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NOTATION SEQUENCE GENERATION AND SOUND SYNTHESIS IN INTERACTIVE SPECTRAL MUSIC

Benedict Carey

A thesis submitted in partial fulfillment of requirements for the degree of
Master of Music (Composition)

Sydney Conservatorium of Music
University of Sydney
2013
« resonant harmony is not formed by seeking higher and higher overtones but by using overtones of overtones. »

Vincent Persichetti.
Statement of originality

I declare that the research presented here is my own original work and has not been submitted to any other institution for the award of a degree.

Signed:.......................................................................................

Date:........................................................................................................
Abstract

This thesis consists of a preliminary analysis of existing spectral music paradigms and proposes a methodology to address issues that arise in real-time spectral music composition and performance scenarios. This exploration involves an overview of meaning in spectral music with a particular focus on the ‘sonic object’ as a vehicle for expression. A framework for the production of ‘interactive spectral music’ was created. This framework takes form as a group of software based compositional tools called SpectraScore developed for the Max for Live platform. Primarily, these tools allow the user to analyse incoming audio and directly apply the collected data towards the generation of synthesised sound and notation sequences. Also presented is an extension of these tools, a novel system of correlation between emotional descriptors and spectrally derived harmonic morphemes. The final component is a portfolio of works created as examples of the techniques explored in scored and recorded form. As a companion to these works, an analysis component outlines the programmatic aspects of each piece and illustrates how they are executed within the music. Each piece has a corresponding recording of a live performance or performances of the work included in the attached DVD, which comprises individual realisations of the interactive works.
Acknowledgements

I am grateful for all of the help and assistance I have received throughout the duration of this project from colleagues, friends, and family. In particular my fiancée Liz has been a true inspiration, especially when it came time to round things up. Thanks for being so supportive and enjoyable to be around all of the time, it would be hard work for most but it must come naturally to you.

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To my parents, I thank you for your help and advice throughout this project, which has seen the realisation of goals that began in my early days as a composer. Without the support you have both given to my development as a musician since a young age I would not have had the ability to undertake such a rewarding learning experience.

Thanks to all of the staff of the Sydney Conservatorium of Music, who have been so good at providing a welcoming atmosphere for anyone engaged in the study of music there. The Arts Music department provided a place for the ideas in this thesis to first find their feet, through corridor encounters with like-minded musicians. In particular I want to thank my supervisor Dr Ivan Zavada who provided me with the motivation and stimulating conversation I needed to understand this project and do the work needed to complete it.
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CHAPTER 1

Introduction

1.1 General aims and background

The development of spectral music has always benefited from advancements in technology, but the movement represents much more than simply the ‘impact of electroacoustics on musical thought’ (Dufourt, 1977). Seemingly to the inexperienced but willing composer of spectral music, among the plethora of technologies and techniques used by spectralists, little information is available indicating why one would want to engage in such practices in the first place. Detached from the theoretical origins of the movement, the tools used by spectral composers represent little more than reappropriated apparatus. Within this thesis, common motivations behind engaging in spectral music practices are analysed as a catalyst for stylistic innovation. This enquiry has led to a realisation of spectralism as a distinct attitude that often melds with the complex personal beliefs of the composer. These beliefs are sometimes metaphorically represented in their music through the composer’s selection or use of ‘sonic objects’ from which to derive pitch material for the composition. But the phenomenon of meaning in spectral music is multi-faceted. What of the affective dimension of perception? For those experiencing spectral music can we speak of predictable emotional responses to harmonic stimuli, and how closely are these responses related to the cultural context of the music? In this thesis three main avenues of inquiry will be pursued: What is spectral music? How does one make it in real-time? What effect does doing so have on the perception of meaning in music? The primary goal of this research was to create a series of software tools enabling the creation of spectral music in real-time to allow for musical experimentation within the framework provided by these questions. This included the creation of a novel system of correlation between harmonic collections and emotional descriptors. These tools
were to additionally allow for new collaborative possibilities, focused on facilitating the performance of real-time FFT analysis influenced improvisations and indeterminate works.

### 1.2 Description of analytical notes and portfolio

The first component of the accompanying compositional portfolio is a set of four electroacoustic studies designed for stereo playback examining techniques of spectralism. The remaining pieces are a mix of real-time spectral compositional techniques and live performance and all pieces are programmatic to some degree. These programmatic aspects are explored in a non-narrative sense. A literal context is created through use of specific ‘source-objects’ from which the compositions are spectrally derived. To this end, these compositions incorporate custom re-synthesis, live DSP-effects and real-time generated notation sequences in various combinations within works exhibiting varying degrees of indeterminacy. Ultimately there is much room for expansion in the field of interactive spectral music. The SpectraScore suite of software tools and accompanying portfolio of compositions are presented as a method of extension of those work methods created by spectral composers of the past into the unfamiliar territory of the live performer-composer.

### 1.3 Context

«…this utopic desire for a musical language articulated on scientific facts, the recurring dream of an art-science, creates a link between the composer-inventors of spectralism and the artists of the Quattrocento. »

Gerard Grisey, 2000

Today, spectralism is a vast and ever-changing field of composition, as one would expect from a movement so closely aligned with technology and scientific discovery. It is therefore unsurprising that the term ‘spectralism’ itself represents a spectrum of definitions. Most sources refer to
spectralism as being an area of composition defined by a fascination with timbre. It has been pointed out however that the term ‘spectralism’ itself is reductive in that spectral music is temporal in nature and not a question of ‘sonic colour’ (Grisey, 2000). In fact, this fascination with timbre forms merely a small part of what is essentially a wider compositional perspective involving the analysis of psychoacoustic properties of sound and modeling of acoustic phenomena for musical purposes (Pressnitzer et al., 2000). Commonly, creating spectral music involves the composer in interdisciplinary research.¹ By using psychoacoustic models of sound perception to inform their compositional practice, spectralists separate themselves from both ‘structuralist’ and ‘hybrid’ aesthetics (Fineberg, 1999). According to Rose (1996), spectral music ‘restricts the individual character of melody, polyphony, and rhythm in the name of fusion and continuity’. This is due to the idea within spectralism that timbre and harmony are to be viewed as a single concept (Teodorescu-Ciocanea, 2003). Joshua Fineberg suggests that the common link among the first generation of spectral composers is that they ultimately had a view of music as ‘sound evolving in time’ (1999). Ideally then, studies of sound perception replace musicological studies as the focus of spectralism resulting in a view of music as a case within this greater context. In reality this attitude is expressed as an aesthetic consequence and not as the application of a particular set of techniques, although there are techniques that are unique to spectral compositional practice. I prefer the predilection of Horatio Radulescu to refer to the ‘spectral technique of composition’ rather than ‘spectral music’ as it makes a clear distinction between aspects of the style and the aesthetics of the movement known as spectralism.

1.3.1 Spectralism in practice

¹ ‘Dufourt, Grisey, Murail in their turn, used information theory, cognitive sciences and neuro-science; relatively new fields which showed, among other things, that the perception of musical timbres (which are, themselves, made up of complex evolving physical structures) cannot be reduced simply to musical operations grounded in the simplifying concept of a note.’ (Pressnitzer et al., 2000)
The ‘technique of spectral composition’ includes an array of processes. While there is no uniform adherence to a set of principles of ‘spectralism’ commonalities between the music of composers working within this style do exist. Generally an identification of sounds internal structure as analogous with larger-scale musical structures is made. Spectralists seeks to explicate this perceived relationship through composition.

Spectral composition of timbre serves two purposes: one is to create a new pitch system based on the overtone series; the other is to reproduce, by means of acoustic instruments, the structure of certain timbres; in other words, to obtain, on a higher level, a mega-timbre that evolves in time. Pitch and timbre are no longer separate concepts but different aspects of the same phenomenon. (Teodorescu-Ciocanea, 2003)

Where a more traditional approach to composition relies on analysis derived from the study of chords, melodies and rhythms, spectral technique relies on Fourier analysis of acoustically produced sounds or a model based on the harmonic series to inspire musical composition. This analysis produces the intrinsic structure of a sound represented as a collection of frequency values deduced through sine wave decomposition. In spectral music, the areas within the spectrum containing the most prominent frequencies are then understood as musical pitches, which are in turn used as the basis for a compositional system combining the spheres of harmony and timbre into a single concept. This practice is also achieved in some spectral works through direct representation of the harmonic series, sometimes calculated without the aid of a computer. The way this data is used compositionally varies from composer to composer. For example, often composers choose to focus on different aspects of an analysed spectrum to emphasise its ‘harmonicity’ or ‘inharmonicity’. This decision sees the ‘sonic object’ positioned as a ‘tonal

---

2 Despite the now common usage of Fourier analysis in spectral music practice it originates from a formula designed for rapidly calculating the elliptical orbits of planetary bodies (Heideman, 1984). Indeed the stipulation that spectral analysis produces musical results is an assumption made to support the co-option of this process into the composer’s repertoire of compositional techniques.
reservoir from which a wide vocabulary of musical material can be drawn. In keeping with this tradition, the accompanying portfolio of compositions is an exploration of compositional possibilities inspired by the techniques of spectral composition but does not represent an attempt to mimic the aesthetics of 1970s spectral music. Nonetheless, the techniques of spectralism are grounded in their cultural origins and only through the exploration of these origins can one take a valid position on how to investigate their extended usage.

### 1.3.2 Cultural origins of spectral music

Spectralism as a compositional practice has its aesthetic origins in music of the past, despite it’s practices being formalised through use of Fourier analysis. Discussions about the origins of spectralism tend to centre on Gerard Grisey, Tristan Murail and Hugues Dufourt. These three influential figures are generally acknowledged as progenitors of spectral thought. By using tools developed at Institut de Recherche et Coordination Acoustique/Musique (IRCAM) to create their compositions they were able to synthesise works embodying this new understanding of sound and music. Although Spectralism is often viewed as something that began exclusively in France amongst members of the *Groupe de l'itinéraire*, Horatiu Radulescu in Romania and James Tenney in the USA were engaged in similar practices around the same time. Some of the artists associated with Feedback Studios in Germany such as Mesias Maiguashca, Clarence Barlow and their teacher and collaborator Karlheinz Stockhausen, despite being somewhat differentiated from the French spectralists in terms of their methods, were similarly engaged in the practices of spectralism.

