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Strange Attractors: A Commentary on Applications of Indeterminacy in my Recent Music

Scott Graeme Mc Laughlin

A portfolio of compositions and commentary submitted to the University of Huddersfield in partial fulfilment of the requirements for the degree of Doctor of Philosophy

December 2008

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Acknowledgements

I would like to thank Dr. Pierre Alexandre Tremblay and Dr. Bryn Harrison for their supervision of my work and their exceptional support in bringing it to fruition. I would also like to thank especially Dr. James Saunders and Prof. Christopher Fox for their supervision and inspiration early on in my studies, and the following people for their advice and support which has all been invaluable over the past three years: Simon Anderson, Aaron Cassidy, Michael Clarke, Lisa Colton, The Contemporary Music Centre (Dublin), Liz Dobson, Samuel Freeman, Richard Glover, Iain Harrison, the HCMF, Scott Hewitt, Ben Isaacs, Joe Kudirka, Alvin Lucier, John McLachlan, Eleri Pound, Heather Roche, Rebecca Saunders, Benedict Schlepper Connelly, Garrett Sholdice, Mic Spencer, Philip Thomas, Nick Williams, Stewart Worthy, the YCC.

Special thanks go to Jessica and our families for their love and support.

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Abstract

This commentary reflects on how indeterminacy has been used in the music I have written over the period of my doctoral studies, 2005-2008. Non-musical ideas play a major role in my compositional language and this is reflected in the the use of 'strange attractors' as a metaphor for the philosophical and aesthetic stance behind composing with indeterminacy.

Chapter 1 introduces aspects of my compositional language and the context for my music. Short sections introduce my readings of important concepts such as inharmonic sound or 'strange attractors' and explain how they inform the music. Specific compositional techniques are then discussed both in terms of how they are applied in my compositional language and their original contexts.

The discussion of indeterminacy is divided into the vertical and the horizontal. Vertical indeterminacy focuses on applications of indeterminacy to pitch organisation techniques such as spectral modelling and frequency modulation are examined as part of a frequency-based harmonic continuum. Different methods of generating ambiguous pitch percepts that sit at the boundaries of the harmony/timbre duality are considered in pieces with text processes. Horizontal indeterminacy includes the effects of using time-space notation to remove some control at the note-level. This leads to an examination of techniques for indeterminacy from larger temporal units through bounded-improvisation and text processes.

Musical contextualisation is provided by looking in particular at the American experimental school of composers such as Lucier

Chapter 2 is the commentaries on individual pieces. These commentaries will discuss the composition of the work, with particular reference to the technical and aesthetic concepts that have been discussed in chapter 1. As not all of the works discussed can be considered as successful, these commentaries will also address issues of language and problems that have arisen through performance of the works.

The conclusion of the commentary briefly examines the points of crossover between the horizontal and the vertical aspects and the importance of developing an approach in which they co-exist.

List of Works Submitted

Tracheids (2006)

- flute, clarinet, bass guitar, percussion: 3 mins

The Lady with the Hammer (2006)

- 2 tuba, 2 trombone, 2 euphonium, 2 piano: 12 mins

Primes (2006)

- for high string instrument and Max/MSP: 10+ mins

Filament (2006)

- guitar quartet: 1 min

Inner Shadow (2006)

- violin, cello, bass clarinet, accordion, acoustic metronome:

Distemper (2006)

- any equal-tempered plucked/struck string instrument and Max/MSP: 10+ mins

Five Bells for Elliott Carter (2006)

- string quartet: 8mins

Whitewater (2006)

- wind instrument(s) and Max/MSP: 10+ mins

For Garrett Sholdice (2007)

- violin, oboe, piano: 6 mins

Bifurcations (2007)

- clarinet quartet: 8 mins

Nano (2007)

- clarinet: 15+ mins

Torsion (2007)

- eighth-tone trumpet: 4 mins

Intra- (2007)

- violin, prepared guitar: 13 mins

Whitewater II (2008)

- 8 or more saxophones: 8-10 mins

The Well-Tempered Prism (2008)

- clarinet, piano: 6 mins

Lorenz (2008)

- saxophone, contrabass, cello, viola, perc: 10 mins

Marx (2008)

- mezzo soprano, viola d'amore and synthesiser: 13 mins

Five Bells for Elliott Carter – Orch. (2008)

- string orchestra: 10mins

1: Chapter 1 - Context

1.1: Introduction

This commentary relates to the works written between 2005 and 2008 (submitted in the accompanying portfolio) and focuses specifically on the varied techniques of indeterminacy used in their composition. The strange attractor is used as a metaphor for my musical application of indeterminacy. Aspects of chaos theory are explored in their role as influences on my way of thinking about both harmonic and temporal relationships, and ultimately the development of my compositional language. The commentary is divided into two main chapters. Chapter 1 examines musical language and contextualisation, while Chapter 2 consists of the commentaries on individual works and an overall conclusion.

In Chapter 1, several facets of my compositional language are examined with respect to technical details, and to musical and extra-musical context. Section 1.2 takes specific terms and ideas and attempt to define generally how my music is informed by them: in some cases this includes examining examples from the portfolio and musical contextualisation. The basic principles of my music as organised sound are covered in 1.2.1: Sound, Ambiguity and Gestalt. In 1.2.2: Chaos and Strange Attractors, I will briefly cover my reading of chaos theory and relate it to musical indeterminacy: this will draw mainly on two works of popular science, *Chaos: Making a New Science* by James Gleick, and *Complexity: The Emerging Science at the Edge of Order and Chaos* by M. Mitchell Waldrop. 1.2.3: Sonification, and not Sonification briefly discusses the idea of sonification and examines the work of various composers who have taken inspiration directly from scientific ideas. 1.2.4: Feedback discusses the concept of feedback in a dynamic system and applies it to musical indeterminacy, while 1.2.5: Evolution examines the formal and temporal aspects of my work and argues that in much of my musical language it is more accurate to view the works as an idea's evolution rather than its variation.

Sections 1.2.6-1.2.8 discuss the more technical aspects of indeterminacy in my language. I have split this into two specific areas which I term vertical indeterminacy and horizontal indeterminacy. The vertical deals with the application of indeterminacy to aspects of harmony and pitch organisation, and the horizontal to temporal aspects such as duration, pitch-motion and form. The reason for this separation is twofold: the techniques used by the two different aspects are sufficiently different to demand separate examination, and both are based in different musical traditions. The vertical aspects are developed from techniques of pitch organisation and generation derived largely from studying the Spectral school of composition focusing on the works of Gérard Grisey and Tristan Murail. Horizontal indeterminacy owes more to the American experimental school as exemplified by Alvin Lucier, James Tenney, Morton Feldman and others. This distinction is of course slightly artificial and areas of crossover will quickly become clear to the reader, a point which will be summed up in 2.2: Conclusions by looking at 'inbetween-ness'.

Section 1.3 is a more involved look at specific musical traditions and their relationship to my music and development as a composer. 1.3.1: Experimentalism discusses my relation to the American experimental school, and focuses on comparing Cagean indeterminacy with that of Alvin Lucier with respect to soundworlds and intention. Aspects of the European approach to indeterminacy are discussed with particular focus on the work of György Ligeti and Witold Lutosławski. 1.3.2: Spectralism looks at the influence of the Karlheinz Stockhausen, Gérard Grisey and Tristan Murail in particular. This section expands on the technical aspects of spectral music that is covered in 1.2.7: Vertical Indeterminacies by briefly exploring my relationship with the spectral approach to time and form.

Chapter 2 is the commentaries on all the works that I have composed during my PhD studies. This portfolio of works is the body of the PhD, the works themselves are my research and these commentaries are in place to discuss aspects of their composition and context. Five of these pieces are text scores and thus have a strong element of indeterminacy, but also some works which are presented here as fixed scores. The indeterminacy in the fixed pieces is not always immediately clear to the score reader, but equally, I would argue that in a blind test it would not be immediately clear to a listener how many of the pieces were text scores. The indeterminacy is not always something which arises from performance, it is an inherent quality built into the basic concepts of my compositional language. Elements such as inharmonic material and mistunings lead to acoustical beating patterns perceivable either as discrete pitches or as fused sound complexes: the musical equivalent of the multistability of the Necker Cube (see *illustration 1* below; p.12).[1] For instance, sustained musical textures can attempt to freeze time, or given enough room would allow a listener to take in a harmony before it is replaced by the flow of the piece's evolution. A fixed score may specify what players do on each step of

[1] The Necker Cube is a well-known optical illusion. The lack of depth perception in the image allows the brain to see it in two possible aspects, but not simultaneously; a phenomenon referred to as multistable perception. See Kruse, P & Stalder, M (eds.), *Ambiguity in Mind and Nature: Multistable Cognitive Phenomena*, (New York, 1995)

the metric grid, but that is only a scaffolding for the music. The qualities of the piece come from an indeterminacy in the nature of sound itself which can be harnessed to music by different types of notation: for example, it has long been accepted in digital sound synthesis that an element of randomness in the form of LFOs and noise makes a sound more 'real'. Music, for me, is an organisation of sound that has in past models focused on 'beautiful sound' rather than simply 'sound'. The civilising aspect of music often aims to smooth out the sonic bumps which nature insists on and takes us a little further from nature, indeterminacy allows some of nature's rough unpredictability back in.

Correspondingly, Alvin Lucier's oeuvre sets itself against the normalising tendency in music that dismisses so many interesting sound phenomena as undesirable:

> It's the idea of control and sameness, like balance in a chord; you want it to be the same as the other chords. Balance is only one idea. There's imbalance too.[2]

To extend Lucier's point, control is only one idea, it can be more interesting to move the control back a few steps and let some chaos in. The results may look messy and incoherent to one who is concerned with controlling every last detail, but messiness does not have to be 'error' in the same way that detail is not an absolute necessity in creating coherence; sometimes more sense can be made of the global when the local detail is in flux. Making a similar point in the context of science, James Gleick describes Benoit Mandelbrot's seminal work on fractals thus:

> Mandelbrot's work made a claim about the world, and the claim was that the odd shapes carry meaning. The pits and tangles are more than blemishes distorting the classic shapes of [classical] Euclidean geometry. They are often the keys to the essence of the thing.[3]

I use indeterminacy as a compositional technique, but also as a political and philosophical stance. Lack of determinism does not have to mean absence of control, it is more about what one chooses to be free and what one needs to control in order to make the whole work. The accompanying portfolio of work aims to express this ideal.

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2 Lucier, Alvin, (transcribed by Anne Guthrie.), *Ostrava Days 2005 Report*, (Ostrava, 2006), 120.
3 Gleick, James, *Chaos: Making a New Science*, (London, 1987), 94.

1.2: Compositional Language

1.2.1: Sound, Ambiguity and Gestalt

My music is composed around a dialectic between clarity and ambiguity in sound. The processes that I use in both the vertical and horizontal aim to either create ambiguity through indeterminate or determinate means, or to use clarity to contain, negate or refocus that ambiguity. Generally, the sound or sound object is the material and the music's form is created or arises from the material's proliferation and the ambiguity between its repetition, transformation and negation.

The material that I work with is often a sound that is static[4] or linear but has an independent inner motion, such as a sustained multiphonic or split-tone, hovering ambiguously between chord and timbre. The archetypal sound for me is a bell, a sound that is made of a multitude of oscillating pitches—some interacting and some independent —all decaying at their own rate but still perceived as a single sound—in gestalt perceptual theory this is the principle of common fate, sounds that start together and continue along the same vector are perceived as one (see below for the Gestalt principles of grouping).

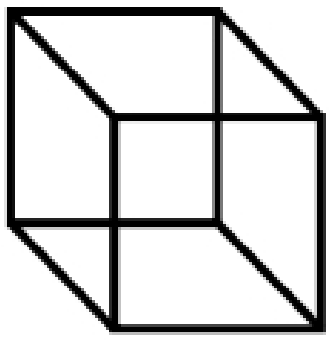


Illustration 1: The Necker Cube

The ambiguity in the vertical component of my music involves harmony that may be perceived as a chord or as a timbre, a multistable harmony. *Illustration 1* above shows the Necker cube, a 2D drawing that demonstrates the phenomenon of multistable perception, where an ambiguous figure can be interpreted in more than one way by the mind but not simultaneously. In my music, inharmonic sounds—such as those of bells, where the

4 'Static' meaning 'motionless', not meaning 'static electricity' or its sound.

partials do not conform to the harmonic series—can be considered as analogous to the Necker cube because the pitch of the sound as perceived by a listener can be changed if they refocus their listening from that pitch and settle on another of the bell's pitches: most inharmonic sounds have several stable pitch centres with varying degrees of relation to each other.

This ambiguity between chord and timbre can be composed in acoustic music to a certain extent but also relies on environmental variables such as acoustics and the resonant characteristics of the individual instruments so it cannot always be relied on for specific effect. But I do not aim to create music where ambiguity is explored as a phenomenon for its own sake in the manner of Alvin Lucier (this will be explained in more detail in 1.3.1: Experimentalism, p.46), I prefer to think of this ambiguity as being always present as an attribute of the musical language.

Horizontal indeterminacy creates ambiguity as to whether it is the music or the listener that is changing. The music hovers between repetition and variation. The technique of evolving sound objects in my music relies on this perceptual ambiguity. In *Nano* for example, the listener will rapidly lose the ability to hear the piece as a whole form unfolding and will only be able to make sense of formal implications from the most recent set of events: the greater the level of difference between events the more likely that the event can be linked to a previous similar event. But by corollary, the more subtle the differences, the greater the perceptual ambiguity and so the more the form becomes about moment to moment difference. Time is expanded as information is reduced: the more information (contrast between moments) that there is, then the easier it is to make long range temporal connections at the macro-formal level. *Intra-*, in its first section, makes use of a perceptual ambiguity in a similar way. By limiting the material to three archetypes and crossbreeding them, it becomes unclear whether elements are being altered or literally repeated. This generates formal ambiguity that allows a play of tension and release.

For ambiguity to play such a part in my formal thinking I need a framework for understanding the perception of sound. Apart from a general understanding of the properties of sound and the auditory system, I take great inspiration as a composer from the gestalt principles of grouping, especially with regards to the blending of sounds and timbral fusion—many individual sounds fusing to form a single timbre or percept—as this occurs in practically all of my works.

The gestalt principles of grouping were developed by psychologist Max Wertheimer in the early twentieth century. They are outlined here by psychoacoustician Roger Shepherd:

- *Proximity*: Things that are located close together are likely to be grouped together.
- *Similarity*: When objects are equally spaced, the ones that appear similar tend to be grouped as being related. If objects are similar in shape they are most probably related.
- *Symmetry*: Because random unrelated objects in the world are not expected to exhibit symmetry, it would be most improbable for unrelated objects to exhibit symmetric relationships.
- *Good Continuation*: If objects are colinear, or arranged in such a way that it appears likely that they continue each other, they tend to be grouped perceptually.
- *Common Fate*: Objects that move together are likely to be connected. This is the strongest principle in Gestalt theory.[5]

In my music these principles may be applied to different perceptual attributes from piece to piece, depending on how the elements need to be grouped. For example, the similarity principle is applied in *Five Bells for Elliott Carter* where different spectra within the same chord are played with different timbres (*sul ponticello* or *sul tasto*). The principle of common fate is used in the same context by applying the same dynamic swell to notes from the same spectra; in *illustration 2* below there are three different spectra within the chord and each has its own dynamic swell position.

5 Shepard, Roger, 'Cognitive Psychology and Music', *Music, Cognition and Computerised Sound: An Introduction to Psychoacoustics* ed. Cook, Perry R. (London, 1999), *32-33.*

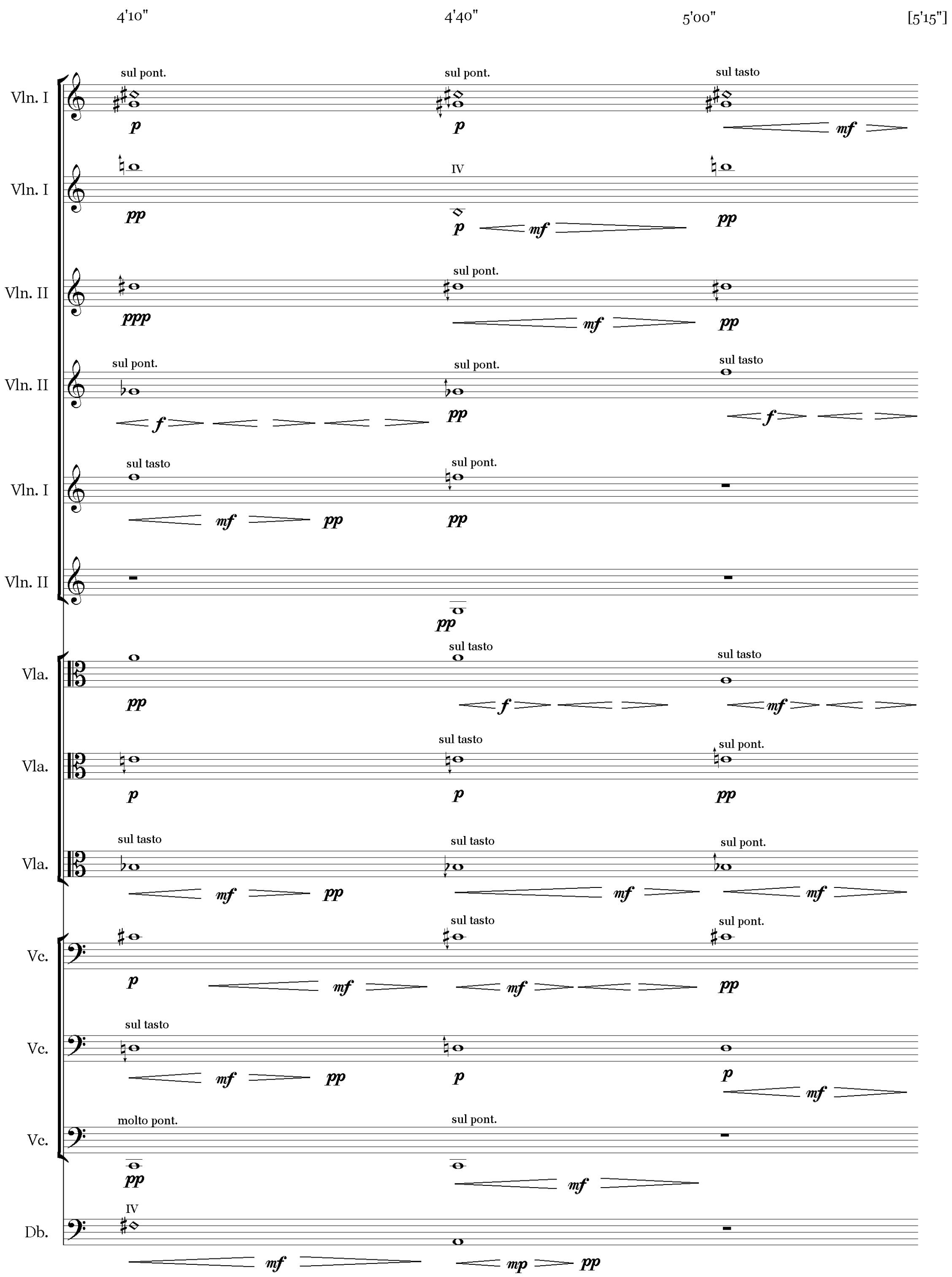


Illustration 2: Five Bells for Elliott Carter, gestalt principles.

1.2.2: Chaos and Strange Attractors

The basic principle of chaos theory is that certain dynamic systems exhibit 'sensitivity to initial conditions'; that imperceptibly small changes in the starting condition of a process may disproportionally affect its future states. My application of chaos theory to music is largely metaphorical, by applying the principles of chaotic dynamics to music rather than engaging in the literal sonification of a chaotic system: *Bifurcations* comes close to being a sonification but only in the very general sense that its structure is based on a bifurcation diagram.

The concept of strange attractors comes from dynamical systems theory; a branch of chaos theory which looks at the mechanisms of how complex systems evolve and change. This aspect of science focuses on process rather than state. The ideas are applied to fields as diverse as condensed matter physics, fluid mechanics, economics and sociology. Strange attractors are a particular class in the general field of attractors, defined by the American Heritage Science Dictionary as:

> A set of states of a dynamic physical system toward which that system tends to evolve, regardless of the starting conditions of the system.[6]

There are three main types of attractor: point attractors, periodic attractors and strange attractors. The simplest attractor is a point attractor, where the system tends towards a single state. An example of a point attractor would a marble rolling in a bowl as it will always end up in the centre of the bowl (at the bowl's flattest point). Periodic attractors settle into a state where any point tends towards one of multiple possible solutions, or it may oscillate forever between them. A strange attractor has an infinite amount of possible stable states which all occupy a finite space; meaning that a point may never settle into a predictable state or intersect its own path. The difference between periodic attractors and strange attractors can be summed up by comparing the solar orbits of planet. A periodic attractor relates to Newtonian physics, where the planets orbit the Sun like a complex clock and ultimately return to a predictable starting point, while the strange attractor is closer to the real orbit of the planets as the complexity of the competing gravities constantly perturbs their paths and ensures they are never in the same place twice.[7]

Music, under certain conditions, can be seen as a dynamic system, especially where there

6 No author, 'attractor', *The American Heritage® Science Dictionary,* Houghton Mifflin Company, (n.p., n.d.), <http://dictionary.reference.com/browse/attractor>, accessed 04/08/08
7 *Ibid.*

is a feedback system that allows the real-time state of the performance to affect its future states. For this to happen the music needs to have an element of freedom and a method of interaction between parts, it is this concept of the musical work as being a collection of dynamically interacting parts that I find interesting. In this way the music can be seen holistically as form that arises out of the interacting parts and is greater that their sum.

Strange attractors are a stimulating metaphor for the idea behind my use of indeterminacy for several reasons. They exhibit infinite variety within a fixed space, as will be demonstrated further on in this section by looking at the Koch curve. This is extended by analogy with music to the infinite possibilities for different pitches within an interval in frequency-based pitch space. Strange attractors move between levels of chaos, order and periodicity which is essential for music as a structure whose form and morphology is based on difference across time. This unpredictable mixture of pattern and spontaneous change imbues attractors with a lifelike aspect which is the basis of much of their fascination for me. These co-principles of evolution and constant change within bounded parameters are the basis for the unpredictable conjunctions arising from indeterminate durations in *Lorenz*, *Whitewater II*, and the pieces which use what I call 'bounded improvisation', *Primes* and *Whitewater*.

Lastly, strange attractors are often powered by feedback loops which contribute their non-linearity. From my point of view, most music can not be considered as a dynamic system, it is a programme which begins and ends when the instructions—usually, the score—end. However, the inclusion of a feedback loop whereby, in performance, some element of the music can effect another element leads to structures that evolve and change. In pieces such as *Whitewater* and *Primes*, feedback loops are used in conjunction with bounded improvisation in order to create pieces that are designed to self-organise from the bottom-up—meaning that I compose small components and the form emerges from their interactions rather than being imposed by a pre-composed (top-down) structure.

The Koch curve is a good example of feedback and of infinity within a boundary. The Koch curve is constructed by the repeated application of a simple transformation as follows: take an equilateral triangle, divide the sides into thirds, in the middle third attach a new triangle which is the same shape but a third the size: the feedback in this system is that each transformation acts upon the result of the previous transformation, thus the system exhibits hysteresis; dependence upon the history of its inputs. This first step in the transformation process transforms the triangle into a six-sided shaped, the Star of David. Repeating this process on the new triangles and then on their new triangles and so on, and the boundary of the shape very quickly becomes complex as shown in *illustration 3*. Also known as the 'Koch Snowflake', this is an early example of the fractal shapes which can be found throughout nature.[8]

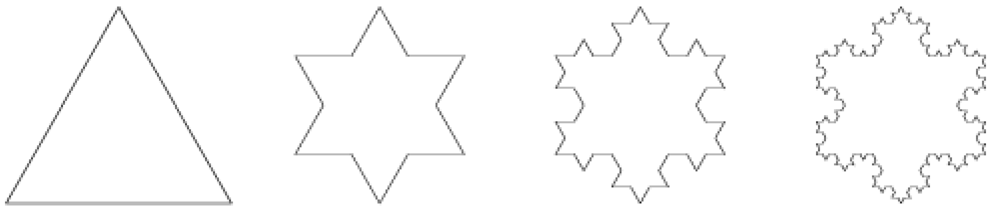


Illustration 3: Koch curve, first three iterations

The interesting part of this from a musical point of view—as will be shown below—is that the total area of the shape remains finite, because the infinities in the curve fold in upon themselves; this can be shown simply by drawing a circle around the shape as it changes, as shown in *illustration 4*. This idea of a bounded set having infinite possibilities is extended in to the idea of bounded improvisation: see 1.2.8.2: Bounded Improvisation (p.40).

