Circular Entrainment

Russell Evan Leichman Snyder
Final Dissertation: MSc Digital Composition and Performance
University of Edinburgh
Edinburgh, Scotland

August 18, 2014

Abstract

Circular Entrainment is an exploration of how contemporary rhythmic theories can be used to conceptualize and generate digital music in an composition and performance setting. This project draws heavily from contemporary theories towards musical rhythm such as circular notation, microtiming, entrainment, and magnification as described by authors such as London, Toussaint, Roads, and Huron. The *Circular Entrainment* composition and performance system is built primarily in the MaxMSP graphic programming environment with MIRA, gen~, and JavaScript extensions. This thesis documents the process that was implemented to merge theory with individual aesthetics in the programming of *Circular Entrainment* and subsequent composition *Rhythmic Meditation*. These applied theories are examined in subsequent chapters to the depth in which they informed the development of *Circular Entrainment*.

Contents

List of Figures

0.1 Preface

The final composition submitted for this project, *Rhythmic Meditation*, is the culmination of an extensive process that transformed theoretical musical analysis into a compositional system. I therefore advocate reading this thesis prior to viewing the accompanying media files in order to gain an understanding of what has inspired this composition, and to appreciate the underpinnings of the *Circular Entrainment* system in which it was developed.

Each section of this thesis starts with a discussion of selected musical theories and research relating to the perception of rhythm, and continues with their respective implementation within the *Circular Entrainment* composition and performance system. Following this, I will lay out my creative and developmental process for both the *Circular Entrainment* composition and performance system as well as the composition *Rhythmic Meditation*. A self critical look back and possibility of further development will be considered in the conclusion section.

0.2 Submitted Resources

The items listed below have been submitted on the DVD accompanying this thesis. When this document is opened as a PDF-file from within the folder **RES_CircularEntrainment2014**, media followed by a the symbol [Play] or [Open] will directly load the respective material. For access from outside of the PDF-file, file paths to referenced materials are given throughout this text. All file paths are relative to the home folder **RES_CircularEntrainment2014**.

In addition to these file links, readers may click on any text in this thesis that is surrounded by square brackets, such as this: [Preface], to be taken directly to the referred section. This allows the reader to jump between different sections with ease, in a way that is usually more typical for reading a printed copy.

0.3 DVD Contents

0.3.1 music

- *Rhythmic Meditation*: [Play]

  `music/RES_RhythmicMeditation.aif`

0.3.2 sounds

- Early sketches: [Play]

  `Aug7_Mix1_RhythmicMeditation.mp3`

- Demo from July 23, 2014: [Play]

  `Demo_July23_01.mp3`

- Safety Groove: [Play]

  `09_SafetyGroove1.aif`

- Synth Output: [Play]

  `SynthFlute.mp3`

- Sampler Output: [Play]

  `Demo_Kick.mp3`

- First Output: [Play]

  `Demo_SpacedNoise.mp3`

0.3.3 code

- Complete code to use *Circular Entrainment*

0.3.4 writing

- Interactive PDF version of this document
- Complete LATEXresources used

0.3.5 videoDocumentation

- Studio Performance [Play]

0.4 Using Software for Circular Entrainment

This software developed for *Circular Entrainment* makes use of MIRA and gen~ in the MaxMSP environment. Although gen~ comes standard in new versions of MaxMSP, this patch may not work on older versions than Max 6.1.3. The MIRA objects used in this project can be downloaded for free from the Cycling '74 website.

http://cycling74.com/products/mira/#resources-anchor

Two external VSTs are used for this project for compression and reverb effects. Because these were purchased under copyright, they are not included in this project. However, all other features of this patch should be functional.

An algorithm to create file paths to sound file samples was generated so that absolute paths are generated for a user once the patch is loaded from within the folder **RES_CircularEntrainment2014**. However, these may not work two instances of this folder exist on the same computer.

Please note that the JavaScript environment in MaxMSP must also be functioning for this patch to run correctly. The patch developed for *Circular Entrainment* can be found here:

[Open]

`File Path: code/RES_CircularEntrainment_Software.maxproj`

The abstractions and JavaScript code used for this patch are found in the same folder.

0.5 Live Performance

A video recording of *Rhythmic Meditation* can be found at this location:

[Play]

`File Path:`
`videoDocumentation/RES_RhythmicMeditation_LivePerformance.m4v`

In this live performance from the 9th of August 2014 at the University of Edinburgh, the *Circular Entrainment* system is used to to perform my composition *Rhythmic Meditation*. The camera angle is deliberately placed to capture performer-system interactions.

Please note that this is *not* intended to be evaluated as the final version of *Rhythmic Meditation*, but rather as a performative example of how interactions with the *Circular Entrainment* interface can generate the complex rhythmic structures discussed in the body of this thesis.

0.6 Final Composition

The recording titled *RhythmicMeditation* in the music folder

[Play]

`music/RES_RhythmicMeditation.aif`

was submitted to fulfil the requirements for the Msc in Digital Composition and Performance at the University of Edinburgh. This recording is an edited, mixed and mastered recording of a performance intended to closely resemble the live performace on the 22nd of August 2014 at the University of Edinburgh.

Chapter 1

Introduction

1.1 Background

When any two similar events occur within a perceptually recognizable amount of time, our minds unconsciously predict a third event based on the pattern established by these first two (Huron, 2008; Hasty, 1999, pp. 84-167). This phenomena is the basis of musical rhythm which originally stems from the greek word 'rhythmos' meaning 'the recurrence of a motion'.

This ancient definition implies, to me, that rhythm is a cyclical phenomena and not one that moves endlessly left to right at absolute points in time. Recent publications on rhythm theories, such as Toussaint (2013); London (2012); Davies et al. (2013); Polack and London (2014); Benadon (2006); Danielsen (2010) also see rhythm in this way and demonstrate a potential shift from our 20^{th} century horizontal conceptions of rhythm.

Despite this new research, however, in modern times a gross majority of music creation tools, such as notation, software and hardware, still use interfaces that make the application of these concepts arduous tasks. When working with even modern step sequencers, I have personally been frustrated by the following:

- Fixed placement of notes
  – [Microtiming], p. [24]
- Simple tempo functions
  – [Entrainment], p. [28]
- Limited, linear rhythmic visualization
  – [Circular Rhythm], p. [18]
- Limited human interaction
  – [Application], p. [26]

From my beleif in the musical potential of contemporary rhythmic theories and an inability to implement them in a coherent workflow, I set out to develop my own system. The outcome of this system is the *Circular Entrainment* composition and performance system.

1.1.1 Music Theory to Digital Reality

Many of the theories discussed in this thesis are complicated and a full understanding of each would go beyond the scope of this paper. However, at the root of most of these theories is a new understanding on rhythm that can be achieved when music is thought of in a cyclical way instead of a linear fashion. A main motivation for developing this system was to experiment with the aesthetic qualities of these theories in the digital music domain.

1.2 Circular Entrainment

At its core, *Circular Entrainment* is a software step sequencer that uses a series of concentric circles as an interface in order to drive samplers and synthesizers in various ways. The name *Circular Entrainment* signifies the marraige of cyclical visualizations of rhythm with princples of fluid rhythmic placement and phrasing of entrainment at the core of its programming. As opposed to traditional step sequencers, *Circular Entrainment* allows more freedom of exact note placements, up to 4 different tempos running simultaneously, user specified phrase lengths, and uses an interface that efficiently translates human interaction into musical output.

The technical details of how these merits are accomplished are found in the numerous **Application** sections at the end of each chapter illuminating the application of the theoretical components discussed.

1.2.1 Programming Model

After a brief search, I found an educational youtube series created by dude837 which greatly aided in the development of my system. I modelled the JavaScript code used to generate various circles from the two part video series "Delicious Max/MSP Tutorial 8: Circular Sequencer"

https://www.youtube.com/watch?v=C1p_xI6b4NA.

I significantly added to this code and combined features from the Max/MSP add-ons Gen and MIRA as well as design a workflow that better implements the theories listed below.

1.3 Theoretical Inspiration

The development of *Circular Entrainment* was influenced heavily by these four different approaches towards rhythm:

- **Circle Rhythms** to analyze musical rhythm in meaningful ways:
  Toussaint (2013), London (2012), Huron (2008).
- **Microtiming** principles found in African influenced music:
  Bayreuth (1998), Danielsen (2010), Polack and London (2014), Danielsen (2010), Davies et al. (2013), Benadon (2006).
- **Entrainment** principles as applied in music and nature:
  Daniell (2012), Danielsen (2010), Huron (2008)
- **Magnification** principles moving between discrete events to continuous sound:
  Roads (2004), Watts (2004)

While an in-depth discussion of each of these theories would be beyond the scope of this thesis, each of the following chapter explains in more detail how these areas of enquiry find an application in the *Circular Entrainment* system.

1.4 Defining Scales of Time

Thoughout this thesis, the following terms are used to explore the time scales in which musical events occur, adopted from Curtis Roads' book *Microsound*. (Roads, 2004).

- **Macro -** The time scale of overall musical architecture or form, measured in minutes or hours, or, in extreme cases, days.

- **Meso -** Groupings of sound objects into hierarchies of phrase structures of various sizes, measured in minutes and seconds.
- **Sound Object -** A basic unit of musical strcture, generalizing the traditional concept of not to include complex and mutating sound events on a time scale ranging from a fraction of a second to several seconds.
- **Micro -** Sound particles on a time scale that extends down to the threshold of auditory perception (measured in thousandths of a second of milliseconds).

For further visual representation of these scales, please refer to fig. [A.1] on p. [55].

By manipulating Macro and Micro controls in real-time, a performer can explore textures that are difficult to create outside of the studio environment. In the final musical composition submitted, *Rhythmic Meditation*, pre-recorded sound files are launched along side *Circular Entrainment* output for aesthetic and musical effect. A complete look into the development of this composition will be covered in chapter [6] on p.[43]

1.5 Artistic Influences

In using the *Circular Entrainment* system for creating music, my main sources of artistic inspiration are the rhythmic practices and phrasing concepts of composer-performers J Dilla (Rock, 2003; Dee and Dilla, 2006), D'Angelo (D'Angelo et al., 2000), Horace Silver (Horace Silver, 1965), Javier Alverez (Alvarez, 1989), and Steve Riech (Reich, 1992).

The late J Dilla's instrumental tracks in particular were inspirational to me. They are put together in a way that sound like they may fall apart at times because tracks push and pull back their speed. The way that J Dilla uses space and variation in instrumental tracks like ”Purple” and ”Thought U Wuz Nice” greatly influenced my final composition *Rhythmic Mediation*.