Viviana Moscovich suggests the forerunners to French Spectralism as Debussy, Varése, Scelsi and Messiaen through their emphasis on an elemental view of sound. Some works by the

---

3 ‘Spectrum as tonal reservoir’ is a noted technique of spectral composition (Fineberg, 2000).
composers Richard Wagner, Olivier Messiaen, Giacinto Scelsi, Frederich Cerha and Per Norgaard that predate the use of FFT analysis in music composition have been classified as ‘Proto-Spectralist’ (Anderson, 2000). Tristan Murail has noted being profoundly influenced by Giacinto Scelsi in his technique of treating an ensemble as a single ‘fused’ entity. He has also pointed out that Stockhausen had at one point influenced Grisey through his use of a single sound spectrum to structure the work *Stimmung* for six voices, indicating that Spectralism is not a uniquely French phenomenon. It seems that the French tradition has become the most noteworthy despite the widespread practice of ‘the technique of spectral composition’.

### 1.3.3 Origins point to future directions

« A few centuries ago, paintings were often copied as engravings, lacking colour, which was only considered a dispensable embellishment: but colour can also be used as an essential aspect of the picture. »

Risset, 2003

Grisey has compared the spectralists with the artists of the Quattrocento based on their practice of interdisciplinary research. This mix of theoretical scientific research and artistic technique was also relevant to the neo-impressionist painters of the late nineteenth century (Malherbe, 2000). It is understood that Georges Seurat, Signac and Cross, the painters generally attributed with the founding of neo-impressionism, knew of Newton’s theory of colour through the writings of Michel Eugène Chevreul⁴. Seurat himself once likened aspects of the theory to principles behind his approach, stating, ‘The purity of spectral elements (is) the keystone of my technique’ (Malherbe, 2000). To Seurat who saw ‘only science’ in his own painting (Homer, 1964), the

---

⁴ ‘It was Chevreul’s theories on the relationality of color perception that would later play such an important part in shaping the Neo-Impressionists understanding of color perception and their use of color in painting.’ (Foa, 2008)
relationship between the two apparently distinct fields was either blurred or non-existent. These painters sought to differentiate themselves from the dominant school of painting at the time through the appropriation of colour theory into their increasingly divergent painting style. Similarly divergent and in a similarly pointillistic fashion, were initial experiments into composing music through the deconstruction of timbre. This process of spectral de-composition and re-composition is comparable to what Georges Seurat spoke of when referring to the act of painting as ‘the art of hollowing a surface’. One starts with a block of sound and finishes with a carefully deconstructed palette of sonic primary colours from which to blend a vivid spectrum of hybrid harmonic timbres. The extracted pitch material merely guides the ear of the composer in an otherwise free process. It is this search beyond the traditions and conventions of their particular discipline that unites these artists through time, and was instrumental in driving them towards innovation and discovery via a comparable method. Through analysis of the commonalities between the motivations of spectral composers and painters associated with the ‘pointillist school’ one can better form an understanding of how to design a system that approximates aspects of spectral technique.

1.3.4 Representation in spectral music

The compositional technique used by spectral composers that is most similar to the technique of pointillism from early neo-impressionist practice is called ‘orchestral resynthesis’ (Grisey, 1972). What is interesting about this technique is that it involves a metaphorical representation of the subject material (Rose, 1996), which is to say that the timbral identity of the subject of spectral analysis is largely retained. This technical link to neo-impressionism can be used to express an extra-musical dimension beyond the microcosm of a musical work. In the case of the opening bars of *Periodes* by Gerard Grisey, the subject of ‘instrumental resynthesis’ is the sound of a trombone playing a low E-flat, which seems to be a somewhat unremarkable, if not arbitrary choice of ‘sonic
object’. But the particular choice of sound may imply beliefs about music and sound that can only be understood through analysis of information external to the score itself. Grisey may in fact have been implying through this practice that he believed in something fundamental about the structure of sound that influences our perception of macro-structures in music. In later works by spectralist composers the ‘sonic objects’ behind their spectral compositions would be used to make statements about the nature of sound, music, religion and even politics in a continuation and extension of this practice.

The technical beauty of *Sunday Afternoon on the Island of La Grande Jatte* is a reminder of Ogden Rood’s discovery that colours blend at a distance, and how Seurat turned this into an interesting technique applied to painting. More importantly, Seurat held the belief that a painter could synthesise emotional states within their work through the application of the spectral decomposition of light to painting technique. Rood’s writings on this matter were based on the work of Hermann Von Helmholtz, someone who was working in the field of sound as well as light and who established the basis of modern theories of dissonance perception on Fourier’s principles of light wave de-composition. These origins of spectral thought in visual art point to a new direction though which to explore the expression of meaning through spectral music, whereby the data collected through Fourier analysis is further considered in terms of its psychoacoustic properties, beyond the usage of frequency components as a basis for a harmonic system. The following chapters represent an examination of this hypothesis.
CHAPTER 2

Meaning and spectrum

2.1 A two-fold model of perception

Spectralism is not just a simplistic replacement of a traditional harmonic system with another one based on the harmonic series. It is an allowance for the influence of psycho-acoustical research generally on the composition of music. Jean-Claude Risset, in reference to musical composition, has suggested that new material made possible through access to digital technology needs to be clarified ‘in the light of perception’. The purpose of this research project is ultimately the creation of a software tool to assist in real-time composition of spectral music, but part of this aim is to interface spectral data with information obtained from psycho-acoustical research in order to continue Risset’s vision within real-time scenarios. John Dewey, who was famous for his pragmatism, wrote ‘If all meanings could be adequately expressed by words, the arts of painting and music would not exist’ (Dewey, 1934). He goes on in this same passage to suggest that there are meanings within works of art that can only be expressed by qualities that are immediately visible and audible. This is one perspective that is especially relevant when applying Risset’s attitude to the creation of music: that works of art can represent symbolically that which cannot be discussed through specification. This attitude is expressed in the work of music theorist and composer Michel Chion who put forward a theory that rejects the existence of a relationship between sound as a physical signal and the perceptual phenomenon of sound altogether:

We cannot deny that every heard sound is the perception of a vibrating phenomenon occurring in the physical world. But it is impossible to claim to deduce from this, as was

---

5 The computer’s synthesized sound material represents a malleability without precedent, it lends itself to new modes of arrangement, to new architectures. But we have to clarify this material in the light of perception’ Jean-Claude Risset, ‘Musique.Calcul secret?’ in Critique No. 359, (1977).
often the case during the 50s and the 60s, that perceived musical values are measurable and identifiable from the particular parameters of this physical signal. Indeed, it is important to distinguish SOUND as a physical signal and thus measurable by machines, and SOUND as a sound object, which arises from a perceptual, qualitative experience, which can no more be identified by a physical phenomenon than the perception of a colour is by a wavelength. (Chion, 1994)

There is a distinction made here that outlines a two-fold perspective on sound divided into the domain of the machine i.e. the discrete and distinguishable ‘parameters of a physical signal’ and the qualitative domain of human perception i.e. the ‘perceptual, qualitative experience’. In section 2.2 evidence from the study of harmony and timbre perception is presented in order to examine the validity of Chion’s distinction, in the light of current research. Additionally, the scope of individualism present in spectralism points to the importance of cultural context when ‘clarifying’ material created through computer-aided composition. To this end, section 2.3 explores the subjective beliefs held by some spectral composers to ascertain the motivations behind their usage of spectral technique.

2.2 Psychophysical perspective

Most people report experiencing an emotional response upon hearing what they define as music (Blood et al., 1999). The correlation of spectral content with emotion is by no means a new practice – however, there are limited real-time compositional tools available that enable it. In relevance to the research project at hand, such a correlation represents a link between the theories of Seurat, and modern research into emotion recognition, via common theoretical origins. Attempts have been made to collect and analyse empirical data on how humans respond to musical sound, in order to describe the phenomenon of music perception. It has been discovered that the perception of dissonant musical material results in a different and less ‘pleasant’

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6 Other musical elements such as rhythm are not explored to a great extent here despite the significance of their impact on our perception of music, although they would be of great relevance to future software development projects in this area.
emotional affect to that of less dissonant material (Maher, 1980). The selection of ‘sonic objects’ from which to derive pitch material for a spectral composition therefore involves important aesthetic implications for the composer.

Many different approaches to this topic have been attempted since early work in the area of dissonance perception beginning with Helmholtz (1877), who defined a dissonance index for pairs of intervals within the 12-tone equal tempered system of tuning based on a psychophysical deconstruction of sound using Ohm’s acoustic law. Plomp and Levelt (1966) expanded on this work with their examination of the importance of critical bandwidth in music and have been cited for their contribution in the vast majority of subsequent literature in the area. William Sethares (1993) has defined an algorithm for the calculation of ‘dissonance curves’, which describe the relative dissonance of an instrument based on its sound spectrum in relation to a chosen temperament. All of these studies define dissonance based on the phenomenon known as ‘beating’. According to Helmholtz the human auditory system displays a natural preference for less complex interference patterns between components of the sounds that it picks up, implying that intensity of dissonance can be correlated with micro-rhythmic activity level. Cook and Fujisawa on the other hand conclude that the ‘perceptual regularities of traditional diatonic harmony are not due to the summation of interval effects’ claiming that ‘Previous attempts at explaining the affective response to major/minor chords and resolved/unresolved chords on the basis of the summation of interval dissonance have been notably unsuccessful’. They cite deviations between findings in prominent studies in the area as being indicators that no proper explanation is yet to be made of our perception of dissonance. In this study they make note of irregularities between studies by Roberts (1986) that produced the experimental values used in

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7 ‘The proposition that the human auditory system responds to a complex sound by generating sensations of the separate components of the sound rather than a sensation of a single integrated sound; thus when we listen to an orchestra we hear the separate instruments although the ears receive only a single complex sound wave. See also Fourier analysis. [Named after the German physicist Georg Simon Ohm (1784–1854) who formulated it in 1843].’ (Coleman, 2008)

8 The difference frequency between two tones made audible by interacting pairs of sine waves.
their study and theoretical values produced by Helmholtz (1877), Plomp & Levelt (1965), Kameoka & Kuriyagawa (1969), Parnscutt (1989), Sethares (1999) and their own work. One possible reason for this discrepancy could be the influence of cultural factors on dissonance perception. One study looks at the influence of spectral manipulation on the perception of sound sources across two cultures – western born and native African (Mafra) (Koelsch et al., 2009). They conclude: ‘…the present findings support the notion that consonance and permanent sensory dissonance universally modulate the perceived pleasantness of music, although the extent of this modulation appears to be influenced by cultural experience.’ Describing harmonic clusters derived from ‘sonic objects’ in terms of a ‘dissonance index’ calculated by a computer is therefore possible, but will produce subjective results.