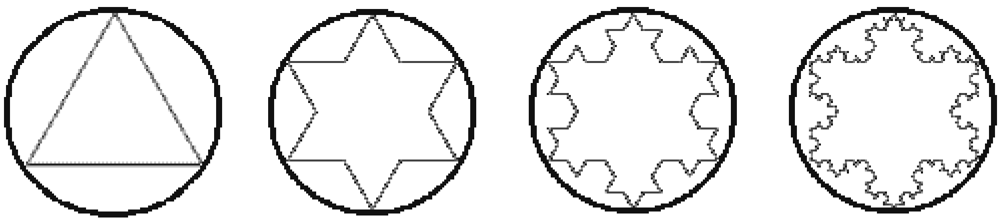


Illustration 4: Koch curve bounded

1.2.3: Sonification, and not Sonification

> Start all over again with listening and understand what happens without any knowledge of what you have read or heard before. Of course, if you come with some well-defined rules and you compare them with what you hear, you will be lost because the rules don't exist a priori. They should not be a priori, they should be born out of what you hear, otherwise you're repeating, you're making an imitation of something that you have as a memory.
>
> \- Iannis Xenakis, interviewed by Morton Feldman

[8] Gleick, *op cit.*, 99

Although ideas taken from science inform much of my music, these pieces are in no way an attempt to sonify these ideas, any more so than they are a narrative or mimetic representation of the ideas. The idea is interesting because of its structural properties and in how those structural properties could be applied in a musical context.

Michael Winter, a composer and student of James Tenney's, defines sonification as follows:

> The parametric profiles of the changing characteristics of sound can be expressed as mathematical functions of time. By using physical scenarios and mathematical functions to determine these parameters, one can distance oneself from aesthetic opinions and attempt to relinquish intuition. This provides another way to create a new music.[9]

Outside the domain of electroacoustic music, Iannis Xenakis is the composer most associated with the mapping of scientific and mathematical concepts onto musical parameters. His biographer Nouritza Matossian has this to say about Xenakis' sonification of such ideas:

> Xenakis never claimed that a rigorous mathematical basis is sufficient to produce a well-formed piece of music. Those who are partially informed about the mathematical theory expect the music to be a mirror of mathematical processes and equations. *Pithoprakta* is no more a translation of probability theory than an artichoke or a celery is a *translation* [Matossian's italics] of the Fibonacci series, or a flowing river is a translation of random functions. [...] Even though underlying structures are shared, particularity of musical resources ensures uniqueness in each one.[10]

Many composers have used fractals in composition and have focused on the aspect of self-similarity because it maps easily to the compositional atom of the cell or motif. Ligeti claimed influence from fractals in the *Piano Concerto* (1988)[11] some of his *Piano Etudes* from the 1980s, such as 'Vertige' from Book Two[12] and 'Autumn in Warsaw' from Book One,[13] in relation to the development of rhythm and pitch cells across the piece.[14] He takes primarily poetic interest in fractals by applying the 'idea' to his own compositional language. Ligeti's inspiration is a version of an ancient theme in Western Art, that of 'unity', a deeper order behind a surface seemingly chaotic.[15]

This feeling is echoed by the Danish composer Per Nørgård: 'Chaos is fascinating because you have an order behind chaos and chaos behind order. That fits very well with my feeling of life too'.[16] Nørgård devised what he termed an 'infinity series' based on fractals

9 Winter, Michael, *On Sonification* <http://www.mat.ucsb.edu/~mwinter/writings.html> (n.p, 2005), (accessed 04/01/07)
10 Matossian, Nouritza, *Xenakis* (London, 1990), 106.
11 Ligeti, Győrgy, *Concerto for Piano and Orchestra*, (Mainz, 1988).
12 Ligeti, Győrgy, *Piano Etudes: Book II*, (London, 1994).
13 Ligeti, Győrgy, *Piano Etudes*, (London, 1986).
14 Steinitz, Richard, 'Music, Maths & Chaos', *The Musical Times*, 137/1837 (Mar., 1996), 17.
15 Steinitz, Richard, 'The Dynamics of Disorder', *The Musical Times*, 137/1839 (May, 1996), 8.
16 Anderson, Martin, 'The Many Patterns of Per Nørgård', *Tempo*, New Series, No. 202 (Oct., 1997), 6.

for melodic variation, which he describes thus: 'it's always developing, it's never repeated. It's just one row working out on many levels.' By this of course he doesn't mean a serial row, although there's surely some inspiration, rather a row of numbers which is put through a fractal-based function to produce a constantly changing series.[17]

Norwegian composer Rolf Wallin takes a more literal-scientific approach by using the fractal's equations to create stochastic maps in pre-composition. In a 1989 lecture given at the Nordic Symposium for Computer Assisted Composition he outlined the contribution of fractals to *Onda di Ghiaccio*, the piece he was writing at the time and his first to use fractals. The piece progresses as a series of 'fields' which use two equations, one for macro-form and one for micro. The stochastic maps generated by the fractals control for each field parameters such as pitch center, pitch range, field duration, 'rhythmic influence' and others. The equations he used are for a 3D 'symmetrically coupled nonlinear system' in which three parameters mutually feed back into each other to create the structure shown in *illustration 5* below.[18] Wallin does not go into details about how this particular structure was applied to the piece, but it is visually clear that the alternating chaotic and ordered areas could have interesting musical applications

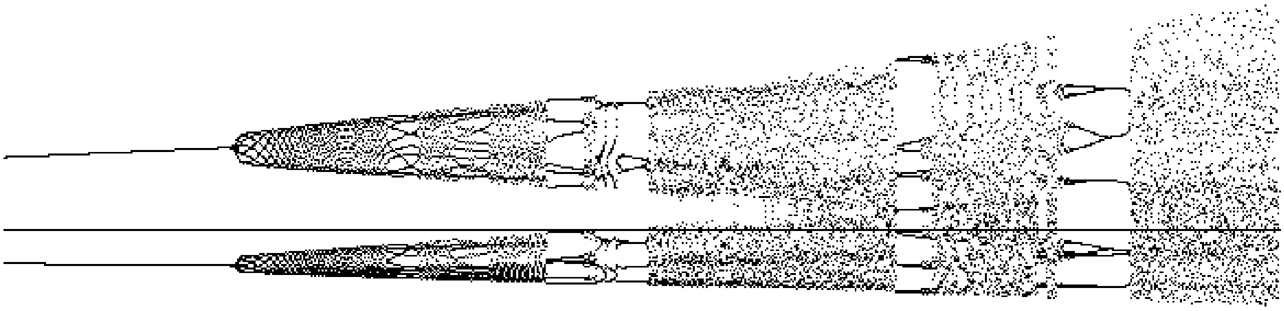


Illustration 5: Symmetrically coupled non-linear system used by Rolf Wallin.

Wallin follows on from Xenakis in using stochastic procedures to generate and proliferate material. Like Xenakis, Wallin is using the cutting edge of scientific ideas with which to create his music; where Xenakis had the IBM 7090 computer running stochastic calculation and basic cellular automata, Wallin has chaos theory and non-linear systems modelling. But like Xenakis, Wallin uses indeterminacy only as part of stochastic calculations and doesn't allow it into the live music. Xenakis considered improvisation—presumably only in scored music—and aleatoricism to be 'an abuse of language and an

17 *Ibid.*, 5.

18 Wallin, Rolf, 'Fractal Music: Red Herring or Promised Land', (n.p., 1989), <http://www.rolfwallin.org/Fractalarticle.html>, accessed 04/08/08

abrogation of the composer's function', although he had more respect for chance when it applied only to pre-formed musical sections as in Boulez' *3rd Piano Sonata*.[19] He was also more forgiving of chance procedures when they were part of an overall calculation such as the game strategies used in his own pieces *Duel*[20] (1959) and *Stratégie*[21] (1962). Equally, the stochastic and probability-based composition that was his major preoccupation contained many elements which were by definition random, but acceptable in his language because the randomness was itself 'controlled' by the composer.

In my music, the mix of order and disorder which so fascinates composers is extended to the live domain by introducing it into open works and text processes. I cannot argue that my approach is any more a 'real' application of chaos theory to music than such approaches as Ligeti and Wallin's, it is simply the approach which resonates most strongly for me. Further connections with sonification will be examined in the upcoming section on spectral modelling (1.2.7.4 - p.34).

I have taken great inspiration from the approach of Ligeti and Xenakis to chaos theory and their attempts to bridge C.P. Snow's Art-Science gap[22] (whether either composer knew explicitly about Snow I cannot say...). Chaos theory and music connect for these composers at the level where they perceive a connection between the mechanisms of their musical language—or their understanding of musical function—and the mechanisms of chaos theory. The connection for me is the same but within a musical language which owes more to the American experimental tradition than Western Art Music. My language is based on the processes involved in the scientific idea, and this informs a process that occurs in real-time, rather than a compositional process that can be manipulated until the desired sonic configurations appear. To explore fully the ideas present in chaos theory it is necessary to include feedback. To do this one needs to move past the fixed score and explore the possibilities of text processes which allow the music to evolve in real-time.

1.2.4: Feedback

Strange attractors are iterative functions which derive their strangeness in part from feedback. The 'sensitivity to initial conditions', that characterises chaotic systems, works because at each iteration of the function, the value from the previous iteration is fed back in. As seen previously in the Koch curve, feedback and recursion are fundamental properties of fractals such as the well known Mandelbrot set, as shown in *illustration 6*:

19 Xenakis, Iannis, interviewed by Mario Bois in *Iannis Xenakis: The Man and his Music*, (London, 1967),12
20 Xenakis, Iannis, *Duel*, (London, 1959).
21 Xenakis, Iannis, *Stratégie*, (London, 1962).
22 Steinitz, Richard, 'Music, Maths & Chaos', *The Musical Times*, vol. 137, No. 1837 (Mar., 1996), 14

with the recursive detail shown in *illustration 7*, the small red rectangle in the left image is shown greatly magnified in the right image.[23]

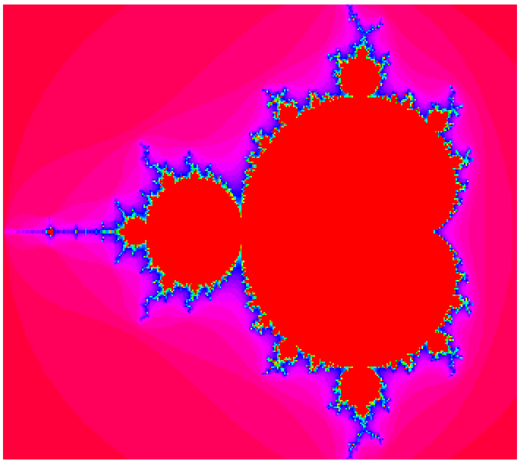


Illustration 6: The Mandelbrot Set in a colour representation

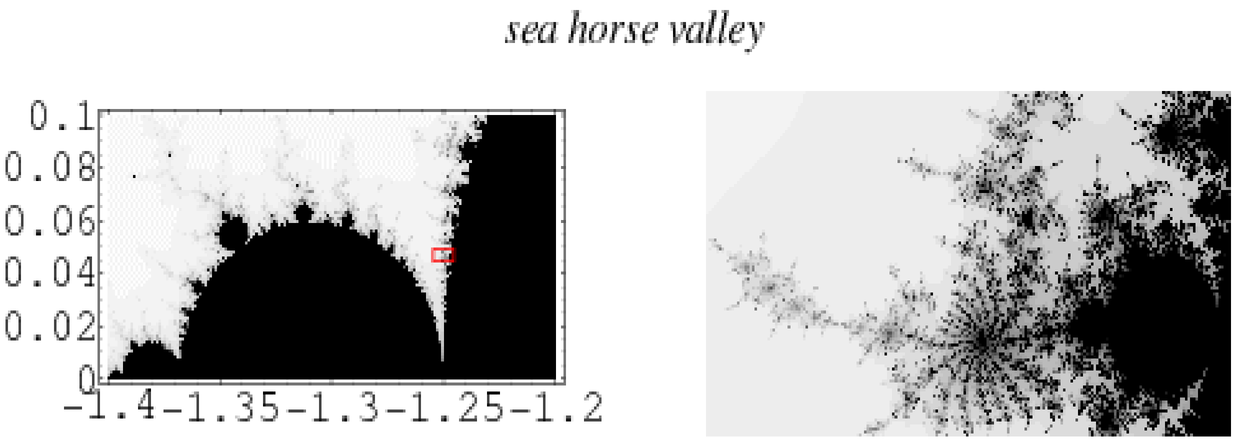


Illustration 7: Mandelbrot set detail known as 'Sea Horse Valley'; the image on the right is a magnification of the red rectangle in the left image.

The text processes in my music use feedback to varying degrees. Feedback is important in *Nano* as the piece is dependent on each event being different from previous events within the space of a limited set of parameters. Each event is an iteration of the text process. The player's memory of what values of the variables they have already played informs them on how to proceed. In *Nano* the feedback is not linearly carried from iterations of a transformation, instead, the memories of previous events build up and inform each other and each new iteration.

Whitewater and *Primes* are completely dependent on the feedback loop between player and computer to evolve both material and form. The computer and player are reacting to

[23] Weisstein, Eric W. 'Mandelbrot Set', *MathWorld--A Wolfram Web Resource.* <http://mathworld.wolfram.com/MandelbrotSet.html>, accessed 04/08/08

each other through the text process and contribute to the other's part. In a continuous dynamical system such as music, feedback also increases the overall complexity by effectively smearing interactions across time. The consequences of one action are usually still happening while a feedback induced reaction begins to happen. In my music the generous durations and slow timescale can lead to several overlapping cause and effect loops, each of which is feeding into the others.

The relevance of this to the music owes much again to the fact that music is a complex dynamical system. Indeterminacy is part of a feedback process which allows the music to evolve in response to its environment in terms of players and spatio-temporal elements. This music is not 'better' in any way than music which allows no indeterminacy, it is simply at another position on the plane of musical possibilities. As James Gleick says of chaotic processes:

> The Euclidean and Cartesian methods of turning equations into curves are familiar to anyone who has studied high school geometry or has found a point on a map using two coordinates. Standard geometry takes an equation and asks for a set of numbers that *satisfy* it. [...] But when a geometer iterates an equation instead of solving it the equation becomes a process instead of a solution, dynamic instead of static.[24]

Xenakis' biographer Noutitza Matossian quotes Ligeti as saying that it was 'worthwhile to try and achieve a compositional design of the *process* of change'. I see the use of feedback and indeterminacy as being similar to that, the compositions aim to model the process of change by making allowing each change to have a direct effect on the future state of the piece.

1.2.5: Evolution

> The world of things living, like the world of things inanimate, grows of itself, and pursues its ceaseless course of creative evolution.
> - D'Arcy Wentworth Thompson (author of *On Growth and Form*)[25]

For reasons both musical and otherwise conceptual, the term 'evolution' will be used throughout this document in reference to the transformation of material across time. Semantically speaking, 'variation' may be the more correct term, but the musical baggage that it has accumulated make it unsuitable. 'Variation' presupposes the existence of a

24 Gleick, James, *Chaos: Making a New Science*, (London, 1987), 226-227

25 Thompson, D'Arcy Wentworth, *On Growth and Form,* abridged version, abridged ed. John Tyler Bonner, (London, 1961) 3.

'theme', a notion which is tied to ideas of absolute and objective truth. This also involves rescuing 'evolution' from the anthropocentric notion of an evolutionary teleology: the idea that things can evolve 'towards' something. The pieces under discussion here have no goal to evolve towards, only the idea that difference is interesting for itself because difference highlights essence.

It is more interesting to consider the idea of evolution, in which there is no beginning or end, only change. Evolution can also mean different possible realisations of a single idea and this relates strongly to the form of my music, where a single idea is repeated and each successive instance of the idea is a different way to realise this idea. Different performances of a piece will of course be different due to the level of indeterminacy. But within each piece there is also a difference between each event because each event is generated from the same text, thus each is an instance of the idea. The score is the instructions on how to realise an event. The piece consists of successive events, successive instances of that idea.

In the biological meaning of evolution, organisms have two forms, genotype and phenotype. The genotype is the basic idea of the organism as encoded as a genome. This genetic information is actualised as the phenotype, which is a specific instance of the organism itself. To be more exact, the phenotype is the 'observable characteristics of an individual determined by its genetic make-up and the environment'.[26] In musical terms this is analogous to the text score being the piece's genotype, and each instance is a phenotype wherein the specific instructions in the score are subject to modification by environmental conditions—such as performers and performance space, and the history of previous instances. The indeterminacies in these works will create differences between instances in the same way that minute indeterminacies in cell division and environmental conditions will create different children from the same parents.[27]

This form of repeated instances of an idea is best demonstrated in *Nano*. The instructions in the score describe the steps necessary to form a single event: a descending scale in sub-semitonal intervals. The final instruction is to repeat the event an indeterminate number of times, with each instance being different.[28] Indeterminacy is generated from a clear and simple mechanism in *Nano* as each event is a different application of the basic formula for event construction. The piece exhibits modular characteristics in that the four variable parameters (starting pitch, tempo, number of notes in event, interval size

26 'Phenotype', *Compact Oxford English Dictionary*, Eds, Soames, Catherine and Hawker, Sara, 3rd ed. (Oxford, 2005), 763

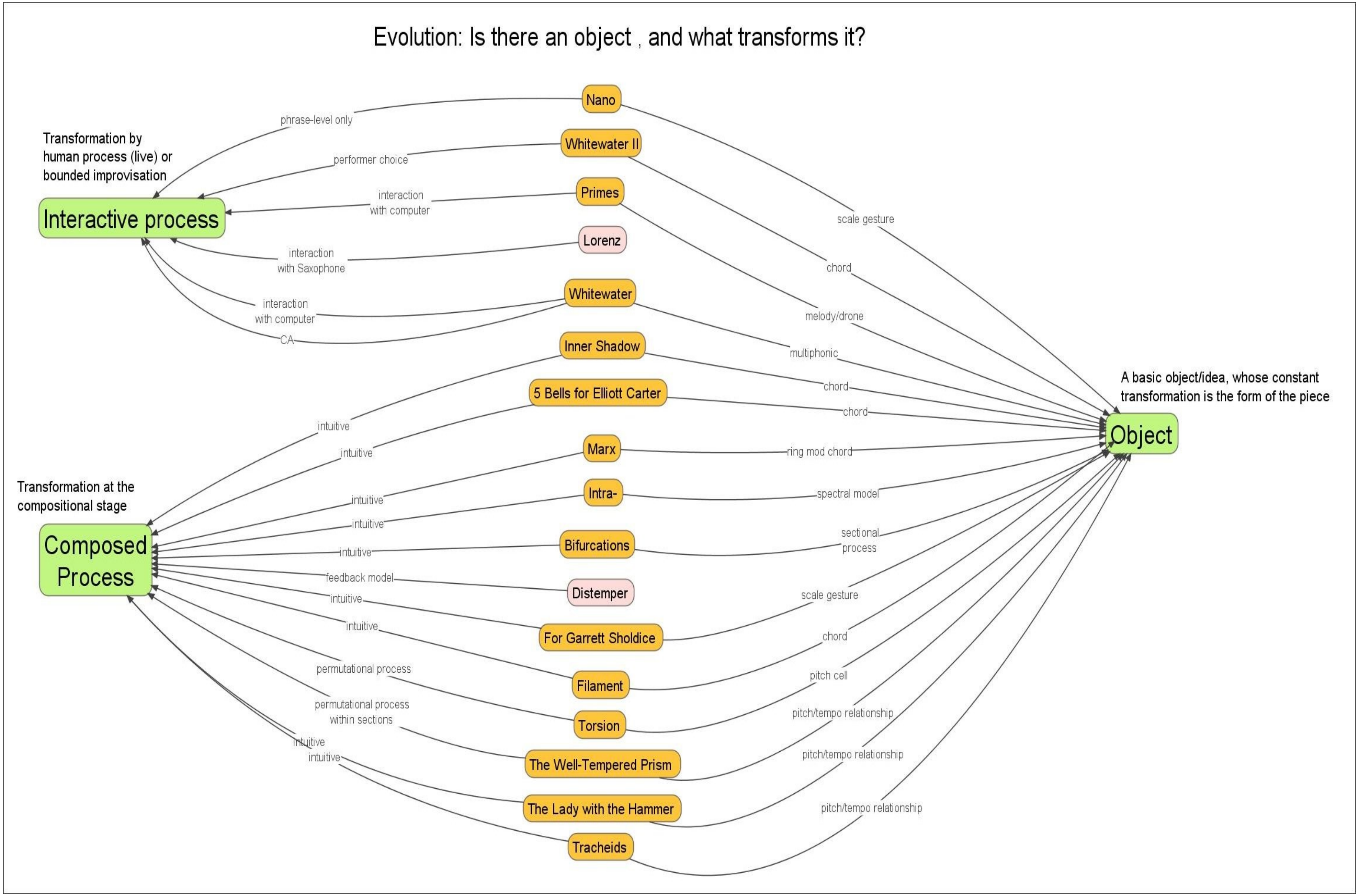
27 Obviously the mechanisms are vastly different, but I believe as a simplified model of environmental forces and indeterminate variables acting on a system, the analogy holds up.

28 The score defines a minimum of 23 times but there is no maximum set.

between notes[29]) are altered for each new instance: new numbers are plugged into the variables. *Whitewater* is another example of this form of repeated instances, but much more involved because of the two-agent feedback process. The instance being repeated here is two-part, the multiphonic played live and its altered re-iteration by the computer. The feedback process means that the two agents co-evolve the soundworld and the material accumulates between them, thus the instance is being smeared across time and blended with other instances.

It should be clear from this example that there is no theme to vary because the compositions are built on an idea which cannot be reduced to a single perfect realisation in sound. The piece is a series of instances, each being a possible rendering of the idea but none more perfect than the last. *Illustration 8* below is a summary of the musical objects in each piece and the method by which they are transformed. Note that *Lorenz* and *Distemper* do not have specific musical objects to transform, these two pieces do not have material in the same manner as the other pieces, they work on relationships instead: see their respective commentaries below (2.1.17 Lorenz and 2.1.6 Distemper) for more thorough discussions of their construction.

[29] Interval size between each note can be different. Not the same interval size for each note of the event.