As a hommage to the recently deceased Horace Silver, I rediscovered some of hi compositions. The jazz genre of ’Hardbop’ has always interested me as it merged bebop harmonies with more groove oriented music such as latin and funk. From personal experience, I know the limitations of jazz and traditional notation to accurately depict the type of feel of compositions like ”The Cape Veridian Blues”.

The song ”Left and Right” has an element about it that make it difficult for me to listen to without moving. I belief this has to do with the microtiming practices of performers in this piece. After reading about the overwhleming amount of work that was done in DAWs to acheive the groove in D’Angelo’s ”Left and Right” in *Musical Rhythm in the Age of Digital Reproduction* (Danielsen, 2010), I found a need to develop a system of alpplying microtiming and entrainment to automate this process.

In Papalotl for piano and electronics, Alvarez approached rhythm as motion discovered (Alvarez, 1989). The way in which Alvarez approaches the speed of changing tempos as another layer musical interest is progammed into *Circular Entrainment* and explored *Rhythmic Mediation*.

For long form composition inspiration, I drew from the principles used in Steve Reich’s early minimalist compositions (Reich, 1992). The fearlessness in which Reich explores the same material with only small variations in compositions like ”Piano Phase” and ”It’s Gonna Rain” gave me the confidence to to the same for *Rhythmic Mediation*.

1.6 Personal Approach

My personal approach to composition as applied to the development of *Circular Entrainment* is one that I have been developing since my undergraduate studies in Psychology and Jazz Performance at McGill University in 2009. During that time I was exposed to a wide variety of music cognition theories that, I believe, can underpin the creation of fulfilling music.

When I was a professional jazz and pop bass player from 2011-2013, I grew frustrated by a lack of knowledge and resources I had acess to in order to create the sonic structures I knew were possible from my undergraduate studies. The active application of music psychology theories in combination with my individual aesthetic goals has been the main drive for my creative processes and brought me to the Univeristy of Edinburgh to fulfill a Msc in Digital Music Composition and Performance.

Chapter 2

Circular Rhythms

The broad concept of rhythm applies to many other areas outside of sound and music, such as the changing of the seasons or human body functions. In these cases, circular depictions are commonplace and have widely been accepted as useful and intuituve. This chapter examines the benefits of circular conceptions of rhythm for musical analysis and composition and concludes with its application in *Circular Entrainment*.

2.1 Musical Rhythm Analysis

Conventional music notation in its linear form is widely recognised and accepted all over the world. Conversely, circular rhythmic notation is relatively novel. Figure [2.1] is an example of how rhythmic information can be transformed into circular notation.

To follow this notation, start at the top and move clockwise. One journey around the circle represents one measure of conventional musical notation. Each

(a) Traditional notation (b) Circle notation

Figure 2.1: Two ways of notating the main rhythm used in Dave Brubeck's "Blue Rondo a la Turk". (London, 2012, p. 101)

dot on the circle represents the smallest musical rhythm in a phrase. This is normally denoted in the denominator of a time signature, such as the 8 in Brubeck's 9/8 composition. The 9 dots spaced evenly around the circle represent the 9 possible musical places that a note can land on in this particular time signature and with the smallest musical rhythm being eighth notes.

This form of notation provides the basis for the cyclical model in the *Circular Entrainment* system. The chapter [Microtiming], p. [24], contains a detailed explication of how I elaborated this model further to suit the aesthetic and pragmatic requirements of *Circular Entrainment*.

2.1.1 Advantages

The benefits that I see when composing using circle notation as exploited by *Circular Entrainment* are as follows:

- Easier to see spacing of notes and density in a phrase
- Notation allows user to focus only on rhythm

- Complex time signatures are not so different from simple [1]
- Repeated phrases physically end where they start, more true to the listening experience.
- Patterns are scalable to various musical lengths [2]
- Rotation and permutation are easier to experiment with

Important musical principles are immediately seen with circle notation, but difficult to see with traditional notation. The music theorist Justin London summarises the rhythm-specific benefits of a circular notation system as follows:

> "If a meter is a stable, recurring pattern of attentional energy, it makes sense to represent this pattern with a circle, for in this way certain aspects of metrical structure will become apparent while at the same time freeing our representation of meter from any particular musical surface." (London, 2012, p. 64)

With these adavantages in mind, Godfried T. Toussaint (2013) found that the circular approach to rhythm lends itself better to the notation and analysis of some rhythms over others. Toussaint argues that certain mathematical properties of musical rhythms are important for their overall effectiveness in musical compositions. Toussaint uses circle diagrams throughout his book *Geometry of Musical Rhythm: What Makes a "Good" Rhythm Good?* (Toussaint, 2013) to demonstrate these properties. One concept which I applied directly to the programming of *Circular Entrainment* is the concept of Maximal Evenness.

[1] see fig. [A] for comparison

[2] The same pattern can be applied to 1/8 notes, 16th notes, 128th notes, etc. without any change in notation

2.1.2 Maximal Evenness

The lines within the circular notation in fig. [2.1](b) can be characterized as a quadrilateral shape, more specifically a trapezoid. This shape occurs as a result of each rhythmic object being spaced as far away from each other as possible within the confines of the circle[3]. The shape that occurs inside this circle is no surprise to contemporary music theorists such as Toussaint and London. Geometric shapes like this, and like those seen in [Theoretical Examples] on p. [54], conform to the rhythmic principle of "maximally evenness". Under this concept, rhythms are distributed in a way that spaces out events as far apart as possible given a specific metrical frame[4].

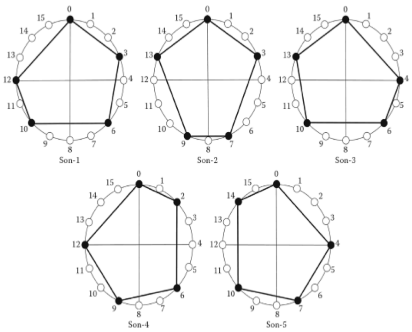


Figure 2.2: All the rotations of a Son rhythm starting on beat 1. (Toussaint, 2013, p. 290)

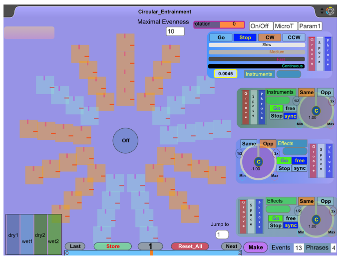
Maximal evenness can be difficult to observe using traditional notation, but as seen in the "Son" rhythm in figure [2.2], maximal evenness is much more obvious in circular notation. The "Son" rhythm, used for centuries in Latin American musical forms, places five events evenly over eight spaces which forms the shape of a pentagon when using circle notation. Toussaint suggest that perhaps the mathematical principles of this rhythm are the reason for its persistance in musical tradition throughout history.

[3]The Brubeck example is a trapazoid because 4 points cannot not be placed exactly over 9. Principles of maximal evenness round those points which do not fit to the nearest point which results in this trapazoid shape. If this example used a time signature that was a multiple of 4, such as 4/4 or 12/8, the resulting shape would be a perfect square.

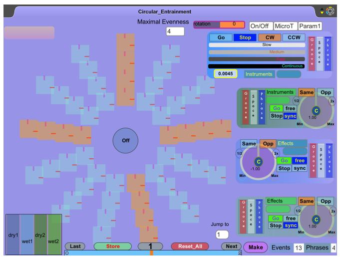
[4]This same principle has been used by theorists for pitch theory to demonstrate mathematical properties of scales(Tymoczko, 2011; Cohn, 2012).

2.2 Application

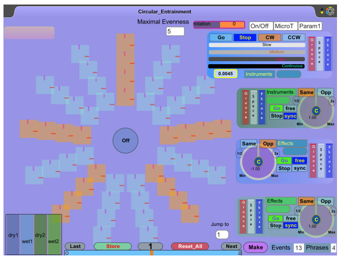
The interface of *Circular Entrainment* was designed to maximize experimentation with different groupings of notes in different phrase lengths. When a user opens the patch, there is no preset circular interface to start[5]. This was intentional to force the user to choose a new interface each time, thus fostering experimentation.



(a) 10 even over 13



(b) 4 even over 13



(c) 5 even over 14

Figure 2.3: Examples of maximal evenness within *Circular Entrainment*.

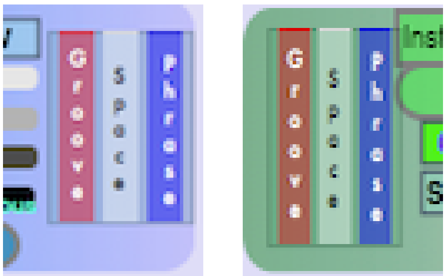
To create new interfaces each time from a blank canvas, I created a JavaScript method embedded within the patch[6] so as to generates objects in the MaxMSP programming environment only after recieiving user specifications.

Once a user specifies how many notes will comprise the circular interface, a function is available to the user to send note on/off messages in a way that utilizes a maximal evenness algorithm I developed seen in fig. [2.3]. A user can further rotate these note distributions left or right along the circle[7] allowing for further experimentation with permutations of these rhythms within the confines of the user defined circle.

[5]see fig. [B.1] in [Images of Circular Entrainment], p. [58] for visual reference.
[6]see fig. [D.1] in [Code Examples], p. [63] for excerpt.
[7]see fig. [B.2] in [Images of Circular Entrainment], p. [59] for visual example.

2.2.1 Musical Space & Phrasing

In addition to configurating rhythm, the location of each sonic object around the circle can be used to drive a panning algorithm that places that object into the space where it lies on the circle. In this way, sonic objects are panned left and right in the stereo field based on their location on the circle.



(a) (b)

Figure 2.4: Examples of controls over space and phrasing in *Circular Entrainment*.

Along with spacing in the stereo field, dynamic phrasing considerations were built into the system using the data from the circular interface as well. When fully utilized, the volume of each circle will gradually increase while the overall volume slowly decreases. I found that this gave the volume of each complete cycle a more musical structure.

Because these effects are not always desired, both spacing and phrasing can be controlled by the user via the self named white and red columns as seen in fig. [2.4]. The abstraction used to accomplish these techniques within *Circular Entrainment*, can be found in the softwareExamples folder:

[Open]

`File Path: softwareExamples/RES_Spacing.maxpat`

Chapter 3

Microtiming

3.1 Definition

Several different definitions of microtiming exist in music (Benadon, 2006; Danielsen, 2010; Davies et al., 2013). For the purposes of this paper, I will define microtiming as a slight rhythmic deviation of a smaller duration than the smallest rhythmic value of a passage, used intentionally for expressive purpose.

