The performance took place on 9/9/2016 between 10pm-10:30pm, Salon Stage POSTCITY at the Ars Electronica Festival in 2016. `https://ars.electronica.art/radicalatoms/en/the-madness-of-crowds/` The performance was a collaboration between myself, Hakan Lidbo (SWE), Synthestruct (US) and Trevor Brown (AU). I produced the performance and also worked in the roles of composer and performer.

The event was an experiment in using a Dynamic Music system within a performance context. The overall concept of the work included the world's largest MIDI controllers, giant cubes that the audience could interact with. These consisted of three giant cubes as shown in Figure 8.1. Two performers improvised on stage to the music being produced via the audience interaction.

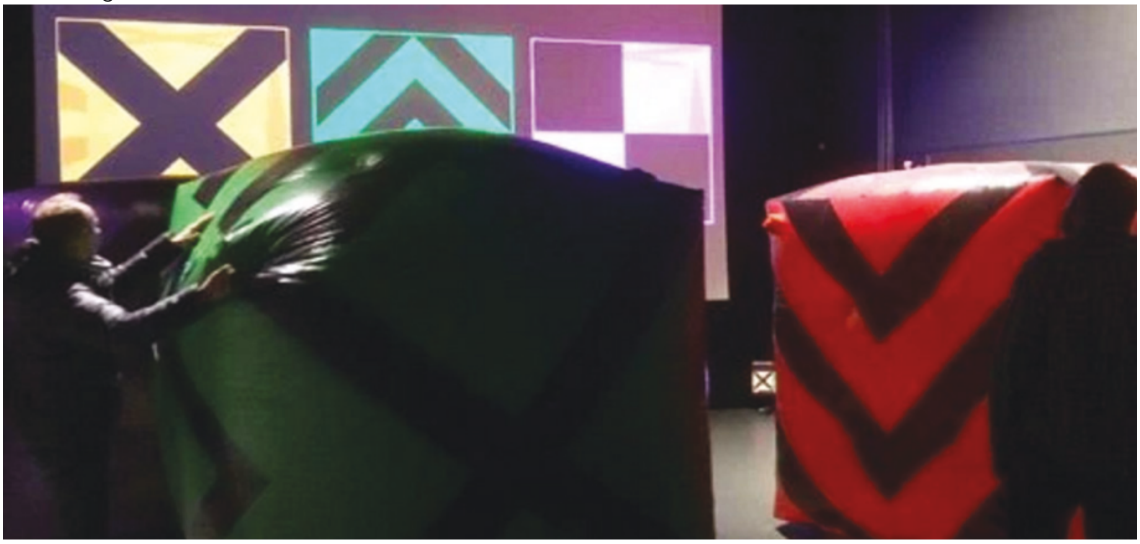
[1]As Chapter 8 discusses my creative works, I have chosen to write in the first person.

[2]The control system used in the madness of crowds, the World's Largest MIDI Controller, was developed by Hakan Libdo and Per Olov Jernberg.

[3]The control system for the Semantic Machine was the semantic player, developed by Florian Thalmann as part of the FAST(Fusing Audio and Semantic Technologies for Intelligent Music Production and Consumption)

[4]Collaborator Jonathan Rutherford worked on the control system for the lighting element of the work

Figure 8.1: World's Largest MIDI Controllers (Cubes) designed by Hakan Libdo and Per Olov Jernberg



The giant cubes were developed by Hakan Libdo and Per Olov Jernberg. By changing the side of each cube, the audience could control a set of loops. Each cube was a different colour and represented a different instrument type: drums, bass or melodic instrument. Each side of the cube had a unique pattern. When the audience changed the side of the cube a new loop was triggered. The loops were matched with a pattern and a side of each cube. The patterns playing a loop of all three cubes were also projected onto a screen to help the audience learn the pattern matching each sound produced. It was the artists' intention that the audience learn to play the cubes as an instrument.

The ability to change to another side of the cube meant that the performance included a high amount of audience interaction. The audience were responsible for selecting the loops for the tracks being performed. Trevor Brown (saxophone, live sound processing) and I (vocals, mixing) performed live, improvising with the audience's musical choices.

The 30-minute performance consisted of five different songs that I had composed. The cubes included sensors that sent information to an Ableton live set via Bluetooth which controlled the musical playback. A short video of performance excerpts can be viewed here `https://youtu.be/4NNCbmQeW8Y` and is also located in Appendix A. More detail into how the work was produced is provided in the next section, including an overview of the musical design.

8.1.1 Compositional Model

Content (Music and Sound Material)

There were five songs used in the performance. Each song consisted of 18 instrumental audio segments or loops. Figure 8.3 schematises the hierarchy of the music's design. The loops were separated into three groups representing the three cubes: drums; bass; and melody. Each group contained six loops. Only one loop per cube could be played at any one time, meaning only three loops could be played at any one time. There were no vocal loops due to live improvised vocals.

Three of the five works were composed and produced by myself. The final two were composed and produced in collaboration with producer/song writer Sofie Loizou. Trevor Brown and I performed live improvising with the sound produced.

Two Works (numbers 3 and 5) were a recontextualization of Rochelle Salt's[5] 'Downbeat Linz' (song 3, Appendix A-3) and 'Going Round Again' (song 5, Appendix A-4). The two works, composed by myself and Sofie Loizou, were recontextualised by creating loops from the song stems and composing extra drum and bass loops.

The other three works were composed by myself specifically for the performance. The process involved creating a large set of loops. These loops were experimented with, tweaked, and improved upon in Ableton live to ensure the work gave some surprising sounds. They offered multiple layers of experience depending on the order the loops were selected in.

All five works can be viewed in Appendix A-1 Madness of Crowds Ableton file, shown in Figure 8.2. Each work is organised as a different scene in Ableton live. Please refer to the Read Me document (Appendix A-2) for instructions on how to use the Ableton file. The loops contained in the Ableton file are also provided in separate folders. The five folders contain 18 loops for each track. They can be located in Appendix A-5 to A-9.

Figure 8.2: Madness of Crowds Ableton File - Image shows how the loops are organised and represents each cube

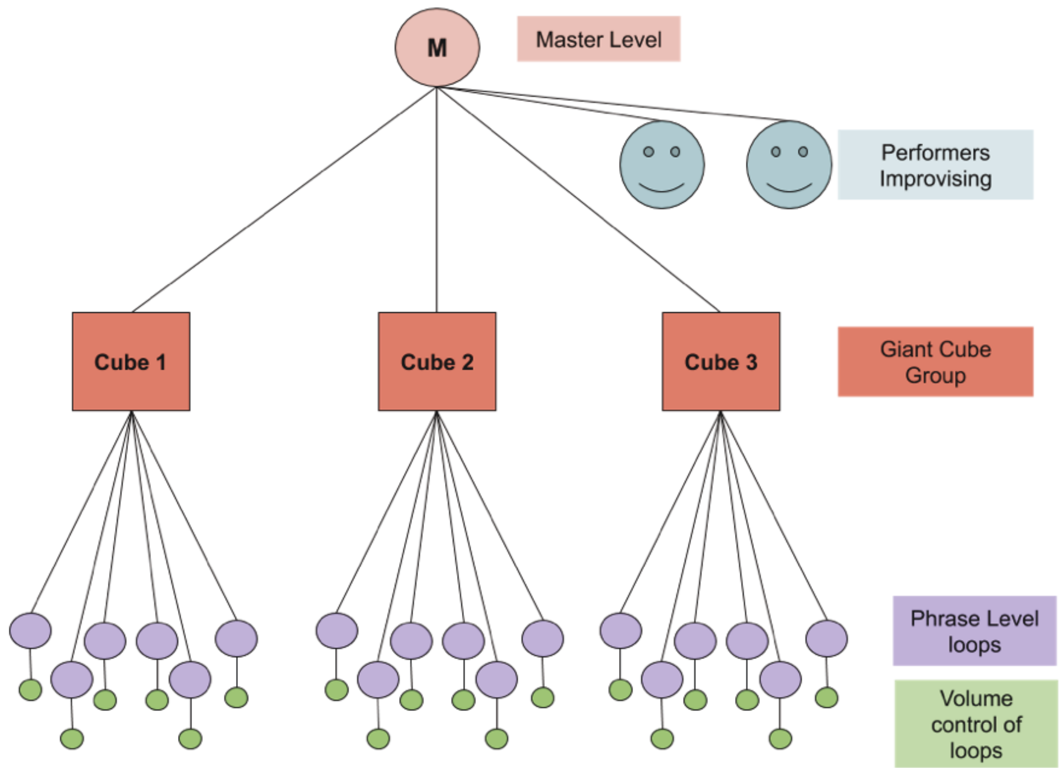
Musical Architecture

All the works were composed or recontextualised into an open form. As shown in Figure 8.3 there were no set rules, structure or duration designed as part of the musical architecture. This, in combination with the performers' improvisations, resulted in a work that continually

[5]Rochelle Salt is a band made up of myself and Sofie Loizou

changes and develops each time it is performed. The improvisers' skills provide variability, structure and consistency to the music selected by the audience.

Figure 8.3: Musical Architecture and Content Used



Control System

The control system was designed by Lidbo and Jernberg. The project used three Texas Instrument Sensor Tags. The Sensor Tag works by sending data via Bluetooth to a laptop computer. Each sensor provided data as to which side of the cube was on top. This data was mapped to Ableton via the MIDI mapping section.

The data from each cube was mapped to the volume parameter of six tracks. Each cube has six sides and each side is assigned to a track in Ableton. For example; side 1 = track 1 volume, side 2 = track 2 volume and so on. As the cube is turned, if the side on top is side 1, the volume of track 1 will be increased to 0 dB. All other 5 tracks will be on -inf dB. The three cubes combined can control a total of 18 tracks' volume.

Each of the three cubes has six dedicated loops resulting with 18 (6 X 3) loops. Each loop is assigned a track. Figure 8.2 shows all 18 tracks. It is only when the volume is increased that a loop can be heard. This allows for the transition of loops to be crossfaded as the cubes are moved. I pressed play in Ableton to begin. The control system can only adjust the volumes of the 18 tracks. Before the start of each new work, it was also necessary to manually adjust the tempo.

Process

The processes used in this performance were interactive. A new sound was heard when the audience moved a cube.

Experience

The works are designed to provide simple and obvious audio and visual feedback. As soon as the cube changes to another side, the two loops are crossfaded instantly. There is also visual feedback projected onto a large screen showing the current side of the cube. Designed by Lidbo this is represented by a shape so that users learn to associate a shape with a sound. This allows the user to learn the system and then play with its possibilities.

The musical design of the work did not accommodate how the audience chose to interact with the giant cubes in this performance. At other events that showcased the giant cubes, the audience interacted thoughtfully by changing sides of the cubes to transform the music. At this performance, however, the audience excitedly threw the cubes around the room. This resulted in a completely unexpected musical output. The energy was chaotic. This was exacerbated by the quick and sudden changes in the loops as the cubes spun mid-air, resulting in chaotic musical output.

Due to the unexpected behaviour of audience interaction, the performance resulted in more possibilities for the audience experience than originally conceived. The improvised performance by myself and Trevor Brown also added to the new experiences for the audience. These musical experiences by myself and Trevor Brown enabled us to bring back some control of the musical structure to the musical output.

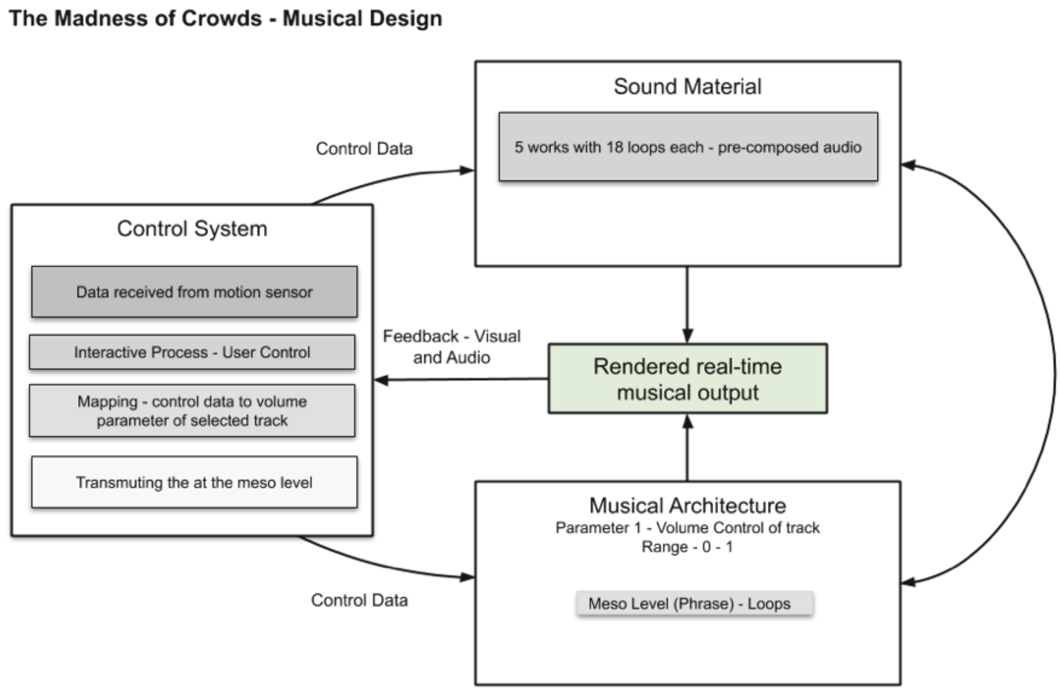
Observation

One of the outcomes highlighted by this performance was audience culture. Technology mediated performances are a new and emerging field. Audiences may not be aware of how to behave within this new context. Other types of performances have a firmly established audience culture. At a classical music concert, the audience will sit and listen. Socially, they may be shunned if they stood up danced and sang along. This audience culture has been firmly developed.

Given that one of the Ars Electronica's main focus areas has been interactive media since the late 1970s, the audience at this event potentially would have been familiar with types of interactive performances. Instructions were presented on how to engage with the work. Given it was 10pm at night there many people drinking and wanting to let loose. Many wanted to play with the cubes, throw them around and try to break things, while others made a concerted effort to try and use the cubes to create music. It would be a valuable experience to produce a number of performances to see how the audience may react in different contexts.

Figure 8.4 provides a summary of the musical design model for the project.

Figure 8.4: Model of Musical Design for the Madness of Crowds Performance



8.1.2 Criterion 1 Variability

This work includes variability in three ways:

- the musical design of the Dynamic Music system;
- the improvised performance by myself and Trevor Brown
- audience interaction.

This results in the work having unlimited variability depending on the improviser's performance and the energy and participation of the audience.

Sub Criterion 1.2 – Variability in the musical design

The music content was composed to include variability within the meso level (the phrase level). The phrases are short audio segments referred to as loops. The loops can be looped for any amount of time and changed at any time. By changing the loops, the audience could feasibly create new sections resulting in everchanging song structures. Variability occurred in the following ways:

- The audience was able to decide on the duration of each phrase and create their own personalized sections and resulting song structure;

- The loop combinations offered variability given the way the instrument loops were layered together. There were three instruments each of which had six loop possibilities;
- The loops were not randomly composed and organised together. Each loop was composed specifically to create variability and to potentially lead to new musical sections including breakdowns, builds and hooks;
- The loops were composed so that they could be used in any combination;
- The loops could be used to create movement and direction through the development of song structures.

The loops were designed without the end goal of being a structured work. Instead, a set of loops could offer variability within an overall style or musical theme. it was hoped this design could offer the options of linear continuation, builds and breakdowns in its playback.

Another level of variability was offered by the fact that not all loops were the same bar length. As all the loops were playing throughout each work, the way the loops sounded on playback would change. This resulted in the variation of rhythmic and melodic possibilities as the loops played out of phase with each other.

Variability in the musical architecture and content	2

Sub Criterion 1.2 – Variability of the resulting form or musical output.

The structure of this work is completely flexible from the phrase level upwards. It offers a very large number of possibilities for each playback. Given the performance involves improvisation by myself and Trevor Brown, another level of variability is added. However, the playback of each work is not everchanging. It is limited to three of 18 loops being played back in some kind of order. Also, the tempo and the key do not change with each playback. It is also assumed that the improvisations will be adding to the existing style and theme of each work.

In reality this performance resulted in a very non-linear musical output given the loops were constantly changing. The loops often didn't get the opportunity to play through a whole 4 to 12 bars. The only repetition came from the improvising performers trying to maintain some continuity in the music, even if this wasn't the composer's intent in the musical design. The musical output depended on whether the audience was aware or not of the control they had over the musical output. Many just wanted to throw some giant cubes into the air.