Evolution: Is there an object , and what transforms it?
Transformation by human process (live) or bounded improvisation
Interactive process
Transformation at the compositional stage
Composed Process
A basic object/idea, whose constant transformation is the form of the piece
Object
Nano
Whitewater II
Primes
Lorenz
Whitewater
Inner Shadow
5 Bells for Elliott Carter
Marx
Intra-
Bifurcations
Distemper
For Garrett Sholdice
Filament
Torsion
The Well-Tempered Prism
The Lady with the Hammer
Tracheids
phrase-level only
performer choice
interaction with computer
interaction with Saxophone
interaction with computer
CA
intuitive
intuitive
intuitive
intuitive
intuitive
feedback model
intuitive
intuitive
permutational process
permutational process within sections
intuitive
intuitive
scale gesture
chord
melody/drone
multiphonic
chord
chord
ring mod chord
spectral model
sectional process
scale gesture
chord
pitch cell
pitch/tempo relationship
pitch/tempo relationship
pitch/tempo relationship

1.2.6: Indeterminacy

> Chance, understood as connections between independent worldlines, has the liberating power to release us from the limitations of our expectations. Given a headstart by subversive intentionality, chance has a chance to outrun intention and thereby open us to the world as it is, not merely as we think it will or should be.[30]

The above quotation comes from the chaos theorist Katherine Hayles, writing about John Cage. Such a quotation is apposite and pertinent to open a commentary aiming to bring together aspects of physics and music. While very few of my pieces directly use models from science, my whole aesthetic outlook is informed by that way of looking at the world.[31] Heisenberg's uncertainty principle and quantum theory closed the door on Newtonian physics by postulating that uncertainty was in the nature of the Universe.[32] The Uncertainty Principle states that:

> One cannot assign exact simultaneous values to the position and momentum of a physical system. Rather, these quantities can only be determined with some characteristic 'uncertainties' that cannot become arbitrarily small simultaneously.[33]

Allied to the rise of ambiguity in physical reality—as described by physicists—are post-modern and post-structural ideas of subjectivity and contextualisation. The notion that the World is made meaningful by interactions and connections rather than fixed identities is both musically and philosophically attractive. Seyla Benhabib, Professor of Government at Harvard University, explains the re-positioning of the subject thus:

> The subject is replaced by a system of structures, oppositions and differances[34] which, to be intelligible, need not be viewed as products of a living subjectivity at all. You and I are the mere 'sites' of such conflicting languages of power, and the self is merely another position in language.[35]

This statement can be translated into a musical context where the subject—as a sound event which can be considered complete in gestalt perceptual terms—is viewed as something in flux, with no fixed or basic identity, only those generated from the

30 Hayles, Katherine, 'Chance Operations: Cagean Paradox and Contemporary Science', in *John Cage: Composed in America*, eds. Perloff, Marjorie and Junkermann, Charles, (London, 1994), 231

31 As I am not skilled mathematically, nor trained to any great degree in scientific disciplines—I completed six months of a degree in Materials Science at the University of Limerick before dropping out in 1992. I must include as a disclaimer that much of the scientific thought drawn upon to produce this work are understood by me on a level sufficient for metaphorical use, but that is devoid of true mathematical understanding and is researched only in the popular literature on the subject: I relate to the concepts but not the technicalities. However, this does not in any way impede my use of these ideas in composition, a subject which is all about the free play of connections, metaphorical or other.

32 Although this interpretation of quantum theory is currently under attack from a growing body of theory supporting Bohmian mechanics. See Mark Buchanan's *New Scientist* article 'Quantum randomness may not be random' in the issue of 22/03/08.

33 Hilgevoord, Jan and Jos Uffink, "The Uncertainty Principle", *The Stanford Encyclopaedia of Philosophy (Fall 2006 Edition)*, Edward N. Zalta (ed.), <http://plato.stanford.edu/archives/fall2006/entries/qt-uncertainty/>, accessed 02/08/08

34 Not a mis-spelling, 'différance' is a term coined by Jacques Derrida with many subtle meanings, the most prominent being a deferral of meaning by referring to other words and concepts.

35 Benhabib, Seyla, cited in Butler, Christopher, *Postmodernism: A Very Short Introduction*, (Oxford, 2002), 51

differences with others and with its environment. This corresponds with a fundamental formal approach in my music in which a single musical event evolves through interaction with other agents. In *Primes* and *Whitewater* this agent is a computer programme (Max/MSP) that has a level of agency in creating locally unpredictable patterns while in *Lorenz* and *Whitewater II* the agents are other players and the rule systems that control them, and in *Nano* it is the player's memory.

Over the course of my PhD studies I have developed techniques involving varying levels and functions of indeterminacy. The following sections will look at vertical (1.2.7 Vertical Indeterminacies , p.28) and horizontal indeterminacies (1.2.8 Horizontal Indeterminacies, p.39), their techniques and applications in my music, as well as some discussion of the context of these techniques in relation to other composers' work.

1.2.7: Vertical Indeterminacies

> Works of Art do not reproduce the visible, rather they make visible.[36]
> - Paul Klee

This section will outline different ways in which vertical material is generated and organised, with focus on the compositional techniques used. 'Vertical' can be taken here to be concerned only with pitch generation and organisation. Issues of instrumental timbre and orchestration are largely ignored except where they have particular relevance, while issues relating to time, pitch prolongation and proliferation will be examined in 1.2.8 Horizontal Indeterminacies, p.39.

This section begins with an overview of the subject matter, presenting some of its aims and relating it to the ‘strange attractor’ metaphor. With regard to strict pitch generation, the context and details of the techniques of spectral modelling and frequency modulation are examined with particular reference to the works of the (then) IRCAM-based Spectral school, most notably Gérard Grisey and Tristan Murail: Grisey died in 1998, and Murail now lives and teaches in the USA. Then the more indeterminate approaches to pitch are discussed, such as detuning, notational imprecision and generation from text processes.

The techniques used here arose from a concern for beauty in sound and, to echo Paul Klee's dictum above, a fascination with the sounds that are not there—such as combination tones and acoustic phenomena. I can speak retrospectively about why I

[36] Klee, Paul, cited in Schneider, Peter, 'How Not to Teach Architectural History', *Journal of Architectural Education*, 34/1, (Autumn, 1980), 23

choose to compose this way, but must include the disclaimer that reasoning in this way is done after the fact: these reasons were not on my mind while composing, rather they have become clear to me through writing these commentaries. At the time, I was fascinated by the sound of the non-equal-tempered harmony in these pieces, the strange sense of ambiguity between note, chord, timbre and noise. I tried to compose with quartertones but could not understand how to create a harmony from them, so I searched for a system and found spectralism, the indeterminacy followed later. What I am trying to achieve in using vertical indeterminacy is the generation and proliferation of complex and dynamic evolving harmonic structures. Indeterminacy is used to create ambiguity between groups of single pitch percepts—such as a chord—and complex pitch percepts formed from fusing single pitches—such as the synthesised multiphonics in *Whitewater*. This ambiguity based on the duality between harmony and timbre drives evolution of the material and in the process generates form out of difference.

1.2.7.1: Inharmonic Sound and Strange Attractors

Many of the works in this portfolio use inharmonic sound as their basic material. By inharmonic sound, I mean that the material is either inharmonic in itself—such as multiphonics or prepared guitar—or it is an inharmonic complex created by combining harmonic sounds—such as the modelling of a multiphonic in *Whitewater II* using sustained saxophone notes where simultaneous harmonics fuse into a single pitch percept. Perceptual fusion is a concept central to most of my work; I use slow sustained soundworlds partly because of a predilection for the sound and partly because that is the speed at which sound most likely to fuse. My preference is for the sounds of bells and other metalophones. These sounds have complex spectra which do not resolve simply into one pitch percept but instead split into multiple simultaneous percepts.

As was discussed previously (1.2.2 Chaos and Strange Attractors, p.16), the strange attractor metaphor connects with inharmonic pitch structures by relating the infinite amount of points in a fractal space to the infinite amount of possible pitches in a bounded frequency-based pitch continuum. For example, the indeterminate text process in *Whitewater II* instructs the players to choose at random from a pitch set which defines a vertical sonority (the pitch bank for the sonority is derived from analysis of a saxophone multiphonic). If this text process were repeated over and over, the accumulation of different pitches would sketch the original multiphonic from which the vertical was derived; the clusters around nodal pitch areas becoming ever denser as the repeats continue. This is analogous to the shape of a strange attractor becoming clearer as the iterations of points accumulate on a graph.

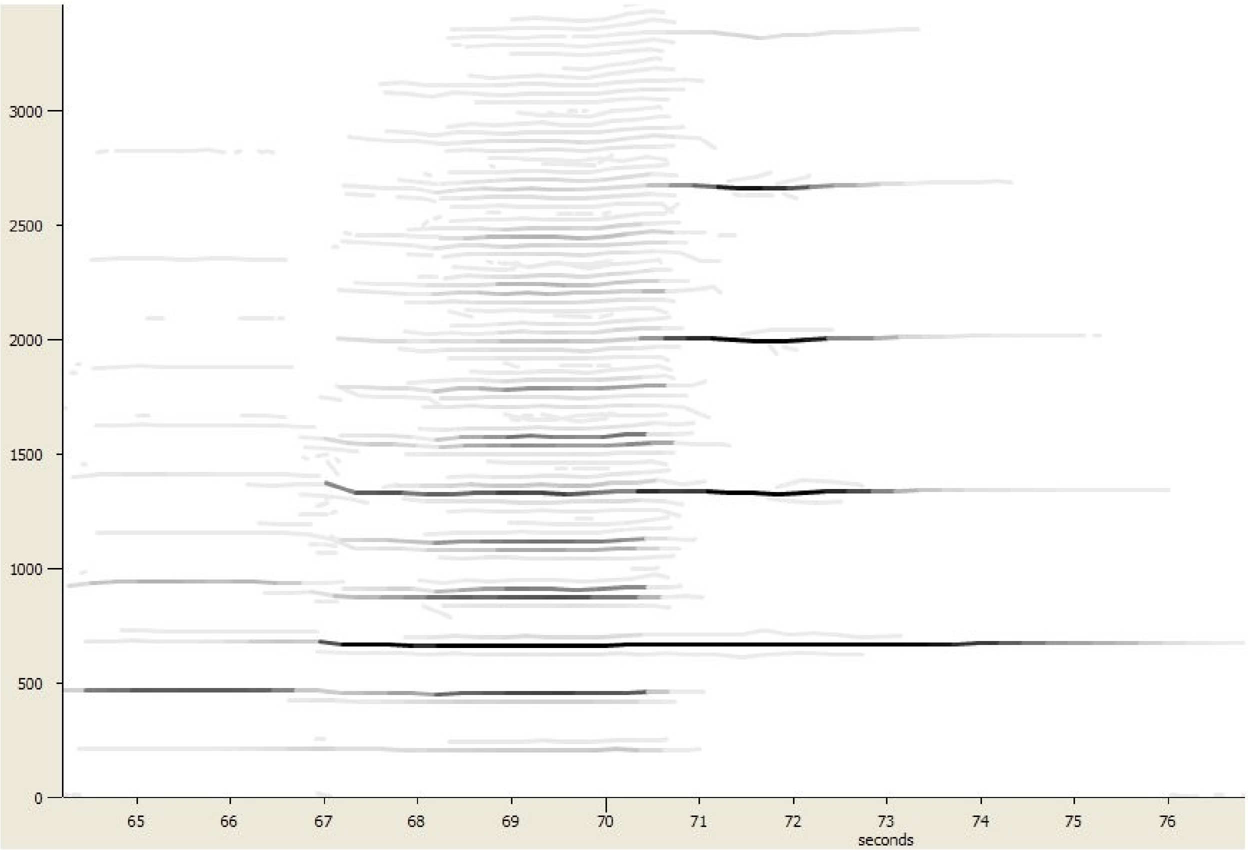


Illustration 9: single pitch → multiphonic → single pitch (from *Whitewater*)

Illustration 9 shows a spectral analysis of a saxophone line where a single pitch becomes a multiphonic and then collapses into a different single pitch. The opening pitch is B♭4 +14¢ showing 1st and 2nd partials,[37] while the closing pitch is the 1st to 4th partials of E5 +12¢. Because this event is performed as a single gesture across one fingering, the single pitches are slightly thin and lack some of their higher partials. However, the analysis clearly shows the difference between the wide and evenly-spaced partials of the harmonic single pitches and the dense spectral complexity of the multiphonic. This complexity results from the perceptual fusion of the strong partials, and the creation of many combination tones due to the intermodulation of the strong pitches.[38] The resultant clusters of pitches which form around the strong partials are clear in this image.

All of my techniques for pitch generation result in microtonal clustering—including octave

37 Or possibly the 2nd and 4th partials of a lower fundamental. The analysis is unclear here because while there is a lower fundamental—and what appears to be a 3rd partial between the two strong partials—this fundamental is not linearly related to the pitches above it. The fundamental is 213hz, compared to the strong pitches which are 470hz and 942hz respectively. However, in my experience, the lowest partials in inharmonic sounds have a tendency to be flat so this may not be abnormal.

38 Scavone, Gary Paul, 'An Acoustic Analysis of Single-Reed Woodwind Instruments with an Emphasis on Design and Performance Issues and Digital Waveguide Modelling Techniques', (PhD Dissertation, Stanford University, 1997), 90-9.

displaced clusters—as substructures of larger pitch structures; this can be seen in *illustration 9* where many two-note clusters propagate up through the registers. *Whitewater,* for example, takes such multiphonics and mixes them with intonationally different clones bred by a computer patch to create even more dense structures, while *Lorenz* uses a text process to make string instrument clusters aggregate around a multiphonic, again making a constantly shifting set of clusters. These clusters are on the boundary between being perceived as either a single complex timbre percept or sets of individual pitch percepts, and this ambiguity drives the vertical indeterminacy. This multistable perception can be applied in a musical context where there is ambiguity between aural interpretation of a sound event as single or multiple percepts. Vertical indeterminacy is often used to vary a vertical pitch group between timbral and chordal states. To extend the metaphor, many of my works can be visualised as a series of Necker Cubes endlessly evolving and inter-penetrating.

When the basic material is inharmonic, there is no clear boundary between 'in-tune' and 'out of tune'. While most of my work uses standard western classical instruments with harmonic spectra, they are usually combined in ways which create an inharmonic whole. Again, the exceptional piece here is *Primes*, which reverses the paradigm by using only harmonic partials, but in a complex way; the computer plays mathematically perfect pitches but the live player can never play as perfectly as that so there is always friction in the form of beats between the acoustic instrument and the computer: see 2.1.3 *Primes*, p.69.

Pitch generation techniques will be examined in the context of when and how they are used to generate indeterminacy. The generative processes are sometimes applied strictly, such as in *Marx* where the pitches generated through ring modulating the voice and viola parts are fixed in the score as the synthesiser part. In other pieces, the generative processes have a strict compositional method but are loosely applied; for example, the spectral modelling in *Whitewater II* is strictly generated but is subject to an indeterminate text process which means that in performance only some of the generated pitches will be used. At the extremes of indeterminacy, some pieces have almost no pitch generation outside the performance context. Game pieces and text scores such as *Nano* rely only on rules of interaction to describe what pitches may be played. In these pieces, the act of composition in the vertical realm is a matter of defining these interactions, and by corollary, the boundaries of the piece.

In my pieces with strict pitch generation there are two main archetypal processes: spectral modelling and frequency modulation. Both tend to generate pitch structures rich in inharmonic pitches and clustering, and both of these techniques are derived from studying the works of the European Spectralists; Grisey and Murail's own writings, and writings about them, give considerable insight into the specifics of their techniques for pitch generation and proliferation.

My interest in the idea of frequency-based harmony originates with Tristan Murail, who used the term 'frequencial harmony' to describe pitch organisations that he says are 'conceived outside the domain of equal temperament [...] and form an unlimited harmonic realm, which happens to be contiguous with timbral space'.[39] He is referring specifically here to a kind of spectral modelling by creating harmonies which are, as he says; '[...] completely invented, through analogies to the spectra found in nature'.[40] This method of thinking about harmony in terms of frequency is present in all of the pieces in this portfolio. A method for dealing with the continuum nature of frequency is an important step towards working intelligently with inharmonic sounds such as the woodwind multiphonics used in *Whitewater*, *Whitewater II* and *Lorenz*, or the metalophone sounds used in *Intra-* and *Five Bells for Elliott Carter.*

The analogy that I am teasing out draws on the idea of the strange attractor as a model for inharmonic sounds because they are often not reducible to a single stable spectrum. The strange attractor is a shape made of fuzzy lines, a shape of indeterminate edges whose indeterminacy sometimes only becomes clear as time goes on. The inharmonic sounds which I compose with such as multiphonics and metalophones are similarly fuzzy in pitch terms because they do not follow the ideal, mathematically perfect acoustic spectrum. It is fair to say that like real planetary orbits, real instruments never have mathematically perfect spectra; physical realities in the form of variable string masses and imperfect conical bores intrude on the maths. But as far as our ears are concerned these slight imperfections generally go unnoticed. However, in the case of inharmonic sounds, the spectra are grossly misformed— relative to that of pitched instruments—and the ear can interpret a single sound as anything from a timbral complex to several distinct pitches.

The spectra of inharmonic sounds are complex because the partials do not line up mathematically and so are not resolvable by the ear into a single pitch. For me as a composer, this lack of alignment allows room for an indeterminacy of pitch that only subtly alters the sound and may allow for imperceptible morphology based on sound event identity. I experimented during the composing of *Whitewater* by making a spectral model of a multiphonic using the strongest sixteen partials and found that the sound's identity did not change significantly if a few individual partials were moved by up to a semitone.[41]

[39] Murail, Tristan, 'After-Thoughts', *Contemporary Music Review*, 19/3 (2000), 8
[40] Murail, *op cit.,* 8
[41] For this to work there had to be no pattern to the displacement of partials; it had to be random amounts in different

Of course this is a subjective claim based on my own perceptions, but it allowed me to proceed with composition based on fuzzy pitches.

1.2.7.2: Frequency Modulation

The technique referred to here as frequency modulation is a simplified version of the mathematics behind frequency modulation. In simplifying the process, calculation of amplitudes was ignored entirely; although still represented intuitively by lowering the dynamic weighting of sideband pitches as they become further from the fundamental frequencies of the carrier and the modulator.

The basic process is to derive pitch sets of any size from two input frequencies *f1* and *f2*, achieved by calculating summation tones and difference tones between two pitches, according the following formulas:

$$\text{sum tones } \{x = f1 + f2, 2f1 + f2, 2f1 + 2f2, 3f1 + 2f2 ... nf1 + nf2\}$$
$$\text{difference tones } \{x = f1 - f2, 2f1 - f2, 2f1 - 2f2, 3f1 - 2f2 ... nf1 - nf2\}$$

Examples of other works using these formulas are numerous, Tristan Murail's *Gondwana*[42] (1980) and Gerard Grisey's *Modulations*[43] (1978) are both analysed briefly by Julian Anderson in his Grove article on Spectral Music; in which he gives a basic demonstration of their application of this formula.[44] The mathematics first caught my attention at a time when I was searching for a formalised method for composition with microtones, but after some research into Spectral Music I found that it was not the technique but rather the sounds and the ideas in Spectral Music which fascinated me. Learning about the frequency modulation techniques in particular introduced me to psychoacoustics and sound perception which led to a fascination with sounds that are technically present but masked by other sounds. I see the frequency modulation technique as a way of bringing these sounds into the foreground.

Frequency modulation as a technique in my work has not been applied strictly in recent works, but the concept of modulation and the generation of material by the interaction of pitch at the atomic level is present in most of my techniques. Multiphonics and inharmonic sound in general contain elements of modulation between their multiple pitches. The products of this are then applied through spectral modelling.

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directions. Moving a significant amount of partials by the same amount in the same direction simply amounts to 'dirty' transposition and is perceived as such.

42 Murail, Tristan, *Gondwana,* (Paris, 1980).

43 Grisey, Gérard, *Modulations*, (Paris, 1978).

44 Anderson, Julian, 'Spectral Music', *Grove Music Online,* ed. Laura Macy (Accessed 07 August 2008).

1.2.7.3: Spectral modelling

Compared with FM, spectral modelling is in some ways the simpler and more freely applied technique of those I have used. Sound material is identified and its spectrum analysed, then the subsequent data is intuitively filtered and reduced to those pitches which present the most interesting harmonies (subject to the composer's taste) and those which provide a close match to the original material. All of my uses of spectral modelling have tended towards the same purposes, to create beat-rich and complex pitch structures by allowing a measure of indeterminacy to blur the spectral model. This is never intended to be a literal representation of the original material, analysis allows the material to be abstracted and freely manipulated; this approach is shared by the Spectralists.

A brief example from the Spectral canon will serve to demonstrate this. In Grisey's *Partiels* (1975), the spectrum of a trombone's low E (82.41hz) is orchestrated across eighteen players.[45] This chord is repeated slowly, to allow for simulated decaying of partials, and with each subsequent repetition the pure spectrum is altered by introducing non-harmonic pitches until after several minutes an inharmonic spectrum is reached and the piece moves on to another process. A much later example of spectral music is Murail's *Le Partage des Eaux*[46] (1996) for large orchestra. Murail takes advantage of the greater analytical power of modern computers—he has worked with IRCAM since the early 1980s —to compose with spectral models of water breaking on rocks.[47]

The first piece in which I successfully applied this technique was *M.Grisey, his Galliard*[48] (2005), for 11 strings (6,2,2,1). In this piece, recordings of bells and other metalophones were analysed and chords derived from the resultant data, the piece's main structural argument involved slow metamorphoses between chords. The group of strings was sufficiently large to make the harmonies fuse into complex timbres during the more intense chordal sections.

All of my uses of spectral modelling have tended towards the same purposes, to create beat-rich and complex pitch structures by allowing a measure of indeterminacy to blur the spectral model. Other examples of composers using spectral modelling in acoustic music include James Tenney and Clarence Barlow. Tenney's *Three Indigenous Songs* (1979)[49] and Barlow's *Im Januar am Nil* (1984)[50] both use instrumental resynthesis to render speech as instrumental pieces by orchestrating the frequencies of the speech phonemes'

45 Grisey, Gérard, *Partiels*, (Paris, 1975).
46 Murail, Tristan, *Le Partage des Eaux,* (Paris, 1996).
47 Murail, Tristan, interviewed by Joshua Cody at Cody, Joshua, 'The Ensemble Sospeso - Tristan Murail', <http://www.sospeso.com/contents/articles/murail_p4.html>, (no date), accessed 07/08/08
48 See appendix A for score.
49 Wannamaker, Robert A., 'The spectral music of James Tenney', Contemporary Music Review, 27/1, (February 2008), 107.
50 Barlow, Clarence, *Im Januar am nil*, (Cologne, 1984).

partials. Barlow focuses on vowel sounds and their formants[51] while Tenney also includes noise elements from the percussion to approximate phoneme transients such as plosives and fricatives.[52]

G. Douglas Barrett, a young American composer and former student of Tenney's, continues this line with more advanced technology by using automatic notation generators to create 'experimental transcriptions of recorded material—field recordings made on Hollywood street corners, video documentation of performance, recordings of other pieces of music…'.[53] Barrett's *Surfaces I-IV*[54] (2007) is the transcription of a four tibetan bowls into a glass-like sequence of overlapping microtonal lines for string quartet; *illustration 10* is a section from the score.
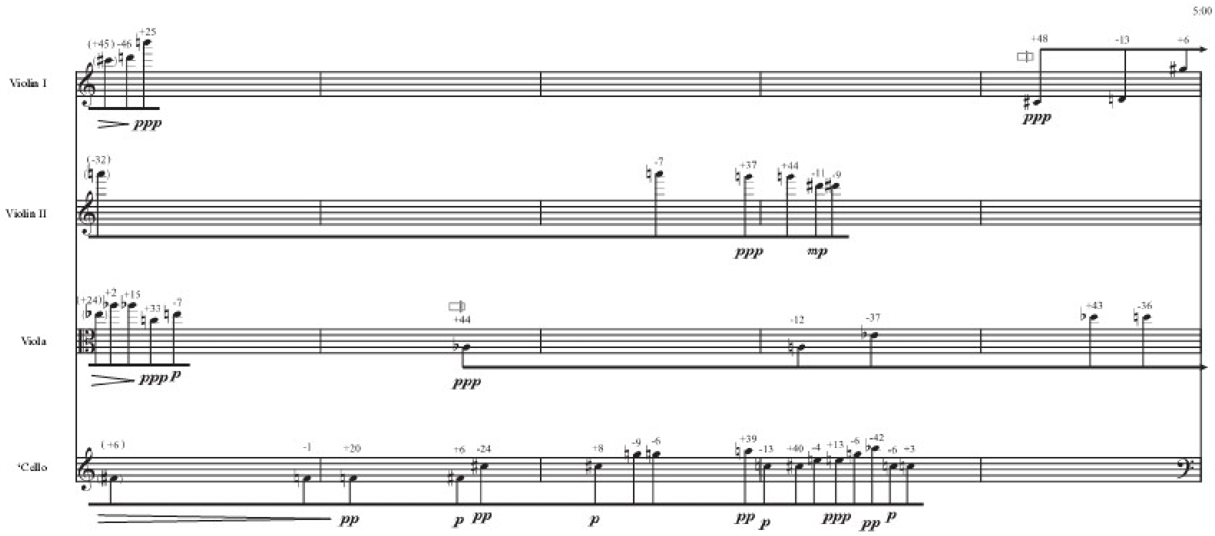
Illustration 10: Surfaces I-IV by G. Douglas Barrett (extract).