3.2 African Influenced Music

Although microtiming is present in various music genres in the form of phrasing (Danielsen, 2010, p. 37), microtiming in African influenced music was the main source of inspiration for adding microtiming options to the *Circular Entrainment* system. In contrast to classical music which mainly uses gradually changing patterns of microtiming over many measures for structures like accelerandos, African influenced music uses microtimng in a more consistant and reoccuring way.

Contemporary analysis, such as the example given in Figure [A.3] on page [57], suggest that unique microtiming patterns are characteristic of different African influenced music genres. I set out to explore various microtiming patterns such as these in *Circular Entrainment* and to develop my own.

3.3 Expressive Potential

Although African-influenced musicians (e.g. jazz musicians) typically make extensive use of microtiming, the analysis of microtiming in jazz music is a relatively recent field of enquiry. One of its pioneers, Fernando Benadon, explains:

> Microrhythms in jazz have begun to receive increasing attention from jazz scholars over the last decade, partly as a result of the widespread availability of inexpensive and easy to use sound-editing software, and partly as a result of a collective need to catch up with an already advanced pitch-based analytical tradition. (Benadon, 2006, p. 73)

As technology becomes more advanced, these analyses can be expected to become more refined and informative of individual use of microtiming.

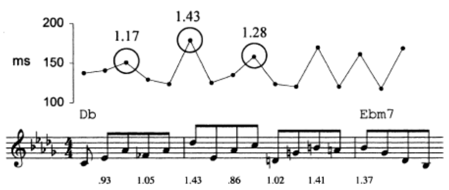


Figure 3.1: Example of microtiming analysis. Bill Evans from (Benadon, 2006, p. 79-80).

Figure 3.1 shows an example of the individual microtiming characteristics of a performing jazz musician.

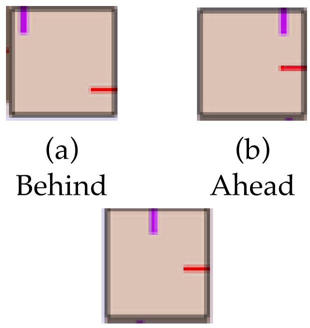
Microtiming theories often face resistance from other realms of music theory as deviations in the timing of one performance to another are not as exact when compared deliberate deviations in pitch. Mcguiness reflects on this:

> The main argument for the musical, rather than random, nature of microtiming deviations rests on the consistency with which deviation patterns are repeated in the same or similar musical contexts. McGuiness (2003)

Although human error may mimic microtiming, a persistence of specific patterns over many performances would suggest that these microtimings are indeed intentional. In traditional musical notation there is no convention to denote these consistent patterns of slight rhythmic variation. I therefore set out to explore my own way to visually represent and interact with these microtiming patterns in *Circular Entrainment* to generate unique rhythmic structures.

3.4 Application

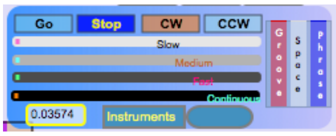
By using touch screen technology, I modified the traditionally binary "on/off" of a step-sequencer to an X/Y grid in order to fluidly place rhythmic objects around the sequencer. This was made possible through MIRA's "MultiTouch" object in MaxMSP which detects a users exact finger placement within a user defined square on an Ipad.



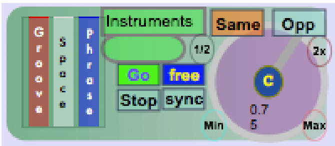
(a) Behind (b) Ahead (c) Center

Figure 3.2: Finger position on the X-position (line on top) of user touch allows for easy application of microtiming.

When the position on the X-axis of a users touch is exactly in the middle, the exact note placement of that rhythmic object is precisely to the beat. However if the user changes the position of his touch on the X-axis, left or right of center, the rhythmic object will occur before or after the exact metrical placement, respectively.



(a) Master Sequencer



(b) Slave Sequencer

Figure 3.3: Examples of sequence controllers in *Circular Entrainment*.

The amount of microtiming in an entire sequencer can also be scaled up or down. By altering the red columns called ”groove”, shown in Fig. [3.3], a user can modify the overall amount of groove (microtiming) in real time for that specific sequence. I have found the interplay between identical sequences differing only by microtiming to create interesting musical effects.

Chapter 4

Entrainment

4.1 Definition

Because the term entrainment is used in diverse fields from physics to meditation, its exact definition is often difficult to agree on. For this project, I define it as follows:

> "Entrainment occurs when two different beats pulsing in close proximity "lock-in" or synchronize to the same rhythm. The weaker pulse is activated and altered to match the stronger pulse" (Daniell, 2012, p. 49).

To me, and as implemented in *Circular Entrainment*, entrainment the a process by which sequences move in and out of sync with each other. In the frequency realm, we can say that a violinist entrains his voilin to 440hz be tuning his string to vibrate in sync with the oscialtions of a tuner. Borrowing Roads' terminology for time scales, tuning frequency may be thought of as extreme entrainment taking place at the Micro level[1].

At the Sound Object or Meso level, Hip-hop artists like J Dilla create sequences which entrain in and out sync using an organic, trial and error approach. Working in a DAW[2], Hip-Hop artists spend countless hours mainpulating the speed of samples until the correct 'groove' is obtained. I sought to discover algorithms to generate musically stimulating entrainment on many different time scales in *Circular Entrainment*. In order to do so, I researched how the human mind shapes its perceptions of reoccurring events in order to adapt this process for entrainment.

4.2 Attention & Expectation

In a 1960s lecture series on Eastern philosophy, Allan Watts gives an interesting insight into how we attend to certain objects.

> "We say about that so what. Show me something interesting. Show me something new. Because it's a characteristic of consciousness that it ignores stimuli that are constant" (Watts, 2004).

Watts goes on to explain that attention has evolved over time for the main purpose of surveying for potential danger, and that once a threat has been reassesssed to be safe, our active acknowledgement of its existence diminshes as it fades into the background.

This assessment of events over a period of time is also important in musical pattern recognition. Figure [4.1] demonstrates how energy spent attending to

[1]see [Defining Scales of Time] on p. [14] for review of time scales
[2]Digital Audio Workstation. Such as Logic, Abelton Live, Garage Band, Sonar etc.

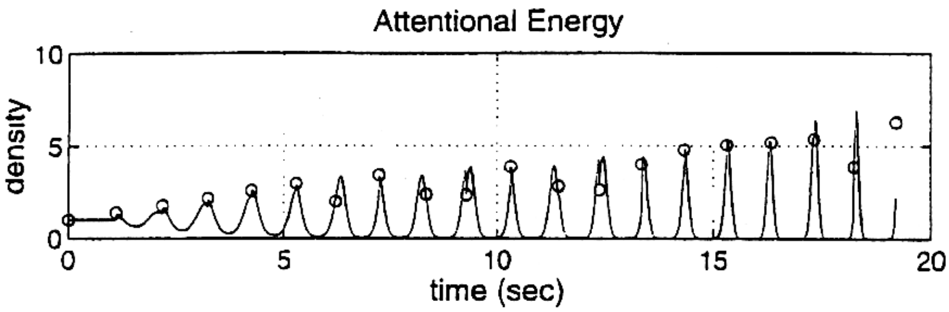


Figure 4.1: Energy spent on attention to stimuli grows in a periodic way over time. (London, 2012, p. 22)

reoccuring stimuli becomes more regular over time. This structure reflects the function of the bar line between the measures in conventional music notiation, in the sense that our energy usually focused towards beat one in meter-based music as discussed below.

The entrainment process by which two rhythmic sequences move in and out of alignment with each other is also an important factor in why music physically moves us. In his chapter on how groove induces movement, Danielsen cites entrainmnet as an important factor:

> Rhythmic organisms interact, more or less effectively, with dynamic flow patterns of events via entrainment: An event's driving rhythm shapes an organism's driven rhythm through adaptations of period and phase. This entrainment process extends to rhythms that reflect ebb and flow of attending energy" (Danielsen, 2010).

This clarified, to me, that compositions which induce motion, like D'Angelo's "Left and Right", must be using entrainment to align a listners body with the musical material.

As mentioned eariler, in meter based music, the listner usually focuses the most attentional energy on beat one. Huron adds insight to this phenomenon, "The downbeat *sounds nice*. One of the simple pleasures of listening to music is hearing events on the downbeat....pleasure is evoked via predictability" (Huron, 2008, 184).

Assessment of events over a period of time is important for musical pattern recognition. Fig. [4.1] shows how energy spent attending to reoccuring stimuli becomes more regular over time. This strucutre reflects the raised level of attention and consequent expectation for events to occur on the first beat in meter-based music.

4.3 Minimalist to DSP Phasing

Minimalist music uses entrainment through a technique called 'phasing'. Phasing is the prominent musical feature of Reich's compositions *Piano Phase* and *Come Out* (Reich, 1992) where two voices start in unison and are slowly moved out of sync.

The main difference between minimalist phasing and the type of entrainment used in *Circular Entrainment* is the scale on which it occurs. In most minimalistic music, this technique is usually used gradually over Meso time scale of minutes and tends to go from in sync to out of sync. Some compositions may only complete one cycle in the entire piece.

I wished to explore how these same rhythmic patterns and phasing principles could move fluidly between different time levels from Meso to Micro. I set out to discover how the same sequence and sonic material transforms as it moves from a once a minute cycle to a 120,000 times a minute cycle. Fascinating sonic results occur when translating strong rhythmic material between different scales of time.

4.4 Application

4.4.1 Sound Object Level

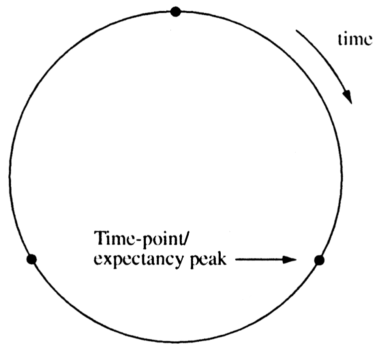


Figure 4.2: Expectancy from three beat meter cycle. (London, 2012, p. 64)

Entrainment princples are applied in *Circular Entrainment* at the Sound Object level through their arrangment. The even spacing of objects around the circular interface help guide a user to create patterns that generate expectations which will inevitably facilitate entrainment. Fig. [4.2] depicts how the circular model is conducive to managing listener expectation over time. This circular architecture, as explored in chapter [Circular Rhythm], greatly aids in creating entrainment inducing patterns at the Sound Object level.