The musical output was unique each time the work is performed. Some of the musical attributes were recognisable on each playback.

Variability of the resulting form or rendered musical output	2

The variability design as part of this Dynamic Music system would be considered compound in complexity. Variability can be found in the design of the sound material and on multiple levels of the musical architecture. These factors contribute to the amount of variability in the rendered musical output.

8.1.3 Criteria 2 Transmutability

The work is transmuted at the meso level via loops. The audience can also decide on the duration of each loop and the combination of the three loops. Therefore, the audience has control over the structure and layering of the work. The system can only control the volume parameter of each track. However, the way the system is used by the audience also increases its transmutability options, pushing the system beyond its design.

An unplanned transmutability occurred as a result of the audience interacting with the cubes. The work was designed to have three loops playing together, one drum, one bass and one melody. However, when the audience threw a cube or held it up on its side, a cross-fade between two loops was heard at a medium volume. This resulted in the possibility of two drum, two bass and two melodic loops being heard at one time.

Sub Criterion 2.1 - The amount of control the transmutability has on the musical architecture

The system can only transmute the volume of the loops at the meso level. However, given the user can create higher structures using it would be considered a compound system in complexity.

The amount of control the transmutability has on the musical architecture	2

Sub Criterion 2.2 - The level of control the transmutability has on the musical architecture

The system can only transmute one parameter, the volume of each loop. Therefore. the control system would be considered simple in the amount of control it offers.

The level of control the transmutability has on the musical architecture	1

Sub Criterion 2.3 - The design of the control system in relation to control and process

The control system is designed to receive data and map it to musical parameters of precomposed sound material. Therefore, the control system is considered simple in its relation to control and process.

The design of the control system in relation to control and process	1

8.1.4 Summation

The Madness of Crowds performance offers a compound level of sophistication in its design of variability in the musical design and a simple level of transmutability within its control system. The Dynamic Music system used in this performance, therefore, focuses on variability in its musical design and audience interaction to offer new experiences.

This is an example of when user experience is required to be part of an evaluation. It is important to test how users will interact with a Dynamic Music system. A user experience

Evaluation of Evaluation of Madness of Crowds				
Level of complexity: NA=0, Simple =1, Compound=2, Complex=3	**0**	**1**	**2**	**3**
Sub-Criteria 1.1 Variability in the musical architecture and content				
The music content was composed to include variability within the meso level (the phrase level).			2	
Sub-Criteria 1.2 Variability of the resulting form or rendered musical output				
Some of the musical attributes are recognisable on each playback.			2	
Sub-Criteria 2.1 The amount of control the transmutability has on the musical architecture				
The user can create sub-structures..			2	
Sub-Criteria 2.2 The level of control the transmutability has on the musical architecture				
The system can only transmute one parameter		1		
Sub-Criteria 2.3 The design of the control system in relation to control and process				
The control system is designed to receive a simple data set mapped to musical parameters.		1		

Table 8.1: Summary Table - Evaluation of Madness of Crowds

evaluation is out of scope of this thesis. However, this example highlights its importance as part of the design of Dynamic Music systems which are based on user interaction.

8.2 GIRD – RiOT Sensor – Max For Live Patch - 2015

https://www.youtube.com/watch?v=g7YYoXM2kBU

GIRD (Gestural-based Interactive Re-mixable Dance-floor) is a gesture-based interactive audio and lighting system that allows audiences to remix, explore and interact with music and lights through dancing and gestures. The project began in September 2015 when collaborator Jonathan Rutherford (Ars Electronica Future Lab) and I participated in a Hackathon at the Music Tech Fest in Ljubljana. Our idea was chosen for a three-month incubation as part of the European Commission funded Music Bricks prize.

A prototype was produced as a result of the incubation. It consists of: two gloves, each containing IRCAM's riot sensor as shown in Figure 8.5; two Max for Live plugins as shown in Figure 8.15 and 8.19; and a lighting system which included a Fade Candy [6] running a processing sketch to control five neo-pixel LED light strips. This evaluation will focus on the musical aspect of this project which is the Max for Live plugin developed by the researcher.

Data received by the riot sensor was classified, organised and transformed using a series of Max matches. A Max for Live plugin was then used to map gestural actions to audio, digital instruments, effects and any available parameters within Ableton Live.

I developed the Max for Live plugins to explore how complex data sets produced by the RiOT sensor could control music. Hence, this project was an experiment to explore how data can be used as part of the composition of music.

The outcome produced two Max for Live plugins;

- GIRD - provided in Appendix B-4
- GIRD Synth - provided in Appendix B-3

Each plugin is described in detail during this evaluation.

[6] Fade Candy is an Arduino based micro-controller developed for driving LEDs

Figure 8.5: GIRD Prototype - IRCAM Riot Sensor Sewn into Gloves.

The protype GIRD is a Dynamic Music system designed for creating and exploring music with gestures and dancing. It was designed so that any composer could create musical works to work with it. The Max for Live plugin's are completely flexible in design. They can be mapped across any parameter within Ableton Live giving complete freedom to the composer.

GIRD is discussed and evaluated with respect to its options as a system not as a standalone work like the Madness of Crowds and Semantic Machine. Two short experiments were designed to explore possibilities and support the development of the system. However, it should be noted that these were not new compositions and were only used to test functionality and showcase the system. As with many music technology projects, the development of the system demanded so much time, there was little time left for composition.

In summary, my role focused on the development of the interactive system and not the composition of sound material. For this reason, the overall Dynamic Music system is evaluated using the experimental creative works as proof of concepts in the evaluation. The compositional element in this work is therefore of less importance in the evaluation than the potential of works that could be created with GIRD after further development.

The compositional design included creating loops from existing stems and creating new loops to extend the audio experience. There were two types of works created to explore the capabilities of the GIRD system.

1. Instrument mode gives the user/s the option to play an instrument or sounds along with the music: for example, drums, samples, synth. (Ableton file provided in Appendix B-1)

2. Exploration mode allows the user/s to dance and explore the music with their bodies to discover new layers and song structures. (Ableton file provided in Appendix B-2)

8.2.1 Compositional Model

Content

The sound material can include anything within an Ableton Live set. This might include audio, MIDI, plugins, VST instruments, digital music instruments and procedural audio. The composer has absolute freedom to design and compose within the confines of Ableton Live.

The two simple examples of how sound material could be used in the GIRD system are merely examples or proof of concepts. They are only designed to showcase how the prototype could work. They are examples of compositional approaches and should not be regarded as compositions in their own right.

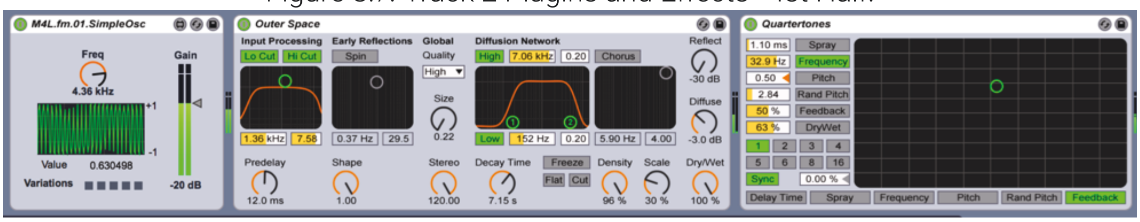
Instrument Mode

The Instrument mode worked with a Max for Live plugin GIRD synth. Figures 8.6, 8.7 and 8.8 show the sound material used two ML4 oscillator and two tracks with a range of audio effects including vocoder; convolution and specialised reverbs; and filter and grain delays.

The GIRD synth Max for Live patch was used to control parameters of the two synths so the user can dance and explore the available sound.

Figure 8.6: Track 1 Plugins and Effects.

Figure 8.7: Track 2 Plugins and Effects - 1st Half.



There was also a set of loops composed of drums and breath that could be triggered as shown in Figure 8.9. With a total of 6 different loops.

Figure 8.8: Track 2 Plugins and Effects - 2nd Half.

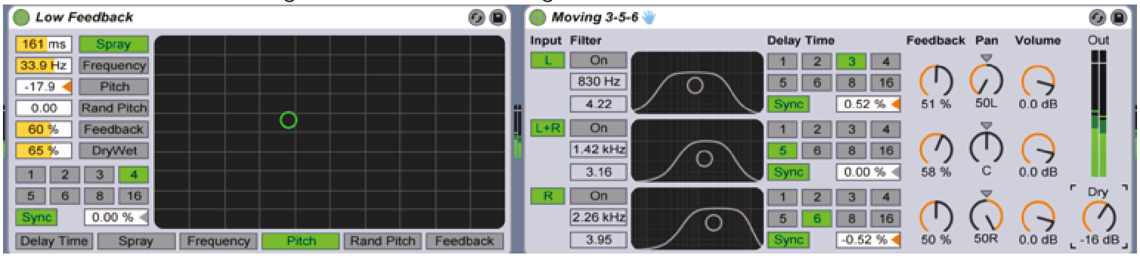


Figure 8.9: Samples that can be Triggered.

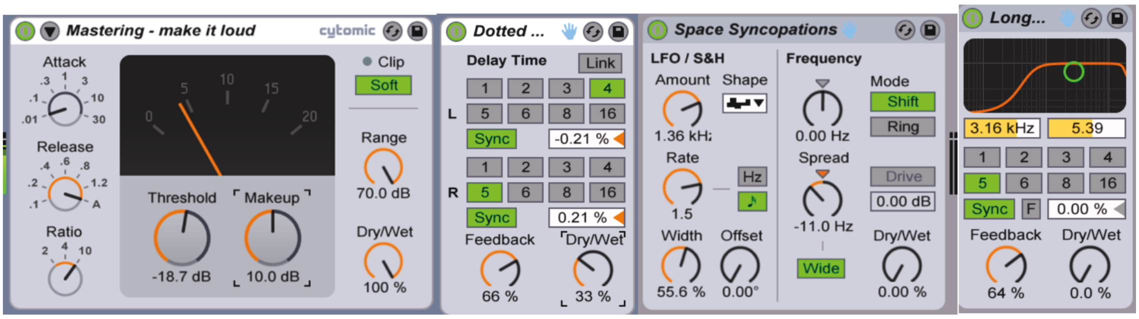
Exploration

The Exploration mode included two sets of five synth loops all at different lengths. There were a total of 16 loops used in this proof of concept. Figure 8.9 shows the loops used which included 10 synth phrases, 1 punch kick loop and a grouped track which contained five different beat varieties including high hats and beats.

Figure 8.10: Exploration Mode Set Up in Ableton.

Effects were also used for each track including frequency shifter, compressor, simple and ping pong delay as shown in Figure 8.11.

Figure 8.11: Effects Used on Tracks for Exploration Mode.



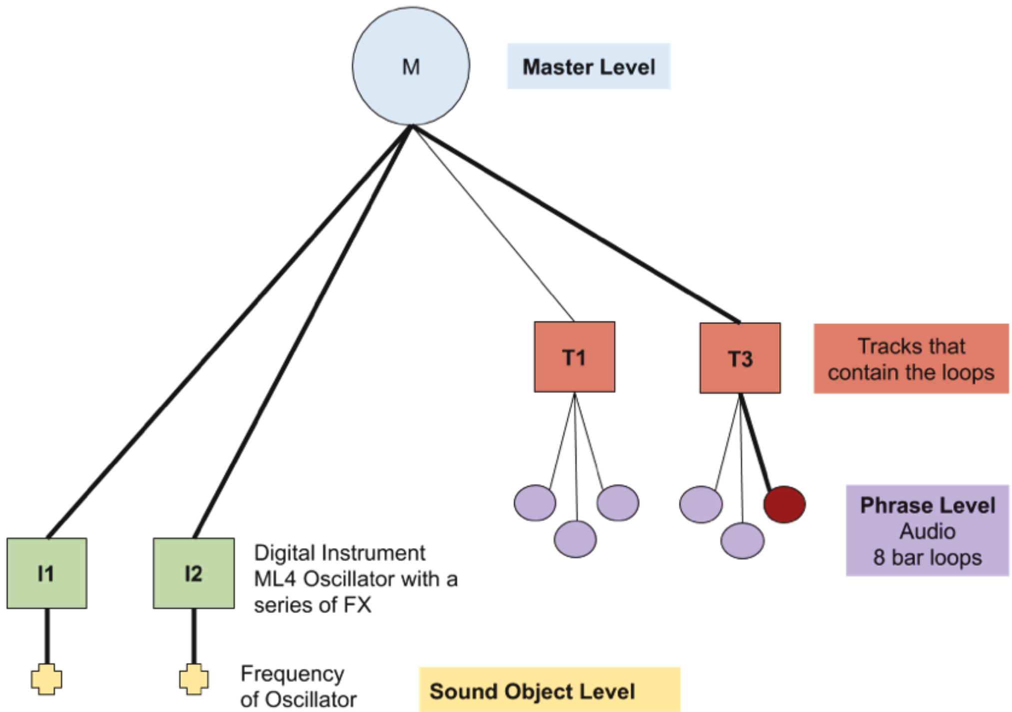
Musical Architecture

The Musical Architecture can be designed through the user's interaction with the GIRD and how the user chooses to trigger and affect the loops, instruments and effects. There could be a structural plan provided in the way the Ableton file is organised. However, for the two proof of concept examples the following designs were developed.

Instrumental Mode

The Instrument mode shown in Figure 8.12 is a series of sounds that can be controlled by the user. It operates as an instrument, not as a Dynamic Music work. The sounds can be combined in different combinations.

Figure 8.12: Instrument Mode Musical Design.

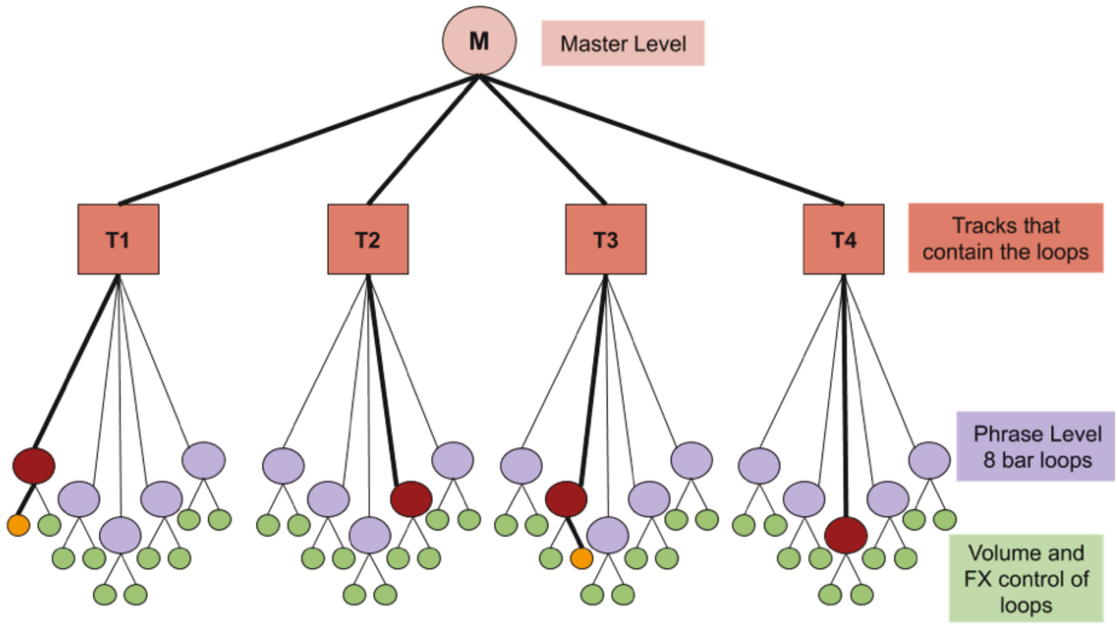


Exploration Mode

The exploration mode consisted of four folders of five to eight audio excerpts designed to be looped. These loops were created from a work called One Drop (Redhead, 2015) which is an 18-stem amorphous work.

Figure 8.13 shows the organisation of the sound material for the exploration mode. Given the work's original compositional design, the loops will all work together in any combination. The loops while having different bar lengths are in the same tempo and key. They

Figure 8.13: Musical Architecture and Transmutability Options.



represent a range of registers, timbre qualities and together can produce a range of sub-structural combinations.