These pieces all share an experimental attitude in that they seem fascinated with seeking greater exactitude in finding compositional analogues to various phenomena —such as Tenney using different percussion for the plosive and fricative phonemes— while acknowledging that this work is not an attempt at literal representation of the object being modelled. At the same time, the fascination seems to require pitch accuracy as a function of the analysis rather than compositional necessity. Spectral analysis is a powerful tool which can analyse pitch to a resolution far beyond the capabilities of human perception.

51 Ox, Jack, 'Im Januar am Nil stillshots and animations', <http://www.jackox.net/pages/introImJan.html>, (No date), accessed 07/08/08.
52 Wannamaker, *op cit.*, 109.
53 Barrett, G. Douglas, 'Bio', <http://synthia.caset.buffalo.edu/~gbarrett/bio.html>, accessed 06/08/08.
54 Barrett, G. Douglas, *Surfaces I-IV*, self published (Buffalo, 2007).

Of the pieces in my portfolio, *Intra-*, *Whitewater*, *Whitewater II* and *Five Bells for Elliott Carter* all use spectral modelling as their basic pitch generation technique. *Intra-* and *Whitewater II* generate pitches pre-compositionally, which are written into the score, while in *Whitewater* the modelling is done in real-time performance by the computer. *Five Bells for Elliott Carter* takes the most intuitive approach, repeatedly altering the intonation and dynamics within a single chord to make it more like the structure of a bell spectrum.

1.2.7.4: Detuning and Notational Imprecision

I made a slow transition from notational accuracy to indeterminacy. Early works in this portfolio such as *Tracheids* and *The Lady with the Hammer* use accidentals that are annotated in the score with specific cent deviations from equal temperament. I was trying to bring out specific difference tones or create timbral fusion by calculating the exact frequencies that these pitches would have, but I was slowly realising that it was the beating sounds and the ambiguous harmonies that I was really searching for. It took several years of spectral experiments for me to understand that rather than specifying difficult intonations which a performer must play with precision, I could simply ask them to detune their instrument relative to others in the ensemble before playing. This would mean that everything would be 'out of tune' and it would be easier to achieve beats and complex clusters. In these cases it was also more practical to have them use a special fingering to reach the occasional 'in tune' note, than to be tuned normally and have many special fingerings for the 'out of tune' notes. When players would ask how sharp or flat I wanted a particular note to be I never had an exact answer. It took time for me to trust the instinct which said that the note simply had to be 'out', and to realise that precision tuning was not the issue. This technique is used in *Bifurcations* and *Whitewater II* specifically.

Notational imprecision is similar to detuning in that the indeterminacy is introduced against the grain of the player's perceptual training and intuition, demanding that they act independently while still working together as a group. The notation in *Whitewater II*, *Inner Shadow*, *Bifurcations* and *Five Bells for Elliott Carter* uses accidentals which are deliberately undefined and explicitly requests that players do not attempt to tune to each other or even to be 'in tune' (as shown in the previous section on detuning), players are expected to play what they see regardless of what is happening around them: there are some subtleties to this which will be examined later.

This may make players speculate as to how far they should trust the fidelity of the notation (or the piece...) if this most basic performative assumption is removed, but removing this basic tradition does not necessarily topple the edifice of harmony entirely, the players are simply being asked to play with intonation which is defined as a field rather than a point.

To illustrate this, an example from Alvin Lucier is required. In a reply to a question about using intonation systems he says that the critical band is too wide for him, because most of his music is concerned only with the phenomena which occur within intervals smaller than 16hz.[55] He goes on to say:

> I don't want my players to be anxious about tuning; they have enough problems in evenly glissading a semitone over such long time spans.[56]

Lucier doesn't mean that accuracy is not important, simply that whatever happens with the field boundaries is acceptable. In this case the boundaries are defined relatively by micro-pitch; as long as the players are within that boundary then the piece will be correct because anything within that proximity will generate the beats which he wishes to make explicit. Further to this, he emphasises the point about imprecision here:

> I wrote a little orchestra piece a few years ago in which the string players sweep slowly up and down. They would often lag behind and speed up quickly to get to the pitch they were aiming for. I should have told them that they could just as well have missed the pitch as long as the sweep was even, but I didn't think of it in time.[57]

Again, what Lucier and I (and others) are looking for is not the strict point-intonation required by hundreds of years of pitch-centric western musical tradition, rather a field condition of being in the right area for interesting things to happen. Often in chaos theory, one finds that the most interesting things happen within a few narrow bands of possibility on the edge of plateaus of non-information—that which is too complex to find meaningful patterns, or that of such utter regularity to be meaningless. Mathematician David Ruelle describes below the response to his early papers on—the then unknown—fractals and their ability to fold an infinite line within a finite space:

> The reaction by the scientific public to our proposal was quite cold, In particular, the notion that continuous spectrum would be associated with a few degrees of freedom was viewed as heretical by many physicists.[58]

While I am not suggesting that musicians find this field harmony concept to be heretical, it does require a different way of thinking.

55 Alvin Lucier (transcribed by Anne Guthrie.), *Ostrava Days 2005 Report*, (Ostrava, 2006), 117.
56 *Ibid.*
57 *Ibid.*
58 David Ruelle, cited in Gleick, James, *Chaos: Making a New Science*, (London, 1997) 139.

The notational imprecision in my works uses the set of accidentals indicated in *illustration 11*, which includes standard accidentals as well as those with arrows to indicate direction of deviation. Pitches in twelve-tone equal temperament and the fairly standard quartertone symbols will have standard intonations—a solid body of pedagogical work exists[59] to provide fingerings and techniques for quartertones on most instruments—but the accidentals inbetween have no fixed interpretation other than in specific performing traditions. In most music these ambiguous accidentals would simply be a tuning question to be 'fixed' before the performance as an issue that is open to the players' interpretation and therefore requires consensus before the group can move on: even the most knowledgeable performer of microtonal music would make sure they understood which system the composer intended by this notation. In my music there is no Rosetta stone for intonation. The performers are expected and encouraged to interpret the accidentals independently and accept the group harmony which arises from this: in some scores, performers are advised simply to aim for beats with their pitch neighbours.
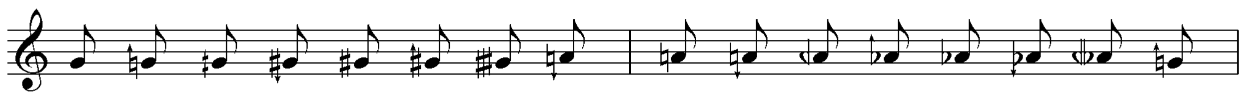
Illustration 11: Notation of microtonal accidentals

1.2.7.5: Vertical Text Processes

Text processes in *Whitewater*, *Primes*, *Nano*, and *Lorenz* have a direct relationship with the pitch organisation and the horizontal indeterminacy to the point where in several of these pieces the two are intertwined: the pitch generation is not an object that the indeterminacy simply acts upon, pitch is generated by the indeterminate process. The intertwining extends also to mixing the vertical and the horizontal aspects of the music, where pieces have no pitch organisation other than organising how to get from one pitch set to the next.

Nano is the most involved example of this in the portfolio. As it is a piece for solo instrument, technically there is no vertical harmony; the text process defines a falling scale whose constituent intervals must all be smaller than a semitone, this process is then repeated indefinitely. It is included here because the pitches generated fall into the same

59 Such as Bartolozzi, Bruno, Brindle, Reginald Smith, *New Sounds for Woodwind*, 2nd edn. (London, 1982), and Rehfeldt, Phillip, *New Directions for Clarinet*, (London, 1977).

categories as the other pieces in the portfolio. The process in *Nano* generates what is in effect a microtonal cluster in arpeggiated-chord form. It could be interesting to write a second version piece in which the clarinet was offstage and a computer patch played the descending scales as clusters of sine wave chords—an inversion of the process, but in essence it is the same piece even with the radical change of soundworld.

In this hypothetical chordal version the vertical indeterminacy would be clearer as the piece would be a series of cluster chords all of the same family; the familial relationship comes from the generative rules in the text process. This leads to a kind of topology of harmony where all the objects generated by the process are stretched, twisted and displaced versions of a generic object which is an ideal solution to the process. Mathematician Eric Weisstein defines topology as:

> [...] the mathematical study of the properties that are preserved through deformations, twistings, and stretchings of objects. Tearing, however, is not allowed. A circle is topologically equivalent to an ellipse (into which it can be deformed by stretching) and a sphere is equivalent to an ellipsoid.[60]

This topological relationship between the process and the pitch structures which it produces can be seen in all of the pieces using text processes. For example, the harmony of *Whitewater* and *Primes* depend on the feedback that is built into their processes, thus the harmony of each new event is a consequence of a previous event; hysteresis in these pieces combines with the restrictions of the process to produce events which are always different but of the same form.

1.2.8: Horizontal Indeterminacies

This section is concerned with time in my compositions, its processes and various levels of indeterminacy. Horizontal indeterminacy involves processes which determine the motion or displacement of vertical material in time. Three main areas of horizontal decision making will be examined: notational imprecision, bounded improvisation and text processes.

Firstly, a brief note on terminology. In his seminal work on time and gestalt theory in music, *Meta + Hodos*, James Tenney devised an analytical method based around what he later termed 'temporal gestalt units' which split a work into different functional and

[60] Weisstein, Eric W. 'Topology', *MathWorld--A Wolfram Web Resource.* <http://mathworld.wolfram.com/Topology.html>, accessed 07/08/08.

Topology can also be summarised by the following joke: a topologist is a person who can't tell the difference between a doughnut and a coffee mug.

perceptual levels.[61] While a full application of his method to my music would not be appropriate here, I will apply his principles to the forthcoming discussion by defining four levels of function in my music:

- Note-level: single sounds: notes, chords, complexes.
- Phrase-level: sequences of sounds which are complete in themselves: events. The terms 'phrase', 'event' and 'object' are used more or less interchangeably throughout this thesis to mean phrase-level units.
- Section-level: only applicable in pieces with well defined macro-formal sections such as *Bifurcations* and *Intra-.*
- Macro-form: the whole piece.

1.2.8.1: Notational Imprecision

This is the simplest form of horizontal indeterminacy, removing rhythmic information from the notation; where there are no strict timings, metric grid or rhythmic notation, temporal aspects of the music are made indeterminate. This notation cedes control of the precise rhythmic placement at note-level to the performer, but still specifies the majority of the event's characteristics.

Notational imprecision in the time domain is a common device used in much experimental music—and a lot of music which is not so experimental—where it is usually called time-space notation; examples include Lutosławski 's *ad libitum* pieces such as *Jeux Vénitiens*[62], Berio's *Sequenza no.1*[63] and Cage's *Atlas Eclipticalis*[64]. I have only avoided that term here so that the connection with the notational imprecision in the vertical domain which was examined in the previous chapter is more clear.

1.2.8.2: Bounded Improvisation

Bounded Improvisation is a term which refers to an extended form of free notation operating at the phrase level and involving improvisation within strict boundaries. It occupies a grey area between improvisation and free notation: essentially it is an extended text notation but sufficiently free that it requires a performer familiar with improvisation to play it with confidence. Bounded improvisation is emphatically not free improvisation, because the performers may only play freely within specific boundaries; the act of composition in these pieces is mainly concerned with defining these boundaries.

[61] Tenney, James, *Meta + Hodos and META Meta + Hodos*, 2nd ed. (no place, 1988), 101
[62] Lutosławski, Witold, Jeux Vénitiens (Paris, 1962).
[63] Berio, Luciano, *Sequenza no.1* (Milan, 1958).
[64] Cage, John, *Atlas Eclipticalis,* (New York, 1963).

Bounded improvisation means that the performer is only given descriptive boundaries of what and how to play, along with an example score. This could be seen as improvisation in the same way as a violinist may improvise a cadenza in a Mozart concerto by adhering to the classical performance tradition: its rules of style, material, gesture etc. Stockhausen's approach to total serialism applied serial processes to parameters of music that Jonathan Harvey describes as 'things normally left to good taste and fine feelings' and left them, as Harvey says 'no longer emotionally determined, but formally determined',[65] bounded improvisation takes the same parameters and allows the performer to sculpt them but under the direction of my score. In my works I am creating a performance tradition for each piece. The performer is free to improvise within the 'tradition' that I set out in the score. Other works using this kind of improvisation include Christopher Fox's series of *Generic Compositions*[66] and Michael Parsons' *Independent Pulses*[67].

1.2.8.3: Horizontal Text Processes

Text processes are another technique for generating indeterminacy. *Nano*, *Lorenz* and *Whitewater II* all use text processes which describe strict actions to be carried out by the performers. The main difference with bounded improvisation is that in these pieces, the score is approached like a recipe: no personal interpretation is required, the performers simply do as the score says. There may of course be instructions with multiple possible interpretations, but always with a certain sound-outcome in mind which guides the performer.

For instance, the percussion and string players in *Lorenz* follow text processes where the way that they choose notes is strict, but is also dependent on perceptual elements. The strings are always chasing a moving pitch target which in theory they should get closer to the longer it stays in the same area. The saxophone has control over its pitch sequence (the strings' target) and the rate at which it passes. These two strategies form a limited feedback loop similar to that of *Primes*: the saxophone 'leads' the strings around but will not let them get too close, unless he runs out of notes. Notwithstanding differences in aural skills, the strings will tend to get better at tracking the saxophone pitch as the piece goes on. The general form of the piece should be a series of wedges, defined by the strings becoming closer to the saxophone and the saxophone moving away but restricted by its need to repeat pitches.

65 Harvey, Jonathan, *The Music of Stockhausen* (London, 1975), 16.
66 Fox, Christopher, *Generic Compositions*, (Fox Edition, 1989-93).
67 Parsons, Michael, *Independent Pulses*, (London, 1992).

1.2.9: <u>Teleology</u>

My music is largely concerned with teleology on the local level and non-teleology at the level of entire pieces. The standard formal archetype here is repetition and transformation of a single object or event. Local teleology is where there is goal orientation within the event itself, but where there is no macro-formal teleology: the succession of events is largely arbitrary. Because the objects are simply being repeated and transformed, they follow no prescribed path and could, theoretically, continue with the process of repetition and transformation into infinity.

Pieces using bounded improvisation (*Primes, Whitewater*) have a certain local teleology thrust upon them in the form of phrase-level improvisation, but again their macro-form is non-teleological. In *Primes* the player is working from a model of melody + drone. This has a clear teleological shape to it, and constantly evolves as the interaction with the computer is unpredictable. Phrases in *Whitewater* are built from interacting with the computer on a note-by-note basis; the feedback loop involved is self-reinforcing so a local teleology will inevitability arise from similarities and conjunctions between both parts. But in both cases this local goal-orientation does not extend to the macro-form. Phrase-level ordering of events is arbitrary and theoretically endless: the piece may stop after three events or three thousand.

Because the performer is improvising, they will always bring their own sense of phrase structure to the piece, and will probably try to influence the macro-form with long term strategies: this is perfectly acceptable. However, the nature of the computer part and the feedback loop, especially in *Whitewater*, means that any form imposed by the player will be constantly modified by the computer's reaction. In *Primes*, the player has a considerable amount of control over the macro-form; the computer's agency is felt in the evolution of the note-level events. The parity of agency in *Whitewater* between player and computer means that both agents are evolving their own material with reference to each other, so neither has the upper hand in macro-formal decisions.

However, saying that the event succession is completely arbitrary would be an exaggeration. Ideally, each event is an instance of the genotype described in the score with no direct reference to each other. In practice, the events are being composed in real-time by the agents involved, and future events will be informed by their memories, emotions and personalities. There are always causes for each event to start and begin, and these will be quite clear from examining a recording of any given performance. My point here is that there is no long-term pattern or causality for events built in to the piece other than the general principle that they be varied instances of the piece's central idea. The macro-form is an emergent aspect of the patterns arising from constant transformation inscribed in the lowest level instructions of the piece.

1.2.10: Modes of Delivery

In my music I use evolution as a means of transformation. Evolution implies constant, but gradual change from one iteration to the next but without any predefined final goal or teleology, implying a continuum of change across infinite time. This extends to the idea that what the listener hears in a concert/installation is only a temporal slice from an infinite piece of music. According to free improviser Mark Wastell, Derek Bailey claimed that '[Bailey's] improvisation was continuous, only broken by moments when he sets down his guitar'; this echoes a feeling shared by many improvisers about their own playing.[68] Swiss composer Manfred Werder actualises this idea in his piece *2 ausführende* (1999) which is performed in chunks. For each performance the composer sends off the next few pages of the score to be played; the entire score would take several days to perform continuously. James Saunders' modular work *#[untitled]* (2000 -) occupies similar territory in that each performance is a new piece built from an evolving and growing set of musical modules. Each performance is a phenotype of *Untitled#*, optimised for that particular performance context. My own *Primes* and *Whitewater* depend heavily on improvising players to transform the material continuously. The performers create the material in real-time—according to the score's rules—and the piece is the evolution of that material as part of a feedback loop with the computer. There is no solution to the piece, and the points of beginning and end are effectively arbitrary.

At this point the biological analogy may break down a little in relation to my own works because the pieces themselves are not truly evolving in time. The score-genotype does not evolve, only the instance-phenotype; because every new performance requires the piece to start again. It could be said that over multiple performances by the same player, their approach will evolve across time. But this doesn't change the fact that the piece of paper remains the same.

One of the beautiful aspects of the strange attractor is how they develop asymptotically over time: always becoming clearer but never reaching perfection. This aspect translates linearly to my music in that the longer an observer spends immersed in the music the

[68] Wastell, Mark, in *Blocks of Consciousness...*, (eds) Mark Wastell, Brian Marley (London, 2005), 7

more interesting it hopefully becomes. Assuming that the material and its transformations are fundamentally interesting to the observer, then the piece can go on for as long as the observer remains fascinated by the process and the inner life of the sound. With that in mind it seems logical that many of these works would be more suited to the installation context than the concert hall. I think that both versions are viable as long as it is clear to the audience how they are expected to listen in order to engage as much as possible with the music.

Many of these works exist in both installation and concert versions. The fixed score works in my portfolio are more suited to the concert hall as they have definite boundaries in their beginnings and endings, while the open works simply begin and then simply stop; there is a certain amount of licence in the more improvised works for the player to shape the form, but there are no formalised ending functions. The pieces themselves do not change much (if at all), but the context suggests that the listener put on 'different ears'. Most of my work involves a single object which transforms again and again, requiring the listener to keep track of many parameters. In practice, as illustrated by information theory, it is more likely that the listener will drift between parameters as the amount of change they exhibit differs: the more change there is, the more that parameter will draw the listener in.

For example, *Whitewater* has been submitted in three recorded versions: a 10 minute solo concert version, a 40 minute solo studio version, and a 26 minute installation version with three players. The only real difference is that the installation version has many players simultaneously moving around a space, as opposed to the single, unmoving, performer in the concert and studio versions: the installation version has four microphones positioned around the space, so the computer only receives input when a player is close to a microphone. This means that in the installation version there is more time for the computer to evolve sounds without being interrupted by new input; new input will eventually re-seed the cellular automaton, thus interrupting evolution and changing the sound.

The situation is similar for the live players. They interact with the computer sound, thus the more it changes, the more they change. But they also interact amongst themselves to find common pitches and create beating patterns. Much of this interaction will not be picked up by the computer as the players spend most of their time moving between microphones (although they are instructed to spend enough time at the microphone interacting with the computer that they can hear the results). Ultimately, all of this should allow for more expansive evolution as the feedback loop between players' improvisation and computer's transformation is wider; the computer and the players both have more time to evolve their parts independently, before the parts interact via occasional microphonic contact.

Installations solve the formal issue of beginnings and endings that many of my pieces have. Even to call it a 'problem' is a relativism because the fact that the pieces have no formal boundaries is only a problem in the concert context and then only to listeners who expect such elements. As an installation the works can be appreciated in their own environment where the listener's beginning is where they pick up the thread. The form of these pieces relies on local teleologies leading to local difference, thus the piece is different for everyone in that for every listener starting at a new place there is a new series of differences: one person's section A→B→C could be another listener's G→F→D. Apart from the intractable problem that some listeners simply do not like to listen to music non-teleologically, this way of listening may render meaningless the trajectories and relationships that different performers may bring to the works, especially over long time frames; there is not much can be done about this.

Manfred Werder's solution solves the problem by allowing the listener to appeal to a sense that this work is part of something larger which is being revealed one section at a time. This offers some level of comfort to those who require a sense of closure, least partially, to their listening. James Saunders' works invert the situation because they all stem from one meta-work and the individual pieces are complete in themselves. Saunders also has the advantage of always composing to order, thus he can fit the material and the form to the performing context.

1.3: Musical Contextualisation

1.3.1: Experimentalism

> I want to find the music, not to compose it.
> - Tom Johnson[69]

The work of the American Experimental school is greatly varied in terms of both sound

[69] Johnson, Tom, 'I want to find the music', *Editions75*, Date Unknown, <http://www.editions75.com/Articles/I%20WANT%20TO%20FIND%20THE%20MUSIC.pdf> (4 August 2008)

and technique. While I admit that their use of indeterminacy has few direct connections with Chaos Theory, what it does have is a commitment to process and the critical function of asking 'what can be music?'. This attitude is ideologically centred around John Cage's classic dictum that composers should 'let the sounds be themselves'.[70] What is most important for me here is that the freedom of sound in Cage's compositions gave so many other composers the permission to take bold steps in applying new ideas to musical form. From the surrealist processes of Fluxus[71] to the literal mathematical processes of Tom Johnson, process in experimental music takes ideas and gives them sonic clothing, sometimes to shock and sometimes to elucidate. The idea of indeterminacy in 20th Century Art music owes most to the American experimentalists, who were always more willing to simply let a sound idea simply 'be' rather than attempting to assimilate it into the metrical grid as many Europeans such as Lutoslawski and Xenakis did.[72] The combination of rule-based processes and indeterminate performance follows the experimental thinking in science where hypothesis leads to practice to test a theory. The act of composition is largely about finding the right rules. As Tom Johnson says above, 'finding the music' rather than composing it.

While Cage is the composer most readily associated with indeterminacy, his methods have always been at odds with how I compose. His music often focuses on the philosophical concept of freeing the sounds at the expense of an intended sonic result. For example, works such as *Music of Changes* (1951) use the Chinese *I-Ching* or other quasi-randomising processes to decide on the details of material and its placement. The indeterminacy here is limited to the set of sound types chosen by the composer—such as instrument type or ranges of pitch and dynamics—but the ordering and placement in time obeys only the logic of chance with no over-riding sonic goal. At the extreme of this line of thought are pieces like *Variations II* (1961). The score of which consists of six transparent sheets, some with lines and some with dots. The sheets are overlaid by the performer and the resulting conjunctions of dots and lines interpreted as sound parameters such as pitch and duration. In his article on Cage in the Grove Dictionary of Music and Musicians, James Pritchett describes the 'flexibility' of the piece as 'being such that it could theoretically describe any imaginable combination of sounds.'[73] To me this flexibility is a step too far as

70 Cage conversation with Bill Womack (1979), in Kostelanetz, Richard, ed.,Conversing with Cage (New York, 1988), 42
71 A worldwide movement which had many American members and very close ties with the American Experimental school, for that reason I include it here.
72 Xenakis conformed to the metrical grid notion to a lesser degree than most composers of the time; in that the surface of his work often obscured the grid underneath. However I still consider his work to be conceptually tied to the grid because his sound ideas are mostly translated into a metrical idea or at least notated in this way: his notation pushed the grid around but this is still a relationship to the grid, many experimental composers simply ignored the grid and concentrated on time as perceived by the performer.
73 Pritchett, James, 'Cage, John', *Grove Music Online*. *Oxford Music Online*. <http://www.oxfordmusiconline.com/subscriber/article/grove/music/49908>, accessed 5 Aug. 2008

the piece has no sound objective, no intention. Cage, I am sure, following his own doctrine of non-intention, would happily agree.