4.4.2 Micro Level

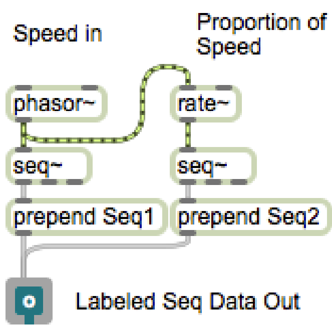


Figure 4.3: Signal driven sequencing in MaxMSP

In order to drive sequencers to precise and extreme speeds, I used DSP[3] to read and send data. Working with the MaxMSP object seq~, as seen in fig. [4.3], *Circular Entrainmnet* allows data output to be driven via DSP. Not

[3]DSP stands for Digital Signal Processing. By using DSP processing speeds of 44,100 events per second, extreme speeds are reached in *Circular Entrainmnet*.

ony does this make finer placement of sound events possible, but also allows for extreme speeds to be reached without dropping data[4].

4.4.3 Meso Level

To explore entrainment at a Meso level, I built a system of control in which speed manipulations from one sequencer can effect others in various manners.

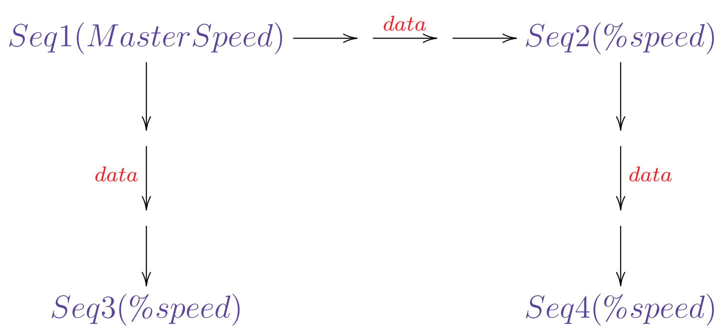


Figure 4.4: Flow of speed data in *Circular Entrainment*.

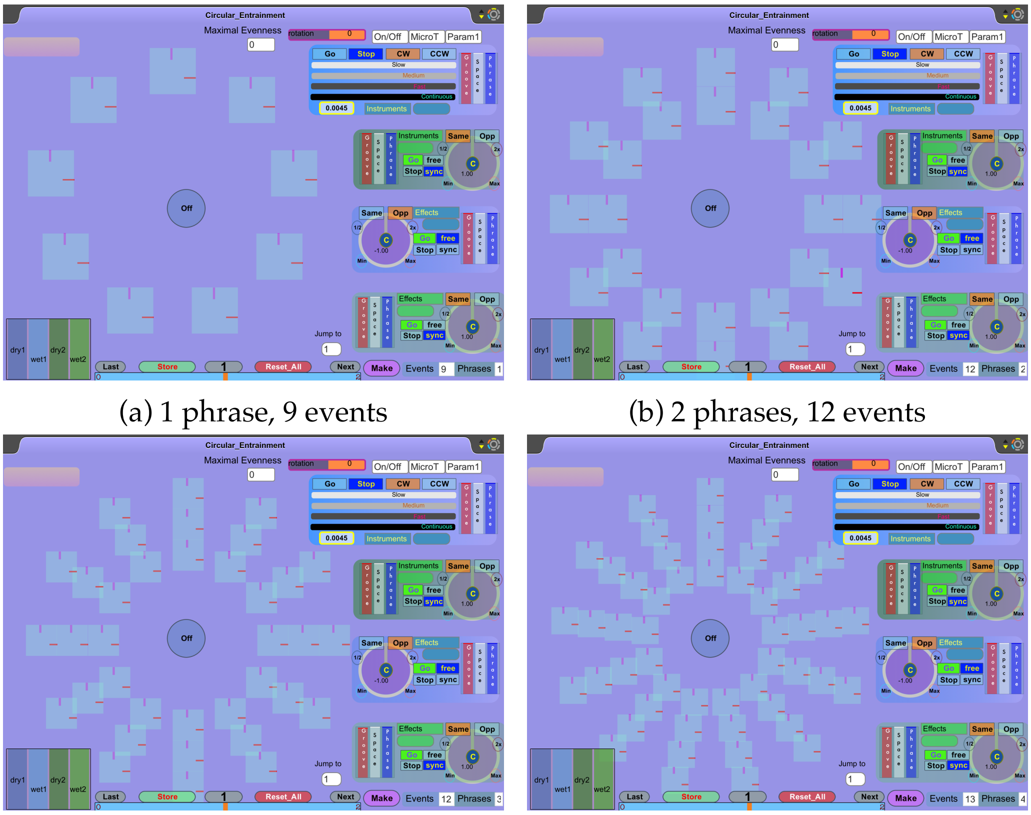
As depicted in Fig. [4.4], layers of interactions were designed so as to allow for hierarchical and individual levels of control. In the depicted example, the speed with which sequencer 3 operates is a function of the speed of sequencer 1.

By using the rate~ object in MaxMSP, DSP driven sequencers are scaled to different proportional levels in real time. In addition to speed proportions, rate~ also allows sequences to become fully synchronized[5]. In this way, once sequences are be entrained in phase with each other, they can be locked together.

Another way entrainment is facilitated on the Meso time level is the user option for phrase length as seen in fig. [4.5]. In addition to the freedom a user has to define the number of sound objects spaced evenly around a circle[6]], a user can experiment with manipulating rhythms over up to four phrase lengths in

[4]Packets of data will be dropped in MaxMSP unless the scheduler is put into overdrive.
[5]the child cycle begins at the same time as the parent begins
[6]As decribed in sec. [2.2] on p. [22

the form of concentric cirlces. The generation of these cirlces was accomplished through the same JavaScript method described in sec. [2.2], p. [22].



(a) 1 phrase, 9 events

(b) 2 phrases, 12 events

(c) 3 phrases, 12 events

(d) 4 phrases, 13 events

Figure 4.5: Examples of different phrase lengths possible in *Circular Entrainment* with various numbers of events. Circles are generated from user specifications.

The result of DSP driven sequencing is a fluid movement from the Micro to Meso levels of musical time. In this way, rhythmic patterns which induce entrainment can move between discrete rhythmic objects to continuous sounds to experiment with their musical proporties at different scales.

Chapter 5

Development of Circular Entrainment

This chapter describes the process of actualizing *Circular Entrainment*. The following are some milestones and discoveries encountered in the building process.

5.1 Samplers and Synthesizers

5.1.1 Gen~

All samplers and synthesizers were built from scratch using gen~ examples as templates. The gen~ extension of MaxMSP allows users to program at a lower level than MaxMSP while still utilizing a graphical user interface. Text based code, similar to C, is automatically generated for a user directly from their graphic programming.

Gen~ allows for lower level control over DSP than regular MaxMSP, but also has a set of drawbacks that will be discussed later in this chapter. Overall, it greatly reduced CPU which allowed for the circular interface to draw the CPU power it needed to function properly.

5.1.2 Sampler Example

There are three different samplers used in *Circular Entrainment* each with a unique approach dealing with sound files. The simplest and first developed one uses this five lines of gen~ code to load and play through samples.

```
Buffer mybuf("drumloop");
mybuf_dim_1 = dim(mybuf);
mybuf_chans_2 = channels(mybuf);
sample_mybuf_3, index_mybuf_4 = sample(mybuf, in1, 0, interp="spline", channels=1);
out1 = sample_mybuf_3;
```

This gen~ code is at the heart of the first sampler built, GenSampler.maxpat:

[Open]

`File Path: softwareExamples/GenSampler.maxpat`

Here is an example of early grooves generated using this sampler:

[Play]

`File Path: sounds/Demo_Kick.mp3`

The only samples used for this project were percussion and bird sounds which had been previously synthesized using the software Common Lisp Music (CLM)[1] .

[1]For more information, go to https://ccrma.stanford.edu/software/clm/

5.1.3 Synthesizer Example

There are five synthesizers used in *Circular Entrainmnet*, all of which create different sounds. One of my favorite synths is a flute synth that I adapted after the MaxMSP examples.

[Open]

`File Path: softwareExamples/Flute.maxpat`

The actual gen~ code can be found in [Code Examples] on p. [64]. In order to make the synth blend with other sounds within my patch, I changed many parameters from the original gen~ example patch. In this early demo, a piccolo sounding instrument plays along with a snare:

[Play]

`File Path: sounds/SynthFlute.mp3`

This synth can be heard in the "Forest" section in *Rhythmic Meditation* along side the bird synthesizer. See the [Composition Guide] for *Rhythmic Meditation* on p. [62] for the exact time this occurs.

5.2 Effects Routing

After thorough deliberation, I decided to apply the same data from the circle sequencer to the effects units as well. These are sequencers are numbered three and four. Microtiming, spacing in the stereo field, and entrainment principles were applied to reverb, chorus, flanger, and bitcrushing effects.

The y-values of user touches within the "mira.touch" objects, which usually control volume for instrument sequencers, control the mix amount for effects

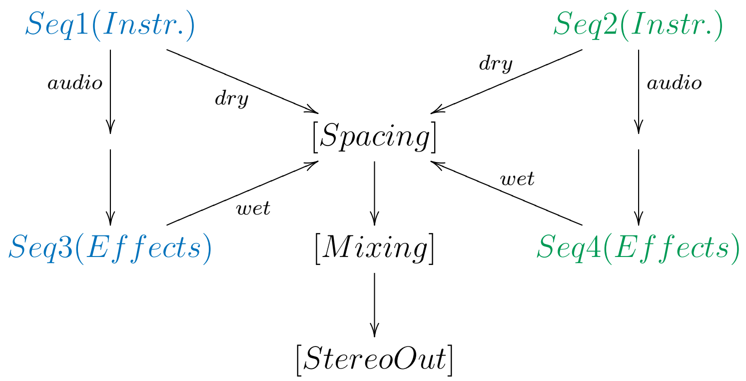


Figure 5.1: Audio flow in *Circular Entrainment*. Data from user interactions with the circle interface feeds into all four individual sequencers. Colored text is the same as the colors representing that particular audio route in *Circular Entrainment*. see fig. [B.3] for screenshots of the patch in action.

sequencers. To visualize the timing of the effects, I made the on/off data for the effects sequencers appear as dots inside the mira.touch objects. This can be seen in fig. [B.3], p. [60], and in the video documentation presented in sec. [6.4], p. [47]. Overall, this approach to using shared data structures between instruments and effects units resulted in satisfying musical output without having to generate more systems of control.

5.3 Macro Controls

The development of Macro controls was the very last stage in the development of *Circular Entrainment*. I implemented a relatively simple system using the maxMSP objects pattrstorage and pattr object to write and recall settings. This user interface, as seen in fig. [5.2], allows the user to store the state of all objects in the patch to be recalled later. In a live performance setting, the user can then recall and modify these settings in real time.