The melodic loops consist of 10 stereo-mixed synth pads, including strings and ambient sounds. The melodic phrases can be played at any time in any combination which can result in qualities similar to a canon and contrapuntal themes. The five percussion loops can add a level of variability in the rhythmic quality of the track by randomly selecting either hi-hats, rock-style beat, disco beat, break-beats with different rhythmic variance. The loops are chosen randomly by the Max for Live patch so the user can experience a sense of the unknown as they change the loops and synthesise the sounds as they dance. It would be difficult to experience the same form of the music twice, however given there are only 10 melodic loops in the same key and tempo the work could begin to sound the same after some time.

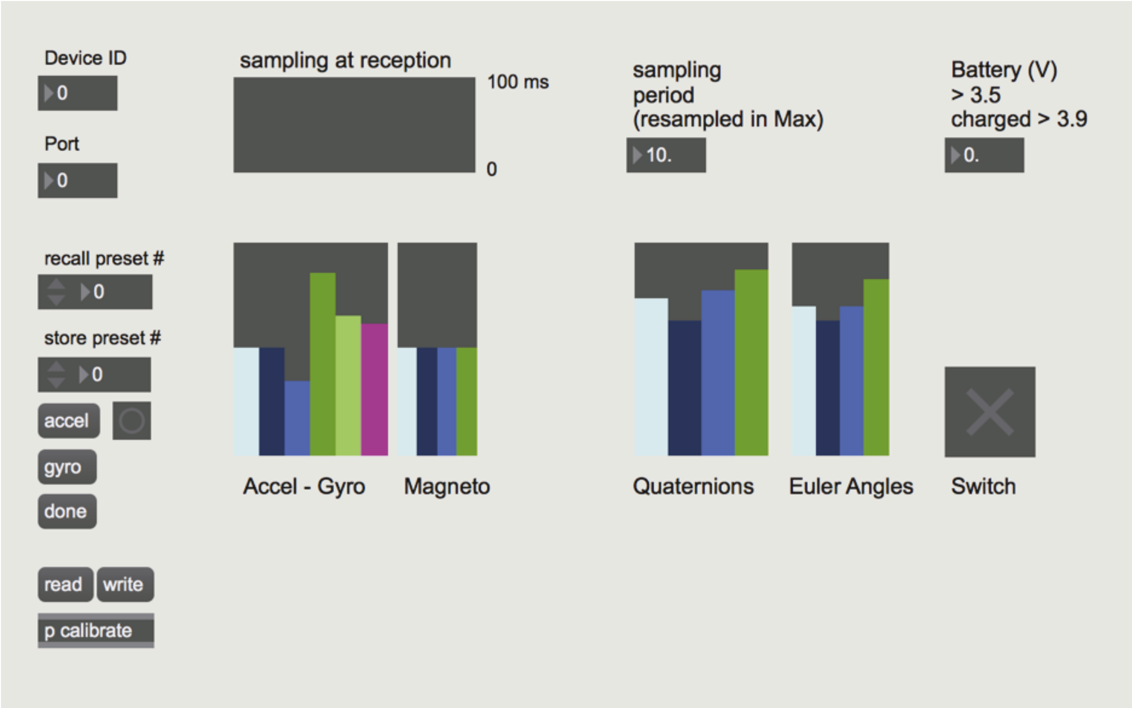
Control System

The control system consists of a Max for Live plugin (containing a series of custom Max patches) and Ableton Live.

The Max for Live patch receives OSC data from the riot sensor via a networked router. A series of Max patches transform that data into a selection of simple gesture interactions which can then be mapped to musical parameters within Ableton Live.

The Max for Live patch contains a series of complex Max patches utilising IRCAMs patches developed for interpreting the data being produced by the riot sensor. Figure 8.14 shows the data being received from the Riot sensor. The Riot sensor includes an Accelerometer, Magnetometer and a Gyroscope which send data via OSC. This data can be used to represent human gestures, movement and dancing.

Figure 8.14: IRCAM Max for Live Patch Showing OSC Data Being Received from a Riot Sensor.



This data as represented visually in Figure 8.14 was then used by a series of patches developed by IRCAM including the kick, spin, intensity patch and others. These patches were customised and developed into a set of gestures. The gestures used were punching the air with some level of force which was based on the kick and intensity patch. The palm up and down were developed using Euler angle and Quaternions data and the spin patch. This data was used to develop the option to map parameters based on their location in a 360-degree space, as shown in Figure 8.17.

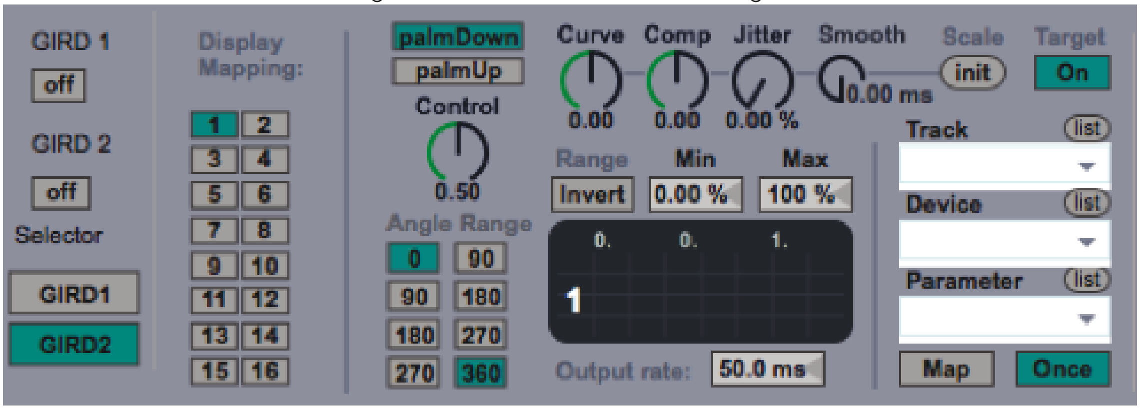
Max For Live Plugin – GIRD

The Max for Live patch – GIRD (Figure 8.15) includes a number of options to map and organise gestures into sound and music. The plugin has been created for two Riot sensors. This can include two different users wearing a glove each or one user wearing two gloves.

Figure 8.15: Presentation Mode – Max for Live Patch – GIRD.

On the far-left side of the patch (as shown in Figure 8.16) are options to select how many GIRD sensors will be used. Each one can be turned on or off. Below this function is the selector. This lets you select which GIRD you are setting up mappings for. The user can

Figure 8.16: 1st Half of GIRD Plugin.



only select one GIRD per time. If both GIRDs turned on, the user can map them both using the same plugin.

The next section 'Display Mapping' enables the user to assign 16 mappings per GIRD. The mappings relate to the gesture of having the user's palm up or down and moving the arm left to right within a 360-degree space. The makes a total of 32 mappings for two GIRDs. This action allows the user to control parameter dials like volume or the wet to dry of a delay effect, MIDI notes and more.

The user can select a palm up or palm down gesture within any angle range between 0 and 360 degrees. This might be 0-90, 0-270 etc, as shown in figure 8.16.

The user can adjust the data input curve, comp, jitter and how smoothly the data will affect the mapping. They can then choose which track, device and parameter they want to map the data to. The data can be classified with the options of it being inverted and the range adjusted. The output rate can also be changed. If the map button is selected the parameter can also be selected by selecting the parameter within Ableton. Mappings are completely flexible and can be assigned to any musical parameter in Ableton Live. This can also include controlling other plugins used within Ableton including one or any series of effects, synthesizers, the sound envelope, VST instrument plugins, tempo etc.

The second half of the plugin is called the GIRD sample Trigger, as shown in Figure 8.18. The user can select the number of players. This will change the options for gestures. The user can assign one or two GIRDs to one player. Or two users with a GIRD each.

The GIRD sample trigger enables users to trigger samples and loops within a 360-degree space. By selected Option 1 or 2 the user can change the space where the loops are being triggered. The loops can be triggered by the user banging within a 180-degree space or if option 2 is selected within a 90-degree space.

The user can also decide if the loops are chosen at random or in an ordered pattern. The random option will trigger loops from track 2 and 3 of the Ableton project. It is currently set to only select clips between scenes 1-5. This can easily be adjusted within the Max patch. However, it was set up like this for the exploration mode project. If using two GIRDS the second GIRD will trigger loops or samples from tracks 4 and 5. As shown in Figure 8.10, where by track 2 is Synth 1 and so on.

Figure 8.17: GIRD Angle Section – User is Purple Square.

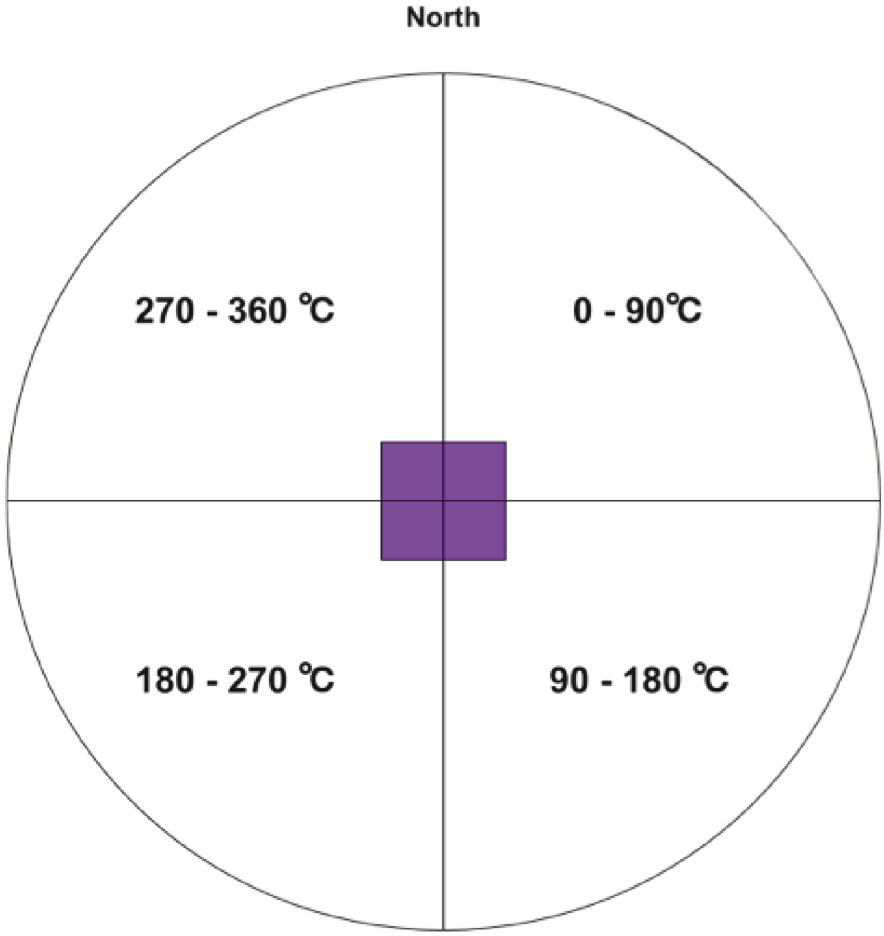
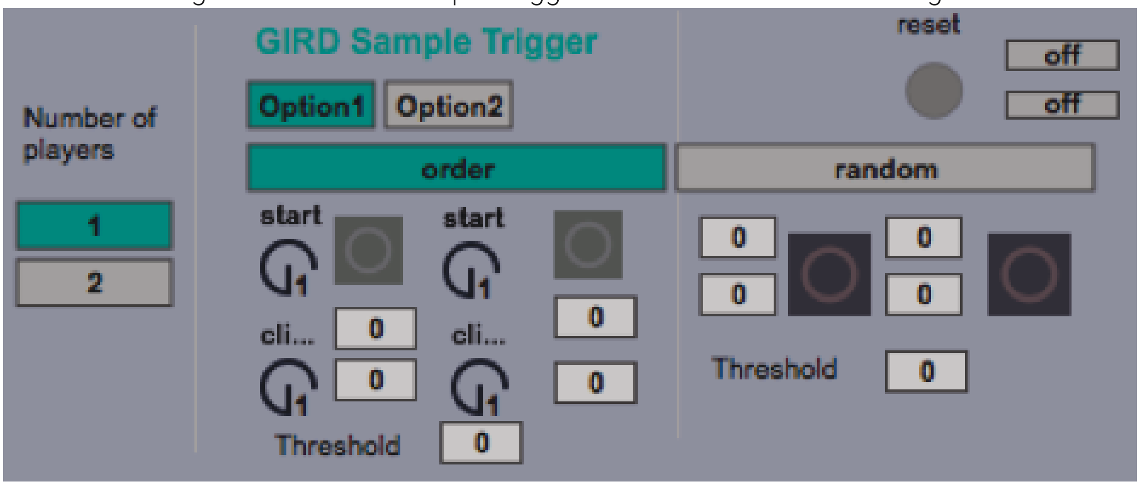


Figure 8.18: GIRD Sample Trigger – 2nd Half of the GIRD Plugin.



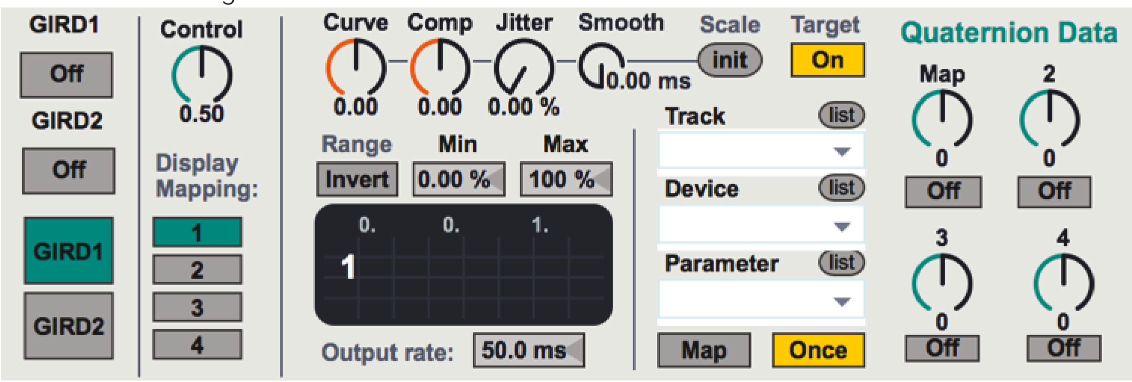
There is an option for the clips to be triggered in sequential order. The user can assign where they would like to start to trigger from, for example scene 5, and how many clips below they would like to trigger sequentially. Again, each GIRD has two tracks assigned which can be triggered. This results in tracks 2-5 being able to be used. The reason track 1 is not allocated is it is assumed the Max for Live plugin will be housed in audio track 1.

In both the option and random selection there is a threshold option. The threshold can change the intensity required for the loop to be selected. A high threshold requires a stronger fist bang while a lower threshold will make it easier to trigger samples by requiring less force in the movements used.

This overview of the Max for Live plugin offers many more options for the composition to be dynamic. It does have many limitations which can be adjusted by changing the Max 7 patches contained within the Max for Live plugin.

GIRD Instrument SYNTH – Max for Live Patch

Figure 8.19: GIRD Instrument SYNTH – Max for Live Patch.



The GIRD Instrument Synth Max for Live patch (Figure 8.19) was designed so that movement could control an instrument in space. It was used to support the instrument mode example.

This patch enabled users to map quaternion data to device parameters in Ableton Live. There is an option of four mappings per GIRD. When the GIRD sensor moves within a space its gyroscope produces four sets of quaternion data. The user can select one to four quaternion data sets to be combined to produce a final data input. This is represented by the control knob which shows these results. Once the data set has been established it can be mapped to any parameter device on any track in Ableton. The user can control the curve, comp, jitter and smoothness of the data signal, invert and customise its range. This permits a large degree of creative tweaking.

Process

The system uses interactive and random processes.

Experience

GIRD was designed as a prototype for the idea that people could dance in their lounge rooms and experience changing or creating music as they danced. Still in its early stages of development the system is not very user friendly. This is because of the limited gestures designed. At a later stage in development a large amount of user testing will be required. A group of people did try GIRD, as can be seen in the GIRD video, Appendix B-3.

The exploration mode was designed to offer a new way to experience music. Due to the random nature of the work the user can't learn how the music will react to their dance and gesture interactions. Unlike learning how to play a game or instrument this mode allows users to move and dance to experience a musical output.

Audio and visual feedback are the only feedback included in the work. These are via the musical changes which correspond to an action or gesture which also correlates to colour changes in the LED lighting system. The work could include more layers of experience with more loops being created, however this current iteration was designed as a proof of concept.

The lighting in the environment plays a vital role. Using individually programmable LED neo-pixels, five individual lighting fixtures were developed. The fixtures have several uses.