My music and Cage's differ greatly due to our different applications of indeterminacy and the differing level of importance we place on specificity of sound intention, but they also connect in one way because his compositional indeterminacy makes structure a perceptual issue unique to each listener. By allowing chance to determine the sequence and nature of sound events Cage creates a music where structure is not forced on the listener but arises out of their own perception: each listener brings their own unique perceptual apparatus and history to bear on the quasi-random musical events and interpret it as patterns accordingly. In my music, a similar but more conditioned experience is created in the works involving emergent structures—such as *Whitewater*, *Whitewater II* and *Nano*—where the structure is not imposed on the listener but rather emerges as a memory process in the listener, an esthesic process where patterns equating to structure arise in the accumulation of similarities.

Alvin Lucier, like most of the post-Cage experimentalists, had his ideas about composition turned upside by an encounter with Cage's music but of course he took Cage's influence and made his own way with the new ideas.[74] Where Cage concentrated on the freedom of sound's identity, Lucier's composition is all about freeing sound's physicality. Lucier uses processes built on diverse scientific sources to explore sound phenomena such as standing waves or acoustic beating patterns as well as occasionally rendering other types of phenomena as sound. Lucier's pieces almost always take the form of a single linear process which he describes thus: 'an action or process, set into motion and sustained throughout the course of the work, produces unexpected and complex results.'[75]

Lucier's aesthetic has greatly influenced how I think about both musical sound and form, and much of my music's procedures are indebted to his work. Apart from the beauty and innovation of his soundworlds, two aspects of his composition have particular interest for me: (1) the way in which he tightly controls the boundaries of indeterminacy in his music; (2) how he designs emergent processes and people processes to control the horizontal aspects of the music. Both of these can be demonstrated by examining his 1968 piece *Vespers.*[76]

In *Vespers,* performers use sondols—'sonic dolphins': devices which produce a loud click,

74 Lucier, Alvin, 'Origins of a Form: Acoustical Exploration, Science and Incessancy' *Leonardo Music Journal*, vol. 8, Ghosts and Monsters: Technology and Personality in Contemporary Music (1998), 5

75 Lucier, Alvin, 'Origins of a Form: Acoustical Exploration, Science and Incessancy' *Leonardo Music Journal*, vol. 8, Ghosts and Monsters: Technology and Personality in Contemporary Music (1998), 11

76 Lucier, Alvin, *Vespers*, in *Reflections* (Cologne, 1995).

used for echolocation—to make their way through a space. The music in this piece is the sound of the space itself, in the form of echoes produced by the sondols. In the score for *Vespers*, it's clear how concerned Lucier is that the performers understand their role, here is an extract from the instructions to performers:

> Decisions as to speed and direction of outgoing clicks must be made only on the usefulness in the process of echolocation. Any situations that arise from personal preferences based on ideas of texture, density, improvisation, or composition that do not directly serve to articulate the sound personality of the environment should be considered deviations from the task of echolocation.

The music is emergent from the people process which is set in motion by the text process of the score: as we can see, the music is not explicitly inscribed in the score but emerges from its processes. People processes is a term that I use to distinguish processes which involve actions carried out by people to achieve a sonic result from specifically musical processes such as augmentation of a rhythm by a set duration in a specified time. People processes include actions like Lucier's echo-following performers in *Vespers* or the string players in my own *Lorenz* who must attempt to match the pitch of the saxophone part according to strict rules. People processes rely on an explicitly scored set of instructions to underscore the hidden sound or artistic purpose. It is imperative that the people in question are open to the music itself and committed to performing it with integrity. Pianist and experimental music specialist Philip Thomas takes a similar viewpoint, describing the role of the performer in Lucier’s music as 'both catalyst and medium for a particular sonic peculiarity [which Lucier's music presents] clearly and honestly with only the minimum of performer intervention.'[77]

Indeterminacy in Lucier's music is tightly bound to the intended sound of each piece. He creates a process whereby a limited space is explored for variation on a specific sonic outcome. As shown above in *Vespers*, the instructions to the performers expressly prohibit actions which do anything other than realise the piece's central sound-idea. Thomas DeLio sums up Lucier's approach below in relation to *Music for Pure Waves, Bass Drums and Acoustic Pendulums* (1980):[78]

> Central to any understanding of [Lucier's *Music for Pure Waves, Bass Drums and Acoustic Pendulums*] is the recognition that its form is identified exclusively with the isolation and magnification of one particular acoustic phenomenon.
> [...]
> [regarding the installation version] At no time however are these parameters [sine

77 Thomas, Philip, 'A prescription for action: a common approach to performing simple, complex, graphic and verbal scores '[lowercasing by author], *Ashgate Research Companion to Experimental Music*, ed . James Saunders, (unpublished draft, 2008), 29
78 Lucier, Alvin, *Music for Pure Waves, Bass Drums and Acoustic Pendulums* in *Reflections* (Cologne, 1995)

freq/amp, drum tension etc.] subject to manipulation by the composer. Instead he accepts the random and spontaneous sonic/visual display which their fortuitous actions produce.[79]

A lot is made in writings on Lucier about how he freely accepts the results of 'fortuitous actions', but this disregards the fact that the piece is set up in a very controlled manner to produce a specific soundworld. Lucier creates the conditions necessary for a certain phenomenon to happen and his concern is with the sound of the phenomenon. Once the boundaries are in place then the performer is free to act in any way as long as it is within the boundaries. Lucier creates a box whose walls are defined acoustically and gesturally, and as with any wall the purpose is both to keep things out as well as to keep things in. The boundaries ensure that if the performance is done with goodwill and commitment that the required phenomenon and its sound result will be all that happens, nothing will happen to break the spell of the performance by introducing extraneous elements.

There are many possible versions and outcomes of an idea. Like a well designed experiment, exploration of these possibilities using indeterminacy removes certain preformed expectations and allows us to experience the unexpected while not removing the intended.

1.3.1.1: Beats and clusters

In the previous sections on techniques, beats are often referred to as a prominent intended sound outcome in my music. This is an aspect of my fascination with physical sound and making sounds visible. Lucier is a powerful example of a composer who makes sounds visible. He takes phenomena such as acoustic beating and composes to show this alone, as he puts it himself, 'having to pare away any musical gestures in a work in order to uncover the true idea in the piece'.[80] But Lucier has no interest in abstract systems used to generate pitches for composition other than the use of number systems to order events and pitches. As was shown above, his interest lies in exposing the physical phenomena itself.

His work gave me permission to focus on a single evolving sound and reveal the complexity that can be found in simple processes. In a certain light, Lucier epitomises the experimental composer; as he says himself:

> Some of my works look like scientific experiments. I have pieces where I simply run a pure wave from the low to high without altering it. If I did alter it, you would miss something. In a scientific experiment you scan all the possibilities. If you start choosing one thing over another, you're relating to personal experience.[81]

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79 Delio, *op cit.,* 100
80 Lucier, Alvin, being interviewed by William Duckworth, *Reflections* (Cologne, 1995), 40.
81 Lucier, Alvin, (transcribed by Anne Guthrie.), *Ostrava Days 2005 Report*, (Ostrava, 2006), 116.

Alvin Lucier's work centers on pieces which expose certain acoustic phenomena, his chief compositional strategy is to reduce the music to only the elements which take part in this phenomena and remove or reduce all other parameters. In his 1983 article on Lucier, Thomas DeLio compares this strategy to that of visual artist Robert Irwin, citing Irwin's remark that 'the reduction was a reduction of imagery to get a physicality, *a reduction of metaphor to get at presence*'[82] [Irwin's italics]. My music follows on from Lucier's in reducing the music to it's materials and processes for themselves rather than putting them in the service of an emotion or narrative purpose.

Lucier's piece *In Memoriam Jon Higgins* (1984) is one of many which focus on the phenomena of acoustic beating patterns formed by the simultaneous sounding of pitches whose fundamental—or occasionally higher partials—frequencies are less than approximately 20hz apart. *In Memoriam Jon Higgins*, written for clarinet and sine wave generator, is a single process wherein a single sine tone slowly rises through a frequency space while the clarinet sustains single pitches. The clarinet's pitches are placed so that they lie just above the sine tone's frequency at that moment, as the clarinet sustains, the sine tone passes through it and the proximity generates beats which accelerate and decelerate as it approaches and passes the clarinet.

Every part of *In Memoriam Jon Higgins* is directed towards demonstrating the phenomena of beating, all other parameters are suppressed to highlight this and reduce the possibility that there is any other way to listen to the piece other than as Lucier intends. The overall trajectory of the piece is a simple linear ascension from X-hz to Y-hz, no distracting changes of direction. The notes of the clarinet enter and leave as silently as possible, if the player is good enough, the clarinet is only noticeable when the listener perceives the beats. The following anecdote from a lecture he gave at the Ostrava Days festival in 2005 illustrates this perfectly.

> Frederic Rzewski asked me why I didn't vary the speed of the rising wave [the sine wave in *In Memoriam Jon Higgins*]. If I did that I would be invoking an idea which comes from other music, that is, to change your idea to interest the audience. I would never do that, it just confuses the issue. You simply set something in motion, don't interfere with it. If you interfere with it, you'll never discover the unexpected.[83]

Where my music differs most from Lucier's is in the focus on phenomena for their own sakes. I take from him the technique and aesthetic of removing compositional elements that are extraneous to the realisation of an idea, but I am not interested in the

[82] DeLio, Thomas, *Circumscribing the Open Universe*, (London, 1984), 92
[83] *Ibid.*

phenomena themselves except as components of a larger language. Lucier generates harmonic and temporal ambiguity as an artifact of his focusing on the sound itself, I focus on the sound itself in order to bring out these ambiguities.

The best example of another composer working in the field of sustained clusters in motion is Phill Niblock. Using multi-track recording and close-micing he creates a very rich and somewhat unrelenting soundworld of sustained drone clusters. His cluster harmony is built up intuitively without reference to systems or models: as he puts it himself:

> I'd rather not be too specific. I'm not into just intonation or overtone systems. What I'm interested in is just big clouds of sound.[84]

Specificity can also work to achieve goals such as Niblock's. Ligeti is an example of a composer using different tunings to widen the intonational space in his soundworld. In his *Ramifications*[85] (1969) for string orchestra he detunes half the orchestra by a quartertone. This is a cheap but effective way to use quartertones without creating too many difficulties for the players (as long as they don't listen too hard to the other half of the orchestra). However, he may have been too exacting here in his use of quartertones. In the light of Ligeti's other intonational experiments it may be that he simply wanted to make the sound a little more 'dirty', rather than extending equal temperament to 24 pitches per octave. This is exemplified in the detuned organ required for *Harmonies* from the *Two Studies for Organ*[86] (1962) and *Volumina*[87] (1966). In *Harmonies*, Ligeti asks for reduced wind pressure in the organ, producing a sound described by Janet Owen Thomas as 'wheezy' and 'indefinite' with 'fluctuations of dynamics and intonation (micro-intervals, glissandos etc) [that] cause a denaturing of the tone colours to produce the "pale, strange, vitiated ones" Ligeti was after.'[88]

After Ligeti had largely abandoned cluster-based harmony in the 1980s, he continued to be interested in denaturing his harmony, which was now much more tonal. An example of an early demonstration of interest in non-12-tone equal temperament harmonies is the use of natural harmonics on the horn in the *Trio*[89] (1982); an idea which was extended to a horn soloist and a quartet of natural horns in the *Hamburg Concerto*[90] (1999). A more systematic approach to mixing intonations was developed in the concertos for violin[91] and

84 Niblock, Phill, (transcribed by Anne Guthrie.), *Ostrava Days 2005 Report*, (Ostrava, 2006), 139.
85 Ligeti, Gyorgy, *Ramifications*, (London, 1969)
86 Ligeti, Gyorgy, *Two Studies for Organ*, (London, 1962).
87 Ligeti, Gyorgy, *Volumina*, (London, 1966).
88 Owen Thomas, Janet, 'Ligeti's Organ Music', *The Musical Times*, Vol. 124, No. 1683 (May, 1983), pp. 319
89 Ligeti, Gyorgy, *Trio: for Violin Horn and Piano*, (Mainz, 1982).
90 Ligeti, Gyorgy, *Hamburg Concerto*, (Mainz, 1999).
91 Ligeti, Gyorgy, *Concerto for Violin and Orchestra*, (Mainz, 1992).

piano[92] (1988 and 1992 respectively). The *Concerto for Violin and Orchestra* involved tuning entire instruments to natural string harmonics. The 7th partial of the double bass's G string is used as the reference pitch for one violin from the orchestra, which tunes its E string up to the resulting F5 -34¢: the violin then retunes its remaining strings as fifths below this F5. By the same process, a single viola from the orchestra retunes by referencing its D string relative to the 5th partial of the bass's A string. This means that one viola and one violin are in standard tuning relative to themselves but are respectively 31¢ flat and 14¢ flat relative to the orchestra. His performance instructions are very clear about maintaining the integrity of the different tunings, as seen in this quote from the performance instructions prefacing the *Concerto for Violin and Orchestra*:

> To reduce deviations in intonation, both scordatura soloists play non vibrato throughout and are careful not to adjust stopped notes to the rest of the orchestra.[93]

Ligeti had no practical interest in tuning systems other than as a method for adding 'dirtiness' to the soundworld of the piece.[94] In a 1978 interview with Péter Várnai he claimed to 'abhor all fixed systems',[95] and later in the same interview talked about wanting music 'not based on quartertones, but mistuned music'.[96] Further examples of this pitch indeterminacy in the concertos for violin and piano involve instruments of uncertain pitch such as recorders[97], slide whistles and ocarinas. The 2nd movement of the *Violin Concerto* features a chorale for four ocarinas which is beautifully mistuned.

Ligeti uses both indeterminate processes such as the reduced wind pressure in *Harmonies,* and specific actions such as the simultaneous conflicting tunings in the concertos, all in order to enrich the soundworld by creating intonational conflict. Detuning instruments out of 12-tone equal temperament is often used by composers for quite the opposite purpose as Ligeti and myself, they wish to make it more precise. Horatio Radulescu and James Tenney are two composers who have used scordatura tuned to natural harmonics so that players can easier perform justly tuned intervals. In Tenney's string quartet *Arbor Vitae*[98] (2007), all the open strings are octave equivalents of partials 1, 3, 5, 7 and 11.[99] This scordatura allows him to create a complex tree structure of just intervals in branching harmonic relationships, described by Tenney's student Michael Winter as 'a series of related tonalities modulating through a richly populated extended

92 Ligeti, Gyorgy, *Concerto for Piano and Orchestra*, (Mainz, 1988).
93 Ligeti, Gyorgy, *Violin Concerto*, (Cologne, 1992), performance instructions (no page number).
94 Steinitz, Richard, *Gyorgy Ligeti: Music of the Imagination*, (London, 2003), 171.
95 Ligeti, Gyorgy, interviewed by Péter Várnai in *Ligeti in Conversation*, (London, 1983), 54.
96 *Ibid.,* 55.
97 Ligeti seemed to consider these as instruments of indeterminate pitch. They are played here by percussionists.
98 Tenney, James, *Arbor Vitae*, (Lebanon NH, 2006).
99 Winter, Michael, 'On James Tenney's Arbor Vitae for string quartet', *Contemporary Music Review*, 27/1, (February 2008), 146.

just intonation pitch space.'[100] In this piece, Tenney follows the compositional school of Just Intonation (JI)—which grew mainly out of Harry Partch's work—by concentrating pitch accuracy to ensure the purity of the just interval. Tenney was highly eclectic and many of his other pieces—such as *Beast*[101] (1971)—uses vertical indeterminacy, this example merely highlights a different purpose for intonation-based scordatura. Here, the vertical aspect, as with Lutosławski and Xenakis, is tightly controlled.

Another example of this kind of thinking can be seen in the work of Witold Lutosławski. The violin solo parts in the 7th prelude from the *Preludes and Fugue*[102] (1970-72) and in *Chain 2*[103] (1988) include the technique of 'placing the fingers close together to produce approximate microtones';[104] see *figure.13.* Lutosławski believed that specific microtonal intervals on the violin would be too closely spaced for violinists to play easily and so accepted the approximation provided by closely placed fingers.[105] This technique is an isolated example of free microtones in Lutosławski's output. When he uses quartertones in works with larger string instruments such the *Concerto for Cello and Orchestra*[106]—and in other works in general—he uses tempered pitches with specific values.[107]

This vertical indeterminacy was a singular occurrence Lutosławski was only interested in horizontal freedom for the performer, and then only in a limited fashion. He advocated a 'clear-cut division between the role of the composer and that of the performer' and did not 'wish to even partially relinquish the authorship of the music [he] had written.'[108]

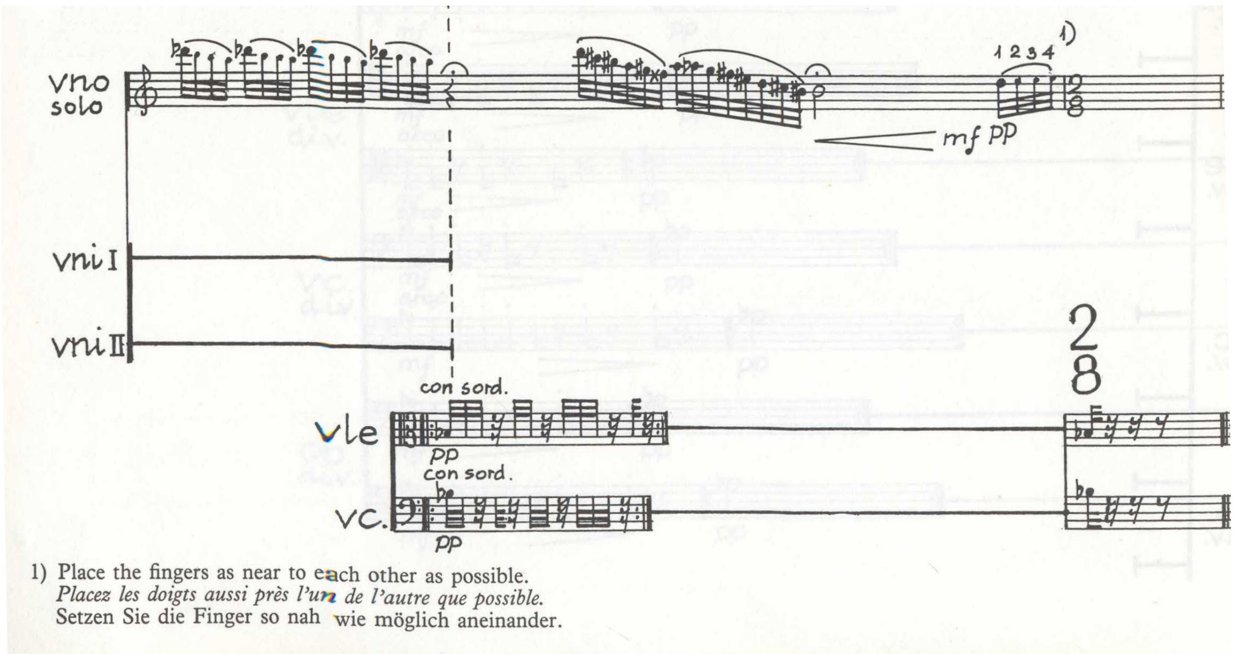

Illustration 12: Lutosławski, *Chain 2;* detail of indeterminate fingering in solo violin part.

Other examples of Lutosławski's horizontal indeterminacy include his use of part-scores in the *String Quartet* (1964), where each player has an independent line. He developed this idea further in the *ad libitum* sections of large scale works such as *Jeux Vénitiens* (1960-61) where players freely follow their own lines within sections; a clever system of repeat bars and conducted cues keeps the players synchronised by section. The indeterminacy in this context is a way to give inner motion to harmonic constructs which are actually static moments in a larger form. Lutosławski's form is definitely teleological, he described his own music as 'finipetal'—tending towards the finale.[109] Lutosławski's reasons for using limited aleatoricism are described by Steven Stucky as 'a means, not an end'; he continues:

> 'The goal is twofold: to accommodate the performer by restoring his interpretative role, and to realize specific textures of enormous microrhythmic complexity and variety.'[110]

Lutosławski's reasons for using indeterminacy as a way to free the performer resonate with the use of bounded improvisation in my own work. Although he claims to not count 'even to the least extent [...] on the possible creative abilities of the performers' our positions on performer choice is similar as he allows them to interpret the rhythm in their own way, allowing for rubato and expression.[111] I would eschew such expressive devices, but go a step further in general indeterminacy by allowing the performers to form phrases and develop material from pitch material which is defined by me. Lutosławski's performers come from the orchestral tradition where interpretation is expected but not improvisation, thus he is right to limit them to what they know. I expect performers from the contemporary music tradition who have experience in improvisation and my music reflects this. I restrict their ability to improvise in a similar way to that of Lutosławski in his own time, but in the context of the performance tradition of experimental music.

1.3.1.2: Feldman and Memory

Towards the end of my PhD studies, I became more aware of the role of memory in the form of my music. The forms that I had intuitively been using since around 2004-05 I was now applying more consciously, allowing me to think more critically about their function. Specifically this relates to the form wherein a single sound-object evolves through repetition and (mostly) minimal variation. The key to this is summed up by Morton

[109]Rae, Charles Bodman, The Music of Lutoslawski, (London, 1994), 24.
[110]Stucky, Steven, Lutosławski and his Music, (Cambridge, 1981), 110.
[111] Ibid.110

Feldman's description of the text provided for him by Samuel Beckett for the opera *Neither*:

> Finally I see that every line is really the same thought said in another way. And yet the continuity acts as if something else is happening. Nothing else is happening. What you're doing in an almost proustian way is getting deeper and deeper saturated into the thought.[112]

As I outlined in 3.2.5 Evolution, this form takes firstly a compositional idea, a shell of a thought that exists only in the mind, and renders it as a sound-object. Then there follows another rendition that will be different in some way, then another that is different again and onwards through a potentially endless series of renderings. Each sound-object is a valid rendition of the idea, but none is 'the idea' itself, because there is no perfect rendition. The form is what is generated from this iteration. From one object to the next there may be a sharp difference or there may be no difference (pure repetition), the patterns in time created by these differences make the form. Memory plays an important role here because each new iteration may depend in some way on the previous: as with the feedback mechanisms of strange attractors, this system relies on hysteresis.

The work of Morton Feldman exerts a strong influence on me in the development of this form. The above quotation in reference to Beckett could easily have been about Feldman's own work, as John Cage said in *Silence*, 'Feldman's music seems more to continue than to change'.[113] This sense of the work as an evolving world rather than a closed piece became more obvious in his late works with their famously extreme durations. As an example, the 90 minute long *Piano and String Quartet*[114] is essentially a series of transformations on a single sound-object consisting of an arpeggiated chord on the piano and a sustained chord in the strings. Apart from a few direct repetitions, the chords never appear the same way twice, but the differences between them are on the edge of what is perceivable. This is achieved in the score in two ways. Firstly, the material itself is often quite neutral, clusters with octave-displaced pitches, simple rhythmic patterns in irrational rhythms that do not establish any 'clear-cut rhythmic shape'.[115] Secondly, the changes that he makes to the material are so slight that they can go almost unnoticed By moving a pitch here or changing a rhythmic value there Feldman is operating on the border of meaningful change, and in this creates a language of ambiguity. However, by working with such small levels of difference Feldman can now create play with this language and use levels of

112 Feldman, Morton, cited in Rich, Alan, San Francisco Contemporary Music Players, Mosko, Stephen (Musical Dir.), *For Samuel Beckett* (sleevenotes), (1991) Newport Classics NPD 85506.
113 Cage, John, cited in Rich, Alan, *op. cit.*
114 Feldman, Morton, *Piano and String Quartet* (London, 1985).
115 Feldman, Morton, 'Crippled Symmetry', *Give my Regards to Eighth Street*, ed. B.H. Friedman (Cambridge MA, 2000), 142.

difference as a method to shape the form. The most extreme examples of this are when he chooses to place a single *fff* event into a piece that is primarily *ppp*: this occurs in many of his works such as *For Bunita Marcus* (1985) and *Trio* (1980).