Two examples of studies aimed at finding a very direct correlation between harmonic configurations and emotional descriptors are represented by Costa, Bitti, Bonfiglioli (2000) and Oelmann and Laeng (2007). The method used in both of these studies involved the playback of the diads to participants who then selected from lists what they deemed to be the relevant emotion response. Below I have reproduced the results from the Oelmann and Lang Study (Table 2.1).

**Table 2.1: Results from Oelmann and Laeng Study 1 (2007)**

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<th>P5</th>
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<td>0.2</td>
<td>-0.6</td>
<td>-0.5</td>
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<tr>
<td>Serious – Playful</td>
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<td>-0.5</td>
<td>-0.6</td>
<td>-0.3</td>
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<td>-0.4</td>
<td>-0.6</td>
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</tr>
<tr>
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<td>0.1</td>
<td>-0.2</td>
<td>0</td>
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<td>Value3</td>
<td>Value4</td>
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<tr>
<td>----------------------------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Inert – Moving</td>
<td>-0.1</td>
<td>-0.1</td>
<td>-0.5</td>
<td>-0.4</td>
</tr>
<tr>
<td>Frustrated – Undefeated</td>
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<td>0.2</td>
<td>0</td>
<td>-0.1</td>
</tr>
<tr>
<td>Yielding – Inflexible</td>
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<td>0.1</td>
<td>0.9</td>
<td>-1.1</td>
</tr>
<tr>
<td>Robust – Weak</td>
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<td>-0.5</td>
<td>-1</td>
<td>-1.2</td>
</tr>
<tr>
<td>Breathless – Breathing</td>
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<td>0.5</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Calm – Angry</td>
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<td>-0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Gloomy – Emphatic</td>
<td>-1.3</td>
<td>-0.1</td>
<td>0</td>
<td>-0.1</td>
</tr>
<tr>
<td>Active - Passive</td>
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<td>-0.2</td>
<td>-0.2</td>
<td>-0.2</td>
</tr>
<tr>
<td>Tight – Loose</td>
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<td>0</td>
<td>0.4</td>
<td>-0.6</td>
</tr>
<tr>
<td>Moon – Sun</td>
<td>-1.1</td>
<td>0.1</td>
<td>-0.1</td>
<td>-0.2</td>
</tr>
<tr>
<td>Vigorous – Frail</td>
<td>-0.1</td>
<td>-0.2</td>
<td>-0.6</td>
<td>-1</td>
</tr>
<tr>
<td>Rational – Emotional</td>
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<td>0.5</td>
<td>-0.3</td>
<td>-0.3</td>
</tr>
<tr>
<td>Clear – Hazy</td>
<td>1</td>
<td>-0.4</td>
<td>-0.9</td>
<td>-1.5</td>
</tr>
</tbody>
</table>
According to McDermott et al. (2010), due to the fact that beating becomes weaker as amplitude differences become more dramatic between two frequencies, the timbre of the instrument heard has an impact on perceived chord character. This study goes on to suggest that ‘consonant chords correlate with musical experience’ and further that ‘harmonic frequency relations underlie perception of consonance’. The impact of the partial structure of the stimulus sound used to prompt results from participants is not taken into account in the studies by Costa et al. (‘Psychological Connotations of Harmonic Musical Intervals’, 2000), where a synthesized organ tone was used, reportedly for the sake of familiarity, and the Oelmann and Laeng study where sine tones were used in for ‘neutrality’. In the case of both studies the lack of an accompanying spectral analysis of the tone used makes it is difficult to compare this work to other studies from
the same topic area in light of the work of McDermott et al. (2010). Furthermore, both studies are hindered by the possibility that stripping a sound back to an ‘Urform’ i.e a conceptual notion uncoloured by cultural perception (Perlovsky, 2009) is not possible. Bigand et al., indicate that musical tension and resolution is the key influencing factor in the perception of musical meaning. They found that ‘listeners rate harmonic events as increasingly tense, the further these events occur away from the tonal root, in both chord sequences (Bigand et al., 1996, 1999) as well as musical pieces (Krumhansl 1996; Toivianinen and Krumhansl 2003; Steinbeis et al., 2006).’ They conclude, ‘Music listeners hence directly link the perceptual phenomenon of harmonic stability to the psychological construct of tension by means of their acquired expectations’. (Bigand et al., 2000) Schellenberg and Trainor (1996) are also aware of the learned qualities involved in music perception ‘… combinations of tones that are musically consonant in one culture could be musically dissonant in another culture.’ (Shellenberg et al., 1996).

So while it is possible to rank chords based on their relative dissonance, it may not be possible to understand them in terms of emotional affect on this basis alone due to the effects of musical context and cultural bias on the perception of meaning. It seems that in order to represent this relationship within a compositional system a multi-dimensional model must be synthesised from current evidence. In a study entitled ‘The influence of pitch height in the perception of submissiveness and threat in musical passages’ (2006) Huron et al. concluded that their findings were consistent with research in speech suggesting commonalities between the two areas. These findings were to the effect that animal speech as understood through analysis of behavioural language exhibits the same universal traits as pitch height within musical passages, where comparable meanings can be found through analysis of extra-musical, programmatic information. Jurien Slitger suggests that the ‘acquisition and functioning of language’ (Slitger, 2007) is grounded in its usage and inseparable from those participating in it. It seems likely that, as when defining the relationship between speech and language, when defining the relationship between
music and meaning one must consider learned responses to particular sound combinations in addition to innate, and instinctive responses.

2.3 Spectralism and belief

It has been observed that the use of FFT analysis in music composition may imply an extra-musical meaning in the music concerned (Teodorescu-Ciocanea, 2003). To what extent this is done and in what way varies from case to case. The assertion that what the composer produces using spectral techniques is music often comes along with certain presumptions and philosophies about the nature of sound/music perception. Inevitably, this extra-musical motivation pushes their music into the territory of referential expressionism (Meyer, 1956).

The tendency among proponents of spectralism to justify their use of spectral technique by referencing its links to the sciences is common. Grisey’s suggestion of the existence of an ‘art-science’ perhaps implies by association that there is a kind of objective truth to be found in such music. Many proponents of the movement claim that forms extracted from within sonic events represent a natural and fundamental order of music as evidenced by the micro-structure of sound. Despite the scientific origins of the techniques used in spectral composition, they are of course not by themselves scientific proofs of musical truths. It has instead been suggested that when ‘new art’ is generated from the analysis of ‘natural’ objects, this indicates naturalism as the philosophical basis for the art piece concerned (Moscovich, 1997).

Extra-musical representation in spectral music is often not the intention of the composer, but sometimes it is unavoidable. Gerard Grisey exhibits a kind of devotional respect for sound that is almost animistic. Grisey proposed that spectral music reminds the listener that sound is in fact living.
Spectralism is not a system. It’s not a system like serial music or even tonal music. It's an attitude. It considers sounds, not as dead objects that you can easily and arbitrarily permutate in all directions, but as being like living objects with a birth, lifetime and death. (Grisey, 1996)

With this anthropomorphic approach to sound Grisey displays this reverence towards the source of his compositions and his muse, sound itself. In the same interview he mentions that while his music represents a ‘state of sound’ it is simultaneously a discourse:

I would tend to divide music very roughly into two categories. One is music that involves declamation, rhetoric, language. A music of discourse… The second is music which is more a state of sound than a discourse… And I belong to that also. I would put myself in this group. Maybe I am both, I don't know. But I never think of music in terms of declamation and rhetoric and language. (Grisey, 1996)

It is the responsibility of composers to both themselves and their audiences, to consciously construct the meanings behind their works, and convey them. This can include indicating, as Grisey did, that his music may include extra-musical references.

### 2.3.1 Spectral morphemes

« …I had only my ear to help me. I heard and I wrote what I heard. I am the vessel through which Le Sacre passed. »

Igor Stravinsky, 1961

Extra-musical representation in its many forms can be found extensively throughout the repertoire of the twentieth century. In his piece *Inori*, Stockhausen reflects his religious beliefs through the use of chromatic scales of prayer gestures. Igor Stravinsky and Olivier Messiaen also utilised this practice to alternate ends. In the case of Stravinsky the use of folk song was in an attempt to create
a ‘primitivistic style’ (Tyers, 1994) in combination with other elements extracted from Russian folk music. Messiaen sought to embed his music with meaning through use of quotation from the natural environment. Messiaen’s use of notated birdsong to represent his devotion to god (Bruhn, 1996) is of particular importance to understanding the literal framework behind his music. Some students of Messiaen, such as John Cage, seem to also have been profoundly influenced by this idea. Much like Olivier Messiaen’s devotion to god is embodied in his work, Cage’s ‘imitation of nature in her mode of operation’ is represented through the use of chance procedures (Jensen, 2009). The primary example of this is his use of aeleatoric compositional procedures derived from the ancient Chinese book of chance, the I ching. Olivier Messiaen has been called ‘the composer who assisted most directly in the birth of the spectral movement’ (Fineberg, 1999). It has been suggested that Messiaen’s ‘resonance chord’ resembles the first example of a fusion between harmony and timbre (Moscovich, 1997). His role as mentor of many of the Group L’itinéraire is noted to have affected the spectralist emphasis on harmony, but it also likely had an impact on their use of quotation from the natural world. His student, Tristan Murail reportedly took a similarly reverential view of sound in his approach to the piece Bois Flotté:

The title was suggested by a piece of wood that you pick up on the shore, washed up by the waves, and which reveals unexpected forms sculpted by the water—a natural sculpture therefore, an objet trouvé. (Alla, 1996)

The use of the term objet trouvé reminds us of his interest in a mimetic form of spectralism (Teodorescu-Ciocanea, 2000). While Marcel Duchamp’s infamous work ‘Fountain’ may have very little in common aesthetically with Murail’s work, there is an undeniable conceptual link that should be explored more intimately. Murail’s purported allusion to the ‘natural sculpture’ in this case indicates an appreciation for ‘natural’ sound structures. This is not too far from Cage’s attitude that had lead to his use of aeleatoric procedures, despite the music itself being wholly different in its execution. Another prominent spectralist, Magnus Lindberg applied an analogy to
his composition of the work ‘Related Rocks’ which conveys a similar appreciation of the structures inherent in nature and applies them to the structure of his music.