- The lights can create atmosphere for the music.
- Users can gesturally control the lighting
- The lights can provide interaction feedback to guide the user based on the music being interacted with.

Summary

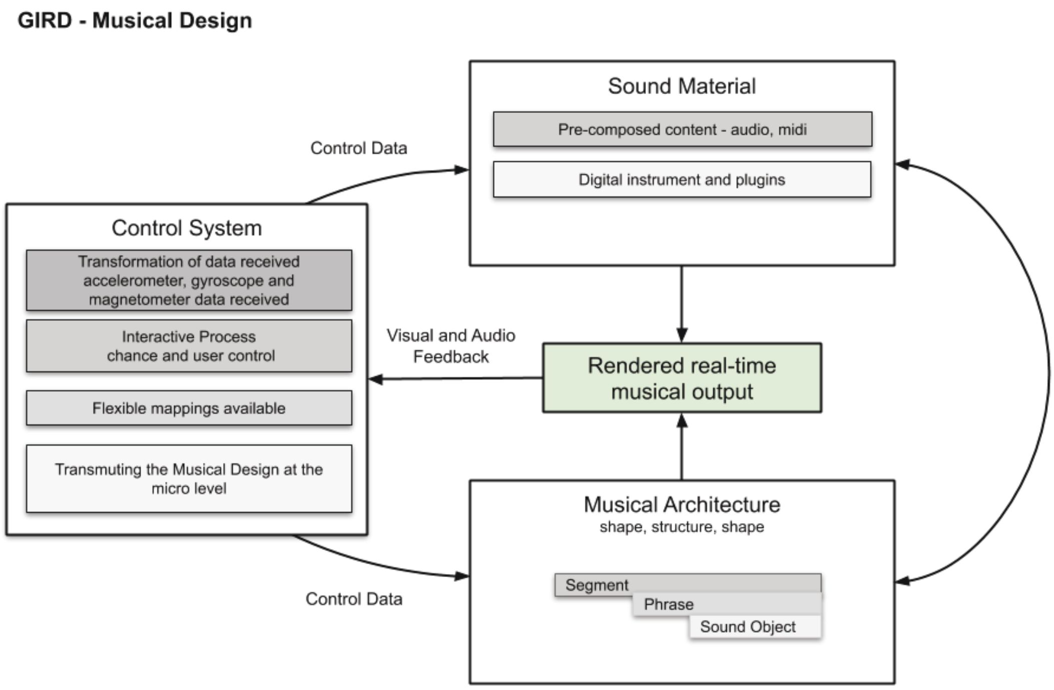
The major limitation with the plugin or system developed in this work was the gesture options it offers. They are not intuitive and quite specialised. To accurately produce experiences for audiences via dance and gesture, machine learning capabilities would need to be created. This is because of the complex data produced by the sensor. Some experiments were conducted using Wekinator which produced promising results in creating gestures and dance moves for individual users. However, this hasn't been integrated into the system at this time.

Another issue highlighted by this work was the time taken to develop the system. The system demanded a large amount time to transform and classify the data to represent meaningful gestures based on different users. This meant there was little time left to experiment with composing works for the system. The proof of concept, however, was successful and shows promise for further development. The compositional model is summarised in Figure 8.20

8.2.2 Criteria 1 Variability

The system was designed to allow for complete variability given it was a system used within Ableton Live. The composer is free to compose any amount of sound and music material to be used as triggered audio, MIDI, digital music instruments, FX, mixing and synthesis. The evaluation includes the overall system evaluation. It should be noted that given the amount of variability available for this project, I used mostly existing sound material due to time constraints, preferring to spend more time in developing and testing the Max patches and Max for Live plugins.

Figure 8.20: Model of Musical Design for GIRD.



Sub Criterion 1 – variability in the musical design

The instrument mode consisted of two tracks each containing an oscillator with a range of effects. The GIRD synth Max for Live patch was used to control up to four parameters of the two synths or tracks. The exploration mode enabled the random triggering of samples and loops at a phrase level and the control of up 16 parameters at a sound object level. Although these examples do not provide complex variability, the options are limitless given the plugin works with Ableton Live. Hence, there is limitless variability by using Ableton Live and Max for Live. The variability can be designed from the micro and sound object levels up.

GIRD max for live patches

Variability in the musical architecture and content	3

Sub criteria 2 – Variability of the resulting form or musical output.

Music produced for the experimental mode uses indeterminate processes with a set of fixed audio options. As the musical output is produced at random, the form of the work is unknown. However, the musical output will always result in a build and breakdown scenario. Depending on the loops chosen and the timing at which they are triggered by the system, the loops result in a canon-like continuation which can produce a greater possibility of variation.

This effect produces a more varied musical output with limited audio. The instrument and exploration modes present minimal variability in the musical playback.

The system has the possibility for maximum variability beyond these examples given the musical architecture is limitless in options. The musical outcome sounds like a new output where everything is changing and in contrast.

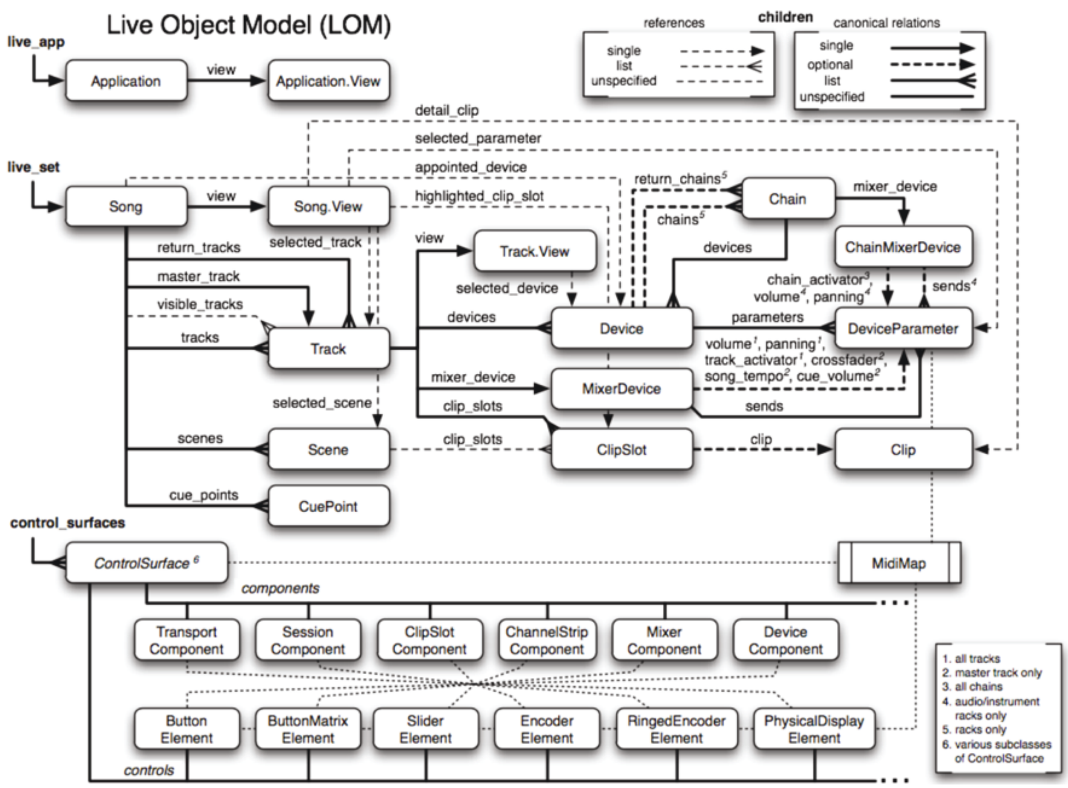
GIRD Max for Live patches

Variability of the resulting form or rendered musical output	3

8.2.3 Criteria 2 Transmutability

Figure 8.21 shows the hierarchical levels within Ableton Live that can be controlled by data. This is obviously required in the design of the transmutability but could also help the composer to design variability with the musical design.

Figure 8.21: 1st Half of GIRD Plugin.



Sub criterion 2.1 The level of control the control system has on the musical architecture

The system can transmute the musical architecture at any and all levels. This constitutes a complex level of control.

The amount of control the transmutability has on the musical architecture	3

Sub criterion 2.2 The amount of control the control system has on the musical architecture

The Max for Live patch can control any parameters selected by the composer within an Ableton project.

The level of control the transmutability has on the musical architecture	3

Sub criterion 2.3 The design of the control system in relation to control and process

The control system is also designed to create and reorganise sound material through the transformation of gesture data. Without the many options provided by the data transforming processes, the system would be simple. The data produced by the Riot sensor was processed into a data set that afforded the ability to map gestures to musical parameters. Hence, it is evaluated as a compound system in relation to control and process.

The design of the control system in relation to control and process Compound	2

8.2.4 Summation

GIRD has the potential to provide a Dynamic Music system with complex variability and transmutability. However, the examples provided do not showcase the full amount of variability possible in the musical architecture. The Max for Live plugin offers more variability than the works themselves showcase.

The variability of the two examples used to present a working proof of concept are limited in the variability of their playback. This shows that there can be a large amount of variability within the Dynamic Music systems design that doesn't produce much variability on the musical output. The two Max for Live patches however have the potential to produce a complex level of variability on playback due to the endless compositional options provided by working in Ableton Live.

GIRD Max for Live patches

8.3 Semantic Machine - 2018

`https://dynamic-music.github.io/semantic-machine`
(Important - to start the music you will need to mouse click anywhere on one of the yellow sliders. The music is not designed to be interacted with. It is contextual-based on weather and GPS data.)

The Semantic Machine (Figure 8.22) is a contextual song-based music application that adapts to the listener's environment. Still in prototype, the music is organised and controlled by the listener's location, time of day and the weather. A mobile phone's location coordinates, weather attributes and time are all factors that affect the rendered musical output. For example, if the work is experienced early morning, the structure may be different than

Evaluation of GIRD				
Level of complexity: NA=0, Simple =1, Compound=2, Complex=3	**0**	**1**	**2**	**3**
Sub-Criteria 1.1 Variability in the musical architecture and content				
There is limitless variability by using Ableton Live and Max for Live				3
Sub-Criteria 1.2 Variability of the resulting form or rendered musical output				
The musical outcome has the potential to sound like a new output.				
Everything is changing and in contrast.				3
Sub-Criteria 2.1 The amount of control the transmutability has on the musical architecture				
The system can transmute the musical architecture at any and all levels.				3
Sub-Criteria 2.2 The level of control the transmutability has on the musical architecture				
The Max for Live patch could control any parameters selected by the composer within				
an Ableton project.				3
Sub-Criteria 2.3 The design of the control system in relation to control and process				
The control system is also designed to create and reorganise sound material through				
the transformation of a complex data set – gesture data.			2	

Table 8.2: Summary Table - Evaluation of GIRD

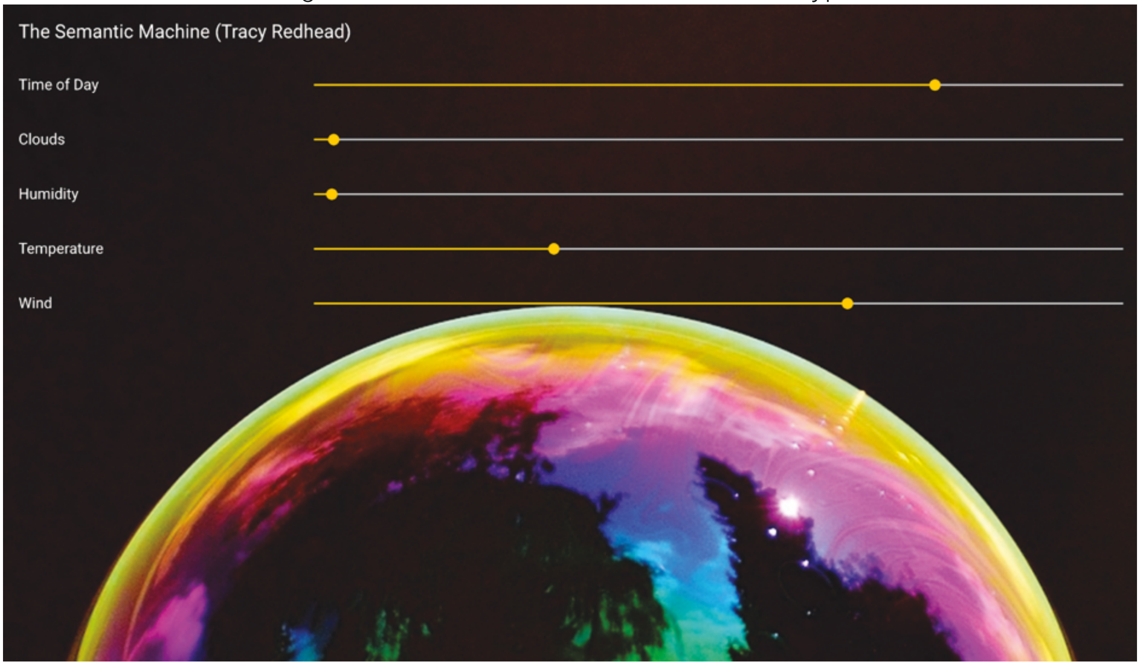
if it is heard late afternoon or evening. If it is a cold day the work will play back only warm tonal instruments. All of these control factors are designed during the composition and modelling processes. An audio excerpt is provided in Appendix C-7, which includes two examples of the rendered musical output of the Semantic Machine. The prototype version is discussed in this evaluation, however the work involved a number of development stages including the proof of concept which are discussed in Appendix D.

The Semantic Machine is the result of a collaboration with myself and Dr Florian Thalmann. I was as an external artist of the Fusing Audio and Semantic Technologies for Intelligent Music Production and Consumption (FAST) project. FAST is a five-year project funded by EPSRC (Engineering and Physical Sciences Research Council). The project partners include Queen Mary University of London, The University of Nottingham, Oxford e-Research Centre, Abbey Road Red, Internet Archive, BBC, Audio Labs and Solid-State Logic. "The project brings the very latest technologies to bear on the entire recorded music industry, end-to-end, producer to consumer, making the production process more fruitful, the consumption process more engaging, and the delivery and intermediation more automated and robust." (FAST Impact Project, 2019)

The work utilises the semantic player technology, developed by Thalmann, as the control system for the Dynamic Music work. "The Semantic Music Player is a cross-platform mobile app that investigates new ways of playing back music on mobile devices, especially unpredictable, context-dependent, and interactive ways. It takes real-time decisions based on structural information and analytical data represented using Semantic Web technologies and reacts to sensor and user interface inputs." (Thalmann et al., 2015)

This collaboration enabled me to focus on developing Dynamic Music compositional ideas without having to develop a complex software system to support them. Building on the semantic audio technologies utilised by the semantic player we were able to explore semantic audio and MIR analysis, feature-based mixing and complex mapping systems. The Semantic Machine prototype was launched in October 2018 at the FAST Industry Day,

Figure 8.22: The Semantic Machine Prototype.



Abbey Road Studios. A short documentary on the FAST launch can be viewed as Appendix C-9 or here `https://www.youtube.com/watch?v=VF4qQRcGfl8&feature=youtu.be`

As part of the FAST launch four mixes of tracks that could be rendered by the semantic player were produced for a vinyl sample. Images from this vinyl record can be viewed in Appendix C-8. There were three mixes demonstrating three musical themes, discussed in the content section and the final mix with all tracks blended to produce simultaneity. See Appendix C-2,C-3,C-4 and C-5 for an audio example of these works. Each mix sounds different and all work to produce a new track when played in unison. For example, three turntables could be used to play each of the three mixes in unison, these tracks then all synch up together merging lyrical/music themes and creating a new perspective.

The evaluation is made up of two developmental stages:

1. Stage 1 – Proof of Concept – Appendix D;

2. Stage 2 – Prototype.

Stage 1 involved producing a large amount of audio to investigate how the system might work. We evaluated how the composed music worked with the control system and refined our processes in a series of steps. Stage 2 built on the lessons learned and refined processes to develop the first working prototype of the app. This process resulted in the prototype discussed in this section. Stage 1 contains a detailed discussion highlighting the complexities and challenges in relation to the musical design and compositional models experimented with see Appendix D.

8.3.1 Compositional Model

Content

A total of 39 stems were produced as shown in Figure 8.23. These were grouped into three themes referred to as Mix1, Mix2 and Mix3. The stems are provided in Appendix C-6 and are organised into separate folders for each theme or mix. These stems were converted into eight-bar audio files and organised and labelled into a structure. This structure is described in the next section.