My own music too aims for this ambiguity between change and non-change.

> Music can achieve aspects of immobility, or the illusion of it. [...] The degrees of stasis, found in a Rothko or a Guston, were perhaps the most significant elements that I brought to my music from painting.[116]

By concentrating on the fine details of transforming his materials in this way, Feldman creates the illusion of motion and simultaneously the illusion of stasis, a formal multistability. In his writings, Feldman speaks of creating and breaking patterns, asking 'when does a pattern become a pattern?'.[117] This concern with the perception of structure on a micro-level is part of Feldman's need for the music to exist in the now, to avoid grand teleological structures. For example, many works from the 1970s such as *Violin and Orchestra*[118] (1979) proceed as a series of blocks of instrumental colour—each negates the last but maybe a repetition from earlier in the score—and the form emerges out of the conjunctions and connections made by memory from these juxtaposed blocks: Boulez said that Messiaen did not compose, he juxtaposed,[119] perhaps Messiaen was searching the same sense of stasis sometimes in his music. Feldman takes influence from Cage's method of disassociating the parameters of sound from their structural roles by (in effect) randomising their ordering, and says that it is 'not involved with the grammar of design'.

In my own music, I follow Feldman's techniques for keeping the music hovering on the edge of change. The main difference between myself and Feldman is that my music has moved away from notating this subtlety of change and instead creates performance situations, such as *Whitewater* and *Nano*, where the principle of subtle change is embedded in the rules. This means that the form of the music is not just realised in the moment of perception but also at the moment of utterance. To apply Feldman's words to myself; 'Before, my pieces were like objects; now, they're like evolving things'.[120]

1.3.2: Spectralism

As is mentioned above, the music of the spectral composers Tristan Murail and Gérard

[116] Feldman, Morton, cited in Rockwell, John, 'Morton Feldman (and Crippled Symmetry)', *Morton Feldman Page*, <http://www.cnvill.net/mfrockwl.htm > accessed 11/12/08
[117] Feldman, Morton, 'Crippled Symmetry', *Give my Regards to Eighth Street*, ed. B.H. Friedman (Cambridge MA, 2000), 139.
[118] Feldman, Morton, *Violin and Orchestra* (London, 1979).
[119] Boulez, Pierre, cited in Cross, Jonathan, *The Stravinsky Legacy* (Cambridge, 1998), 55.
[120] Rockwell, John, *op. cit.*

Grisey was very important for the development of my musical language both in terms of techniques and aesthetics. When I discovered spectral music, it was the techniques that I was most attracted to because they allowed me to create the microtonal soundworlds that I was interested in. It took time for me to realise that it was the sound itself that was interesting to me, and the ways in which these sounds could be used structurally. My PhD studies show a fairly linear progression from using spectral techniques abstractly through to a greater understanding of the nature of sound and perception. I have discussed above (1.2.7 Vertical Indeterminacies) what I have learned from the spectralists in terms of techniques, here I will briefly discuss what I learned from them in relation to time.

The first composer to mention must be the proto-spectralist Karlheinz Stockhausen. I have only been dimly aware of his contribution to spectral music until recently, many of his discoveries are simply presumed in the writings of the spectral school, or considered common knowledge to anyone who had ever slowed down a digital sample (or tape reel, or vinyl record) to the point that the pitch became pulse. When I wrote my early spectral pieces I completely unaware of his formulation of the relationship between pitch and tempo that *Tracheids*, *The Lady with the Hammer* and *Primes* take as their starting point. It is almost impossible to generalise about Stockhausen's soundworlds and compositional techniques, at best I can say that while I was never attracted to much of his music in more than a passing manner, there are plenty of instances where I have found something fascinating in a technique that he has used or a sound that he has created.

Stockhausen's work in spectralism may have been, for me, overshadowed by that of Grisey *at al*, but in researching his work I have some across a surprising number of connections in relation to his use of indeterminacy: Stockhausen would have heard Cage's lectures at Darmstadt in the 1950s,[121] but he also had an interest in probabilities and information theory that would have contributed to this, he studied Communication theory and phonetics with Werner Meyer-Eppler in Bonn from 1954-1956.[122] In Stockhausen's *Klavierstück XI*[123] (1956) there are examples of structural indeterminacy where the pianist may choose from any of 19 groups of notes 'playing the first that catches his eye'. This technique was hardly novel—see many open-form pieces or those influenced by the mobiles of Alexander Calder, such as Boulez' *3rd Piano Sonata*[124] (1963) and many works by Earle Brown—but Jonathan Harvey notes as the most interesting aspect of this piece Stockhausen's suggestion that the piece be played twice or more in a single concert.

121 Harvey, Jonathan, *The music of Stockhausen* (London, 1975), 13.
122 *Ibid*., 124-125.
123 Stockhausen, Karlheinz, *Klavierstück XI* (London,1956).
124 Boulez, Pierre, *3rd Piano Sonata* (Paris, 1963).

Stockhausen considered the power of the open form to be the possibility that the more one hears the piece the more clear the structure will become, based as it is on probabilities. My own work with bounded improvisation leads to the same conclusions, in that works such as *Whitewater* and *Nano* have more power to communicate their relationships and structure over a longer time scale of listening. The more bounded the area, the clearer the details are under repeated or extended listening, and the greater the contrasts appear: performer Heather Roche explained to me that while performing *Nano* she is amazed at how wide a semitone begins to sound.[125]

Stockhausen uses indeterminacy to varying levels in many of his other works, especially after his development of 'moment-form' in the late 1950s where he seeks a 'concentration on the Now' to make 'vertical sections which penetrate across a horizontal portrayal of time to a state of timelessness'.[126] This is another example of where Stockhausen and I agree in principle but not always in execution. My work also attempts to sometimes freeze the horizontal—in *Whitewater* and *Primes* the harmony is smeared across time by the computer part, and in *Five Bells for Elliott Carter* a chord from Carter's *3rd String Quartet* is suspended in a set of spectral transformations—but with the exception of *Five Bells for Elliott Carter* the moment is always a product of the past. Harvey describes Stockhausen's 'impatience with the teleology of musical moments which are always a result of past musical events'.[127] Many of my forms rely on the feedback system where the 'now' can only be a product of a particular past, and each performance of the piece will have a series of different 'now' that depend on the previous 'now'.

Although written without the influence of Stockhausen, some of the text scores in my portfolio—*Primes*, *Whitewater* and *Lorenz* especially—are similar in several ways to text scores of his such as *Ylem*[128] (1972) and *Stimmung*[129] (1968). Both of our scores have complex texts that must be internalised by the performer before the piece can be performed. This is different to a standard musical score because while there is always the possibility that even the most difficult score can be sight-read (assuming that the notation in this case is a direct representation of the intended sound), these text scores exhibit a kind of 'irreducible complexity'[130] in that all aspects of the score must be learned and then put together. These scores are also dependent on performer input outside the normal range of musicality, the performer is often required to create their own phrase-level

125 Personal communication, 21/06/08.
126 Harvey, *op cit.*, 85.
127 *Ibid.*
128 Stockhausen, Karlheinz, *Ylem* (Kürten, 1972).
129 Stockhausen, Karlheinz, *Stimmung* (London, 1968).
130 An argument used by the supporters of creationism and I.D. (intelligent design) to suggest that some biological systems and objects must have been designed (by a 'creator') because they could not have evolved from less complex predecessors as they could not function at a lower level of complexity. The eye is frequently, and wrongly, used as an example of this.

structures or supply the musical detail where only a structure and a principle or intended sound-outcome are given.

Stockhausen's music also extends out to extremes of conceptual art and musical theatre, much of which has open-ness and indeterminacy built in but bound by a context or quasi-narrative. These works I consider to be largely outside what I can discuss in relation to my own music.

The composers of the Paris-based spectral school, Grisey and Murail, have a much more direct relationship with my work than Stockhausen does because, as seen above, their techniques of pitch generation and transformation were an important influence on the development of my own compositional language. Apart from the techniques of spectral modeling and frequency modulation, I take from the spectralists their concepts and aesthetics that relate to time, as Grisey states:

> Strengthened by an ecology of sounds, spectral music no longer integrates time as an external element imposed upon a sonic material considered as being 'outside-time,' but instead treats it as a constituent element of sound itself.[131]

He goes on to talk of the 'hypnotic power of slowness' and the spectral 'obsession with 'continuity, thresholds, transience and dynamic forms.'[132] All of this is clearly set out in the seminal spectral works of the 1970s such as Grisey's *Partiels* (1975)—see 1.2.7.4 Spectral Modeling (p.34). *Partiels* begins with a long section where a pure spectrum on E is repeated while each new iteration is further distorted until it reaches a threshold of inharmonicity and breaks apart. The second section is another linear transformation from alternation of different harmonies and timbres (the line between these is blurred smoewhat in this case) to a homogeneous consonance, and this again ruptures into a new section, flurrying but harmonically static. The fourth section is another contrast of timbre and harmony and again is reached via a linear transformation that culminates in an abrupt change and a negation of the preceding soundworld, and this then slowly loses energy and collapses into noise and silence. Tristan Murail commented on these early pieces—which were for me, the most interesting and influential—that 'there is continuity, but there are also ruptures and many other types of transition'.[133]

While I definitely absorbed all of these formal concepts in my own music, I can see some distinct differences between my own work and the spectral composers. Some of my earlier works, such as *Poetics of Knots* (2003), *After-Images* (2004) and *Prisma* (2005), are

131 Grisey, Gérard, 'Did you say Spectral?', trans. Fineberg, Joshua, *Contemporary Music Review*, 19/3, (January 2000), 2.
132 *Ibid.*
133 Murail, Tristan, 'After-Thoughts', *Contemporary Music Review*, 19/3, (January 2000), 7.

similar to these early spectral works in that successive sections use the same spectral (or proto-spectral) material but create noticeably different soundworlds; a sectional approach to form but with an underlying unity. As my language developed I moved more towards the same type of formal models as before and that are exemplified by *Partiels*—those that rely on linear continuities within a section and a rupture to signal sectional change—but increasingly brought the material to the fore by reducing the level of difference from section to section; *M.Grisey, his Galliard* (2005) alternates dense and sparse material that is essentially the same, with occasional ruptures (mm.46-51, m.76 and m.96). By the beginning of my portfolio my work is settling into the mature archetype where the material has become a single idea and each section is another way to render that idea as sound, later as exemplified in later pieces such as *Nano* and *Whitewater*. Here, the spectral goal, described by Murail as 'the capacity to control the finest degree of change',[134] is put into service as the facilitator of a language of ambiguity.

[134] *Ibid.*

2: Chapter 2 - Works

2.1: Commentaries

2.1.1: Tracheids (2006)

Flute, clarinet, bass guitar, percussion: 4 minutes

Tracheids was written partly as an experiment to see if a strict relationship between frequency and tempo would be perceivable to a listener: though the piece is not written as a study, the tempo/harmony relationship was the primary material and the piece was composed in a manner that would highlight this aspect. Tempo and harmony are related through fundamental tones that are sufficiently low to be perceived as pulses rather than pitches. These pulses form the tempo for a given section, as marked by constant crotchets on a tenor drum, and the same pulse is also the fundamental tone for the harmony in the section, for example, 1.71667Hz = 103bpm = 'A' (concert 'A' at 440Hz is the 256th partial of this fundamental). The tenor drum keeps a constant pulse while the other three instruments sustain a harmony derived from the given related spectrum. Successive sections are marked by abrupt changes of tempo and harmony which, because they can be very subtle—such as the tempo change from 109bpm to 115bpm at m.20—happen mainly on a point between two crotchets to emphasise the change.

At the time of composition, I was unaware of Stockhausen's work in relating tempo to frequency; from the mid 1950s, 'the "prime mover" of his his music'.[135] In his article '...how Time Passes...',[136] he explains how 'duration and pitch are only different areas in one time scale reaching from an impulse every eight seconds to 6000 impulses every second',[137] and how this was incorporated into his use of the serial method to create a tempo scale or tempo series where the tempi were related to the durations and pitches. Although the basic concept of relating frequency to tempo is the same, many instances of Stockhausen's application of the concept are diametrically opposed to mine in terms of sound. In works such as *Gruppen* (1955-57), Stockhausen continues equates rhythms and tempi with harmonies or tonalities and, as Harvey describes it, Stockhausen...

> [...] fluctuates his tempi within his twelve-step scale': Harvey elaborates on this by saying that if the music stayed in one tempo 'it would be the equivalent of tonal

135 Stockhausen, Karlheinz, cited in Harvey, Jonathan, *The Music of Stockhausen* (London, 1975), 30.
136 Stockhausen, Karlheinz, '...how Time Passes...', *Die Reihe 3*, (Pennsylvania, 1959).
137 Harvey, Jonathan, *The Music of Stockhausen* (London, 1975), 30.

music (having only one tonal centre instead of many).'[138]

In my music I believe that the listener needs some time and repetition in order to perceive these relationships and so my music tends to have a very slow rate of change. Jonathan Harvey, being a spectral composer himself, appears to be in sympathy with this when he later says that 'this is not to say that Stockhausen has written the ideal music for the purpose; it is by no means educational music'.[139]

While writing *Tracheids*, I was still trying to understand the techniques of spectral music and as a result there are several aspects which are unsuccessful. Because I was interested at the time in very dissonant harmonies, I made no effort to select pitches that would emphasise the fundamental pitch of each section, so there is no sense of that section having a specific pitch weighting. The opening five bar section is based on a fundamental tone of A, but the pitches used are B2 +52¢, A♯4, D5 +57¢, these pitches are obscure harmonics of A which will not in any way promote a sense of A being the fundamental pitch. In this case, my concern for 'interesting' harmony undermined the piece's idea. But with that in mind, if I had made more effort to emphasise the fundamental pitch then the sense that the tempo could be explicitly linked to harmony would also have been lost as the harmony would have been overstated and there would be no reason to even consider linking the tempo to the harmony. The correct approach I feel would have been to find a common ground where the harmony only changes very subtly, so allowing the tempo changes to come to the fore.

Ultimately, I consider this piece as an unsuccessful experiment for two reasons. Firstly, I do not believe that the human perceptual apparatus can connect tempo to harmony in this way, the tempo differences in some cases are almost imperceptible—for example, A=103bpm, A♯=109bpm—and secondly because I did not choose my harmony with care to emphasise its relation to the tempo. I am satisfied with some compositional elements and it is clear that the piece is not inconsistent with my compositional language. The piece uses a block-sectional structure where the sectional boundaries are sharply emphasised and the sectional material is a sound object which evolves as the piece progresses: this can also be seen in works such as *-Intra*, *Bifurcations*, *Whitewater II*, and *Inner Shadow.*

2.1.2: The Lady with the Hammer

2 tuba, 2 bass trombone, 2 euphonium, 2 piano: 12 minutes

[138] *Ibid*., 32.
[139] *Ibid*., 34.

The title refers to Galina Ustvolskya, the Russian composer whose unusual orchestrations —such as *Composition no.2: Dies Irae* for eight double basses, piano and wooden box[140]— and use of obstinately repeated clusters had a strong influence on this piece. The influence of the spectral composers is also unavoidable in the piece's harmonic structure as all the harmonies are derived from prime-numbered partials of very low E (1.29Hz), and in the middle section (mm.146-175) from G♯ (1.62Hz). As with *Tracheids*, these sub-audio fundamentals also act as the tempo for each section.

The basic technique in this piece is to have the brass acting in pairs to sustain dyads that all activate the same combination tone. The two pianos act as resonators for this combination tone by using silently depressed keys to let the string at the combination tone pitch vibrate in sympathy with the brass. In *illustration 13* the pianos are holding G5 and G4 open (as well as the low E1, which is left open for most of the score for general resonance), these are the 304th and 152nd partials of E (1.29Hz) and both are octave multiples of the 19th partial (G = 24.47Hz, a tone below the low A on a grand piano). The brass pairs play dyads that sum to either 304 or 152, thus in theory they should all produce combination tones that will cause sympathetic vibrations in the open piano strings G4 and G5:

Trombones:	partials 251 and 53
Euphoniums:	partials 233 and 71
Tubas:	partials 109 and 43

(mm.14-16) tuba and euphonium: partials 263 and 41

140Ustvolskaya, Galina, *Composition No.2: Dies Irae* (Hamburg, 1973).

The concept is taken to its logical conclusion in the final bars of the work where there are pitchless tongue sounds at tuplet speeds which represent the prime-numbered partials below audibility: in this scheme triplets are the 3rd partial, quintuplets are the 5th partial and so on.

This piece was written closely after *Tracheids* (around Christmas 2006) and can be considered as an unsuccessful experiment for the same reasons as *Tracheids*, that is, too rigorous an application of theory without fully understanding the practical implications; but I did learn a lot about my own harmonic language in the process of writing it. The main
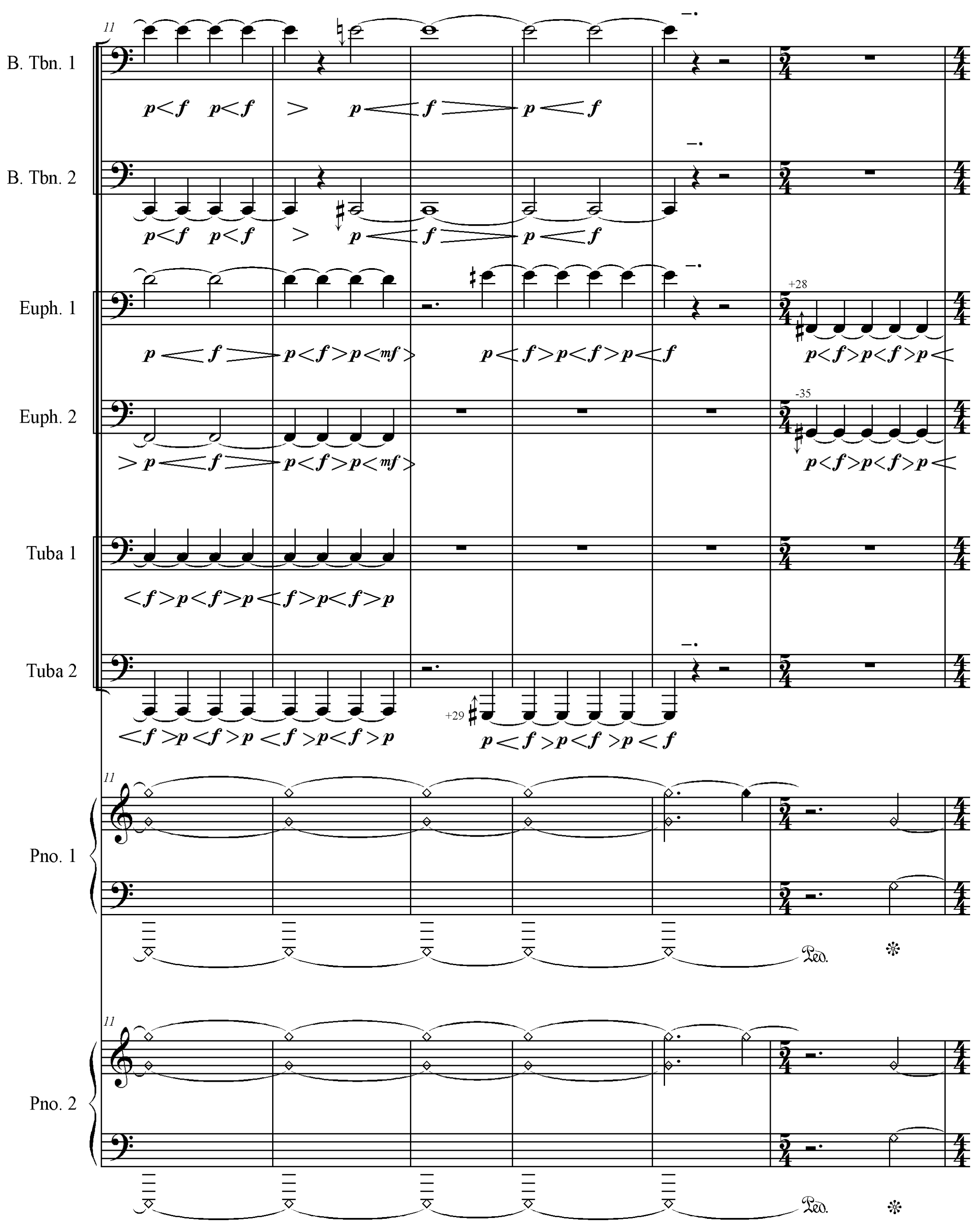
Illustration 13: The Lady with the Hammer mm.11-16

problem is that the combination tones are not audible, and do not cause the open piano strings to vibrate. I had assumed that because acoustically generated difference tones were audible (first order difference tones at least) then combination tones would also be audible, but as Rossing, Moore and Wheeler point out in *The Science of Sound*, 'no one has presented convincing evidence that even simple sum tones $(f1 + f2)$ can be heard'.[141] Even if the combination tones had worked, there was also the problem that the performance space would need to have a very dry acoustic in order to hear the piano resonance above the reverberation of the brass fading away. The brass should theoretically have enough acoustic power to cause the piano strings to vibrate at any pitch (assuming the sympathetic vibration did not work), but the open piano strings used in the piece were often too high to sustain for any length of time or with any volume, thus the sound of the brass chords dying away would mask any piano resonance.

It would be possible to rewrite this piece with another more effective way to represent the combination tones—any instrument with the correct range would work really—but I was dissatisfied with the overall sound of the piece and so would rather rethink it as a new piece than try to fix the existing version. I found that I was most satisfied with the close harmonies, where notes less than a semitone apart grind against each other (see *illustration 14* below) this led to my considering harmony more in terms of closely-spaced clusters and formed the model for a lot of my subsequent harmonic ideas.
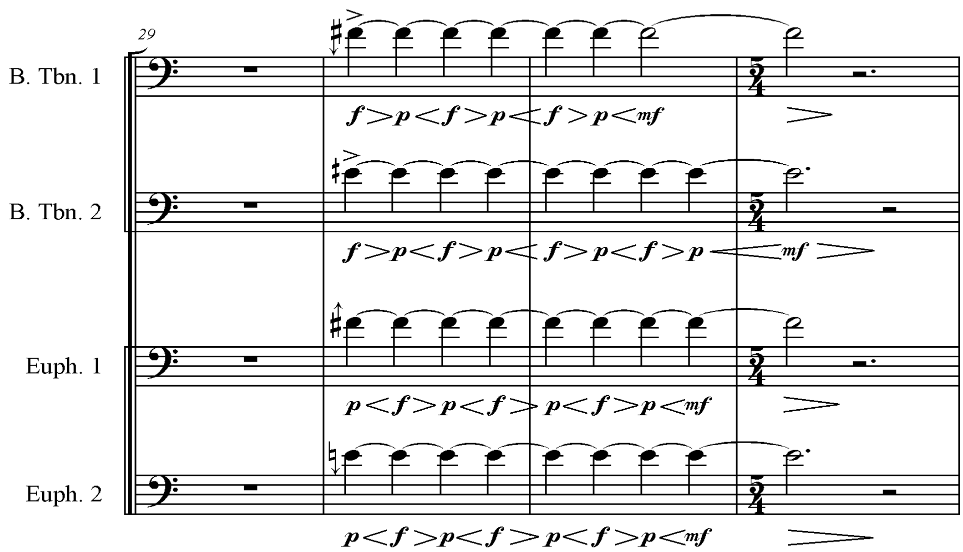
Illustration 14: close harmonies in *The Lady with the Hammer* (mm.29-32)

141Rossing, Thomas D., Moore, F. Richard, Wheeler, Paul A., *The Science of Sound*, 3rd edn. (San Francisco, 2002), 160.