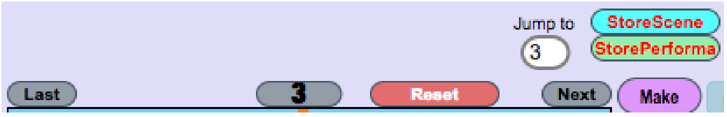


Figure 5.2: Macro controls in *Circular Entrainment*. User can save the state of all objects to be recalled again during a live performance or at a later time.

The Macro controls of *Circular Entrainment* can be used to finely tune settings in the studio and create sweeping changes in a performance setting. They also allow the creation of diverse and changing sonic landscapes as I have demonstrated in my composition *Rhythmic Meditation*.

5.4 Problems & Solutions

5.4.1 Filter Explosion

Figure 5.3: CPU running at 775% its maximum capacity.

In my first offical run through, at about five minutes into *Rhythmic Meditation*, a horrible noise reminiscent of an explosion at a styrofoam factory occured followed by a complete failure of my patch. Even on reboot of the patch, it did not produce any sound. I understood that the CPU was overloaded from the display in fig. [5.3] as my CPU had never gone over 40 percent before.

I believe this was a result of a filter being overloaded. After further investigation, I discovered an instability in the gen~ filter example that is supposed to be an equivalent substitute to MaxMSP's biquad~ object. This problem was fixed by taking out all my gen~ filters and replacing them with the standard MaxMSP biquad~ object.

5.4.2 Clicks and Tempo

Keeping track of synthesizer speeds in order to avoid clicks from instruments turning on and off was another challenge. Because I originally intended to have multiple patches running simultaneously, I did not use a global variables to keep track of tempo. Keeping track of four speeds proportionally related to each other, as depicted in fig. [4.4] on p. [33], was difficult and often a miscalculation resulted in clicking.

Another source of clicking was a result of a the indeterminate nature in which my synthesizers were originally programmed. Initially, I wished to have notes with unfixed ending times. However, I quickly learned that this resulted in clicks if the next sound started before the first had ended. One solution I implemented was to put samplers into poly~ objects. This allowed for a greater degree of uncertainty to occur as many instances could occur at the same time without effected each other. However, at extreme speeds even several instances of a patch were not enough.

The final solution was to embrace these clicks at extreme tempos. Sounds and materials are so distorted at this point anyway that these clicks are not offensive to the original sound. In this way, I took a potential flaw in my patch and turned it into a feature.

5.4.3 Concerns about GUI

I found MIRA, the MaxMSP extension to facilitate control using an Ipad, remarkably stable throughout the development process. However, one of its set backs is that it is not able to read GUI objects embedded in BPatchers even when those objects are normally compatible with the MIRA environment. The only way to display GUI objects was to connected them to be displayed from the main patcher. In combination with large number of objects generated via JavaScript, the result is shown in fig. 5.4, an unavoidable web of patch cables appears when the patch is unlocked.

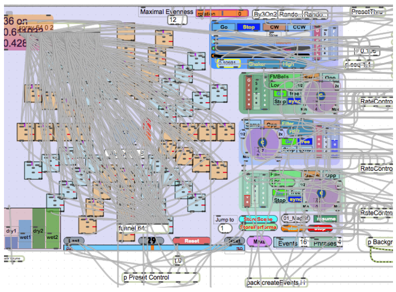


Figure 5.4: Building a system with MIRA can lead to an unavoidably high number of cables from an incompatability with BPatchers.

In order to improve on this unhandy structure, I implemented a clear function into the JavaScript code so as to clear the patch easily and open it in a cleaner state each time it is opened[2] as well as hiding cables on lock.

At first, I had aspirations of running two to four of copies of *Circular Entrainment* simultaneously. However, after several months of development, it transpired that the graphic objects within MaxMSP drew more CPU resources than I had anticipated. This was a major constraint in the size and complexity of my patch and ultimately forced me to compromise on having only one instance.

Although my initial goal of having a self contained system to generate all sound sources would not be reached, I believe the samples that I designed to be launched alongside *Circular Entrainment* ended up adding more value to the subsequent composition *Rhythmic Meditation No. 1* than would have been possible with four instances.

[2] see fig. [B.1] on p. [58]

5.4.4 PattrStorage and Play~

On the day of my video documentation performance, I encountered an issue that I was not able to fully reconcile. The pattrstorage object seemed to exert control over playback objects such as sfplay~ and play~ despite there being no connection on any level to these objects. When Marco presets were changed in *Circular Entrainment*, sound file play back would occasionally stop in a pattern that I was unable to discover.

The solution I found was to completely remove the playback unit from the patch. This, however, led to a greater delay time between sample launch and user interaction than would have been desired. This was remedied with more thorough planning, which then resulted in the transitions occurring in a regular way.

Chapter 6

Rhythmic Meditation

My composition, *Rhythmic Meditation*, is intended to be a one continuous piece of music. To achieve this, however, I developed sections prior to performance in order to guide spacing and improvisation within this composition. The full guide used for *Rhythmic Meditation* can be found on page [62] in the [Composition Guide].

An important aspect of this composition is the freedom the performer has to move between sections and modify each section differently each time. As a result, no two performances will ever the same and encourages a user to experiment in live performance.

6.1 Musical Development

6.1.1 First Output: Spaced Noise

The first sound output from *Circular Entrainment* is spaced noise with no effects.

[Play]

File Path: sounds/Demo_SpacedNoise.mp3

Despite being pleased with the sound output per se, I found this output to move too much in the stereo field. This was when I decided to implement control over the spacing in my patch as discussed in the section [Musical Space & Phrasing] on p. [23].

6.1.2 Middle Output: Groove Begins

Finally at this stage, I was able to create musical output that embodied many of the theoretical concepts I had previously researched. An example of output from this stage can be found here:

[Play]

File Path: sounds/09_SafetyGroove1.aif

I could fluidly manipulate entrainment, microtiming, and scales of time fluidly using the circle interface in real time. I sampled this particular output in the "Low Groove –> Gross Noise" section of my final composition[1].

6.2 Composition

Once the basic foundation of *Circular Entrainment* was laid, I started the development of a compositional form to utilize its features. Because *Circular Entrianment* was developed with the composition process of a piece like *Rhythmic Meditation* in mind, I was able to shifted my focus onto artistic questions and large form

[1] see [Composition Guide] for exact location.

structures without worrying about the technical aspects of the compositional process.

6.2.1 Meditation Guide

One of the transcending goals of this composition is to promote an understanding and connection between listeners and their surrounding world. After showing early and middle versions of my composition to non-colleagues, I was confronted with confusion about many aspects of the peice. In particular, there was a clear lack of understanding that the piece explored different levels of time with the same rhythmic patterns.

Around this time, I was introduced to a lecture series of 20th Alan Watts,(Watts, 2004). Watts explores precisely the concepts I wished to express in my composition from a more universal and spirtual point of view. In addition to this, the style of these recordings are reminiscent of samples used in HipHop, a genre from which I drew strong music inspiration from for this project[2].

After implementing samples of Watts' lectures, I was pleased to find a higher overall level of understanding from listeners. On a performance level, I found these samples also served as markers in my structure to help me retain the overall form of my composition while still allowing for improvisation.

6.3 Rough Draft

After presenting the following first version of my composition to Prof. Michael Edwards, we agreed on several aspects that could be changed in order to en-

[2]see section [Artistic Influences], p. [15] for specific references.

hance the composition and listening experience.

[Play]

File Path: sounds/Aug7_Mix1_RhythmicMeditation.mp3

6.3.1 Lack of Impact

Overall, my louds were not loud enough - not in volume so much as impact. As a result of the diverse sonic landscapes traversed in *Rhythmic Meditation*, loudness techniques like compression would have negatively affected quiet sections if put on the master output. I decided to implement a compression unit within *Circular Entrainment* and direct only the more percussive sounds to that output which allowed them to be percieved as louder during more rhythmic sections where loudness is important.

Another way I increased impact was to mix the samples being launched to embody a more complementary frequency space to the instruments from *Circular Entrainment* that would accompany it. In this way, I made sections more impactful by distributing spectral energy in a wider plane. Moving quickly from a narrow frequency space to a wide frequency space resulted in an overall increase in impact.

6.3.2 Too Much All The Time

With the implementation of the macro control system discussed in the section [Macro Controls] on p.[38], It was now possible to drastically change sonic material at the push of a button. However, I was overly eager to use this ability and created many changed that did not necessarily relate to each other in musically meaningful ways.

Another reason why initially there were too many sections was my wish to incorporate every preset of every synthesizer I had developed. After spending considerable time and effort to program *Circular Entrainment* with a wide array of features, I wanted to showcase the variety of sounds it could generate. This, however, led to an overflow of musical material. Once I prioritized the artistic vision for *Rhythmic Meditation* over the technical abilities of the Circular Entrainment system again, I conceded to limit the amount of sounds used. Consequnetly, a more cohesive musical composition emerged. This also allowed me to focus more on micro manipulation of sequencers which actually helped emphasized the rythmic prinicples discussed earlier in this paper.

6.4 Video Documentation

The following is a video recording of a live performance of *Rhythmic Meditation* from August 9th, 2014. The purpose of this video is to demonstrate how the *Circular Entrainment* interface can generates the complex rhythmic structures discussed previously as applied in *Rhythmic Meditation*.

[Play]

```
File Path:
videoDocumentation/RES_RhythmicMeditation_LivePerformance.m4v
```

The angle of this video is intentional to emphasize performer-interface relationships.

6.5 Final Version

The following is a mixed and mastered version of *Rhythmic Meditation* submitted to fulfil the requirements for the Msc in Digital Music Composition and Performance at the University of Edinburgh.

[Play]

`File Path: music/RES_RhythmicMeditation.aif`

This version is an edited, mixed, and mastered studio performance. In the process of implementing smooth changes and exploring deeper rhythmic development of material, the length of this composition grew seven minutes in duration. A guide to this composition, as used to guide performance, can be found on p. [62

In the conclusion section, I will critically evaluate the process to create *Circular Entrainment* and *Rhythmic Meditation* as well as consider new directions in which I plan to grow on the basis of this project.

Chapter 7

Conclusion

7.1 Further Development

7.1.1 Features

From a perspective of personal reflection, I feel I have come a long way as a digital composer through this project. Even so, the finite amount of time and resources available for this project put constraints on the ideas that I was able to manifest and implement. I see potential to develop it further in the following directions:

- Adding equations to generate probabilty of microtiming at particular metrical beats as found in Mali drumming as examined in Polack and London (2014).
- Spiral GUI: Have objects be wedge-shaped in order to fully interlock in a spiral.
- 3D binaural surround: Create an algorthim that uses head related transfer functions to create a 3D space based on circle data.