The stems all had the same fixed section structure. However, to conform to the branched section design (explained in the next section), a series of new sections (Figure 8.24) were organised so the work could be extended.

Once all the eight-bar loops had been created, labelled and organised, they were ready to be integrated into the control system. The eight-bar loops were analysed by the semantic player to minimise the number of audio files required by deleting clones. This helped reduce the content file size.

Figure 8.23: Stems in Theme Groups.

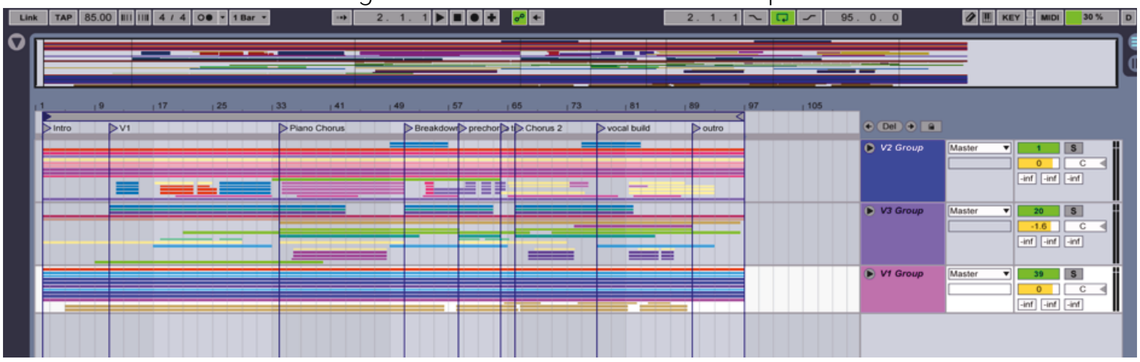
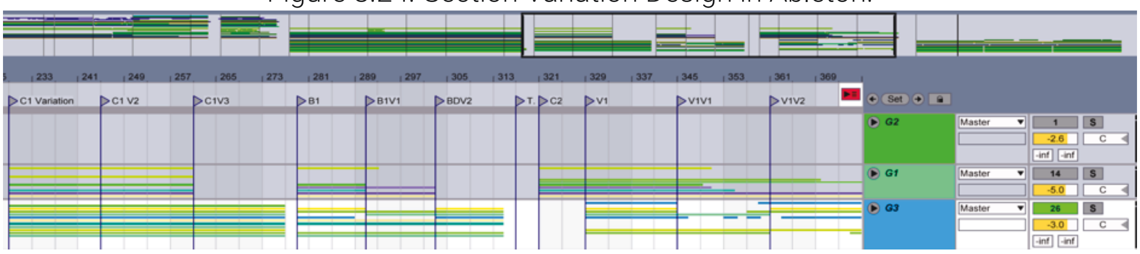


Figure 8.24: Section Variation Design in Ableton.



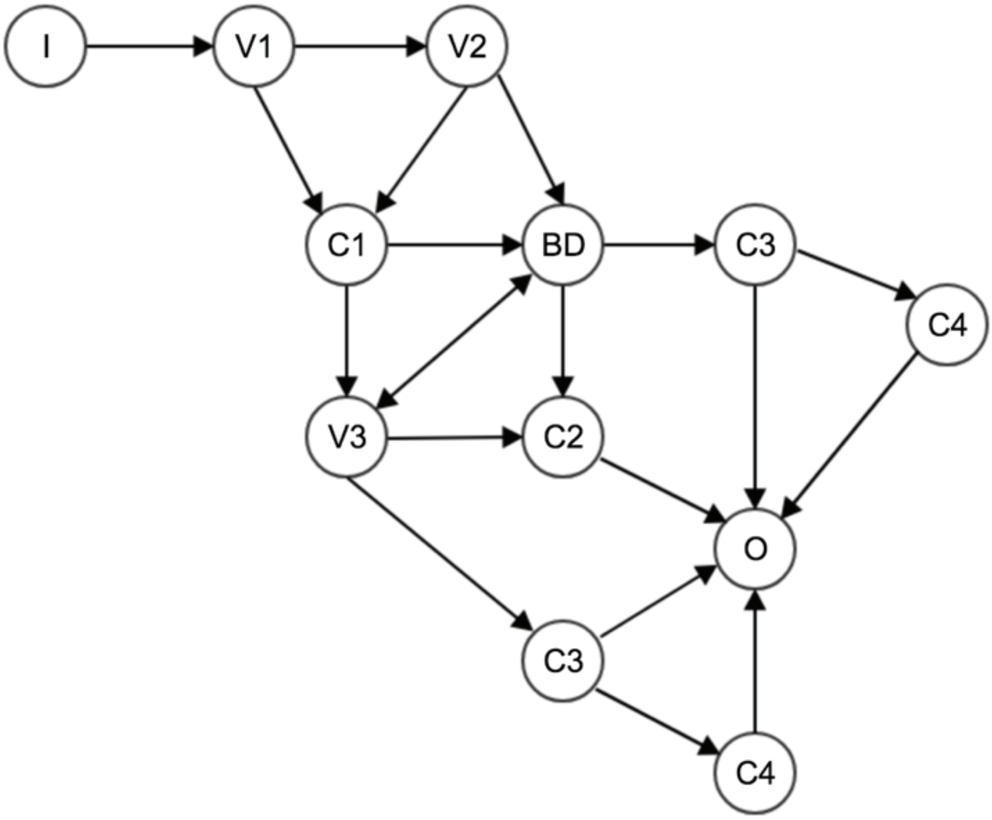
Musical Architecture

The experiments conducted in the earlier stages of the collaboration, which can be viewed in Appendix D, highlighted the need for a more structured compositional approach. Due to the large amount of audio produced for the 85bpm version, the prototype was developed using only one tempo. It is planned to extend this in the future.

The overall structure was designed to include variability in the song sections, instrument arrangement, vocal parts and the mix. The composition of the sound material was created so that the track always sounded like a structured and organised song which built in energy and intensity.

A branching song structure was created as shown in Figure 8.25. The semantic player selects which pathway it takes in real-time based on the time of day according to data provided by the mobile phone.

Figure 8.25: Branching Song Structure for Semantic Machine.



Appendix D describes the compositional process in the earlier stages of the project. This included the composition of two works. The first work was composed at 85 bpm and was used as the base to build from. The second work was originally composed at 133 bpm. Loops from this track were subsequently transposed to 85 bpm. A new work was composed with these loops to match the section and dynamic structure of the first work. New vocals were recorded at 85 bpm. The second work was produced in this way so the two works could be blended together in unison. A third track was composed with newly created instrumentation and loops and a new lyrical theme. Again, this third work was composed to the same structural map. All three works could be played in unison and blended together to form a structural simultaneity.

During this compositional process a multiscale approach to composition and mixing was required. All three works needed to be mixed down to stems. These stems were required to work in any combination. That is, any stem from any of the three works had to work together in any combination. This requirement informed the way the works were composed. All three works are fairly sparse so that they can be layered.

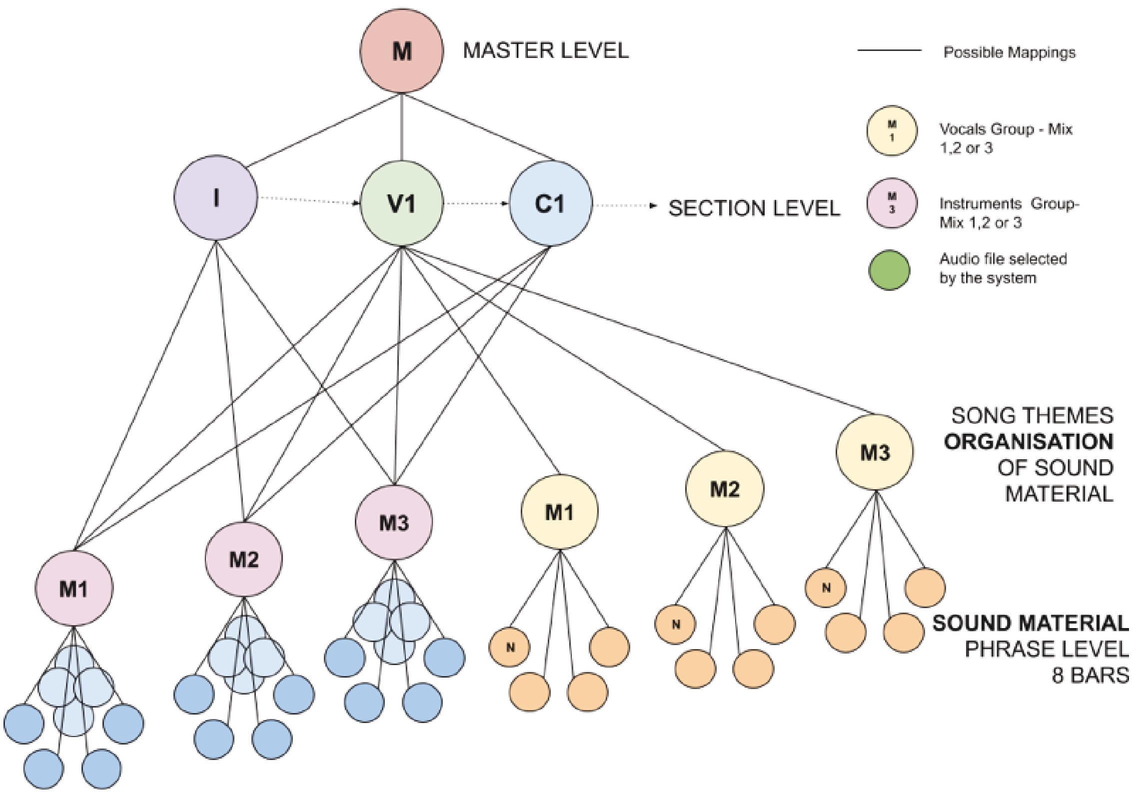
In relation to the mix, not only did each work need to sound balanced individually but also when blended in simultaneously. Individual stems from all three works needed to work together in different layered combinations. It felt like a 360 degree approach to mixing, where all 39 stems needed to be mixed so that they would sound balanced in any combination, whether it was three stems or all 39 playing together. It took a large amount of time to check levels, phase and EQ across all variations[7].

The variability composed in the lyrical themes were designed to work in parallel and to support each other. For example, the chorus in work 2, when layered with work 1, functions as backing vocals. When used in a different combination it sounds like the lead vocal.

Composing three songs as a structural simultaneity enabled a dynamic and structural map that could add variability and an emotive element.

The three works were named Mix 1, Mix 2 and Mix 3. They could be understood as the three different themes used in the work. For an outline of the themes used see Appendix D. Figure 8.26 shows the way the music and sound material is organised into the musical architecture. It also shows the options for how the control system can transmute the musical architecture.

Figure 8.26: Organisation of Sound and Music Material.



[7]Gary Bromham performed additional mixing and mastered the Vinyl tracks and stems

Control System

The semantic player is the control system that controls the musical architecture within the Dynamic Music system. The data used to control the system is

- GPS coordinates
- weather API – temperature, clouds, humidity, wind
- Time
- Data produced from the analysis of the sound material (audio)

The semantic player automatically analysed all the added audio files using standard feature extraction algorithms and annotated each object with descriptive features. The features included; log centroid, spectral flux, intensity, and average onset frequency. Thalmann designed feature-based mixing based on the data being received by the system.

GPS coordinates of the user's location are sent by their mobile phone to an online weather API. The data received back from this API which include the weather parameters at that location is then used by the system. It uses this data to makes decisions on how the track will be transmuted. This is based on a set of rules designed by the composer and features that have been extracted from the sound material.

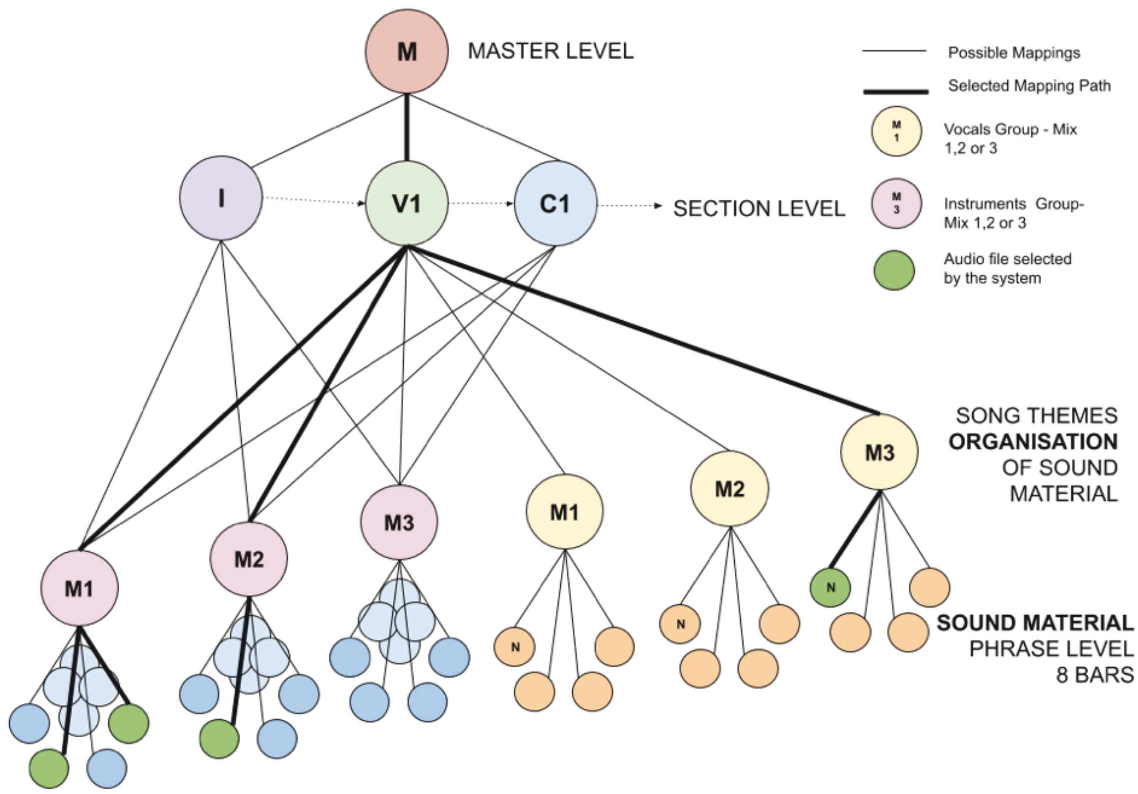
The control system uses contextual and system control. The contextual data from the mobile phone and the weather API provide the control system with data. This is used by the control system and is mapped to musical parameters. The control system can also make decisions about the transmutability design based on the descriptive features it has analysed in the audio or sound material. The data-led transmutations designed in the prototype were:

- The amount of clouds control a delay effect on the drum audio being used in the track. If it is very cloudy the drums have a large amount of delay added to them. If there are no clouds the drums have no delay. If there are no drums used in the playback there will be no effect.
- The temperature data utilises the spectral flux data of the audio for feature based mixing options and selection of instrumentation. If it is a cold day the semantic player will only select audio that has warmer frequencies. If it is a hot day the semantic player will only select cooler frequencies. The spectral centroid is a measure of the frequency spectrum. If the audio has a lower spectral centroid measurement, the audio will sound warmer. If the audio has higher frequency measurements, the sound of the audio will be cooler.
- The time of day data is used by the system to select the pathway through the song sections.

More transmutability options are planned for the final release of the app.

When the work starts, the semantic player decides which themes are to be used in this instance of the rendered musical output. The system can select Mix 1, Mix 2, Mix 3, Mix 1+2, Mix 1+3, Mix 2+3 or Mix 1+2+3. Figure 8.26 shows how the control system can navigate through the song, selecting the song structure and instrumentation. Once the semantic player knows which theme folder the audio it is using is from, it will decide which audio to play. The player can then select whether the version will have vocals. The folders containing the vocals are separated from the instrumental options so that the work can be instrumental. In Figure 8.26 the thick line represents the way the control system is transmuting the musical architecture. In this instance, it is playing Verse 1 and it will go to Chorus 1 next. This decision was based on the time data received from the user's mobile phone. The system is playing two audio stems from Mix 1 and one stem from Mix 2. Hence, it is playing a total three stem pathways, these could be any instrument. It has chosen to play vocals from Mix 3, however it selected an option of no vocals. The system, therefore, is playing audio from all three mixes. It has made the decision to play the particular stem pathways due to the data it has received from the weather.

Figure 8.27: Transmutability of the Musical Design.