	E	F	F#	G	G#	A	A#	B	C	C#	D	D#
Partial no. 1	1.29	1.36	1.44	1.53	1.62	1.72	1.82	1.93	2.04	2.17	2.29	2.43
7	9.02	9.52	10.08	10.71	11.34	12.04	12.74	13.51	14.28	15.19	16.03	17.01
11	14.17	14.96	15.84	16.83	17.82	18.92	20.02	21.23	22.44	23.87	25.19	26.73
13	16.74	17.68	18.72	19.89	21.06	22.36	23.66	25.09	26.52	28.21	29.77	31.59
17	21.9	23.12	24.48	26.01	27.54	29.24	30.94	32.81	34.68	36.89	38.93	41.31
19	24.47	25.84	27.36	29.07	30.78	32.68	34.58	36.67	38.76	41.23	43.51	46.17
23	29.62	31.28	33.12	35.19	37.26	39.56	41.86	44.39	46.92	49.91	52.67	55.89
29	37.35	39.44	41.76	44.37	46.98	49.88	52.78	55.97	59.16	62.93	66.41	70.47
31	39.93	42.16	44.64	47.43	50.22	53.32	56.42	59.83	63.24	67.27	70.99	75.33
37	47.66	50.32	53.28	56.61	59.94	63.64	67.34	71.41	75.48	80.29	84.73	89.91
41	52.81	55.76	59.04	62.73	66.42	70.52	74.62	79.13	83.64	88.97	93.89	99.63
43	55.38	58.48	61.92	65.79	69.66	73.96	78.26	82.99	87.72	93.31	98.47	104.49
47	60.54	63.92	67.68	71.91	76.14	80.84	85.54	90.71	95.88	101.99	107.63	114.21
53	68.26	72.08	76.32	81.09	85.86	91.16	96.46	102.29	108.12	115.01	121.37	128.79
59	75.99	80.24	84.96	90.27	95.58	101.48	107.38	113.87	120.36	128.03	135.11	143.37
61	78.57	82.96	87.84	93.33	98.82	104.92	111.02	117.73	124.44	132.37	139.69	148.23
67	86.3	91.12	96.48	102.51	108.54	115.24	121.94	129.31	136.68	145.39	153.43	162.81
71	91.45	96.56	102.24	108.63	115.02	122.12	129.22	137.03	144.84	154.07	162.59	172.53
73	94.02	99.28	105.12	111.69	118.26	125.56	132.86	140.89	148.92	158.41	167.17	177.39
79	101.75	107.44	113.76	120.87	127.98	135.88	143.78	152.47	161.16	171.43	180.91	191.97
83	106.9	112.88	119.52	126.99	134.46	142.76	151.06	160.19	169.32	180.11	190.07	201.69
89	114.63	121.04	128.16	136.17	144.18	153.08	161.98	171.77	181.56	193.13	203.81	216.27
97	112.06	118.32	125.28	133.11	140.94	149.64	158.34	167.91	177.48	188.79	199.23	211.41
101	130.09	137.36	145.44	154.53	163.62	173.72	183.82	194.93	206.04	219.17	231.29	245.43
103	132.66	140.08	148.32	157.59	166.86	177.16	187.46	198.79	210.12	223.51	235.87	250.29
107	137.82	145.52	154.08	163.71	173.34	184.04	194.74	206.51	218.28	232.19	245.03	260.01
109	140.39	148.24	156.96	166.77	176.58	187.48	198.38	210.37	222.36	236.53	249.61	264.87
113	145.54	153.68	162.72	172.89	183.06	194.36	205.66	218.09	230.52	245.21	258.77	274.59
127	163.58	172.72	182.88	194.31	205.74	218.44	231.14	245.11	259.08	275.59	290.83	308.61
131	168.73	178.16	188.64	200.43	212.22	225.32	238.42	252.83	267.24	284.27	299.99	318.33
137	176.46	186.32	197.28	209.61	221.94	235.64	249.34	264.41	279.48	297.29	313.73	332.91
139	179.03	189.04	200.16	212.67	225.18	239.08	252.98	268.27	283.56	301.63	318.31	337.77
149	191.91	202.64	214.56	227.97	241.38	256.28	271.18	287.57	303.96	323.33	341.21	362.07
151	194.49	205.36	217.44	231.03	244.62	259.72	274.82	291.43	308.04	327.67	345.79	366.93
157	202.22	213.52	226.08	240.21	254.34	270.04	285.74	303.01	320.28	340.69	359.53	381.51
163	209.94	221.68	234.72	249.39	264.06	280.36	296.66	314.59	332.52	353.71	373.27	396.09
167	215.1	227.12	240.48	255.51	270.54	287.24	303.94	322.31	340.68	362.39	382.43	405.81
173	222.82	235.28	249.12	264.69	280.26	297.56	314.86	333.89	352.92	375.41	396.17	420.39
179	230.55	243.44	257.76	273.87	289.98	307.88	325.78	345.47	365.16	388.43	409.91	434.97
181	233.13	246.16	260.64	276.93	293.22	311.32	329.42	349.33	369.24	392.77	414.49	439.83
191	246.01	259.76	275.04	292.23	309.42	328.52	347.62	368.63	389.64	414.47	437.39	464.13
193	248.58	262.48	277.92	295.29	312.66	331.96	351.26	372.49	393.72	418.81	441.97	468.99
197	253.74	267.92	283.68	301.41	319.14	338.84	358.54	380.21	401.88	427.49	451.13	478.71
199	256.31	270.64	286.56	304.47	322.38	342.28	362.18	384.07	405.96	431.83	455.71	483.57
211	271.77	286.96	303.84	322.83	341.82	362.92	384.02	407.23	430.44	457.87	483.19	512.73
223	287.22	303.28	321.12	341.19	361.26	383.56	405.86	430.39	454.92	483.91	510.67	541.89
227	292.38	308.72	326.88	347.31	367.74	390.44	413.14	438.11	463.08	492.59	519.83	551.61
229	294.95	311.44	329.76	350.37	370.98	393.88	416.78	441.97	467.16	496.93	524.41	556.47
233	300.1	316.88	335.52	356.49	377.46	400.76	424.06	449.69	475.32	505.61	533.57	566.19
239	307.83	325.04	344.16	365.67	387.18	411.08	434.98	461.27	487.56	518.63	547.31	580.77
241	310.41	327.76	347.04	368.73	390.42	414.52	438.62	465.13	491.64	522.97	551.89	585.63
251	323.29	341.36	361.44	384.03	406.62	431.72	456.82	484.43	512.04	544.67	574.79	609.93
257	331.02	349.52	370.08	393.21	416.34	442.04	467.74	496.01	524.28	557.69	588.53	624.51
263	338.74	357.68	378.72	402.39	426.06	452.36	478.66	507.59	536.52	570.71	602.27	639.09
269	346.47	365.84	387.36	411.57	435.78	462.68	489.58	519.17	548.76	583.73	616.01	653.67
271	349.05	368.56	390.24	414.63	439.02	466.12	493.22	523.03	552.84	588.07	620.59	658.53
277	356.78	376.72	398.88	423.81	448.74	476.44	504.14	534.61	565.08	601.09	634.33	673.11
281	361.93	382.16	404.64	429.93	455.22	483.32	511.42	542.33	573.24	609.77	643.49	682.83
283	364.5	384.88	407.52	432.99	458.46	486.76	515.06	546.19	577.32	614.11	648.07	687.69
293	377.38	398.48	421.92	448.29	474.66	503.96	533.26	565.49	597.72	635.81	670.97	711.99
307	395.42	417.52	442.08	469.71	497.34	528.04	558.74	592.51	626.28	666.19	703.03	746.01
311	400.57	422.96	447.84	475.83	503.82	534.92	566.02	600.23	634.44	674.87	712.19	755.73
313	403.14	425.68	450.72	478.89	507.06	538.36	569.66	604.09	638.52	679.21	716.77	760.59
317	408.3	431.12	456.48	485.01	513.54	545.24	576.94	611.81	646.68	687.89	725.93	770.31
331	426.33	450.16	476.64	506.43	536.22	569.32	602.42	638.83	675.24	718.27	757.99	804.33
337	434.06	458.32	485.28	515.61	545.94	579.64	613.34	650.41	687.48	731.29	771.73	818.91
347	446.94	471.92	499.68	530.91	562.14	596.84	631.54	669.71	707.88	752.99	794.63	843.21
349	449.51	474.64	502.56	533.97	565.38	600.28	635.18	673.57	711.96	757.33	799.21	848.07
353	454.66	480.08	508.32	540.09	571.86	607.16	642.46	681.29	720.12	766.01	808.37	857.79
359	462.39	488.24	516.96	549.27	581.58	617.48	653.38	692.87	732.36	779.03	822.11	872.37
367	472.7	499.12	528.48	561.51	594.54	631.24	667.94	708.31	748.68	796.39	840.43	891.81
373	480.42	507.28	537.12	570.69	604.26	641.56	678.86	719.89	760.92	809.41	854.17	906.39
379	488.15	515.44	545.76	579.87	613.98	651.88	689.78	731.47	773.16	822.43	867.91	920.97
383	493.3	520.88	551.52	585.99	620.46	658.76	697.06	739.19	781.32	831.11	877.07	930.69
389	501.03	529.04	560.16	595.17	630.18	669.08	707.98	750.77	793.56	844.13	890.81	945.27
398	511.34	539.92	571.68	607.41	643.14	682.84	722.54	766.21	809.88	861.49	909.13	964.71
401	516.49	545.36	577.44	613.53	649.62	689.72	729.82	773.93	818.04	870.17	918.29	974.43
409	526.79	556.24	588.96	625.77	662.58	703.48	744.38	789.37	834.36	887.53	936.61	993.87
419	539.67	569.84	603.36	641.07	678.78	720.68	762.58	808.67	854.76	909.23	959.51	1018.17
421	542.25	572.56	606.24	644.13	682.02	724.12	766.22	812.53	858.84	913.57	964.09	1023.03
431	555.13	586.16	620.64	659.43	698.22	741.32	784.42	831.83	879.24	935.27	986.99	1047.33
433	557.7	588.88	623.52	662.49	701.46	744.76	788.06	835.69	883.32	939.61	991.57	1052.19
439	565.43	597.04	632.16	671.67	711.18	755.08	798.98	847.27	895.56	952.63	1005.31	1066.77
443	570.58	602.48	637.92	677.79	717.66	761.96	806.26	854.99	903.72	961.31	1014.47	1076.49
449	578.31	610.64	646.56	686.97	727.38	772.28	817.18	866.57	915.96	974.33	1028.21	1091.07
457	588.62	621.52	658.08	699.21	740.34	786.04	831.74	882.01	932.28	991.69	1046.53	1110.51

Table 1: prime-numbered partials in Hz

2.1.3: *Primes* (2006):

Any high string instrument and Max/MSP: 10 minutes or more

Primes is an early incarnation of the interaction model that developed into *Whitewater*, but with a very different harmonic idea. *Primes* is a text piece based on the pure acoustic spectrum, with focus on the dialectic between the computer's perfect spectrum and the near impossibility of the human performer's task to play intervals in perfectly tuned just intonation.

In *Primes*, the performer has a single basic gesture which they repeat throughout the piece, modifying it in response to their own improvisatory skills and to the response of the computer. The gesture is in two-parts: first, an improvised melodic fragment (the score defines a simple melodic model) in long tones which uses only pitches from the harmonic spectrum, and secondly, this then becomes a drone which generates acoustic beats through near unison playing with the computer part: a main source of tension in the piece is this shifting duality of foreground and background as the player moves between melody and drone. The computer has two simultaneous processes, (1) quasi-randomly generating a cloud of sine waves which are prime-numbered partials of a fundamental (signalled by the performer), and (2) generating whichever prime partial is closest to the player's current pitch. The computer part is a quasi-random slave to the performer, it must follow the performer's choice of fundamental (which can be altered in real-time) and has no agency to steer or end the piece.

The performer's part uses 'bounded improvisation': where a boundary is put on the accepted types of material and how it may be used, but within this boundary are infinite possibilities. The score defines only the moment-to-moment interactions, thus the form is emergent, a function of a limited feedback loop between performer and computer. The computer reacts to the player in a very limited fashion, but is constantly undermining and limiting the player's response by its unpredictable actions. Form emerges from a bottom-up process whereby the same macro-gesture is repeated many times, and each repetition is part of an evolving form. Of the two pieces in this portfolio that use bounded improvisation, Primes is simpler than Whitewater because the level of interaction between computer and performer is largely one way: the performer seeds the computer part and then reacts to the computer's material, reseeding it in the process: this forms a loop of seeding → reaction/reseeding → reaction.

Use of bounded improvisation in this piece is extensive and functions to create horizontal indeterminacy at all levels. The player is supplied with harmonic material and a phrase archetype, then expected to improvise around this model. The indeterminacy is double in that the player's own improvisation is indeterminate and then this is subject to modification by the player in response to the computer part, which is itself changing in response to the player. Together this forms a contextual indeterminacy, where the agents act inside a feedback loop of change in response to change. Added to this is the unpredictable nature of the computer patch, errors in analysing the input pitch mean that the computer's output is not always predictable, adding another cause of indeterminacy. It is possible that a poor signal between violin and computer could lead to so many errors that the piece would be undermined—for example, if the trackers never read the pitch correctly and consistently played pitches that the violin could not generate beats from—this can only be mitigated against by careful rehearsal and management of the equipment.

As was mentioned in the chapter introduction, *Primes* stands out from the later pieces in the portfolio because its material is the natural harmonic series rather than the inharmonic soundworlds of most of my works: although like earlier pieces such as *Tracheids* and *The Lady with the Hammer* it does make use of prime-numbered partials to create and inharmonic sounding world from the harmonic series. *Primes* however, also attempts to introduce indeterminacy and impurity to the harmonic series by contrasting the mathematical perfection of the series with the imperfect 'live-ness' of the performer: a similar contrast is used in *Marx* (2008) between the synthesiser and the acoustic voice and viola d'amore.

Like its successor *Whitewater, Primes* is written for solo performer and computer. The computer's material is sine waves whose frequencies are prime-numbered partials of a fundamental that is defined in real-time by the player: the patch listens for three percussive taps in a row, and the pitch-class that follows that is taken as the new fundamental. *Primes* uses prime-numbered partials up to the 503rd and these are, unlike the low end of the harmonic series, very far from tonal sounding. They often have harmonic characteristics that are very close to the inharmonic sounds I usually employ, such as broken octaves or fifths, and local clustering: prime numbers can clump together in small groups, such as {41, 43} or {277, 281, 283} and these create very close clusters as high partials. Assuming a very low fundamental of G♯ = 1.62hz [equivalent to a tempo of 97.2bpm] partials 277, 281 and 283 are a cluster of A4 + 31¢, A4 + 60¢ and A4 + 71¢. Because the part of the patch controlling these sine waves is quasi-random, it is only through chance conjunction that a cluster such as this will arise. But this chance is increased because prime numbers tend to happen in clumps; *illustration 15* shows a section of prime-numbered partials on G♯ = 1.62hz to demonstrate this.

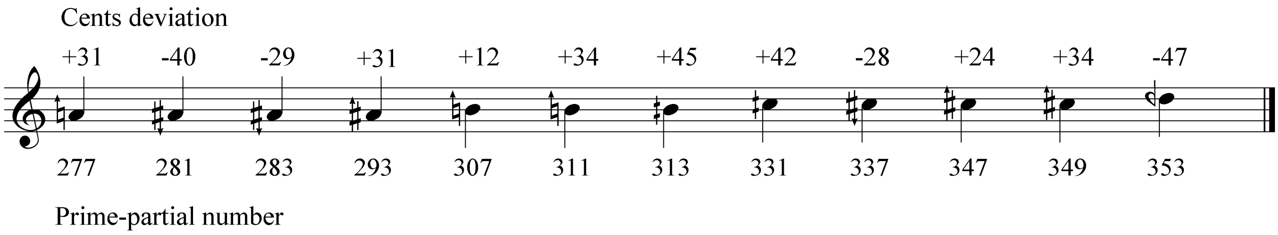

Illustration 15: Prime-numbered partials from fundamental G♯ = 1.62hz

The fundamental pitch was also mapped to the tempo of the randomly generated prime partial sine waves; the fundamental was the tempo. Using the example above, a fundamental of G♯ = 1.62hz is equivalent to a tempo of 97.2bpm. The frequency of the fundamental supplied by the violin at the start of each section is simply divided by 64 to give the tempo for the section. The patch assumes that the violin note sounded is the 64th partial, the player is instructed only to use the octave G3-G4 to sound fundamentals: this reflects that the first performance was by a violinist.

In the harmony of *Primes* there is a conflict between the mathematically perfect harmonic pitches played by the computer and the live player's attempt to match this or to create beats by mistuning to it. Tension in the piece is created by the live player moving between two roles: a foreground role where they play melodies against the web of prime-numbered partials from the computer, and a role where they blend into the computer part by playing long drones around its pitches. This tension is increased by the computer using two 'tracker' drones to detect the pitch of the violin and play the nearest prime partial to it. Beats are generated firstly as a by-product of the violin attempting to play perfectly in just intonation while in close proximity to the perfectly intoned computer pitches, and then deliberately by the live player's drones mixing with the computer's.

The computer is essentially a processor rather than a truly interactive component. The patch follows the performer's pitch, has no agency to change sections or end the piece, and has limited agency to create pitches of its own: only the quasi-random generation of background pitches. The performer has their own material that seeds the computer (providing the patch with something to react to), then the performer responds to the computer's performances. The most suitable metaphor for interaction in *Primes* is that of the ventriloquist act, where the computer is a life-like dummy, under the performer's control.

Primes creates a beautiful soundworld and works well in itself, but falls short of some of its original aspirations. The piece was written early in my research into spectral music and as such it incorporates some ideas which are impractical or not implemented correctly. The main idea was that there would be a clear sense of 'key change' when the violin alters the fundamental during the piece, but this exaggerates the importance of spectral pitches alone in determining key identity: this problem is in the same category as the problem of 'key' identity in *Tracheids*. The point of using prime partials is that they are the least tonal sounding but at the time I failed to make the simple link that tonality requires tonal relationships to be perceivable.

On the recording of *Primes* submitted for this thesis, the performer required a fixed score as she could not fully integrate the improvised element in time for the performance: see *Whitewater* commentary below (2.1.8 Whitewater – p.84) for more discussion of this issue.

2.1.4: Filament (2006)

Guitar quartet: 1 minute

Filament consolidated my work on creating sound objects which are harmonically static on the macro-scale but exhibit complex motion on the scale of the micro-interval. The macro-level structure of the piece is a single gesture that becomes a sustained tremolando chord across the quartet. At the micro-level the chord is based on an E-major/minor triad but uses constant sub-semitonal glissando motion across all the instruments to avoid the chord settling on a single harmonic identity. As *illustration 16* shows, the chord begins with three non-tempered pitches, G5 and two G♯5 with different intonations, bounded by F5 and B5. This sound object is both ambiguous at the level of pitch and (under the right acoustic circumstances) will fuse into a single sound-mass as there are no strong attacks that would allow one instrument to dominate the texture and all the instruments are constantly in motion (both through glissando and tremolando). This chord is sustained for about two thirds of the piece before a recapitulation of the opening gesture leads to a more stable E triad with the upper and lower pitches constant but still with the major/minor ambiguity as G and A♭ glissade[142] across each other.

[142] The word 'glissade' is taken from the writings of Alvin Lucier and James Tenny as a more elegant alternative to using 'glissando' as a verb: compare 'glissading' to 'glissandoing'. 'Glissade' has a similar root to 'glissando' in that it also means in French 'to slide'. See the Lucier quotation on p.37 (footnote 56).

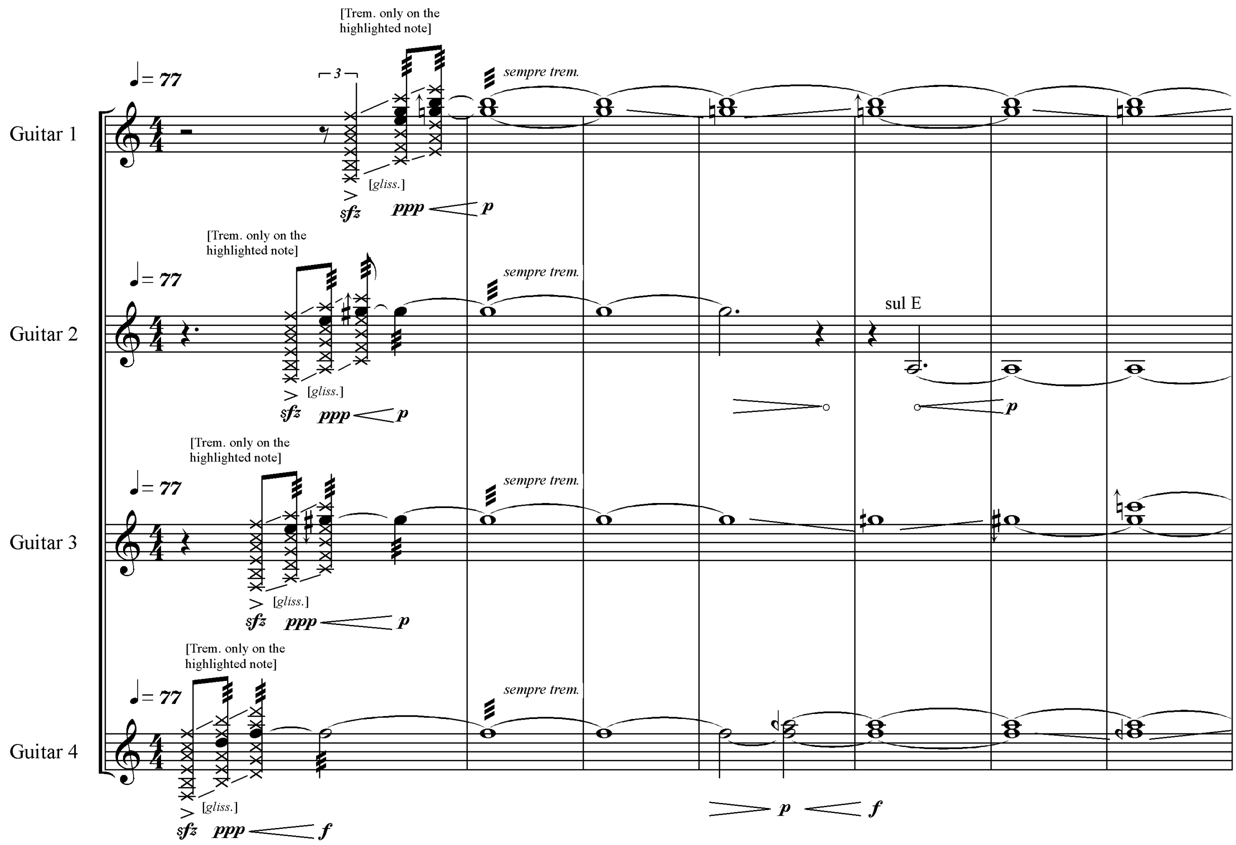

Illustration 16: Filament, opening bars showing sustained chord

Creating this pitch ambiguity derived from my interest in inharmonic spectra and is based on my attempts to model my harmony on the harmonic attributes that I had observed in bell-like sounds. The *Filament* chord is thus based on a triad but with multiple simultaneous contradicting pitches such as the multiple major and minor thirds that are all unequally tempered to some degree, as well as the flattened dominant (B5 -50¢) and the sharpened tonic (E5 +50¢, or sometimes a semitone sharp at F5): there is always one tempered triadic pitch present in the chord in any given bar, but this is always compromised by other untempered triadic pitches. This harmonic development was a step towards vertical indeterminacy, the pitches within the chord are unstable but it is a carefully defined instability and localised to a specified harmony and tonic.

2.1.5: Inner Shadow (2006)

Violin, cello, bass clarinet, accordion, acoustic metronome: 6 minutes

Inner Shadow was commissioned as part of the Samuel Beckett centenary celebrations in Dublin. Samuel Beckett has always been a powerful source of inspiration for me, especially in his construction of ambiguity, both in language and in form. The influence of Beckett in this piece may also explain the use of theatrical gestures in this piece as they appear in almost no other work of mine: the last minute of the piece the violin and bass clarinet slowly walk off-stage while still playing, and there is an acoustic metronome which beats at 60bpm for the duration of the piece, thus the piece is bound by the gesture of the metronome being switched on and off.