- Build an online system for long distance collaboration and learning utilizing web APIs to generate and manipulate sound.
- Program more tactile controllers, such as a PS3-controller, to be used with *Circular Entrainment*.
- Record and export midi or osc data to further manipulate in a DAW.

I experienced through this project that the process of programming software to fit my own musical interests resulted in a faster and more efficient workflow than would have been possible using a standard DAW. Although extensive work went into this project before any sounds could be produced, I had a more personal relationship with the sonic output and new material was produced at a higher rate than would have been possible had I only worked in a standard DAW.

7.1.2 Compositions

The type of compositions that can be created in *Circular Entrainment*, exemplified by *Rhythmic Meditation*, are wide and varied. There are many grooves that would lend themselves to electronic dance music. If different soundfiles were launched along side the output of *Circular Entrainment*, new and exciting compositions could be arrived at with ease.

As a professional bass player, I can envisage adding baselines over top and under a new compositions which could potentially open up another dimension of sonic input and interaction. However, the process of implementing another voice poses questions of how to interact with the current system and how to effectively translate the concepts reflected in the *Circular Entrainment* system to more conventional instruments which were out of the scope of this project.

7.2 Critical Reflections

7.2.1 Circular Entrainment

Overall, I am very satisfied with achieving an application of contemporary rhythmic theories to digital composition in the form of *Circular Entrainment*. Having a narrow focus on rhythm resulted in a system that is unique and very specific in its application. While this can be seen as a strength of the project, it is at the same time a weakness in that its use as a stand-alone composition and performance tool is limited to rhythmic development.

When taking the role of a user of *Circular Entrainment*, especially during the live performance of *Rhythmic Meditation*, I found myself desiring more tactile feedback whilst performing. The lack of physical controls from performing with an iPad meant that a focused concentration on the screen was necessary throughout the performance. As a result, I felt inhibited to engage the audience in a way I normally would.

Contrary to my beliefs, I discovered that when sequences are sped up to Micro time scales, the exact rhythmic patterns used are somewhat trivial. Patterns with maximal evenness sounded identical to those with the same number of sound objects but placed in a different arrangement. At the Micro level, I found it more effective to think about density than about musical rhythm. This was eye opening to me as I used to think techniques that rely on random sampling, such as granulation, could benefit from more rigid structures. I now understand that at the Micro level, the ear does not discern the rhythmic principles of microtiming or entrainment in the same way as it does at slower speeds.

7.2.2 Rhythmic Meditation

From the constructive feedback I was given on my composition from colleagues and non-colleagues, I am satisfied that *Rhythmic Meditation* achieved all its overarching objectives: to encourage thought about a listener's surrounding world and the meaning of rhythm in it and to showcase the abilities of *Circular Entrainment* to facilitate the rhythmic concepts of microtiming and entrainment.

However, one weakness I felt in *Rhythmic Meditation* were the actual sounds that were produced within the system. This arose from an unexpected amount of time that went into developing the systems which facilitate the complex rhythmic principles discussed in this document at the expense of instrument development. Perhaps this could have been remedied by collaborating with another musician who only focused on the sound design of the project. In future manifestations of *Rhythmic Meditation* and new compositions, I plan on developing and refining the synthesizers, samplers, and effects to push the qualities of individual compositions further and allow for more improvisation within the confines of the compositions unique aesthestic goals.

Another weakness I felt was the overall performance environment in which *Rhythmic Meditation* occured. I felt that the audience experience could be improved upon considerably by adding visual representations of *Circular Entrainment* data. Although the GUI for *Circular Entrainment* is an engaging and comprehensive guide to which sounds are happening where in *Rhythmic Meditation*, I felt it did not promote the aesthetic direction of *Rhythmic Meditation*. I believe visualizations of *Circular Entrainment* data taylored to individual compositions could have furthered my artistic goals by promoting an understanding of rhythm through the visual domain as well as the sonic.

Appendix A

Theoretical Examples

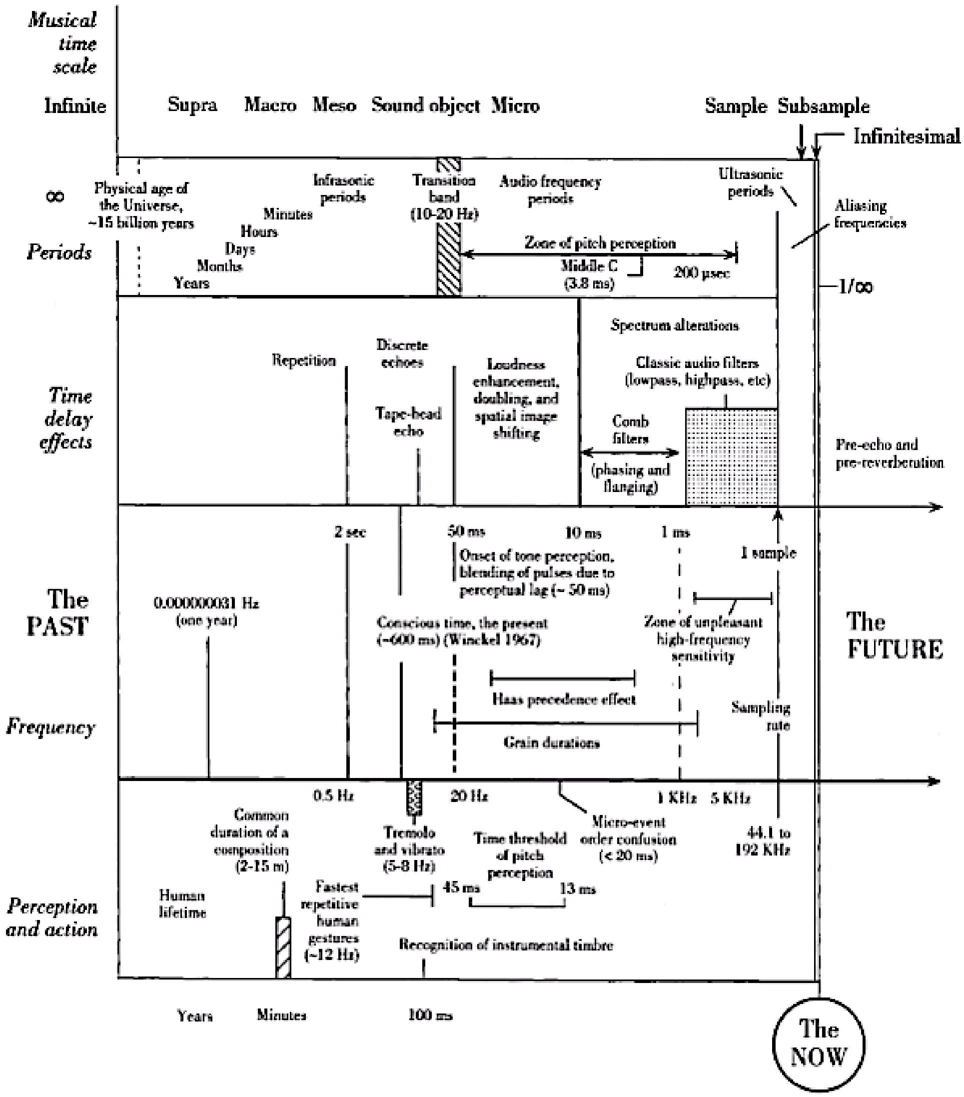
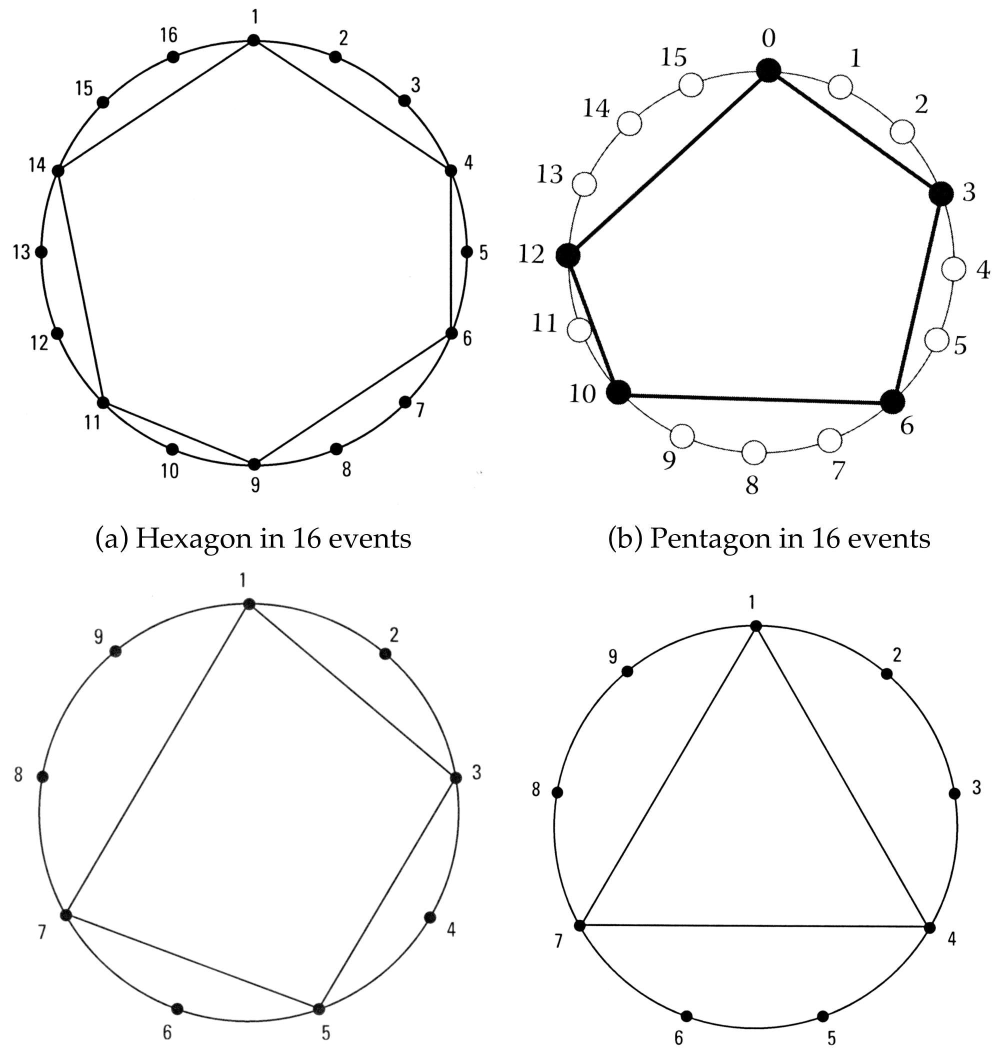


Figure A.1: Visual representation of time scales discussed in this paper (Roads, 2004, 5).
—->[Defining Scales of Time], page [14].