Now, at the very time when I was involved in building up the dramaturgy of the work, I happened to see a geological exposition, and was struck by the immense natural variety of stones, rocks, minerals, collected from far corners of the earth; and it was at the same time a completely unified assemblage. And this struck me as a beautiful metaphor, not just for the work I was composing, but for how I feel about music in general: the notion of taking very different sound objects, and exploring, from different perspectives and different distances, qualities they share. (Lindberg, 2000)

In this same vein, Jonathon Harvey presented an ‘apotheosis’ of a religious object through choice of the ‘sonic object’ from which to derive his piece Mortuos Plango, Vivos Voco (1980). This eight-track electroacoustic work is entirely derived from the sound of the tenor bell at Winchester Cathedral and the voice of the composer’s own son. As can be seen in fig 2.1 the bell’s acoustic properties feature quietly heavily in this work.
He indicated that for this reason it is a ‘very personal piece’. (Harvey, 1981) The boy’s singing which is often heard throughout the work in a mostly unaltered form is performed in a choral style, synonymous with the long history of European devotional music. Despite this Christian
symbolism, Harvey was in fact a Buddhist who had not wholly rejected his Christianity. The Latin text used in the piece is embedded with aspects of Christian devotion but could be interpreted as Buddhist sentiment - ‘I count the fleeing hours, I lament the dead: the living I call to prayer.’

I don’t particularly lose any of my love of Christianity or any other thing that I’ve come into contact with in my life – I tend not to reject them but to enrich them with other areas. (Harvey, 1999)

Harvey later honoured Messiaen as a forerunner to French spectralism in his work *Tombeau de Messiaen*, and he may well have been influenced beyond the microcosmic world of this one piece. Perhaps Messiaen’s example had a direct influence on the composers approach to devotional music. His apotheosis of the Winchester Cathedral Bell is a prime example of a mimetic use of spectral technique. It also represents a common theme in spectralism, defined as ‘Spectralism as an archetypal approach’ (Teodorescu-Ciocanea, 2000). In her article *Timbre versus Spectralism*, Livia Teodorescu-Ciocanea clarifies that this practice represents ‘an attempt to retrieve the magic dimension of music and its lost signification’. She points out that Corneliu Cezar is also interested in this style of spectralism, referring to the religious aspects connected to cosmogony in his music. It would seem that more often than not those engaging in spectralism are tied up in various beliefs, sometimes entirely unrelated to music, that lead them to spectral technique. The reasons are highly idiosyncratic, and this points to the scope of individualism that is present in spectral music.

The composer’s intention and the resultant act of perception by a listener are two very separate events, brought together by a common stimulus. Bringing these elements closer together is an important focus of many spectral compositions, evidenced by the ambition of spectralists to use interdisciplinary research in their compositional practice. In Chapter four the examination of the compositional system will continue this notion, following the establishment of a context for doing so in real-time, which is the primary goal of this thesis.
CHAPTER 3

Spectralism in real-time

3.1 Background to live spectral music

Real-time spectral music is music that utilises data collected through Fast Fourier Transform (FFT) analysis towards the performance of live sight read or improvised music. This is made possible by the increasing availability of computers and software that can be used to perform FFT analysis, a particularly efficient way of performing Fourier analysis. Up until the advent of personal computers powerful enough to compute the sizeable calculations involved, the only tools available that enabled the composition of spectral music and were accessible to composers were located in academic institutions. This meant that the act of incorporating Fourier analysis into the compositional process was relegated to the studio, and musicians devoid of the technical knowledge required to engage in this experimental practice were denied the privilege. Furthermore, it was not possible to integrate spectral material collected during a performance into the composition of the piece being performed. This presented composers and performers of improvised spectral music with fewer musical elements over which real-time control could be implemented. Such an approach is best suited to compositional idioms that rigidly define the parameters of a performance and leave less room for interactivity or spontaneity than their interactive counterparts. Despite these technical limitations, early innovations in spectral music regarding improvisation did occur. An early example of a piece for spectrally based improvisation is Saxony (Tenney 1978), for saxophone and cumulative tape-delay system. This piece introduces the idea of the ‘cell’ to the performer of spectral music - a small segment of notation that provides suggestions of pitch material and performance instructions. Each cell represents a continuation of the ascension towards the highest playable harmonics on the saxophone based on a single low E-flat. The order of the cells is then reversed and this process piece is completed when the performer
returns to the low E-flat once more. A degree of rhythmic and expressive freedom is allowed in terms of the exact interpretation of each cell. Structurally the piece moves through each cell in isolation, in a fashion reminiscent of Stockhausen’s ‘moment form’ pieces such as Kontakte and Kreuzspiel. Both are considered to be ‘pointillist’ works, a term that would later be used to describe spectral compositions and is applicable also here. Recently Catlin Milea has created music incorporating his use of cell notation and spectral harmony (2012). This further pushes the ideas of spectralism into the territory of Jazz improvisation using similar methods to those founded by Tenney. Roomtone Variations by Nick Didkovsky (2009) also experiments with introducing spectral information derived from the performance space into live-scores for use with improvisation and represents perhaps the first example of real-time FFT analysis and live score creation combined in a compositional context.

3.2 Sound bonding and spectralism

If the act of discovering a new experience of sound is the focus of a spectral work, then a composer need not be limited to doing this sonic exploration in private. The idea of sharing that moment of discovery with an audience presents a new and exciting way of engaging with sound. Dennis Smalley has proposed a system of describing and analysing musical experience called spectromorphology⁹, which is closely based on the work of theorist and father of the Musique concrète movement, Pierre Schaeffer (Chion, 1983). Smalley has also outlined a related phenomenon he labels ‘source-bonding’¹¹. He refers to an animal tendency; upon hearing a sound we are prone to latch onto some local physical action and hold it responsible for the production of sounds that we hear coming from the same space. One way to confront this inevitable dilemma in

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a concert hall setting is to inform the audience that they must change their approach to listening as has been done in the past by composers of acousmatic music in the pursuit of ‘closed listening’\textsuperscript{12}. Another approach is to make this sound bonding the focus of the performance, presenting the audience with a physical and present experience.

3.2.1 Constructing meaning through interactive spectral music

The phenomenon of ‘source-bonding’ prevents a composer from combining electroacoustic and ‘live’ acoustic sound sources without positing a relationship between these two sound worlds\textsuperscript{13}. Whether this relationship is strongly or weakly bonded will determine in some respects the level of separation perceived between the sonic entity and its origin. It is not essential that programmatic aspects are added to a musical performance, but such devices serve to strengthen the bond between cause and aural effect. It is hypothesised that by strengthening the bond between the ‘material object’ and the sonic result the musician is engaging with a literal language as well as symbolic musical language, a hybrid of both linguistic and musical expressive systems. Just as the movement of spectralism shares tendencies with neo-impressionism, the use of extra-musical ‘sonic objects’ is paralleled by the concept of the ready-made art object or \textit{objet trouvé} in sculpture, which adds another expressive dimension to the art form.

3.3 Towards a better integration of acoustic and electronic sound

Just as there is much that divides how electronic and acoustic methods of sound production are perceived, technical differences in how sound is produced through these methods can effect how they are best integrated in a ‘live’ scenario. Grisey has suggested his \textit{‘le principe de la generation instantanee’} or ‘principle of the instantaneous generation’, where each gesture is an impetus to the


\textsuperscript{13} Within his framework for understanding acousmatic music Smalley points out that a ‘spectromorphological approach cannot deal adequately with electroacoustic music which is very anecdotal or programmatic, that is, music where a very wide palette of sonic references may be employed.’ (Smalley, 1995).
construction of the next. This provides a compositional model for creating music in real-time based on spectral principles. Many of the necessary tools for creating ‘live’ spectral music are already in existence in the form of custom software. The Spectral Toolbox (Sethares et al., 2008), a series of Max/MSP externals and abstractions for producing spectral effects were recently developed. These tools that are based on an extension of the phase vocoder (Chowning, 1983) offer a very high level of real-time control over a sounds spectrum as well as facilitate the use of keyboard tunings associated with the sound byte concerned. It seems logical however that the same level of control should be present when the generation of spectrally derived score fragments is the compositional aim, so as to better integrate both ‘live’ sound and computer-controlled sound in performance.

In the area of ‘live’ performance technique, more modern instrumental techniques used in the performance of contemporary music can produce highly unpredictable results. Take for example the case of the regularly unpredictable spectra produced by extended techniques for woodwinds such as multiphonics, timbre trills and harmonic glissandi. The spectra of these performance techniques vary from instrument to instrument and require specific fingerings and articulations that in turn also vary. This means that they are routinely performed differently and require piece-specific rehearsal to achieve. If it is the case that the spectra of these events has an affect on the perception of the harmonic makeup of the piece as is suggested by the principle of local consonance (Sethares, 1993), then these spectra should and can be considered in the execution of harmonic material within the composition. Electronically generated sounds are on the other hand more easily controlled in live scenarios. The possibility to structure music around the spontaneous aspects of a ‘live’ performance should therefore be available to composers and performers through better coordination of these elements with those which are controlled to some extent by a computer.
3.3.1 An opportunity for better integration

There are performers who are quite adept in more modern techniques of sound production and are engaging in improvisation within a spectralist framework. Introducing adequate tools to guide their improvisations would surely be of use. Allowing them control over elements of the composition beyond their own instrument, such as electronic accompaniment, would lead to a better integration of electronic and acoustically produced sound. This assumes that the musical instrument in the hands of the trained performer is a more easily wielded and accurate controller than the keyboard, mouse or mixing desk. Reliance on this method of software control is a trade-off between creative control and functionality, but it greatly reduces monetary expense, such as would result from investment in sophisticated custom controllers as well as reduce the number of participants required to perform with the system. It also saves on the kind of time that would be required to train on new equipment, making it a logical choice.