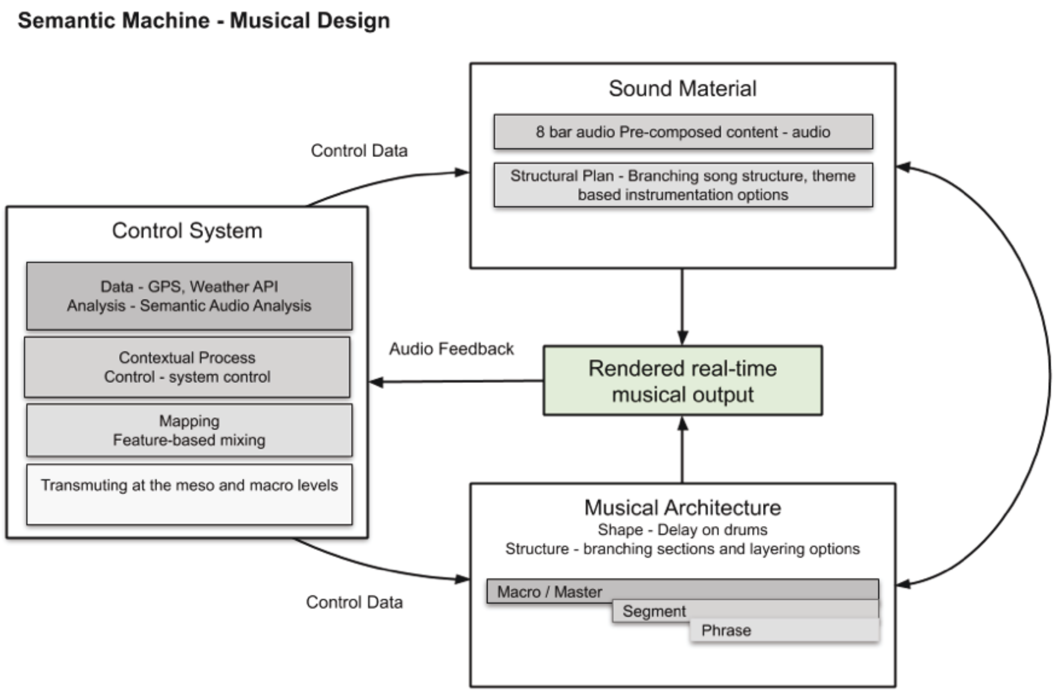


Process

The process used is contextual and autonomous. It is designed as a listening experience. The user can't change the musical output unless they change their location or the weather parameters change. The autonomous process is the automatic analysis of audio features which are used to make decisions how the music is organised on play back.

Summary

Figure 8.28: Model of Musical Design for the Semantic Machine.



8.3.2 Criteria 1 Variability

Sub Criterion 1 – variability in the musical design

Variability is pre-composed into the sound material used in the Semantic Machine using the following compositional tools.

Meso Levels

- The branching song sections
- Blending of three different themes
- Instrumentation is organised into seven instrument arrangement options. The semantic player can select Mix 1, Mix 2, Mix 3, Mix 1+2, Mix 1+3, Mix 2+3 or Mix 1+2+3. The player can then select whether the version will have vocals
- Three lyrical themes, see Appendix D
- Mixing parameters

Variability is designed at the phrase and section level of the musical architecture as show in Figure 8.27.

The audio was mixed with limited effects to enable more room for the control system to mix musical elements. This limited mix enabled for more variability in real-time mixing.

The work does include a large amount of pre-composed audio that is designed to be dynamic. The musical architecture does not offer variability any lower than the meso level. The work also includes variability within the meso level with a branching song structure, layered instrumentation and lyrical and vocal variation. The musical content is composed to include variability within the substructure levels including a branching structure.

Variability in the musical architecture and content	2

Sub criteria 2 – Variability of the resulting form or musical output.

The rendered musical output of the Semantic Machine prototype can sound like a different song, however it does keep the same key and tempo. The musical output is not evaluated as complex, since even though it can sound like a new song, it can't produce everchanging combinations. There is however a very large amount of variability given the many possibilities for sound material, song structure pathways, instrumentation selection and mixing options.

Variability of the resulting form or rendered musical output Compound	2

8.3.3 Criteria 2 Transmutability

Sub criterion 2.1 The level of control the control system has on the musical architecture.

The data can transmute the musical architecture at the meso level and above.

The amount of control the transmutability has on the musical architecture	2

Sub criterion 2.2 The amount of control the control system has on the musical architecture.

The control system can control the song structure, effects on the drums, the choice of which instrument theme to use, the choice of instrumentation played, and the vocal audio played if any. This is a total of five parametric changes which is evaluated at the compound level.

The level of control the transmutability has on the musical architecture	2

Sub criterion 2.3 The design of the control system in relation to control and process.

The control system is designed to make decisions via feature analysis. This would be considered a complex system.

The design of the control system in relation to control and process	3

8.3.4 Summation

The prototype of the Semantic Machine is an example of a compound Dynamic Music system.

Evaluation of the Semantic Machine				
Level of complexity: NA=0, Simple =1, Compound=2, Complex=3	**0**	**1**	**2**	**3**
Sub-Criteria 1.1 Variability in the musical architecture and content				
The musical content is composed to include variability within				
the substructure levels including a branching structure.			2	
Sub-Criteria 1.2 Variability of the resulting form or rendered musical output				
The rendered musical output of the Semantic Machine prototype				
can sound like a different song, however it does keep				
the the same key and tempo.			2	
Sub-Criteria 2.1 The amount of control the transmutability has on the musical architecture				
The data can transmute the musical architecture at the				
meso level and above.			2	
Sub-Criteria 2.2 The level of control the transmutability has on the musical architecture				
This is a total of five parametric changes which is				
evaluated at a compound level			2	
Sub-Criteria 2.3 The design of the control system in relation to control and process				
The control system is designed to make decisions via				
feature analysis. This would be considered a complex system.				3

Table 8.3: Summary Table - Evaluation of the Semantic Machine

Given the complexity of the control system processes this project has the potential to produce a more complexity in its rendered musical output by increasing the transmutability design and/or increasing the amount of sound and musical material.

8.4 Findings

The next section discusses and compares the evaluation of the three creative experiments and observations made throughout the process.

Many music technology projects result in artists spending most of their time developing the technological aspect of the project. This leaves little time for the composition of the musical elements. When I was able to collaborate with other artists who were developing the control system, I was able to focus on compositional design elements. This included composing sound material and the musical architecture in relation to variability and transmutability. In the GIRD project, I was limited by time constraints to focus on the compositional elements and had to use pre-existing material to test and refine the project.

These limitations are an important consideration when working with Dynamic Music. Dynamic Music requires the development of a system. As discussed in Section 6.1, the components of this Dynamic Music system are sound material, musical architecture, experience and a control system. The design of these components requires a varied and often interrelated skill set. For example, a composer will need to be aware of more than just how to create variation in the musical material. Transmutability, variability and experience are all interlinked in the design of Dynamic Music. The Madness of Crowds project highlights how experience can affect the transmutability and variability of the work. The unexpected interaction by the audience extended the transmutability of the control system resulting in an increased variability of the musical output.

The work GIRD resulted in a system prototype which allowed for unlimited variability and limited transmutability. In future development versions of the work the system may also be built to have unlimited transmutability if machine learning techniques are integrated. The user experience in the project will also play a large part in the musical design in this work.

Dynamic Music that involves user interaction will require further levels of testing using music interaction evaluation techniques to access user experience and the overall affect that has on the musical output. The testing would happen at a later stage of development than discussed in this thesis's framework. A composer can design surprises and predictability but will never be sure how that will be perceived by the listener. The same applies to Dynamic Music composition. The composer must create something from nothing. This can be refined through a number of processes in the design of the work. There are many levels of evaluation that are required before user experience testing is required. For example, the way the control system transmutes data will affect the way the musical architecture needs to be designed and vice versa.

The relationship between transmutability and variability was further examined in the Semantic Machine project. As discussed in Appendix D, the multiple stages in its development emphasise that evaluation processes inform the development of all the components. In the early stages of development, a number of compositional approaches were produced that didn't produce the intended outcome. This required re-evaluation of the Dynamic Music system's components once the musical materials were integrated with the control system, leading to further and continued development of the content, musical architecture and control system.

One of the main issues highlighted during this evaluation was the need for a more curated approach. This lead to structural rules and instructions being created. A branched section structure, re-designed sound material and an improved control system enabled the system to realise emotional dynamics that were required in the musical output to realise the work's concept. At this time a system utilising AI and semantic technologies is limited in its curation of music. It can only achieve what is provided within the context of its learning or semantic parameters and algorithms. The human element of understanding emotion and dynamics in music is needed for the curation of the musical output and overall concept of this work.

Chapter 9

Conclusion and Implications

The thesis investigates the role of interactive technologies on popular music making. Popular music has always adapted to new technologies, however interactive technologies challenge the currently accepted forms of popular music making (Section 1.1). From a creative perspective, my Ph.D. journey began by wanting to explore how popular music making can provide deeper and more engaging experiences for audiences; and the composition and production of changeable and amorphous music.

The thesis introduces two interconnected problems for musicians and the music industry wanting to embrace changes in technology and communication:

1. the relationship between fixed song forms and dynamic composition; and
2. the need for a criteria that encompass the relationship between static and fluid song forms.

It asks how can interactive technologies be used to develop new forms of popular music?

The thesis addresses the research question by providing:

- definitions on the field of Dynamic Music as a point of departure
- a discussion on Dynamic Music in relation to form, structure, process and time
- the four components of a Dynamic Music system: experience; content, musical architecture and control system.
- a model of the musical design of Dynamic Music
- a set of criteria used to evaluate Dynamic Music as a changing form in comparison to static forms of music.

This chapter discusses some implications resulting when interactive technologies are applied to the creation, production, dissemination and experience of popular music making. It presents a series of points of departures based on key themes from the thesis.

9.1 Static and Dynamic Music Forms

Popular music making methods are so engrained in our understanding it is difficult for artists and the industry to see beyond static forms. For music to move beyond static forms, a shift in perception is required. Music is experienced in time and doesn't represent any specific moment in time. Everything constantly changes; music changes each time it is performed.

Digitisation has changed most areas of music including distribution, production and consumption. However, the potential of digitisation and its disruptions, in this context, seem unexplored in relation to the recorded music form. Music is still primarily being released as a static single, ep or album. It is fixed in form. As a composer this seems limiting given the potential of digitisation.

We find ourselves in a paradox: if popular music is now digitized and can be represented by data, it has the potential to be entirely transformed by the interactive technologies now dominating our lives globally.

The recorded music industry has fundamentally changed the way music is perceived by society. It means it's the same each time it is experienced. This has become the accepted understanding for experiencing recorded music. Even in a live performance context many audience members want to hear a song exactly like it sounds on the recording. Music making processes based on fixed forms are now institutionalised in our society and dominate processes in music making and the industry itself. It is however perplexing that musicians still produced static recordings given the available processes for producing music have changed so significantly. Recordings are no longer limited by analogue processes and these fixed forms now only represent a metaphor for a moment in time. This thesis suggests that recorded music has the potential to change and adapt just as music was experienced before analogue technologies could capture it as a moment in time. Digitisation and interactive technologies can produce recorded music that changes each time it is played back. Whether it evolves or is recontextualised, it offers artists and audiences new ways of experiencing music.

Dynamic music works can be understood as a new form of music which doesn't fit into the traditional recording industry. The Music Technology Industry has evolved with digitisation, globalisation and the internet. At this heart of this industry is interactivity, technology and software. Dynamic music works which are based in software, technology and interactivity may well form the basis or even an important branch of future music works produced within an the new and ever-evolving music technology industry.

New important works are currently pushing the boundaries of popular music with their integration of interactive technologies. Many were reviewed in this thesis and include concept albums, EPs or singles; album apps; locative works; artificial intelligence; data sonification; and systems and formats. These important emerging works involve complex new approaches to music making. Nevertheless, all of these works share a commonality. They all involve data-led transmutability and their approaches towards composition, form and structure could be viewed similarly. It is for this reason that Dynamic Music is used as an overarching term to define music which can adapt and change based on data input and thus offer an experience beyond static forms.

Composing and producing dynamic forms involves very different approaches to that of static music making. There are limited tools and frameworks available to composers and producers to help distinguish these different approaches between forms. The presented compositional model for the musical design of Dynamic Music systems helps provide a foundation for artists wanting to embrace these concepts. The Dynamic Music form is an open form and the result of a process. Given its form is not fixed it requires a more complex musical design.

By using a clear set of criteria, it is possible to evaluate and provide a clear distinction between Dynamic Music and static music forms. The criteria are directly related to the compositional model presented for Dynamic Music. They provide a foundation to help more artists understand and build approaches to Dynamic Music making.

9.2 The Dynamic Music Producer

One implication of this research is the development of a new role and skill set for musicians wanting to embrace the area of Dynamic Music. We are now in a situation where there are many new approaches and expert skills required to make future music products. This includes skills in transmutability; data science; programming; interaction design; user experience; composition techniques that produce variability; and the production skills to design new mixing and mastering techniques for Dynamic Music.

The skills required to write, record and produce an album are well defined. The process requires a range of experts depending on the collaborating artists' skills. However, the skills required to realise the musical design of Dynamic Music challenge traditional roles in popular music making. Even within a gaming context, Collins (2008) concludes that approaches to Dynamic Music, "... require new ways of thinking about music, and will require new software tools and teaching methods to accommodate them."

In the context of popular music making, a role dealing with the composition and production of Dynamic Music, is yet undefined in academic literature and the music industry. However, throughout the contextual review it is clear a new artist role is emerging. Robert Thomas, Yuli Levtov and Hakan Lidbo are examples of cutting-edge musicians and artists working in a new role which brings a unique set of skills. Each of them calls themselves something a little different: Adaptive Music Producer; Reactive Music Producer; and Interactive Music Producer, respectively. The works they have produced provide examples of different approaches and playback systems. All of these can be grouped as part of the Dynamic Music form defined by this thesis.

Within game audio literature there has also been some discussion about the established roles for composers and sound designers working in gaming composition. The role's of technical sound designer and audio director integrate the compositional and technical implementation tasks.

> "The 'audio director' is responsible for the entire soundtrack, from dialogue, ambience, sound effects and music. Not only this, but also working with the audio programmers on the desired technical requirements and direction of the audio and the wider design and art team in augmenting and leading feature design." (Bridgett, 2009)

However, Young (2013) discusses a gap between audio asset production and implementation. He specifies this gap as being one of the main hindrances in game development. This is because the music and audio production remain in the realm of the sound designer or composer, and the implementation into the game sits with the programmers. "This gap results in a production bottleneck, fed by the time spent, exporting, transferring, converting, importing and implementing and other time-consuming steps between different audio development stages." (Young, 2013)

This issue in gaming could be helped with a more detailed understanding of variability and transmutability of music within a gaming context and how they are central to the composition of content and architecture with the design of the control system and its manipulation and mapping of control data. Skills in transmutability may help to provide game composers with the skills required for implementation.

The Dynamic Music Producer role refers to an emerging skill base required for popular music producers to navigate and manage a diverse range of interactive technologies in popular music contexts. It involves a high level of creative and artistic skills with an understanding of the four components of a Dynamic Music system including: interaction design including user experience, music interaction and human computing interaction; sound and music production; composition and variability; Dynamic Music form and structure; and data led transmutability.

A Dynamic Music work may involve a collaboration with researchers, interaction designers, composers, or computer scientists among others. In the generative works *AIR*, and *Reflections*, Brian Eno and Peter Chilvers create a team whereby Eno is the composer creating content and Chilvers is the architect composing a system. It is a collaboration in variability and transmutability design. They collaborated interdependently on the final design.

Just as a record producer is not an expert in all the roles required to create an album, a Dynamic Music Producer would not need to be an expert in all areas of Dynamic Music design. A record producer works with a range of experts and has an understanding of what is required to produce the best album possible in each unique situation. A Dynamic Music Producer will also work with a range of experts to ensure the delivery of the best work possible to meet the artist's vision. The role involves having an understanding across all the components of a Dynamic Music systems and the ability to bring everything together.

9.3 Control

The roles of music making are increasingly becoming blurred with the development of new software environments. White (2015) for instance introduces the concept of convergence in which performance, composition and production processes happen simultaneously in real-time. Dynamic Music is also performed, composed and mixed in real-time. (Section 6.2)

Control is present in the composition and performance of the content, processes, musical architecture and the control system designed. A control system can broadly be viewed as a highly complex piece of notation that represents a song system. The level of control in the transmutability and/or variability in the music is completely up to the vision of the artist. There may be many different melody lines composed depending on the amount of variation required, yet these melody lines are still subject to quality control. There are endless variations that can be explored. This does not reflect a lack of quality or artistic control. The content and processes used, just as in fixed form music making, still require an aesthetic sign off just like traditional recording processes.