(a) Hexagon in 16 events

(b) Pentagon in 16 events

(c) Trapazoid in 9 events

(d) Triange in 9 events

Figure A.2: Examples geometry in musical rhythm. Different geometrical chapes contain properties that I find useful for creating rhythmic phrases. Notice how odd-time signatures (c) and (d) look very similar to even time signatures (a) and (b). Toussaint (2013); London (2012)
—->[Maximal Evenness], page [21].

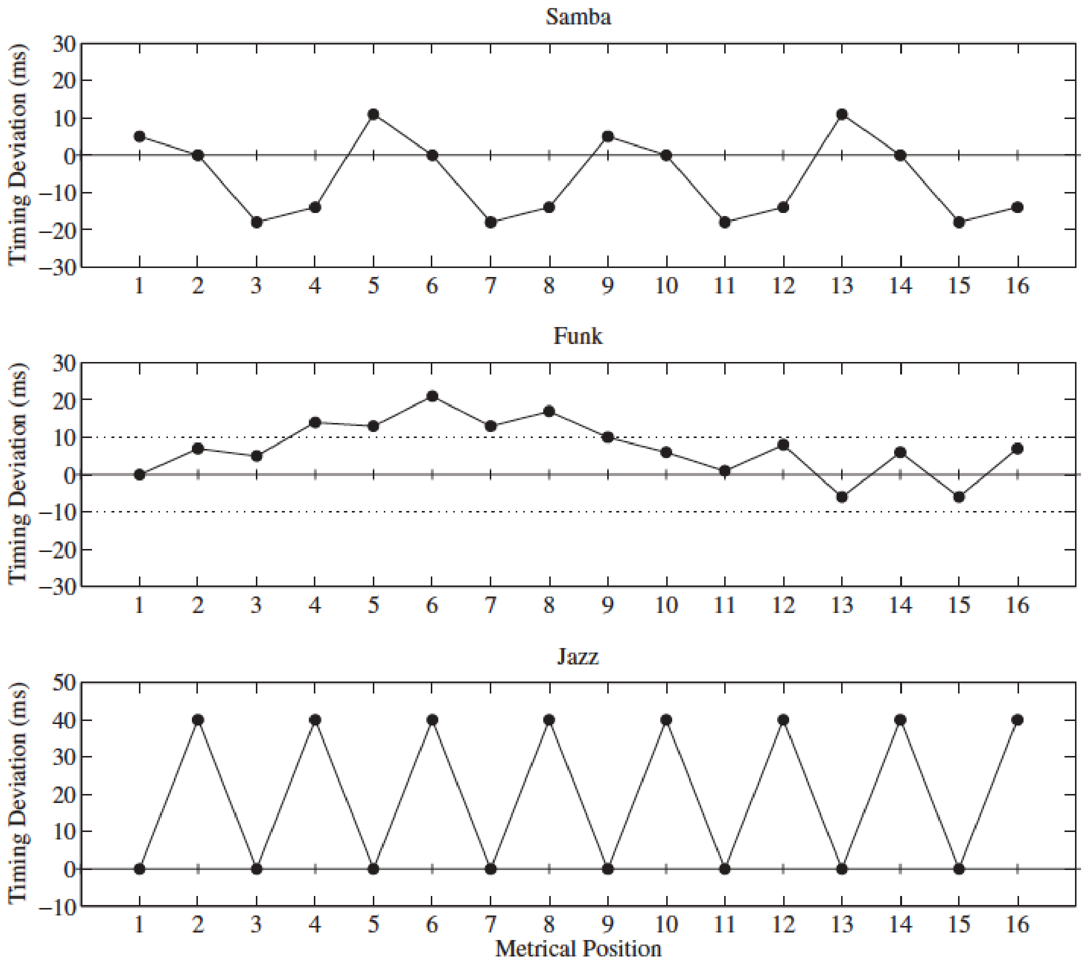


Figure A.3: Microtiming in various African influenced music. (Davies et al., 2013, 501)

—->[African Influenced Music], page [24].

Appendix B

Images of Circular Entrainment

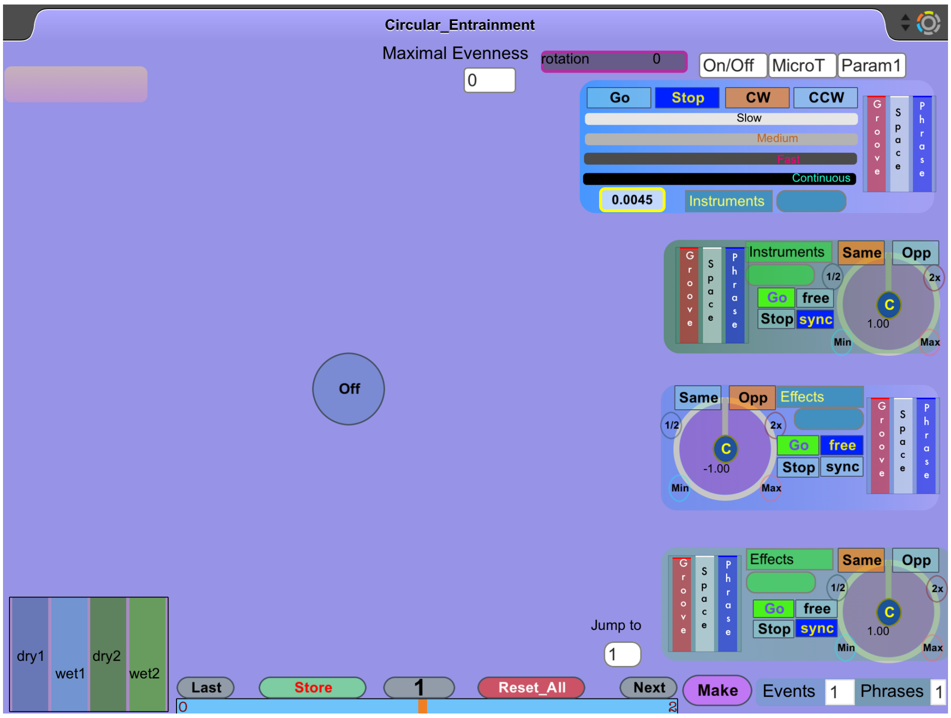
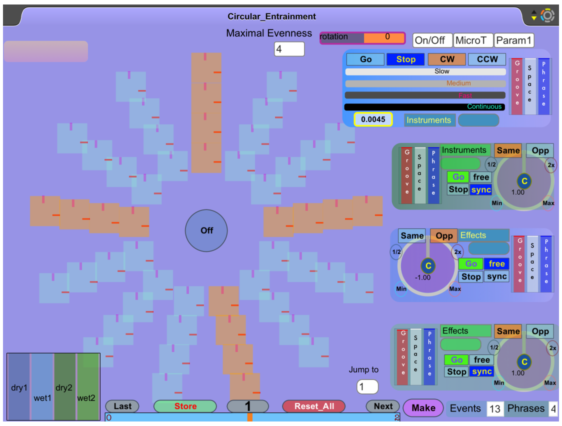
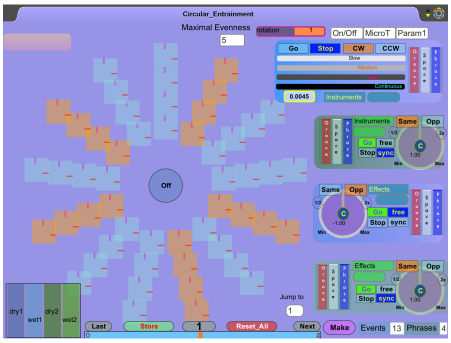


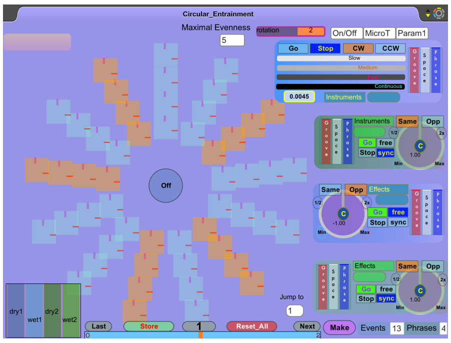
Figure B.1: Opening screen on Ipad of *Circular Entrainment*. User must specify phrase length and number of events wanted each time patch is loaded. Intended to inspire experimentation with various combinations.
—->[Application], page [22].



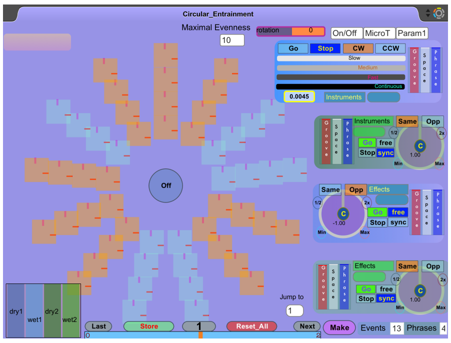
(a) 4 over 13, no rotation



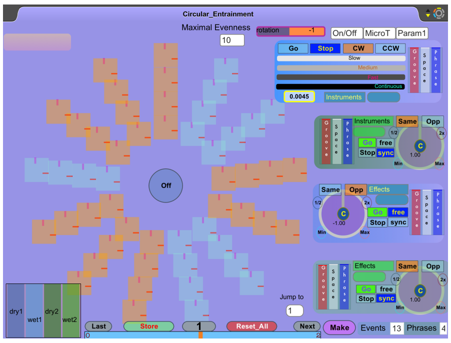
(b) 4 over 13, rotated +1



(c) 4 over 13, rotated +2



(d) 10 over 13



(e) 10 over 13, rotated -1

Figure B.2: Examples of using the rotation feature with maximal evenness to explore rhythmic displacement.
—->[Application], p. [22]