3.3.2 Creating a model for a real-time generative score system

‘E-scores’ and ‘extreme sight-reading’¹⁴ become involved when traditional live instruments are chosen as the method of sound production for the performance of a real-time spectral work. There are currently no commercially available software solutions that specifically enable the performance of spectral music from a ‘live’ generated score. However, many well-known open-scored works exist today that are useful models for aspects of a real-time e-score system. Scoring techniques used by Karlheinz Stockhausen in Stop (1965) allow for specification of musical gestures presented on discrete staves within a rough time space notation framework. This technique allows for interpretation by the performers without sacrificing all control over the general contour of the piece. Two works by the same composer representative of his more

deterministic period\textsuperscript{15} of the 1950’s, *Elektronische Studie I* (1953) and *Elektronische Studie II* (1954), specify exact parameters for the production of an electronic piece of music in a clear graphical format. Iannis Xenakis has also used similarly graphical techniques in his UPIC system (1977), combining a graphical user interface with a sound synthesis engine. Witold Lutosławski’s *Venetian Games* (1960-61), Terry Riley’s *In C* (1964) and James Tenney’s *Saxony* (1978) also provide excellent models for an e-score system with their use of celfic notation. More recently efforts have been made to allow music to be generated during the performance using algorithmic means. Karlheinz Essl’s *Champ d’Action* (1998) incorporates a real-time composition algorithm into a feedback loop between performers and conductors. The performers are guided by a laptop-displayed score, which is generated by algorithms triggered by the conductor, who in turn responds to aspects of the performance in selecting the next algorithm to trigger. Jason Freeman created his piece *Flock* (2007) for saxophone quartet using a custom system that incorporates specialized music notation displayed on saxophone mountable tablet computers. A combination of deterministic and indeterminate notation such as that present in *Flock* allows performer, composer and the parameters of the live analysis component adequate influence over the resulting compositional gestures leaving the level of mixing of these elements up to the performer/s concerned (Fig. 3.1). This approach uses graphic notation as opposed to traditional western notation, but in the case of spectral music specification of pitch material is crucial. *Macaque* (Hajdu, 2012) a tool for the transcription of spectral data to be used in non real-time scenarios is available as a free download. This could be easily adapted for use in real time scenarios. It presents an example of the most direct usage of a sounds spectrum, ‘orchestral resynthesis’ (Grisey, 1972). This is analogous with the technique of additive synthesis from the world of electronic music. Carpentier and Bresson (2010) have developed an effective system for the

analysis and orchestral resynthesis of sounds through use of both notation and sampling called Orchidee. This system relies on access to a large database of prerecorded sound and is not ‘real-time’ in the strictest sense of the word. It does however represent an ideal implementation of the principle, which takes the partial structure of the ‘resynthesis’ orchestra into account to create a more accurate picture of the source sound. ‘Maxscore’ (Hajdu and Didkovsky, 2010) offers the use of traditional western style notation within the Max/MSP environment allowing access to a host of data-processing tools including FFT analysis. In Room-tone Variations by Nicholas Collins (2011) the natural resonant frequencies of a space are detected using a feedback system and then converted into their closest tempered equivalent, which is then displayed on an electronic score using Maxscore. Quintet.net (Hajdu, 2004) allows the users to collaborate over a wide area network using a precursor to Maxscore to display score data on remote computers (Fig 3.2).

FIGURE 3.1: Score Excerpt from Flock (Freeman, 2007) demonstrating the use of real-time generated graphic notation
Many of the necessary tools are already in existence in the form of custom software. They are of as much value to the composer of traditional, studio based spectral composition as they are to that of interactive spectral music. The Spectral Toolbox (Sethares et al., 2008), a series of Max/MSP externals and abstractions for producing spectral effects were recently developed. These tools that are based on an extension of the phase vocoder (Chowning 1983) offer a very high level of real-time control over a sounds spectrum as well as facilitate the use of keyboard tunings associated with the sound byte concerned. It seems logical that the same level of control should be present when the generation of spectrally derived score fragments is the compositional aim, so as to integrate both styles of software tool and performance.

Grisey has suggested his 'le principe de la generation instantanée' or ‘principle of the instantaneous generation’, where each gesture is an impetus to the construction of the next. This provides a model for creating music in real-time based on spectral principles, to be used in conjunction with the real-time spectral effects already in existence. This can be achieved through the development of custom software tools that bridge the gap between the methods of non-interactive styles of spectralism while incorporating the philosophies of traditional spectral music creation.
CHAPTER 4

Examination of the compositional system

4.1 SpectraScore system

In his book ‘20\textsuperscript{th} century Harmony’ Vincent Persichetti writes, ‘Resonant harmony is not formed by seeking higher and higher overtones but by using overtones of overtones’. I suggest that this concept need not be confined to highly technical spectral compositional methods that consider only combinations of tones in isolation and assume a ‘natural’ resonance with the audiences ‘innate’ emotional responses. Redefining ‘resonant harmony’ as the perception of musical ideas which resonate with personal beliefs, and cultural predispositions of the listener, and ‘overtones of overtones’ as literal notions strongly implied by the selection of particular tone combinations is presented here so as to strengthen the bond between the composer’s intention and the perception of meaning in music by the audience in the music of the accompanying portfolio.

The SpectraScore system automatically groups spectral data collected during performance according to emotional descriptors. This is done based on a dissonance evaluation algorithm, used to calculate a ‘dissonance index’ by which pitch material is organised and displayed for improvisation purposes. Firstly, it is important here to reference the work of Leonard B. Meyer when approaching this conceptual territory. Meyer makes an important distinction between ‘absolute expressionist’ and ‘referential expressionist’ positions on musical meaning. The ‘absolute expressionist’ group takes the stance that emotional meanings arise in response to music without reference to the ‘extra-musical’ world beyond the music itself. Any work aiming to correlate emotional descriptors and specific harmonic configurations (such as my own) would therefore find itself positioned in the latter group, that presupposes an existence of referential meaning within any symbolic musical language. I must be clear from the outset that I do not seek to imply that there are basic hard–wired relationships between particular emotional descriptors and
particular harmonic structures, common to all humans. But I will show that creating such a relationship can be compositionally useful.

A primary impetus for the implementation of this system of correlation is the work of Dr Robert Plutchik, a psychologist who proposed in his *Emotional Circumplex Model* (Fig 4.1) that there is a psycho-evolutionary basis behind our emotions and that these emotions are co-dependant and interrelated. This makes it possible to graph Plutchik’s proposed eight primary emotions - anger, fear, sadness, disgust, surprise, anticipation, trust, and joy, over a diagram not unlike the colour wheel. The intention is to plot these descriptors in terms of positive/negative valence and potency across a two dimensional interactive graph deduced from the results of *Structure of Emotions* (Morgan et al., 1988) so as to compare them with a dissonance score deduced from calculations based on the work of William Sethares’ *Tuning, Timbre, Spectrum, Scale* (1998) and Vincent Persichetti’s *Twentieth Century Harmony* (1961)

![Plutchik’s Emotional Circumplex Model](image)

FIGURE 4.1: Plutchik’s Emotional Circumplex Model (Plutchik, 1984)
4.1.1 Previous correlative systems

As part of *Ada: Intelligent Space*, a project created for the Swiss National Exposition Expo in 2002 a correlation between music and emotion was made in order to synthesise music targeting a series of desired emotional states. This project was a large collaboration between neuroscientists and musicians from various institutions around the world and represents a rather sophisticated piece of artificial intelligence of which musical expression was only one expression of the emotional states it synthesized during the exhibition. SpectraScore on the other hand functions as a compositional system, a score and an instrument and contains only a basic correlative system, not a system of artificial intelligence. The assessments drawn about the emotional content of sounds through it are offered merely as suggestions to the performer, and provide a necessary system for structuring these sounds. My application of a metaphor to music composition follows on, perhaps more directly, from similar attempts made to categorise sounds based on finite series’ of ‘non-musical’ descriptors. Many attempts have been made to correlate sound and colour for example Sabaneev and Pring (1929), Skriabin (1910) and Hector (1918). Luigi Russolo famously created his ‘Futurist Manifesto’ *The Art of Noises* in 1913, noteably at around the same time that Marcel Duchamp presented a urinal at the 291 gallery in New York and established the tradition of the *objet trouvé* in sculpture. With similarly appropriative intentions, Russolo developed a system of categorisation that represents a fusion of both ‘musical’ and ‘non-musical’ sound worlds. In doing so he has divided up a spectrum of sounds into groups unified by both their acoustic qualities but also the referential meanings associated with them.

**TABLE 4.1: Categories of sounds from *The Art of Noises* (Russolo, 1913)**

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This chart represents a system of organising primary musical ‘colours’ according to dynamic and timbral features, seemingly related sometimes also through their associations with behavioural language. For instance sounds from group one could perhaps elicit a fight or flight response, whereas sounds from group three could likely illicit caution and curiosity. On the chart is written: ‘In this list we have included the most characteristic fundamental noises; the others are but combinations of these.’ This same organisational principle involving A) reducing a perceptual phenomenon down to an assortment of fundamental building blocks and B) further dividing aspects of said phenomenon into primary and secondary classes is used in both the structure of Newton’s colour wheel (so fundamental to the work of Seurat) and Plutchik’s emotion circumplex.

These systems seek to expand the range of sounds and organisational methods available to the composer, so as to include noise and sound structures from the entire world of human experience. A problem arises however when one wishes to create a harmonious relationship between instruments that are classified as ‘noise makers’ and traditional orchestral instruments,
which are optimised to produce spectra closely approximating the harmonic series. ‘Noise’ sounds are generally harmonically ‘dissonant’ when compared to ‘musical instruments’, or are at least less flexible in terms of tuning. One solution for this problem is to create software which analyses the properties of sounds produced by ‘noise makers’ so as to create closely related score fragments that can be interpreted by musicians playing conventional instruments. This method repositions these noisy ‘sonic objects’ as the core elements in a composition replacing chord function with a collection of curious resonators.