The amount of the controls the audience, performer, user and or machine have to transmute a work is also part of the musical design itself. The composer may want to give full control of the work over to a machine to realise a process that has been composed. Brian Eno states that Generative Music "specifies a set of rules and then lets them make the thing" (Eno, 1996) He is interested in exploring what the processes he has created will create themselves, then refining the possible musical outputs. "I wanted something that had an organic quality to it. Had some sense of movement and change. Every time you played it something slightly different happened." (Eno, 1996)

It is up to the composer how much control they design in a composition and what parts of the composition can change. Full control could be given to the audience, or the composer can produce a system whereby all the possible musical outputs are controlled. For example, a composer may design a work which allows the user to change volumes, effects and predetermined mixes of a work, thereby limiting the variability to ensure the rendered musical output always represents a desired aesthetic.

As highlighted in *The Madness of Crowds* (Section 8.1) work, the audience may not always use the system the way the composer intends. The composer needs to either keep refining the system until they feel it represents their vision or be open enough to allow the work to evolve and create open forms based on interaction.

Criticisms of Dynamic Music have often been about the listener wanting to only hear a song the way the songwriter intends (Section 1.4). Many popular music makers also find the notion of a song that changes challenging to their art. However, when a music form is viewed as the result of a process, it is the process itself that artists are in control of. The artist can create a compositional model with any level of control, it is an aesthetic choice. For Dynamic Music to produce innovative results it needs to evolve with artistic processes in the field. This brings us to a bit of a chicken and egg scenario. If popular music artists don't understand the processes underpinning Dynamic Music forms, they will not understand that they are still in control of the musical design.

Recorded music is still perceived as a static artform. As these perceptions start to change, artists may well begin to experiment with the concepts of control discussed throughout this thesis. Audiences may begin to change their perception of recorded music.

The ability to control music and the types of control continues to evolve with digital transformation. When comparing the levels of control of a fixed form with a dynamic work there is no loss of artistic control by the composer, only a change in the processes of music making in both the compositional model and rendered forms.

Control in the design and experience of Dynamic Music is still evolving. Given that artists need to understand these new processes, a new set of complex skills is required for artists to unlock the potential of future Dynamic Music forms.

9.4 Designing Dynamic Music

A Dynamic Music system can produce new experiences if it has either a high level of variability and/or transmutability in its musical design. A high level of both variability and transmutability may also offer more in terms of musical experience. However, just because a system has a high level of both does not mean it is a better Dynamic Music system. That is an aesthetic judgement.

Whether a Dynamic Music system is a work in its own right or a system which can include a range of works, it needs to offer something beyond the static form of music. It is designed based on a concept or the artists intent. If the concept demands a complex system with high level variability and transmutability to be realised, then it can be evaluated based on its ability to meet the artist’s vision.

The Madness of Crowds project (8.1), resulted in a large amount of variability in the playback of the music without requiring a complex system to realise the work. Reversing this scenario may also hold some weight. The more complex the system is in how it can transmute the musical architecture, the less variability may be required in the composed musical material. This is highlighted for instance by the working of *Bronze Format* (Section 4.1.7), which can analyse and recontextualise music using algorithms to create endless versions of a work. This creates a way forward for the design of future Dynamic Music systems.

AI based processes (Section 3.2) have the potential to help minimize the time it takes to compose the large amount of variability and transmutability in content and architecture required by Dynamic Music systems. Guy Whitmore discusses the following possibilities for AI:

> "the AI does everything, you can work with it to a degree, and then you can compose with just a little bit of AI." Guy Whitmore via (Velardo, 2017)

With new technologies like AI, machine learning, smart algorithms and new software, artists have even more tools available to create compositional models with the ability to refine a multiplicity of possible music outputs.

Contextual and other extended musical experiences are already being demanded by consumers. Spotify and other streaming platforms have been experimenting with introducing Dynamic Music, like *Spotify running*. It is an interesting space to watch as Spotify and streaming services have huge potential to play Dynamic Music. Streaming services may become the most important platform for audiences realizing and experiencing Dynamic Music works.

> "These streaming services cannot be utilities, it's not enough... they almost have to make music a verb - it has to just move." Jimmy Iovine, Apple via (Potts, 2017)

Dynamic Music has the potential to expand the streaming model with dynamically produced music in the future. However, there are a few issues still holding back Dynamic Music. These include the pre-existing relationship audiences have with fixed forms of music and an openness to accept change in the musical form. Dynamic Music works may be designed for passive listening, whilst others demand active engagement. For example the *VW and Underworld Play the Road* (Section 3.1.8) is designed for the action of driving. *The Madness of Crowds* would not work in this context. Dynamic Music works can be designed for different listening contexts: running, driving, playing, meditating, sleeping, weather etc.

Dynamic Music challenges the popular music industry's business model of exploiting songs based on fixed/static playback. Its distribution and entire value system are based on traditional awards, charts and supporting media like radio, TV and films. Dynamic Music disrupts this value system. In order for it to work the industry needs to adapt to allow for new forms of popular music that can incorporate interactive technology. However, there is no need to transform the entire popular music industry in order for Dynamic Music to gain in popularity. Dynamic Music can be understood as one branch of popular music. It will co-exist and evolve within all forms of popular music.

Despite these challenges, Dynamic Music offers new ways of experiencing music. To realise this potential more research is required in audience experience. The research calls for further studies in the way audiences perceive popular music such as cognitive embodiment and its ability to immerse and engage audiences in new ways. Design processes can be evaluated based on the experience it offers audiences. This utilises evaluation techniques used within the music interaction and cognitive behaviour and science fields.

This research has unearthed a new question: If the listener interacting with Dynamic Music can't understand that it is changing, how successful is the work? Most obvious changes in music include unexpected changes, lead melody changes and timbre changes in the lead vocal. In order for Dynamic Music to gain popularity, perhaps its musical changes need to be simple and obvious in order to build a listener culture. As a result, designing predictability and surprise in the music is another criterion which could be evaluated.

Related to experience is the potential for storytelling and narrative within Dynamic Music forms. Storytelling in a dynamic work is an important part of the process. It is a very different skill to that of producing a fixed work. While narrative and music is an area beyond the scope of this thesis, in a pop song the composer usually has three to four minutes to tell a story. Narrative in a song can range from a simple one line lyric about the singer's perspective repeated over again, or it can involve a story consisting of sections, commentaries and transitions. A Dynamic Music work allows for multiple stories, perspectives and metaphors to intersect. The ability to introduce multiple actor's points of view and new ways to express ideas and concepts.

The concept of fixed and Dynamic Music in relation to time is discussed in the thesis using the metaphors of timelines and timestream. Music is a time-based artform. In western culture, popular music is experienced as a fixed and unchangeable recorded medium, a consumption-based product. Static recordings have a strong nostalgic relationship for audiences. After all, if music is perceived as a moment in time this is similar to a memory. As technology becomes better at storing our memories and experiences, there won't be such a need to rely so much on music to satisfy our ritualistic and nostalgic sensibilities. These changes in memory storage may well enable a future where branches of popular music will represent and fulfil us in new ways.

For Dynamic Music forms to gain popularity they need to develop and be experienced by audiences. Dynamic Music requires a platform so audiences can begin to understand its potential. Videos have their own platforms (YouTube, Vimeo and others) and static recorded music has streaming services and radio. As Dynamic Music matures it could completely change the way audiences experience music.

Laurie Spiegal asks in 2000:

> " Will we be able to move our hands through the space around us, shaping the sounds as we listen, roughing them up here and smoothing them there, and pushing and pulling areas of sonic fabric up, down, toward and away, together and apart? What might be the variables with which we interact? In what dimensions might we move?"

Almost 20 years on from Spiegal's speculation we are at a time where these concepts are a reality. As the culture surrounding Dynamic Music grows what new experience will music offer in the future? The possibilities and potential for Dynamic Music are only just being realised.

Chapter 10

Glossary

10.1 Definitions of Key Terms

Adaptive Music

Mostly used in gaming and is defined as non-linear music. The music is composed to adapt and takes form to support the game-play and actions of the user.

Algorithmic Music

Generating music using mathematical approaches for example markov chains, stochastic algorithms, automata and fourier analysis.

Artificial Intelligence (AI)

Is an area of Algorithmic Music, it uses learning, problem solving and or knowledge base algorithms to create music. This includes machine learning and deep learning algorithms.

Autonomous Music

System led music, the music works independently of user direction. This could include, generative, AI compositions and systems.

Dynamic Music

Is defined as an overarching term that describes all forms of music which react, adapt and respond to data; whether it be input, control or autonomous data. Given music is and always has been dynamic when performed, the thesis uses the term Dynamic Music within the context of recorded and digitised music associated with a software system.

Generative Music

Music is created by a system and is ever changing.

Interactive Music

The user controls the interaction, the audio and/or visuals can be controlled in real-time by the direct actions of the user.

Interactive Technologies

"Interactive technology allows for a two-way flow of information through an interface between the user and the technology; the user usually communicates a request for data or action to the technology with the technology returning the requested data or result of the action back to the user." (IGI Global, 2020) Interactive technologies include but are not limited to mobile phones, wearables, Internet of Things (iOT), sensors, video games etc

Interactivity and Music

Music is and has always been interactive. It can be interactive in how a musician plays an instrument, communicates with other musicians, and finally the audience. Audiences interact with music in different ways to; by dancing; listening and; clapping, singing or playing along. This thesis is concerned with digitised and recorded music and how these forms can be produced to include interactivity.

Popular music

Is defined as "forms and genres of music-making that are most accessible to, meaningful to and enjoyed by large numbers of people." (Australia Council for the Arts, 2019) It is not to be confused with pop or mainstream music only and includes a wide variety of cutting-edge, niche and established genres. It could also be understood as music which is produced and sold as part of the contemporary music industry. In Australia it is described as popular contemporary music.

Popular music making

Includes the composition, performance and production of popular music.

Reactive Music

Context based on and reacting to data or the environment in which the data stream is constantly updated.

Responsive /Contextual Music

The music adapts to the user's environment or actions (not direct actions). The system uses the user's contextual data to influence the playback of the music, for example location, weather, heartbeat etc.

Variability refers to the options created for the music to be changeable through the musical and sound content and musical architecture of a Dynamic Music system. The compositional tools used by the composer to create variability.

Transmutability refers to the range of capability of the control system's use of data to transmute and create content and musical architecture. The design of the control system within a Dynamic Music system and how the data received or produced by the system can control and change the music.

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Appendix A - Madness of Crowds

Madness of Crowds – Creative work

The creative works are found in the supporting media folder.

1. Ableton File - Containing the 5 Tracks
2. Read Me Instructions for the Ableton file
3. Rochelle Salt *Downbeat Linz* Mix - Song 3
4. Rochelle Salt *Going Round Again* Mix - Song 5
5. Loops Folder - Song 1 (Contains 18 Loops)
6. Loops Folder - Song 2 (Contains 18 Loops)
7. Loops Folder - Song 3 (Contains 18 Loops)
8. Loops Folder - Song 4 (Contains 18 Loops)
9. Loops Folder - Song 5 (Contains 18 Loops)
10. Performance Excerpt - `https://youtu.be/bAqDqgF8U6E`
11. Other Video link - `https://www.youtube.com/watch?v=RJ6dXnJz6sg`

Appendix B - GIRD

GIRD - Gestural-based Interactive Re-mixable Dance-floor - Creative Work

The creative works are found in the supporting media folder.

1. Ableton file - Instrument Mode
2. Ableton file - Exploration Mode
3. Max for Live Patch - Instrument SYNTH
4. Max for Live Patch - GIRD
5. Video - `https://www.youtube.com/watch?v=g7YYoXM2kBU`

Appendix C - The Semantic Machine

The Semantic Machine

The creative works are found in the supporting media folder.

1. The Semantic Machine Work - `https://dynamic-music.github.io/semantic-machine` **(Please Note - to start the music you will need to press the play button located at the top right. You will also need to have approved location services for this browser or webpage in your settings.)**
2. LP Track 1 - *Have it All Mix 1*
3. LP Track 2 - *Fever Mix 2*
4. LP Track 3 - *Thinking For You*
5. LP Track 4 - All Tracks in Unison (Mix 1, 2 & 3)
6. Stems for all 4 tracks used in the Semantic Machine Prototype
7. Audio Sample recorded from the Semantic Machine App
8. Abelton File - Stage 1 Semantic Machine Energy Levels
9. FAST Documentary - `https://www.youtube.com/watch?v=VF4qQRcGfl8&feature=youtu.be`

Appendix D

STAGE 1 Semantic Machine Evaluation – Proof of Concept

Sound material

The first stage of content development involved composing sound material to see how the semantic player might work.

Initially two unique songs in the key of G minor were composed at different tempos. These two songs were then systematically merged into one work. The tempo for the first track ”Have it All” was 85BPM, and the tempo for the second track ”Semantic Machine” was 133BPM. Stylistically the works were composed based on the use of simple melodies and hooks, as well as common structures such as verse, chorus, bridge, climactic points, simple harmony and intimate vocal techniques.

The sound objects were composed and produced using a large range of software including Abelton Live, Kontakt, Reactor, Aturia Laboratory, personalized drum racks, drum packs as well as various plugins including Max for Live, Universal Audio and a large range of soft synths. Live recording was limited to make tempo adjustment easier.

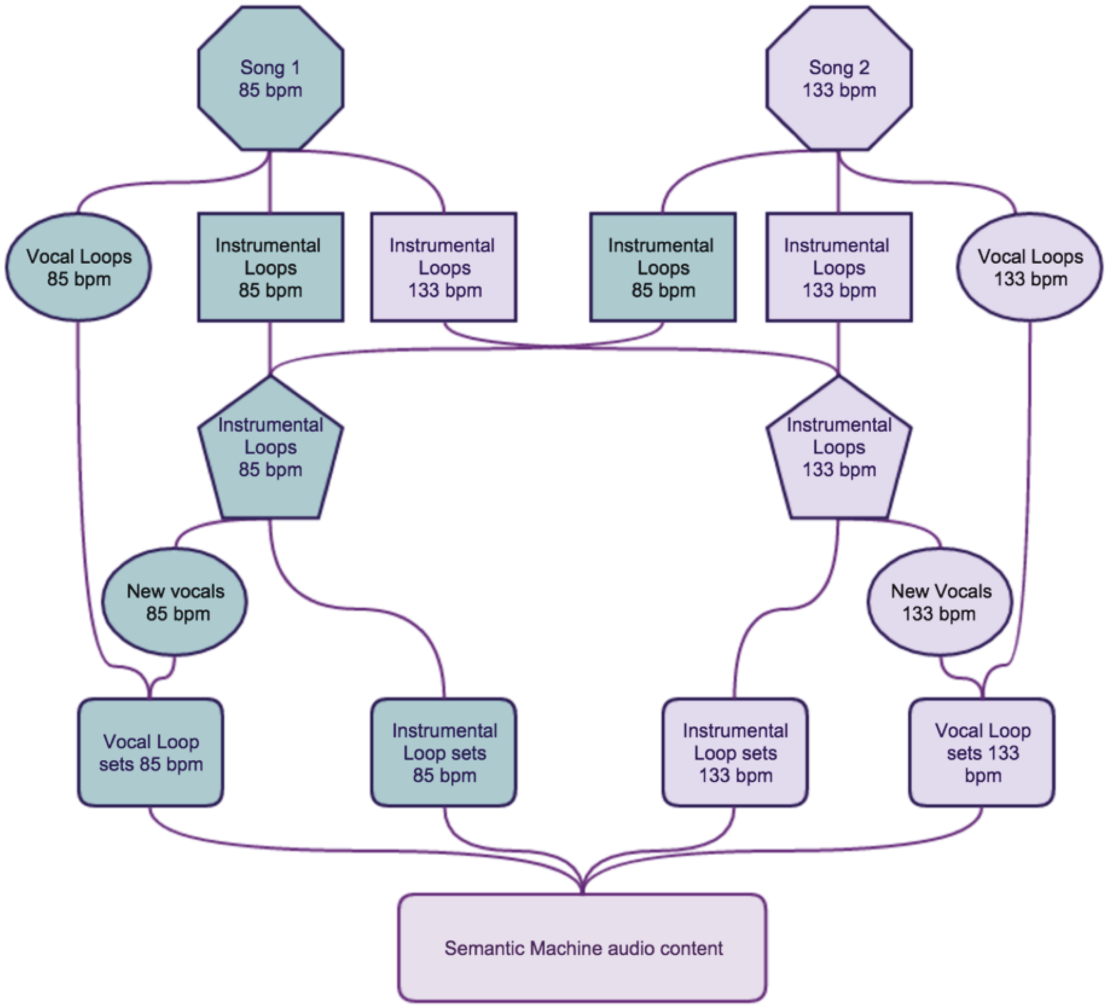
The sound objects were organised into phrases or a set of loops and then arranged into a basic song structure using a launch pad. The structure consisted of an intro, verse, chorus and middle eight. Now in a linear arrangement, works were then embellished with extra details and instrumentation in order to create a more dynamic and emotive piece.