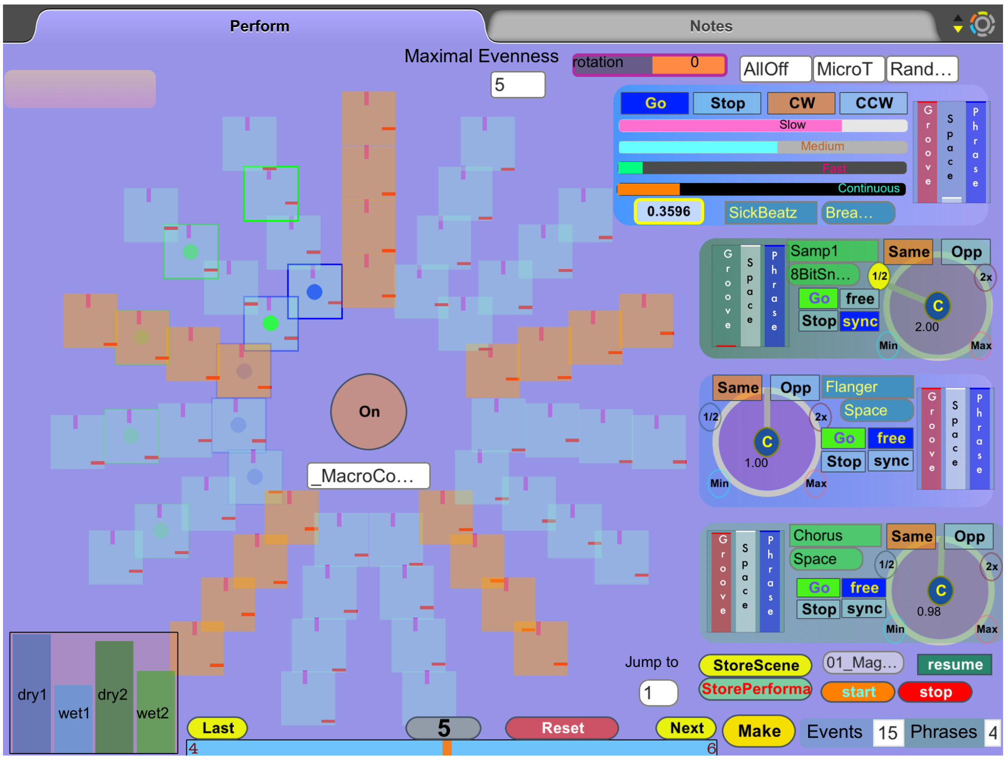


Figure B.3: *Circular Entrainment* in action. The blue and green square and dots represent four sequencers running simultaneously. The sequencer controllers on the right have the same colored background as colors that represent them. On the right hand side are all four sequencer, starting with one on the top to four on the bottom.
—->[Effects Routing], page [37]

Appendix C

Proposal and Guide

C.1 Thesis Proposal

To view my submittied thesis proposal click on this link: **Thesis Proposal** or access this pdf through this relative file path:

`webpages/thesisProposal.pdf`

C.2 Composition Guide

The following is the performance guide used for *Rhythmic Meditation No. 1*. It can be used as a guide to follow along with the submitted recording as well. To play the sound file which is guide is based on, clikc here: [Play] or find the sound recording through this relative file path:

`music/RES_RhythmicMeditation.aif`

Composition Guide

Section	Characteristic	Preset#	SoundFile	Time
Intro	Slow & quiet	1-4		0:00
	To&From Continuous	5	1_Magnification	0:25
	Climax	6	–end–	1:16
Transition1	*Fast*	7 (blank)		1:21
Groove Series#1	Groovey & Strong	8-10		1:22
	Stay&Explore	11	2_Pattern1	4:58
Transition2	*Soft/Loud*	12	3_Noise1	6:43
Slow->Fast	Slow–>Medium	12	–end–	8:55
	Medium–>Fast	13	4_FastToSlow.aif	9:05
	Fast–>Continuous	14	-v-	9:12
	Max Continuous	15	-v-	9:25
	Groove w/ Sample	16	–end–	9:41
	Stay&Explore	17	Enormous rhythms	11:58
Transition3	*Seemless*		05_AmbientCafe.aif	11:55
Groove Series #2	SlowBackground	18	-v-	12:05
	Accel and Fade	18	–end–	12:31
Forest	*Sparse Bird and Flute*	19-20		13:18
AngryBirds	IntroChime	21 (blank)	06_AngryBirds1.aif	15:58
	FastBreak1	22	-v-	16:11
	Pause	21 (blank)	–end–	17:10
	Go!	22	07_AngryBirds2.aif	17:15
Transition5	*Fast Transition*			18:14
Groove Series #3	Groovin'	23-25		18:15
	Fade, HiHat last	26		21:37
Transition6	*Sparse HiHat*	26	08_ShowMe.aif	21:55
Low Groove	Low & Dirty	27-28	09_SafetyGroove1.aif	22:16
to	Stay&Explore	29		23:24
GrossNoise	Stay&Get Dirty	30	*StartToGrow*	24:50
Begin the End	*High Point*	32	Noisey	25:42
The End	*Universal*	33	Ending.aif	26:03

Appendix D

Code Examples

D.1 JavaScript Loop in MaxMSP

```
var xpos = 0;
var ypos = 0;

for (var i=0; i< numTouch / 2; i++) {

        xpos = touchInset + touchRadius;
        xpos = xpos + touchRadius * Math.sin((i/(numTouch/2)) * Math.PI * 2);
        ypos = touchInset + touchRadius;
        ypos = ypos + touchRadius * Math.sin((i/(numTouch/2)) * Math.PI * 2 - Math.PI/2);

        // Create the touches
        var newTouch = this.patcher.newdefault(xpos, ypos, "mira.multitouch");
        newTouch.varname = "mira.multitouch" + i;
        newTouch.patching_rect(xpos, ypos, touchSize, touchSize );
        newTouch.tap_tap_count(1);
        newTouch.tap_enabled(1);
        newTouch.color(1., 1., 1., 0.);

        // Create the toggles
        var newToggle = this.patcher.newdefault(xpos, ypos, "live.toggle",'ignoreclick', 1, 'border_left', 0);
        newToggle.varname = "live.toggle" + i;
        newToggle.patching_rect(xpos - 0.5, ypos - 0.5, touchSize + 1, touchSize + 1);
        newToggle.activebgcolor(0.574499, 0.91463, 0.849059, 0.35);
        newToggle.activebgoncolor(0.992761, 0.641168, 0.034859, 0.44);
        newToggle.bordercolor(0.992761, 0.641168, 0.034859, 0.0);
        newToggle.message("background", 1);
```

Figure D.1: Example of JavaScript loop within MaxMSP Environment.
For the full code click here: JavaScript File or follow this relative file path:
maxPatch/CircularEntrainment.js
—->[Application], page [22].

D.2 Gen~ Synthesizer and Sampler

D.2.1 Synthesizer

```
Delay delay_1(1000);
Delay delay_2(1000);
History history_3(0);
clamp_4 = clamp(in4, 0., 0.8);
clamp_5 = clamp(in1, 20, 80);
tap_6 = delay_1.read(clamp_5);
mul_7 = tap_6 * 0.9;
clamp_8 = clamp(in2, 20, 80);
tap_9 = delay_2.read(clamp_8);
expr_10 = tap_9 * tap_9 * tap_9 - tap_9;
mul_11 = expr_10 * 0.4;
add_12 = mul_7 + mul_11;
mul_13 = add_12 * clamp_4;
mul_14 = mul_13 * 0.2;
out1 = mul_14;
mul_15 = add_12 * 0.7;
expr_16 = 0.7 * mul_15 + 0.3 * history_3;
mul_17 = tap_6 * -0.9;
clamp_18 = clamp(in3, 0.1, 0.8);
mul_19 = in5 * clamp_18;
add_20 = mul_19 + 1.;
add_21 = add_20 + mul_17;
history_3_next_22 = expr_16;
delay_1.write(expr_16);
history_3 = history_3_next_22;
delay_2.write(add_21);
```

Figure D.2: A synthesized flute using C++ like code in gen~.

Appendix E

Acknowledgements

Special thanks to Prof. Michael Edwards, Prof. Martin Parker, Prof. Owen Green, Fiona Keenan, and my collegues Cameron MacNair, Mikael Lind, Mahesh Raghvan, Daniel McGurty, Wolfgang Thomas, Timø Preece, Vanessa Garber, Athos Tsiopani, John Loranger, and Tina Krekels for all their help and insight during my Msc in Digital Composition and Performance. Also, special thanks to Kevin Hay who pointed out to me that rhythm was a topic often untapped by DCP students.

I could not have done this project without my loving family and girlfriend who have been supporting me during this entire process.

Bibliography

Alvarez, J. (1989). Rhythm as motion discovered. *Contemporary Music Review*, 3(1):203–231.

Bayreuth, R. P. (1998). Jenbe music in bamako. *Iwalewa*, Forum 2:pages 23–42.

Benadon, F. (2006). Slicing the beat: Jazz eighth-notes as expressive microrhythm. *Ethnomusicology*, 50(1):73–98.

Cohn, R. (2012). *Audacious Euphony: Chromatic Harmony and the Triad's Second Nature*. OUP USA, New York.

D'Angelo, Method Man, and RedMan (2000). Voodoo.

Daniell, S. L. (2012). *Rhythm as an archetypal element of the psyche : a transpersonal perspective*. Thesis. M.A.

Danielsen, A. (2010). *Musical Rhythm in the Age of Digital Reproduction*. Ashgate, Farnham, Surrey, England ; Burlington, VT.

Davies, M., Madison, G., and Silva & Gouyon, P. . F. (2013). The effects of microtiming deviations on the peception of groove in short rhythm. *Music Perception*, 30(5):497–510.

Dee, J. and Dilla, J. (2006). Donuts.

Hasty, C. (1999). *Meter As Rhythm*. Oxford University Press, New York.

Horace Silver (1965). The cape verdean blues.

Huron, D. (2008). *Sweet Anticipation: Music and the Psychology of Expectation*. MIT Press, Cambridge, Mass.; London.

London, J. (2012). *Hearing in Time*. Oxford University Press.

McGuiness, A. (2003). *Groove microtiming deviations as phase shifts*. PhD thesis, Open University.

Polack, R. and London, J. (2014). Timing and meter in mande drumming from mali. *MTO a journal of the Society for Music Theory*, 20(Number 1).

Reich, S. (1992). Reich: Early works - come out, piano phase, clapping music, it's gonna rain.

Roads, C. (2004). *Microsound*. The MIT Press.

Rock, P. (2003). Hip hop underground soul classics: Lost and found.

Toussaint, G. T. (2013). *The Geometry of Musical Rhythm: What Makes a "Good" Rhythm Good?* Chapman and Hall/CRC, Boca Raton, FL.

Tymoczko, D. (2011). *A Geometry of Music: Harmony and Counterpoint in the Extended Common Practice*. Oxford University Press, New York.

Watts, A. (2004). *Out of Your Mind: Essential Listening from the Alan Watts Audio Archives*. Sounds True, Incorporated, Boulder, CO, unabridged edition edition.

Word Count: 9619