4.2 The Process of Interactive Spectral Composition using SpectraScore

Figure 4.2 illustrates the process of interactive spectral composition as implemented in the SpectraScore system. A selection of ‘material objects’ (Dhomont) are made to resonate and a snapshot (200ms) of these resonances are analysed using an FFT calculation. The results of this calculation represent the ‘sonic object’, quantised to some degree, which further undergo a number of transformations to determine the most essential tones within the analysis, initially comprised of thousands of frequency components. Once the most fundamental tones of the ‘sonic object’ have been determined a dissonance calculation is performed, along with a number of musical calculations such as finding the closest key area and mode to the note collection. These parameters are utilised in the generation of: scales and chords, melodic improvisation guides, Markov chain melodies, probabilistic orchestral resyntheses, dissonance calculation and additive resynthesis. In addition specific emotional descriptors are defined relating to the dissonance calculations performed, which may be used to trigger samples of speech associated with the descriptor. This information is summarised as a number of scores, which can be handled in a variety of ways by the user i.e. for distribution of spectral components to an ensemble or solo performer for improvisation purposes via e-scores, or providing parameters for a sound synthesis engine.
FFT Analysis

- Material Object 1 → Sonic Object 1
- Material Object 2 → Sonic Object 2
- Material Object 3 → Sonic Object 3
- Material Object 4 → Sonic Object 4

(Sound producing devices are sounded into microphones)

(Most prominent frequencies in each spectrum based on amplitude and regularity of detection within analysis window of 200ms)

Musical Analysis

(Generation of: scales and chords, melodic improvisation guides, Markov chain melodies, probabilistic orchestral resynthesis)

Psychoacoustic Analysis

(Detection of: tonal centre, central key area, dissonance ranking and emotional descriptors)

Sound Synthesis

(Resynthesis, MIDI to Synthesisers)

Score Display

(Improvisation guides and traditional notation displayed on e-scores, performance instructions)

Figure 4.2 – The process of interactive spectral composition as implemented in the *SpectraScore* Max for Live effects
4.3 Spectral techniques synthesised in real-time

A number of traditional techniques of spectral composition are made available to the composer in real-time through the SpectraScore software. They are:

• FFT analysis (SpectraScore FFT)
• Resynthesis
  • Sine wave resynthesis (SpectraScore ReSyn)
  • Probabilistic orchestral resynthesis (SpectraScore ORS)
  • Interpolation between various ‘spectral nodes’ (SpectraScore Nodes)
• ‘Spectral modality’ (SpectraScore Scores)
• ‘Spectral cell’ based improvisation (SpectraScore Scores)
• ‘Spectral collection as harmonic morpheme’ (SpectraScore Plutchik’s Flower)

4.3.1 FFT Analysis

With SpectraScore, the spectral data collected through FFT analysis is implemented in the generation of electronic accompaniment and scored pitch aggregates (see Fig 4.4). From this, performers can improvise melodic fragments within a specified harmonic and structural context or follow real-time scores. Accurate spectral analysis algorithms had to therefore be carefully

* The relevent Max for Live module is listed in brackets
selected and implemented for this whole process to function correctly. After examining the available solutions, Max/MSP seemed the most viable environment in which to develop my software. This is due to its range of real-time DSP objects and the availability of the JMSL based Maxscore objects, and also the existence of Max for Live (Ableton, Cycling ‘74), which makes the task of performing electronic live music much easier. Maxscore enables the use of conventional western notation, and offers support for microtonal notation, something that is essential to the accurate representation of spectral data. For the FFT calculation the objects fiddle~ and pitch~ (Pucket, 1998) were initially trialled and the later reworking of the fiddle~ object, sigmund~ (Puckette et al., 2004) proved to be the most useful to my purposes after much testing. Further data interpolation and quantisation was in the end required to extract stable pitch information from the data streams being produced by sigmund~ and this object with all of its imperfections proved to be the best choice for a resynthesis patch used in the composition portfolio. After further testing it was discovered that this object was not appropriate for use with the e-score component of the software due to pitch detection inaccuracies and the gabor~ object (Schnell, Schwartz, 2005) was trialled, which is available as part of the FTM overlay for Max/MSP (Schnell et al., 2011). This object is no longer adequately supported in Max version 6 and zsa.freqpeak~ (Jourdan, Malt, 2008), found to be as accurate as gabor~ was implemented, to maintain compatibility. This also simplifies the installation stage, as the FTM installer adds excessive unnecessary functionality to the software for the purposes of the SpectraScore software.

4.3.2 Live scores
The live generated score window is for viewing data collected through FFT, but it is also useful in performance scenarios. The leftmost score window displays the analysis pitches transposed to one octave and ordered from left to right in terms of prominence within the analysed spectrum. This takes into account not just amplitude, but how often each frequency is detected within the specified time window. As with the orchestral resynthesis module this represents a metaphorical view of the ‘sonic object’, and is not a literal re-synthesis of the source material. Through treatment of the ‘sonic object’ as a metaphor from which a scale can be derived melodic improvisation is made possible within traditional performance scenarios. I have referred to this earlier as ‘spectral cell’ based improvisation. Also, if the user is to click on any of the notes in the scores they are played back through MIDI channel 1 for the purposes of previewing.

### 4.3.3 Automated mode selection

Using micro-modes taken from the overtone series, Calin Ioachimescu introduced the idea of ‘Spectralism and Modality’ (Vieru, 1980) in his compositions. To increase the versatility of the software in improvisation situations, a feature was implemented that selects and displays the closest musical mode to the loudest and most commonly detected analysis pitches. After a database of common modes is analysed to determine the mode with the highest number of common notes with the analysis pitches, that mode is displayed in notated form and as a word. In faster passages of music where slow careful sight-reading of quartertones and previously unseen pitch material is an issue, the musician can resort to the mode. This feature makes the software more useful to Jazz musicians engaging in interactive spectral music in a traditional format. The collection of modes used see appendix A.2
4.3.4 Resynthesis

Additive synthesis is a common technique used to perform resynthesis, it is presented here as an expression of conceptual notions of spectral music. Each material object analysed by the software is recorded as a set of nodes placed within a two dimensional graph. The x-axis represents pitch class and the y-axis amplitude. Results are available in scored and resynthesised form for previewing or musical performance. This module may be used to create synthesised textures that are closely related to both the ‘sonic object’ and pitch material displayed in the various scores that SpectraScore generates. If no audio is present to transform other than this sin wave resynthesis texture, electronic sounds may still be produced.

4.3.5 Sine wave resynthesis

The sixty-four loudest partials from the analysis are stored and reproduced using a bank of oscillators. These oscillators allow for control over pitch and amplitude and both parameters are extracted from the spectral collection. This resynthesis is paralleled by an orchestral resynthesis but they are not identical. The orchestral resynthesis only contains thirteen members and is quantised to the closest quartetone whereas the sine wave resynthesis contains sixty-four members and reflects the exact frequencies detected at the analysis stage.
4.3.6 Probabilistic orchestral resynthesis

The orchestral resynthesis created using SpectraScore is not an attempt to closely represent the subject of analysis, but merely create a metaphorical representation of it. These resynthesised textures are created through implementation of a probability algorithm, which selects the thirteen members of the chord based on their prominence in the spectral collection. This means that if a pitch is particularly prominent in a spectral collection in terms of its amplitude or occurrence it will be more likely to appear within the resynthesis chord. The detected frequencies are quantised to the nearest quartetone based on a rounding system that is similar to the one used by Tristan.
Murail in his preparation of *Gondwana* (Rose, 1996) Currently, the chords are spread out over the whole range of a string section consisting of parts for Violin, Viola, Cello and Double Bass but plans exist to expand this ensemble in future versions. Previewing notes via clicking on them is also available through MIDI channels 1-13 as is playback of the entire chord simultaneously over MIDI. For future implementations, having access to all of this material on one screen in a more compact format (i.e a grand staff) could present the concept of this module to the user more clearly.

### 4.3.7 Interpolation between ‘spectral nodes’

Interpolation is a common spectral technique used by composers such as Gerard Grisey and Tristan Murail (Rose, 1996). In his piece *Gondwana* Murail creates a stepwise transformation between two chords by pitch shifting every element of chord A very gradually until all instruments land on the composite notes of chord B. In SpectraScore this same technique is available between up to five spectral collections. A node-based controller (Fig 4.6) is available that allows the user to slide between these node configurations in real-time. Each morph between two points on the controller involves a multi-point interpolation on the node diagram, which is translated into glissandi in the case of the sine wave resynthesis and automatically updates the score of those performing orchestral resynthesis.

### 4.3.8 Spectral collections as harmonic morphemes
A graph resembling Plutchik’s Emotion Circumplex (Plutchik, 1984) was created to represent the emotional states detected in various pitch collections by the SpectraScore module Plutchik’s Flower. This system involves real-time tracking of psycho-acoustic properties of live sound. Calculating what is summarised as a ‘roughness’ factor, the roughness~ object (Mcallum and Einbond, 2008) for Max/MSP was trialed for use to calculate the dissonance factor of ‘sonic objects’. Eventually this was replaced with a custom external developed by John Matthews (University of Wollongong) for this project called mxj Dissonance. It represents a direct implementation of the formula created by William Sethares for calculating sensory dissonance (Sethares, 1994). In addition, a secondary method of deriving a ‘dissonance score’ was implemented using ideas presented by Vincent Persichetti in his book 20th Century Harmony which result in a ranking of the 12 possible chromatic interval pairs based on their respective level of dissonance. By implementing both components within SpectraScore a synthesis between cultural and psychophysical aspects of perception was created within a two dimensional graph not unlike Plutchik’s Emotion Circumplex. The ‘dissonance index’ detected using Persichetti’s method is reduced to a number between 1 and 8 for comparison with ranked emotional descriptors.
extracted from a study on the structure of emotions over three-dimensions (Morgan, Heise, 1988). In this study a number of participants made evaluations of three emotional dimensions subsequently interpreted as activity level, positive/negative effect and potency. The emotional descriptors used in both Plutchik’s emotion circumplex model and the study by Morgan et al. were compared to achieve a synthesis of both structures and facilitate automated selection of emotional states associated with chord clusters from spectral analysis. The information taken from Persichetti is represented as a point on the graph within the boundaries of the particular emotional descriptor chosen based on the correlation of intensity and harmonic complexity. The proximity of this point to the middle of the graph represents intensity of emotion and is determined by the level of sensory dissonance calculated from a spectral collection using the formula developed by Sethares.