At this stage a series of improvised melodic and rhythmic vocal parts were recorded using the rough structure as the instrumental bed. It was hoped that these improvisations would offer a range of ideas for different vocal approaches that the music inspired. This process produced a number of improvised song directions. The strongest melodic ideas were chosen to be explored with lyrical ideas.

After recording the lyrics for both songs, an extended set of loops was created to incorporate the new parts developed throughout the process. The songs were also mixed at this stage to ensure an overall balance and quality loops. There were many effects used in the sound design process but automated effects were kept to a minimum as the work was designed to be mixed in real-time by the semantic player.

Figure 9.1 demonstrates the process of merging the material and it was extended to offer more variability. Given most of the loops were MIDI, it was simple to transform both of the songs' loop sets to both 85 and 133 BPM. The vocal stems were edited into longer loops of complete verses, choruses and middle eights. Melodic hooks and vocals containing important lyrical content were cut into short loops for an extra vocal section.

Figure 10.1: Composition Process.



The loops produced from both tracks at 85bpm were combined as were the 133bpm loops.

New arrangements and structures were then explored with this mix of loops, investigating how the two songs' instrumentation worked in different combinations. This led to new vocal parts being recorded at the different tempos. It was important to explore the melodic, rhythmic and emotional delivery at different tempos. New vocal ideas were also introduced so the track had more flexibility and pathways to be explored.

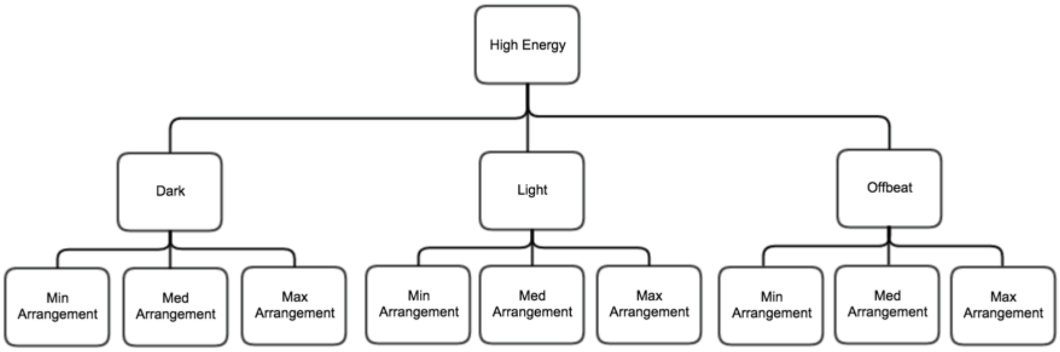
Organizing the Sound Material

The above processes resulted in a large library of instrumental and vocal loops (around 200). The resulting loops were not organised into any sub-structures.

The first experiment conducted involved adding all the loops at a tempo of 133 into the semantic player. Loops were added to the player with no rules, tags or structure to see how the semantic player sorted and played back the work. The semantic player automatically analysed all added audio files using standard feature extraction algorithms and annotated each object with descriptive features. Thalmann then conducted some experiments in feature-based mixing by defining high-level parameters that transformed the musical material in an attempt to add more variability to the musical result. The results were evaluated, and it was agreed that the semantic player used too many loops at once and did not do justice to the work. The rendered musical output lacked balance and movement. The decision was made to develop a set of instructions about how the loops might work together.

The next stage of development consisted of a more curated approach to musical design. The loops were re-edited, down-sized, sorted and arranged into groups that might give multiple structural options with different moods, dynamics and energy. At the tempo of 133 there were six moods or energy levels created including; high energy, energy, breakbeat, chill, ambient and journey. Each energy level had a dark and light subset and some moods also had an offbeat subset as shown in Figure 9.2.

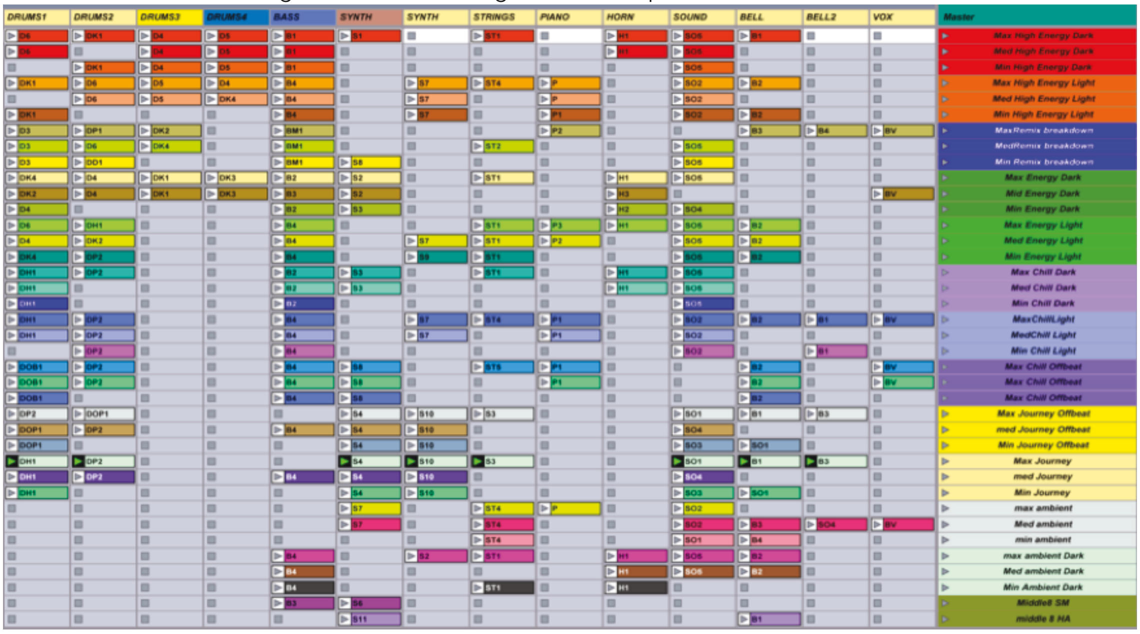
Figure 10.2: Sound material Organisation System.



Within each energy level subset there were three arrangements of loops with minimal, medium and maximum orchestration as shown in Figure 9.2. The full arrangement of loops at 133 bpm within the energy level subsets is highlighted by Figure 9.3. The Ableton file can be viewed in Appendix C-7.

The loop sets were designed to provide a large number of arrangement options for the semantic player. Filler sets were also produced to assist the music to transition between energy levels from light to dark, intense to ambient to chilled etc. In order to be imported into the Semantic Player framework, the loop library was organized into folders and the researcher's semantic tags were incorporated into the name of each audio file. This way of organising the loops was then integrated into the Semantic Player. There were issues with memory and streaming the large amount of audio required for this design. Only a small set of loops were integrated into the semantic player to test how the rendered musical output might sound. The results lacked structure and dynamics. There needed to be more instructions built into the musical design, some kind of structural and energy map.

Figure 10.3: The Organized Loops in Ableton Live.



Artistic Concept and Lyrical Themes

- **Have it All - Mix 1** - The lyrics begin with the subject wanting to be able to live life through the eyes of a man, to wrap herself up inside a man's mind and see how he sees the world through his privilege. The dreamy ambient song style explores the mind and dreams of the man as it builds to a peak where the subject states that 'she will find a way to wrap herself up inside his eyes and then she will have it all'.

- **Fever - Mix 2** - Is based from the view-point of the semantic machine, which is an analogy of a possible future where a machine or system knows you too well. It serves as a reminder that our data is being collected. The semantic machine knows everything you do and what you're going through as you do. It highlights the ethical implications of semantic and AI technologies. These technologies offer exciting future possibilities, however the ethical issues around the use of our personal data needs to be made part of the conversation, as these technologies begin to influence our everyday lives. Data profiling makes for good user experience but can also be used in unethical ways like the social profiling used by governments such as in China.

- **Thinking for You - Mix 3** - This explores the concept of the semantic web and the ethics behind it. It uses metaphors of dance mania or the dancing plague in the 14-17th centuries. People that caught this disease danced in a trancelike state until they died from exhaustion. Scientists have described dancing mania as a mass madness. The work aims to explore new ways technology is infiltrating our lives, for example the data your life is producing creates a bubble, where you only see things you might like. That data keeps you inside your bubble without providing new points of view.

As we dance to forget we become oblivious to the dangers of biased knowledge and information. Its dark concepts also remind us that our data is being collected and could potentially be sold to the highest bidder.

Appendix E

Proof of Concept
Components of the Musical Design Model for a Dynamic Music System
`http://tracyredhead.com/?q=content/play`

In order to show how the presented model for musical design works, a simple Dynamic Music system is used as a proof of concept. This example is a Dynamic Music web application with a simple control system. It demonstrates how the control data can manipulate the architecture at the macro level only.

It involves a multitrack app I created which plays the song 'Is this your world?'. The song was produced and mixed by Tim Powles in 2007. The app allows the user to change the volume of specific instruments. The app consists of eight stems representing groups of eight tracks or instruments. These include electric guitar, acoustic guitar, bass guitar, lead vocals, backing vocals, synthesiser, drums and boast. The user can adjust the volume of each track to change the musical playback. Based on this interaction the model discussed in Chapter 6 for the Musical Design of dynamic music is presented.

The app is browser-based (shown in Figure 9.4) and requires a computer and web-browser with flash to view it.

Figure 10.4: 'Is This Your World' Mixing App Screen Shot

The Dynamic Music system is the whole project, including the musical content, musical architecture and control system.

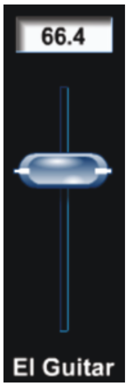
The Content

The dynamic music system consists of eight stems. These stems were composed for a static medium. They all start and finish at the same time and when layered together create the static version of the song. The concept behind this artwork was to develop a simple app where multi-track stems could be interacted with by audiences.

Control System

The controlling input is a volume slider. Data is produced each time the user moves a vertical slider. The slider data produces a data stream which can be any number between 0 to 100. This data stream is mapped to change the volume of a stem. The app's control system receives the control data from the slider with a data range of 0-100.

Figure 10.5: 'Is This Your World' Volume Slider Screen Shot



In Figure 9.5 the slider has produced the data value of 66.4. When the slider is moved to the top, the data it produces will be 100. As the user moves the slider down a series of data will be produced for example 100, 95, 80, 60. This data becomes the control data for the system. The data set required to change the volume parameter is 0 - 1, whereby 0 is no volume and 1 is the highest volume level. The control system is hence designed to transform the ratio of the data stream being received by the volume slider (0-100) so it can control the volume parameter which requires a data range of 0-1.

Process

Within the control system, the process used is considered to be interactive, given the user is interacting with the system by moving a slider. This work can be classified as an interactive music system.

The process used to transmute the architecture is interactive which involves mapping the control data produced to a volume parameter of an electric guitar stem or other stem.

For example the user is able to listen to the track and change the volume of the electric guitar.

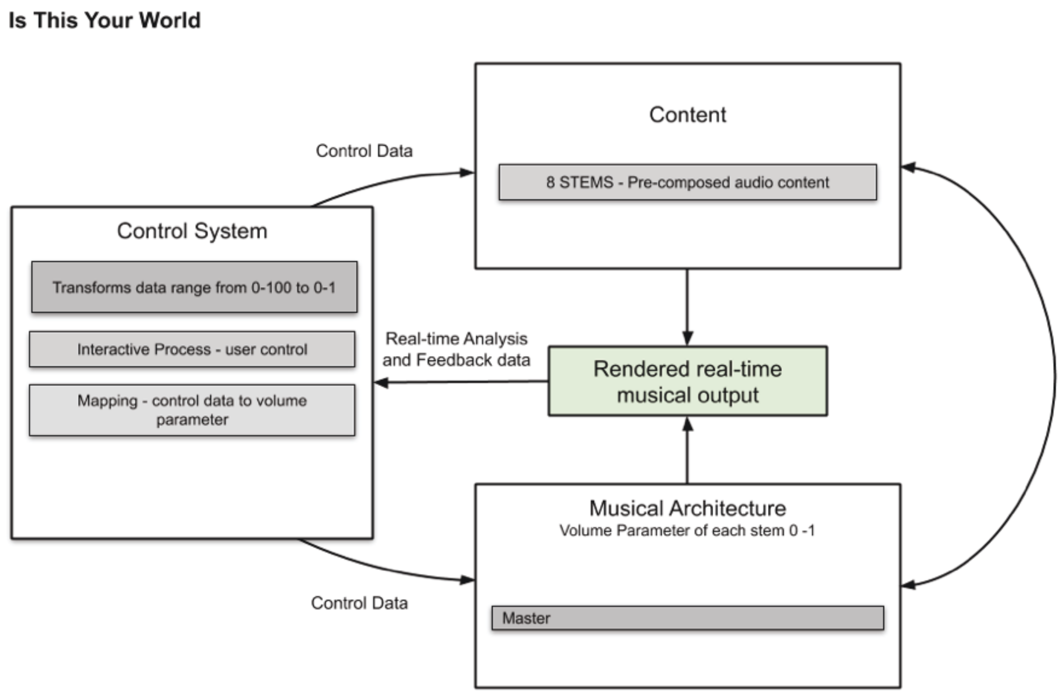
Experience

Due to the interactive process, user experience needs to be discussed to understand how their actions are affecting the music. There is audio and visual feedback produced by the system: the user can see the slider move and the volume number change and they can hear the result of the volume change.

Musical Architecture including the Musical Content

The musical output is dynamic given the musical architecture is not fixed in time. This is because each iteration of the volume fader's output will always be different. The sound material is made up of eight stems at the macro level. The control system can transmute a) the volume parameter and b) the volume range 0-1 of each stem.

Figure 10.6: Model for the Musical Design of 'Is this Your World'



Summary

This is an example of a simple system given the control data can change the architecture at the master level or macro form only.

In summary, as Figure 9.5 demonstrates, the control system receives the control data from the slider with a data range of 0-100. It is then designed to transform the ratio of this data to work with the volume parameter which requires a data range of 0-1.

The system is user controlled with an interactive process (an action causes a reaction consisting of stimulus, feedback, communication, pattern recognition or symbolic, experiment of prediction, new stimulus).

The level of control the system provides is at the macro level of the musical architecture. In this case the master level of production.

At the master level the control system can transmute a) the volume parameter and b) the volume range 0-1 of the sound material (eight stems).

This results in the volume control of the stems affecting the musical architecture at the master level to produce the rendered musical output.

There is audio and visual feedback produced by the system, the user can see the slider move and the volume number change and they can hear the result of the volume change. This is designed with the aim of the user being able to understand how their actions are affecting the music.

Appendix F - Impact and Published Outputs

Impact and Other Published Outputs from the PhD

During the PhD a number of works were explored that were not part of the Methodology. They have been listed here as well as published documentation.

- WIRED article - MTF Berlin (2016) https://www.gq-magazin.de/auto-technik/articles/wir-waren-hinter-den-kulissen-von-viktoria-modestas-auftritt-auf-dem-music-tech-
- MTF Berlin Documentary (2016) https://www.youtube.com/watch?v=ueYwDGosxiM
- MIT Media Lab Documentary - MTF Berlin (2016) https://www.youtube.com/watch?v=u63XuItu63o
- MTF Scandi Talk (2015) https://www.youtube.com/watch?v=3j61U-XJ444
- MiXD Symposium, Integra Labs - The University of Birmingham (2016) https://www.youtube.com/watch?v=YnJw6IqdMVM
- The Interactive Music Producer - Interactive Audio Systems Symposium, September 23rd 2016, University of York, United Kingdom https://www.york.ac.uk/sadie-project/IASS2016/IASS_Papers/IASS_2016_paper_19.pdf
- The Semantic Machine is featured in the book - Creating ArtScience Collaboration - Bringing Value to Organizations by Claudia Schnugg. https://www.palgrave.com/gp/book/9783030045487