4.3.9 Speech and music correlation through emotional descriptors

The EmoDB Player uses samples taken from the Berlin Database of Emotional Speech (Burkhardt et al., 2005). This database was created through voice acting, based on emotional trigger words and all samples are spoken in German. Each phrase in the database is chosen for its flexibility of interpretation. Using the trigger words the actor turns a simple phrase like ‘The washcloth is on the table’ into an example of speech encapsulating a particular emotion. The EmoDB Player plays back whichever expression is related to the emotional state detected by the Plutchik’s Flower module in SpectraScore.
CHAPTER 5

Composition portfolio

5.1 Practical Considerations

Using a computer to perform live composition introduces the techniques and aesthetics of algorithmic composition into the mix. Incorporating too many arbitrary decisions into the algorithms used to generate the notation sequences appearing on the score results in compositions with a character that is not perceivably related to the sound world of the spectrum inferred from the audio being analysed. Relying solely on compositional material developed without musicological analysis and a subsequent reforming of that material to best suit the composition, results in bland, un-unified compositions. The improbability of successfully ‘re-working’ material in the studio before a performance poses issues for consideration; It is important when creating new material from acoustic sound sources in real-time to use intuitive algorithms to replace the absent ‘reflective’ composer. These algorithms must be designed in a way that allows for the informed influence of the performer’s musical sensibilities. It is not imperative or preferable for the purposes of working with real time analysis that processes propelled by computer-generated randomisation perform the majority of compositional decision-making. The factor of indeterminacy introduced by human improvisation to the composition however, extends the influence of the individual over the sound world of the composition. This creates an open system for the generation of performer controlled, but algorithmically determined material. It has been suggested that such systems create music that is more pleasing to listen to (Eldridge, 1997). This presents part of the solution to the ‘absent composer’ problem. Pieces that are pre-composed in their entirety, as well as some that are only partially pre-composed, and others that are purely generative have been included in this portfolio of interactive spectral music. This level of variety
within individual compositions creates a clearly perceivable aesthetic contrast between the various approaches, creating a further aspect of variation and interest.

5.2 Application of spectral techniques within the portfolio

*Four Spectral Landscapes* is a series of electroacoustic studies that explore the compositional concept of resynthesis. These pieces were composed in an effort to demonstrate the aesthetic consequences of using spectral analysis to derive whole compositions through algorithmic means. All melodies, chords and rhythms were generated based on spectral material collected from drones played on acoustic sound sources:

- Spectral Landscape I is based on a choir singing long sustained tones in unison.
- Spectral Landscape II was generated from a sustained horn tone
- Spectral Landscape III uses a sample of an orchestra tuning, detuned by two octaves
- Spectral Landscape IV is derived from Bandura harmonics recorded from the lowest string on the instrument (C#)

All four pieces are designed for stereo playback and are best heard through loudspeakers. The pieces *Autopoiesis* and *Magnetic Visions* rely on customised software programs derived from *SpectraScore* for performance. Each performance starts with the choice of a ‘material object’ (Dhomont, 1999) or simply put, an acoustic resonator of any kind that carries a specific significance. This sound is analysed, and the subsequent analysis pitches are used to structure the composition based on the frequencies detected in each sound source. This method of real-time composition of course relies rather heavily on the sight-reading ability of the performers. *Magnetic Visions* is thus comprised of very simple material so as to allow for this. *Autopoiesis* is a more ambitious composition in terms of playability due to the rhythmic complexity of gestures.
that must be sight-read. Of primary interest in *Autopoiesis* and *Magnetic Visions* was combining live acoustic sound sources with electronically generated sounds. John Cage, in his piece *Imaginary Landscape No. 4* (1951), calls upon the use of transistor radios in place of conventional instruments. In a sense, this keeps the piece relevant to the time in which it is performed through an aleatoric method of quotation. In the same fashion, my two pieces request that the performance ensemble choose the objects from which to derive the composition so as to position the pieces as vehicles for expression.

*Midnight all a Glimmer* explores both sine wave resynthesis and orchestral resynthesis. All of the string textures presented were pre-composed with the aid of the *SpectraScore* software and altered to achieve the desired harmonic effect. The sine wave resynthesis textures reflect the player’s performance technique quite closely and are real-time in the most basic sense of the word.

*Amniosis* was the first test of the concept of improvisation based on derived spectral collections. Each player was given a music role within the ensemble and relied heavily on frequently updating notation fragments derived from the found percussion also heard in the piece. They were also briefed on mood characteristics of the music that were inferred from the accompanying film. This experiment provided insight into what information would assist performers in creating convincing improvisations, which in turn led to the creation of the *Apotheosis* series of pieces. In *Apotheosis of Four Sacred Objects* the most important technique applied is the use of ‘spectral collection as harmonic morpheme’. The player is presented with instructions about which emotion to try to express using small excerpts from the derived spectral collections. Accompanying this are orchestral resynthesis textures based on the same spectral collections generated through a probabilistic algorithm. In addition to this a sample player using samples extracted from the Berlin Database of Emotional Speech (Burkhardt et al., 2005).

### 5.2.1 Spectral Landscape I-III
Each of the first three pieces in this collection of studies is generated from a single spectral subject. Variation was created through pitch modulation of the subject and selective control over the sensitivity of frequency detection at the FFT analysis stage. The more sensitive the analysis, the more pitches would be compared to the detected fundamental pitch of the ‘sonic object’ to check if they were present in the natural harmonic series associated with that fundamental pitch. If so then they were passed to a sequencer where they were recorded along with the other 13 voices that were being tracked through this process. This resulted in score fragments that were rich in harmonic variation and easily manipulated and refined through MIDI.

The first piece makes use of a wide variety of electronic timbres and a variation of the rate of harmonic detection from extremely sensitive to mildly so, and is as a result less static than pieces II and III. The second piece uses a very slow but gradually increasing rate of frequency detection in the analysis and samples of horns and strings for resynthesis and makes heavy use of silence to emphasise a sense of space between the highly dissonant chords. The third piece in the collection is timbrally quite static but harmonically active and was particularly focused on the act of generating chords and melodies. Overall, a rapid but microtonal fluctuation on the subject of analysis but a varying rate of harmonic detection developed varied pitch material with internal harmonic complexity and interesting aeleatoric tonal consequences.

5.2.2 Spectral Landscape IV

This study takes four sonic objects as it’s inspiration; All are plucked natural harmonics from the lower C-sharp string of the Bandura, a chromatic folk lute of Ukrainian origin. All of the compositional elements have been derived from these sounds through FFT analysis and they can therefore be considered forms of re-synthesis. The various elements presented in this mix are:

- The samples of the harmonics themselves
• A synthetic string ensemble presenting a series of orchestral resyntheses of the 13 loudest partials in the spectrum of each object
• Arpeggios on various synthesised instruments (mallet-like and square-wave based) based on the closest mode to the analysis taking the loudest partial as the tonic
• Arpeggios on synthesised bongo-like percussion
• a series of sine-wave based resynthesis textures

The composition follows a ‘moment-form’ formula (Stockhausen) whereby each ‘moment’ is separated by a set interval and is considered a separate entity existing in a musical space. However, with the gradual introduction of sine-wave glissandi between these gestures (created by interpolating between pitch configurations resynthesised from the samples themselves) and a loosening of the rhythmic rigidity of these forms, each ‘moment’ becomes more unified with the next. Arpeggios expand out from each ‘moment’ propelling the gesture to the highest audible octaves. High violin-like melodies begin to penetrate through a canopy of textures in in the B section of the piece and therefore pair away from the main orchestral resynthesis timbre. Through doing so they begin to form into melodic lines and highlight a natural voice leading between each of these large string chords. Finally, a sine-wave ‘smear’ of all of the previous 50 most commonly detected partials fades through revealing a bed of familiar tonality, drawing on the pitch material presented throughout the piece.

5.2.3 Magnetic Visions I-III

The Magnetic Visions series of pieces represent a meeting of the concept of ‘ready-made’ art and the aesthetics of live ambient music. Erik Satie first spoke of ‘furniture music’ that is, music which does not profess to wholly occupy the attention of the listener, but to add to the ambience of the space in which it is played. The magnetism implied by the title is the attraction between the
real sound of the found percussion object and the pitches within the electronic scores used by the
performers, which are determined by a live analysis of it. These pitches are used to create a
harmonious composition set in the closest mode from a selection chosen by the composer in the
tradition of Satie’s ‘furniture music’ but with a twist. The music is to be representative of the very
object from which it is derived. If the performance ensemble were to in fact choose a piece of
furniture as the subject of this composition it would appropriately encapsulate the novelty of the
concept. An ‘Ur-score’\(^{17}\) was created specifying scale degree relationships, timings and dynamics
for the piece. The performance begins with a single sounding of the found percussion being
analysed for its spectral content in front of the audience and the scores being created based on this
FFT analysis and a subsequent reconfiguration of the ‘Ur-score’. This information is then
displayed to the performers who are to sight-read and coordinate a performance of the piece, along
with the live electronics part which is generated from another, this time continuous live FFT
analysis of their performance and that of the found percussion object.

Magnetic Visions I is in fact an entirely pre-composed piece, which can be considered as the
‘Urtext’ from which future realisations evolve. In the case of Magnetic Visions II, two virtual
Disklaviers were used that are tuned a quartertone apart. They are triggered via MIDI in response
to the timings laid out in the ‘Ur-score’ and the performance of the found percussion (in this case a
triangle was used). Magnetic Visions III is for 3 vocal quartets and uses a bell the as found
percussion.

### 5.2.4 Autopoiesis

Autopoiesis means self-production or self-creation and is a recent word created by means
of the two ancient Greek words *auto* and *poiesis* (birth, creation or production). (Arnoldi,
2006)

\(^{17}\) This expression is merely intended to describe the fundamental and unfixed nature of the skeleton score (a record
of interval relationships and timings) used to structure the composition around an unknown key area.
This piece is an example of a large ensemble work that is generated from a ‘sonic object' chosen by the performance group. This is done to reflect the process of autopoiesis in nature through the increasing rhythmic unity between groups within an ensemble subdivided into four. The piece begins with the chosen sonic object resounding three times. One of these note events is analysed and used to generate the pitch material for the piece, which is subsequently applied to the skeleton score. One of the techniques used here is a kind of virtual delay, where each note played by the wind group is passed through a small string ensemble. This technique serves to unify the subdivisions of the ensemble. The whole string ensemble is divided up into four groups that are led by the either recorder, saxophone, clarinet or bass guitar. As the piece progresses a network of digital delays is introduced, further cluttering the texture while maintaining a strong pulse, resulting in a blended, pulsating mass with the same pitch character as the featured ‘sonic object’. The final goal of the piece is reached when all performs shift into rhythmic phase with one another to play the closing bars.

5.2.5 Midnight All a Glimmer and Fumes

The title of this piece was inspired by the poem *The Lake Isle of Innisfree* by W.B Yeats (Yeats, 1890):

Lake Isle of Innisfree

By W.B. Yeats

I will arise and go now, and go to Innisfree,
And a small cabin build there, of clay and wattles made:
Nine bean-rows will I have there, a hive for the honey-bee,
And live alone in the bee-loud glade.
And I shall have some peace there, for peace comes dropping slow,
Dropping from the veils of the morning to where the cricket sings;
There midnight's all a glimmer, and noon a purple glow,
And evening full of the linnet's wings.

I will arise and go now, for always night and day
I hear lake water lapping with low sounds by the shore;
While I stand on the roadway, or on the pavements grey,
I hear it in the deep heart's core.

(Yeats, 1890)

In this piece the sound of the guitar is used to generate the spectral accompaniment and the large chords played by a thirteen-piece string ensemble. The style is that of a *cadenza apogonata*, or accompanied cadenza, but the point is not to dazzle the audience with virtuosity. The plucked chords that comprise the guitar part represent a design that emphasises subtlety of touch and sensitivity to the sound of the guitar. These spectra act as a catalyst for the large string resynthesis created by the live ensemble and spectral electronic accompaniment. In performance, a longing for the fantasy world of *Innisfree* is evoked, a place where the light of morning, noon and midnight are at once alive illuminating the lonesome central character who features in the poem. *Fumes* functions as a prelude to *Midnight All a Glimmer*, which sets up the mood of the ‘pavements grey’, a desolate industrial landscape. The resolution of the tension set up in the piece is representative of an escape to *Innisfree* from within this wasteland through the mind to the ‘deep hearts core’.

**5.2.6 Amniosis**
Amniosis ponders the reflection of our human form within human made forms and vice versa. This correlation is made in order to bring into question our disassociated relationship with our natural origins. This is done in both the mediums of video and audio/music. The word ‘amniosis’ refers to a psychological state of being metaphorically within ones mother. This metaphor when extended over humanity reminds us of how we are unable to entirely escape from our own literal amnion, the Earth. It is simultaneously a statement that we have not yet grown as a species to support ourselves without our natural environment. In the video created by James Walker, human forms are superimposed over buildings, machines, footpaths, and bridges – essentially aspects of our environment in the civilised modern world. This highlights the self-similar shapes, which we humans have created to house ourselves in place of the natural forms that had hosted us before.

Ominous sound textures highlight the menacing character of ebbing water, whose tides may slowly break the banks of coastal cities around the world like Sydney, where the footage was shot, in the near future. In the music, SpectraScore is used to extract modes that are related to the analysed spectral data present in the found percussion used in the piece. In our recording, this included various human made forms such as ornamental bells, wind chimes and a wooden guiro.
The score fragments derived from the found objects, and a scale indicating the prominence of partials within the spectrum are sent to the instrumentalists who improvise a textural accompaniment. The performers are instructed to use the video as a guide to what level of activity they should exhibit in their improvisation. They are also briefed on the conceptual nature of the work and instructed to keep the textures well blended and unobtrusive, in the style of ambient music.

5.2.7 Apotheosis of Four Sacred Objects and A Completed Portrait of Stein

An apotheosis according to the Oxford dictionary is ‘the elevation of someone to divine status’. A Completed Portrait of Stein takes Gertrude Stein’s reading of A Completed Portrait of Picasso as its starting point. The examination of Stein’s voice revealed harmonic patterns that were used to compose the piece. The accompanying electronic parts are generated live using effects such as delay, looping, reverb and the same sine wave resynthesis effect used in Magnetic Visions. This is done to explore speech patterns in an effort to find defining features of the subject with less regard for the literal meanings behind the spoken text.

Apotheosis of Four Sacred Objects explores this notion of worship; this is done through spectral representation of four ‘sonic objects’ in pre-scored and live generated material. The components of the composition are:

- The live sound of the bass recorder
- Tape loops and delay networks
- Orchestral resynthesis
- Speech samples taken from the Berlin Database of Emotional Speech (Burkhardt et al., 2005)

The process that takes place is a live emotional and musical evaluation of a subject. A sound is analysed and musical qualities are extracted from it as well as emotional descriptors. Structurally
this piece is divided into a number of very short sections in the format ABABABAB. The A sections are pre-composed and the B sections are generated in real-time. The correlations made in this piece are a source of inspiration for the performer as well, as they must improvise segments based on short collections of notes with the help of an associated emotional descriptor in the B sections.
6.1 Summary of topics covered

In this thesis three main avenues of inquiry have been pursued in order to facilitate the creation of a software tool for creating interactive spectral music. They were: What is spectral music? How does one make it in real-time? What effect does doing so have on the perception of meaning in music?

‘Spectralism’ the style and ‘the techniques of spectral music’ proved to be two separate areas for consideration. The concept was explored that the term ‘Spectral Music’ refers to an array of divergent styles united through assumptions about sound and music. An analysis of the two-fold nature of music perception was performed that revealed certain incompatibilities between both cultural and psychophysical influences. By dissecting the techniques of spectralism from the style of spectralism it became clear how to proceed with the construction of a software tool that enabled the creation of spectral music in real-time based on this analysis of music perception. This synthesis of ideas was in the end realised as a series of Max for Live effects for performing the types of analysis commonly used by spectralists and applying them to the creation of notation sequences and electronic sound synthesis. A portfolio of compositions was created exploring the use of this software for the purposes of creating both ‘formalist’ algorithmic compositions and more programmatic works in a variety of styles and for different sound/instrument combinations demonstrating the flexibility of this new work method.

6.2 Future directions
SpectraScore is currently a new piece of software, and it will likely take many reiterations before a fully feature rich version will be available. This process often involves feedback from users to determine the best course for future developments. Without having completed this process, immediately obvious is still that a number of features could at least be expanded so as to increase the usability of the software. Examples of features that could be added are:

- Allowing user access to the database of scales used in the mode correlation section
- Allowing user control of the temperaments used for playback and display
- Allowing user control over display elements such as clefs, register and including an option for non-music readers
- More options for users in terms of specifying the kind of orchestral resynthesis i.e. register, instrument choices, number of instruments, instrumental combinations
- Allowing the user to specify emotion response correlation parameters i.e. user definable maps for correlation between harmonic configurations and emotional descriptors

The SpectraScore software and accompanying composition portfolio represent but a small part of the potential for creation within the field of spectralism. It was seen in this thesis that the practice of spectral decomposition for use in art and music has common origins in the sciences. This knowledge has been be used over time to explore both visual and audible phenomena within related artistic frameworks. Proponents of this field therefore do not need to exclusively focus on audible phenomena, this technique can also be used as an intermediary through which to explore aspects common to sound, vision and potentially, the other human senses. Bearing this in mind I present a range of aspects for the current system that could be improved upon in future versions of the software:

- Access to visualisation software so as to apply spectrally deduced data to visual paradigms
- Analysis tools for the decomposition of visual sources and associated analysis that
seamlessly interacts with the audio based tools

- Access to lighting equipment though MIDI or another associated protocol
- Expansion of notation generation to included extended notational styles such as graphic notation

### 6.3 Concluding remarks

It seems clear after this examination that the subjective, literal beliefs that people construct in order to better understand music establish a quintessential cultural context. Without an understanding of this context, generalised psychoacoustic studies remain useless to the composer. For this same reason, occasionally music falls on improperly prepared ears and controversy ensues. Through this controversy, caused by such unanticipated innovation, music continues to simultaneously dazzle and baffle those who care to open their scope of attention enough to let the ‘new’ in. When aiming to generate music in real-time based on sounds with an inherent yet unknown tonality and correlate them with emotional descriptors the limitations imposed by what we understand of perception can become prohibitive. Despite the results resembling music that may be of a less culturally coherent nature there is no law that states that music itself need represent an entirely familiar emotional experience. Such a system would serve little purpose to a composer of experimental music in any case. Instead, by using the principles of ‘Momenten Form’ (Stockhausen) and ‘le principe de la generation instantanée’ (Grisey) one can push forward into the world of experimentation and discovery in the tradition of spectralism. The focus of such a discipline remains the experience of sound itself and does not seek to rigidly define but to explore and experience.

The dual nature of the composer of interactive spectral music is that of a listener, experiencing things for the first time with their audience, and a vessel for the reinterpretation of
that experience of sound. This perspective of music liberates them from the grand narrative of the composer as a keeper of ‘musical secrets’ and disseminator of ‘truth’. It instead positions them within the audience as an active participant in the collective animal experience of perception.


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1 See Harwood
A.1 SpectraScore – Read Me file

SpectraScore Readme file

System Requirements

Minimum:
Processor - 2.3 GHz Intel Core i7
Memory - 8GB 1600 Mhz DDR3 RAM

Installation
1. Ensure that you have Ableton Live (8.2.8 and up) and Max for Live (6.0 and up) installed
2. Mount the .dmg file “MaxScore-0.4.5-osx-installer.app.dmg”
3. Run the installer included in “MaxScore-0.4.5-osx-installer.app.dmg”
4. Open JMSL_License_installer.jar
5. Drag the included license file “JMSL.lic” onto the open window
6. Run the SpectraScore installer
7. Follow the prompts
APPENDIX A

A.2 SpectraScore – Mode chart
B.1 Software Installer CD: SpectraScore – DVD 1
C.1 DVD Tracks: Composition Portfolio – DVD 2

C.1.1 Four Spectral Landscapes
Track 1: Spectral Landscape I – 5:20
Track 2: Spectral Landscape II – 3:56
Track 3: Spectral Landscape III – 6:40
Track 4: Spectral Landscape IV – 9:04

C.1.2 Magnetic Visions
Track 5: Magnetic Visions I – 5:17
Track 6: Magnetic Visions II – 4:08
Track 7: Magnetic Visions III (MIDI realisation) – 4:15

C.1.3 Plutchik’s Flower
Track 7: Autopoiesis (MIDI realisation) – 7:22
Track 8: Fumes – 7:35
Track 9: Midnight All a Glimmer – 11:03

C.1. Apotheosis
Track 10: Amniosis – 14:26
Track 11: A Completed Portrait of Stein - 6:23
Track 12: Apotheosis of Four Sacred Objects – 7:40

Total Duration 93 minutes 15 seconds