This piece continues my development of close harmonies with microtonal clusters and perceptually fused sound objects. Formally the piece is a series of sections based on the same material and marked by abrupt transitions: sometimes to silence and sometimes to a static bridging passage. The material in each section is based around a microtonal cluster and as in *Filament* the harmonic identity of the chord is in flux because at any given moment at least one pitch in the chord is glissading slowly across a sub-semitonal interval. This internal motion imbues the chord, and thus the sound-object as a whole, with an inner life made up of beating patterns and timbral fusion between the instruments, all of which leads to a level of ambiguity between chord and timbre/sound-object.

Inner Shadow is an early score of mine to include indeterminacy: one of my first experiments in that area. Despite the metric notation—although the first version was a quasi-graphic score—some of the main sound attributes are not fully notated and thus become indeterminate to a certain degree; indeterminate within certain boundaries. The score is metric in order to keep the players together but the pitches are often microtonally indeterminate (a little sharp or a little flat) and the texture is dependent on the pulsing of the instruments, this is only included as a text instruction in the score so the exact speed of pulsing is indeterminate.

The graphic score (which, unfortunately, has since been lost) was not abandoned because it did not represent the music properly; I moved to a metric notation purely because the ensemble found the graphic score too awkward to learn quickly, they wanted something in a language that they could assimilate quickly. I believe that the graphic score was a more truthful representation in that musical elements that were loops were portrayed once and the player looped them, this is to my mind a more truthful representation of the nature of the loop than the metrical grid representation. The graphic score also showed more clearly when instruments played together—a gesture for example—and when they were independent, while the metric notation at least implies rhythmic concurrence if not outright defining it, and this undermines the attempt to portray certain phrases as being rhythmically independent. The graphic notation may not be perfect, but it is closer to my intentions. The metric notation is not ideal, but at the time it was a fair compromise given the limited rehearsal time.

The use of the metronome was not originally intended to be theatrical, it ended up being so because it seemed (to the ensemble) to make more visual sense if I walked to the stage and started the metronome, rather than a member of the ensemble doing it: I appear to 'switch on' the piece. The ticking of the metronome is a constant element in *Inner Shadow* that acts to gauge how static the ensemble music is. When the ensemble music is active, the metronome fades into the background as one more mechanism in a cluster of mechanisms. When the ensemble has more static music, the metronome comes insistently to the foreground. There is no counterpoint between the two because the rhythm of the instruments is mostly an indeterminate but constant pulsing that the metronome simply blends into. When the instruments are static and sustaining the metronome stands out as the only moving sound: in gestalt perceptual theory, this is the principle of figure and ground, a combination of principles that (mainly) describes the grouping of moving objects against a relatively static background.

As an aside, after the first performance of *Inner Shadow*, a member of the audience mentioned to me that Beckett often used a metronome in his rehearsals to train the actors to move with a certain timing, I am unable to find reference to this in sources on Beckett but would like to believe that this is accurate, not to validate my use of the metronome but merely as an interesting coincidence.

2.1.6: Distemper (2006)

Solo equal-tempered plucked/struck string instrument and Max/MSP: 10+ mins

Distemper is the first in a projected series of works called *The Book of Functional Harmony*, all of which use Max/MSP to deal with the problem of writing in my microtonal language for equal-tempered instruments. Each piece solves the problem in a different way and with a different aesthetic, some are game pieces and some fully composed.

The approach taken in *Distemper* is to record long sections (typically 1 minute long) of audio in real-time and then play them backwards—by reversing the file—and slightly faster or slower to alter the pitch. One objective of this technique is to create beating patterns between the real and recorded parts. For the other objective, the recorded part is played back in reverse to allow the player to create sound events without attacks. The player must time their attack so that it coincides with the reversed attack in the recorded layer. This should create a sound object with a long fade in (the reversed tail of the note) that crescendos to the doubled attack of live and recorded note and then fades out on the long tail of the live note. These recorded layers then build up in a manner that owes a large debt to Alvin Lucier's *I am Sitting in a Room,* partly because of the increasing density of the piece and partly because the piece echoes Lucier's wish (as he says in his piece) to 'smooth out any irregularities [his] speech might have'[143] by smoothing out the instrument's attacks. *Table 2* shows the layering of sections as they alternate between normal and reversed playback.

	Section (time→)									
Live	A	B	C	D	E	F	G	H	I	J (tacet)
Computer		A rev	B rev A	C rev B A rev	D rev C B rev A	E rev D C rev B A rev	F rev E D rev C B rev A	G rev F E rev D C rev B A rev	H rev G F rev E D rev C B rev A rev	I rev H G rev F E rev D C rev B rev A

Table 2: sections in *Distemper* showing layering of recorded parts.

The speed alterations are applied more intuitively. To avoid a sensation of sudden pitch change at the beginning of each section, the speed alterations are applied gradually; ten seconds at each end of the file playback are devoted to accelerating or decelerating the recorded part—to and from normal speed—as required. As the piece builds up layers the various speed changes cause layers of beating in different registers. In *Illustration 17* the computer part (lower stave) shows reversed sounds with hairpins indicating approximate length of tail and the letters 'd' or 'u' indicating whether the pitch will be down or up relative to tempered pitch. This version of *Distemper* uses a single pitch class (E) almost exclusively in order to highlight the beating patterns: this also draws on Lucier's approach in that the composition is limited to the phenomena that the composer wants the listener to hear, eschewing other surface musical details that may distract without contributing to the phenomena (in this case, the beating effect between closely tuned pitches, and the smoothing of the attacks by introducing the reversed sound-tail).

[143]Lucier, Alvin, *I am Sitting in a Room* (New York, 1970).
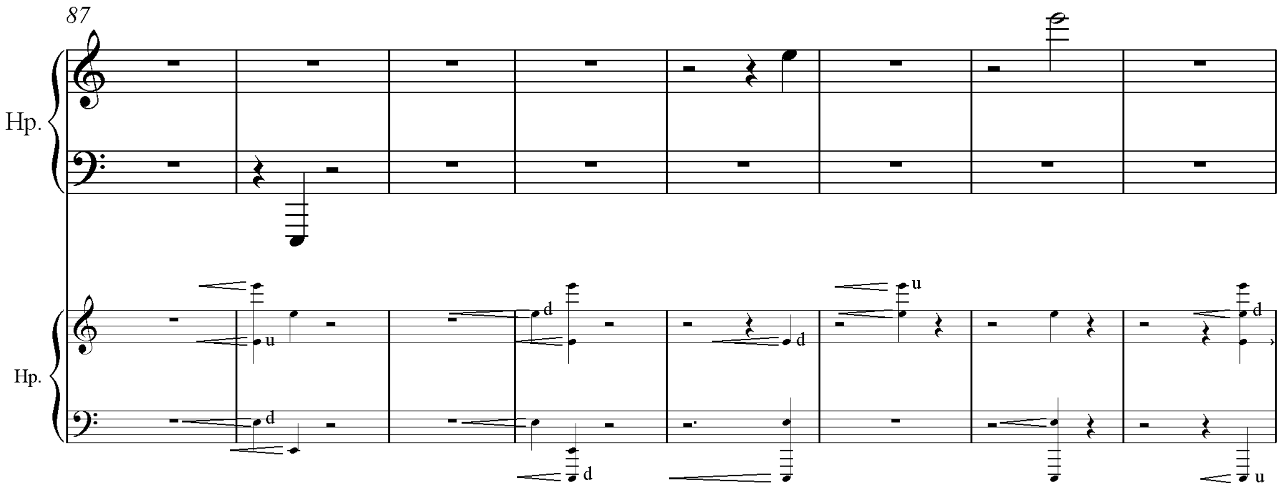
Illustration 17: Distemper, section D. Upper stave is live part and lower shows computer part (playback of recorded live sections, hairpins indicate reversed sounds).

The version of Distemper submitted with this portfolio is fully notated. I was interested in doing a version that allowed bounded improvisation but never found the right set of boundaries, this remains a possibility for a future version.

2.1.7: Five Bells for Elliott Carter (2006)

String quartet: 8mins

Five Bells for Elliott Carter – Orch. (2008)

String Orchestra - 12 violin, 6 viola, 6 cello, 2 double bass: 10mins

This work—in both versions—begins with the premise that the twelve note chord which both opens and closes Elliott Carter's *3rd String Quartet*[144] can be frozen in time. The chord is frozen in a process which alters the intonation and dynamic weighting of the pitches in order to make them more like a generic bell spectrum. Many possible bells can be made from Carter's chord, the piece's moves through several of these before returning to the Carter original. To stay close to the Carter—and allow my piece to act metaphorically as an extension of it—this piece was written for string quartet, but that was found to be unsatisfactory for various reasons and so I rewrote the piece for string orchestra—scores for both have been submitted in the portfolio but only the string quartet version has been recorded so far. The following discussion will begin with the quartet version and then move

[144] Carter, Elliott, *String Quartet no.3*, (New York, 1973).

on to the rewritten version and the reasons for the rewrite.

Carter's twelve-note chord requires all the performers to play triple-stops, a technique that requires very heavy bow pressure and cannot be sustained for long. The intensity of the triple-stopped playing then gives way to the static tableaux of the chord frozen in slow legato arpeggios. The players maintain the same pitch-classes for eight minutes, with subtly altered intonation and gentle dynamic shifts as the piece progresses through a series of bell-like configurations. The bell spectra are created by emphasising two opposing harmonic centres within the chord and so creating a multistable harmonic object. This is achieved by altering the intonation of pitches in such a way as to create ambiguity around which harmonic centre each pitch belongs.

Illustration 18 is an excerpt from my score showing the original Carter chord and the first few transformations—note that transformations are randomly ordered rather than sequential. Dynamics have been removed from this example but the reader can assume that single pitches are focal, thus have higher dynamics, and small noteheads in chords are pitches to played very quietly. The second chord in *illustration 18* is made bell-like by choosing the viola B♭3 as the strong partial. To support this the violin's top G♯6 is flattened slightly to make it a 7th partial and the second violin's F5 is the 5th partial. Common attributes of bell-like spectra include the prominent minor 9th, B5 in this chord, and placement of the major third D (D3 on the cello) below the perceived fundamental while the minor third C♯4 is above it; the minor triad sound is especially characteristic of church bells, a well known example being those of St Paul's Cathedral in London. Beats are created between the viola's F5 and flattened G♭4. A secondary strong tone G3 should also be apparent due to the strong support of its 5th partial B5 in the violin and the cello's D3.

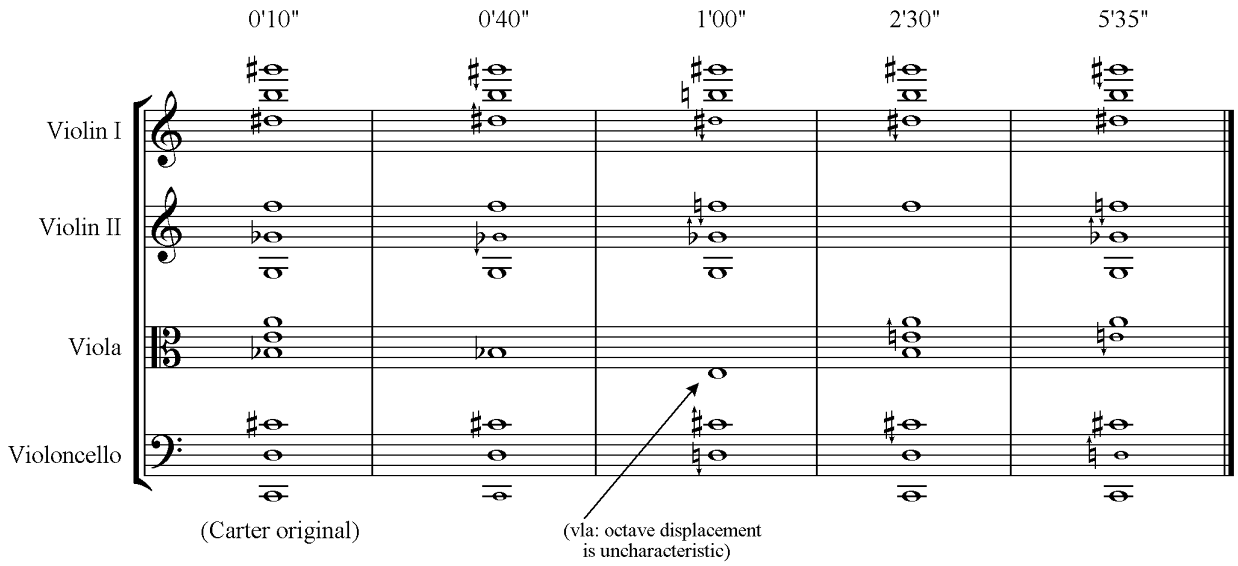

Illustration 18: Carter's chord and some transformations from *Five Bells for Elliott Carter.*

In *Five Bells for Elliott Carter,* the degree of mistuning due to notational imprecision is not significant. As each separate chord in the piece is a different alteration of Carter's original total chromatic chord in such a way as to imply a bell spectrum, the degree of mistuning is not as important as the fact that successive chords are different, thus contributing to the form of the piece. As was shown above, the bell spectra pitches involve either altering a pitch in twelve-tone equal temperament so that it matches a harmonic partial to support a lower pitch in the chord, or altering a pitch to create unison or octave beats within the chord. Because the bell spectra are inherently inexact in terms of strict mathematical relationships between partials there is no need for notational precision here.

The score controls the macro-form of the chord sequence by specifying the timing, dynamic and intonation for each section. The moment to moment details of the note movement are left indeterminate. A simple example of this is in defining events by bow and breath lengths—seen also in *Lorenz*, *Nano* and *Whitewater II.* This is partially used to avoid notes and events being broken up by a bow re-taken or a new breath, which is never smooth enough not to break a still sound. The other reason is to generate a time unit which is variable in duration but within limits. The duration of a violin bowstroke for example is dependent on parameters such as register, dynamics and tone colour but will generally last between six and ten seconds. This may seem like a wide variation—and in a faster and more rhythmically dynamic piece it would be unacceptably wide—but in slow music such as this the differences at note-level are not in the perceptual foreground: they are all simply 'long notes'. In *Five Bells for Elliott Carter* this is used to blur the chord changes. The players are bowing independently, with full bow draws each time, but must complete each bow before changing pitch. So when the time indication for a chord change arrives, they must finish their bow before changing, thus staggering the chord.

The piece has been performed on two occasions; the premiere was by a student group who were not a regular quartet, and the second performance was at the Ostrava Days Festival 2007 by Sonar Streichquartett. While both performances were well received, neither performance of the work has been entirely convincing to me because the expected harmonic fusion was not perceivable; the changes to the intonation and pitch weighting did not create bell-like sounds. There is no perceptual fusion because the players are bowing slowly alternating double stops rather than sustained chords and no matter how smoothly they bow it is still possible to perceive each player separately and so the pitches do not fuse into a unified—although multistable—timbre as expected. I assumed after the first performance that these problems were due to inexperienced players, but the Sonar Streichquartett performance showed that the problems were built into the piece.

On another level the piece still 'works' because there is a sense that something is always changing and the piece keeps moving. But the piece does not work in the way it was originally supposed to. However, I still consider the quartet version to be a viable piece because I like how it sounds and accept that the thought processes used to compose a piece are not necessarily related to how a piece should be heard. The quartet version sounds like a piece of music, not like a failed experiment. The failure of the idea behind the piece to work opens up the possibility of a new version that addresses its problems, I see the problems as being that:

- The string quartet as a medium is too thin for the proliferation method I used. If all players attacked the chord simultaneously each time then perceptual fusion may have been more successful, but the overlapping entries allowed individual instruments to stand out too much, this undermines the perception of all four instruments as a single timbre.
- The 1st violin part is very high, even good players cannot sustain these double-stops without some squeaking: the Sonar Quartet's 1st violinist used a mute in their performance, this alleviated the problem slightly. Perhaps replacing the upper note with harmonics would work, if this were feasible. Lowering the A-string to Ģ would be an elegant solution but would require that the top note be fixed, with no intonational changes possible. This would be acceptable as the note is so high that

it does not blend well with lower pitches but a harmonic may be blend better.

The solution to these problems was to rewrite the piece for a larger string group. In 2008, *Five Bells for Elliott Carter – Orch.* was written for 12 violins, 6 violas, 6 cellos and one double bass. The first alteration is that the strings no longer play arpeggios so that there is less motion within the chords. Also, this means that all the pitches are audible continuously, thus increasing the possibility of spectral fusion. Because each player now only has a single pitch—or occasional double-stop—to sustain, there is more room for controlling the morphology of the chord through dynamic swells. These link particular pitches together due to the gestalt law of common fate: if there is no other dynamic motion within the sound mass then a group of pitches swelling together should be treated by the ear as a single object. If there are multiple groups of independently swelling pitch groups within the chord then this should foster ambiguity as to which is the pitch centre, or which relationships the ear should follow.

Many decisions about register and orchestration have been taken with respect to spectral fusion. For example, at time index 5'35" the strongest note is A4 in violin-6, but this is played on the G-string where it is so far up the neck of the instrument that the short string length creates a very muted sound, compounded by the instruction to play *sul tasto*. This means that although it is the loudest pitch by dynamic it should not stand out from the chord as it is weak in high frequency overtones, the overtones of the other pitches will mask these and allow the A to blend. The muted sound for one group of pitches in this chord is contrasted with a mistuned G♯ minor/major triad in violins 1, 2 and 5 played *sul ponticello* that due to its low dynamic may or may not be perceivable as a separate sound object, I would hope that the effect is subtle enough to cause a disturbance in the overall perception of the chord and not enough for it to become a separate percept.

In some other cases the strong pitches in the chords are allowed to stand out, not all the chords are orchestrated to create such ambiguity. I elected to avoid an overly dogmatic approach to orchestrating the chords, the variation between orchestrational principles allows each chord to have its own character, rather like bells in the real world.

Other alterations include the maintaining of the string quartet for the loud beginning and endings of the work, this keeps in place the metaphorical association with Carter's quartet and also means that when the full string ensemble comes in there is a change of space from the chamber to the orchestral, to reflect the change in how time will be perceived relative to the soundworld of Carter. The piece has also been extended slightly by making all the sections 20-30% longer, to allow more time for each new chord to settle and for the ear to be pulled into the new harmony more—thus more time for psychoacoustic effects to come into play and for the mind's ear to create relationships in the harmony.

2.1.8: *Whitewater* (2006)

Any wind instrument(s) and Max/MSP: 15 minutes or more

The aim of *Whitewater* is to use multiphonics as harmonic material and focus on their inharmonicity. The piece also aims to build on the interaction model used in *Primes* and make a piece that is truly interactive on the harmonic level. To achieve this, *Whitewater* uses bounded improvisation with a choice of material that is wider (any stable multiphonic and its constituent single pitches) but with a more robust harmonic identity than *Primes. Whitewater* also improves on the interaction by using a computer patch that has equal agency to the live player in terms of leading the evolution of the piece.

To contribute meaningfully to the harmonic evolution of the piece and on an equal footing with the live player, the computer uses a cellular automaton as a life-like spectral filter. The computer analyses the input multiphonics in real-time and responds with its own version in the form of sine waves, the computer then breeds new versions of the multiphonic by treating each partial of the spectral data as a cell in a cellular automaton—see below for a detailed discussion of the cellular automaton. The player's subsequent interaction with these 'bred' multiphonics creates a loop whereby the cellular automaton keeps altering the data and at the same time is constantly reseeded by new data from the performer, which is itself is a response to the what the computer does. Unlike *Primes*, the computer here has complete agency, it has the same level of responsibility as the performer to alter or stop the piece. The computer's agency is quasi-random and not a true intelligence like the live player, but the material and the interactions allowed by the score are simple enough for both agents to contribute equally: in effect, the live player is brought down to the level of the computer in terms of decision making. Left to its own devices, the computer may become locked in a loop or may simply stop, depending on the particular material in circulation at that moment, the player's job is to lead the computer – as a charmer leads a snake.

2.1.8.1: Cellular Automata

For me, if one chooses to accept a definition of music as organised sound, the organisation needs to be perceivable on some level. For music to be understandable it must have a level of perceivable organisation which falls between two possible states—the extremes and boundaries of which differ for each listener. At one extreme is the state of order[145], with minimal variety and maximal predictability, while the other extreme is that of maximal variety and correspondingly minimal predictability known as chaos. Music is a lifelike entity which exists in the area between these two states.[146]

Strange attractors also exist in this 'inbetween' state which is characterised by a variable mixing of order and chaos. The attractor never comes to rest in either state but also doesn't necessarily fall into a periodic oscillation; it may be infinitely varied. Strange attractors sit at this boundary between chaos and order in the same way that indeterminacies in music may oscillate in a seemingly random way inside a fixed space. In my portfolio are examples that represent this process in sound, such as the ever shifting harmonic relationships between live multiphonics and the evolving computer-generated multiphonics in *Whitewater*, or the overlapping independent lines of *Lorenz*.

Cellular automata are a class of logical automaton processes in which the repeated application of simple interactive rules to a set of two state (on-off) cells on a grid can produce an astonishing variety of complex systems.

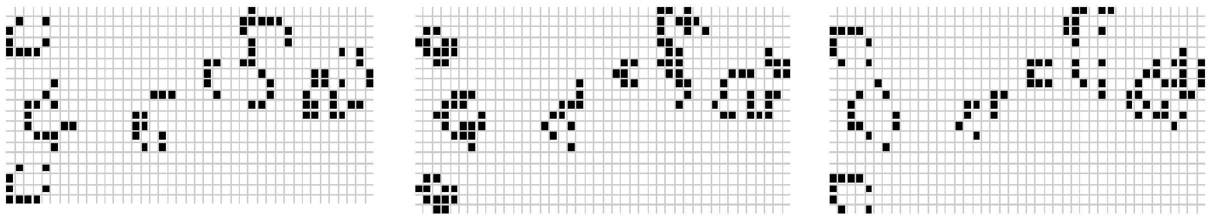

Illustration 19: Three successive generations of a Game of Life cellular automaton (l-r).

The best known example of these is John Conway's 'Game of Life' from 1970, which owes its name to the surprisingly life-like dynamic structures which can arise from many starting conditions. *Illustration 19* shows three successive generations taken from a Game of Life run. The continuous evolution of the shapes is clear even in a small sample such as this. Cellular automata are used in my piece *Whitewater* as the engine by which the computer evolves material from the multiphonics received as live input.

From my musical perspective, systems that lie between chaos and order—represented by cellular automata such as Game of Life—are the most interesting because they maintain

145As an aside. In the Discworld novels of Terry Pratchett there are minor characters called 'the Auditors' whose purpose it is to reduce the Universe to extreme order by removing all variety and individuality. They occasionally fall foul of a fatal attack of vanity by referring to themselves in the first person. See Pratchett, Terry, *Reaper Man*, (London, 1991) or Pratchett, Terry, *Hogfather*, (London, 1996)

146Eco, Umberto, *The Open Work*, (Cambridge MA, 1989), 51.

the balance between known and unknown that is essential for musical interest. This is put to work in my portfolio most clearly in the works which use text processes and bounded improvisation rather than fixed scores. The rules defined in the text score allow the piece to self organise in a manner analogous to the self-organisation of cellular automata and strange attractors. By limiting the mechanism of transformation, the identity of the piece stays within acceptable limits to ensure it always sounds like the same piece. By working within a continuum—such as frequency values instead of discrete pitches—there is an infinite range of possibilities for evolution so that the space is never exhausted.

The Max/MSP patch for *Whitewater* uses a cellular automaton to filter partials. Under the cellular automaton rule system, cells may tend to the extreme states of either chaotic proliferation, or total order if all the cells die. What is more typical is the middle ground solution, that the grid settles into one of an infinite number of possible states of periodic oscillation: where some or all of the cells are locked into a predictable pattern. For *Whitewater*, this is the most musically interesting phenomenon as it allows the player greater options for interaction.

However, the preceding description of generic cellular automata refers only to the process itself, the system becomes more complex once we examine its application in *Whitewater* where the cellular automaton is a process embedded in a two-agent text process. In this situation, rather than being left alone to evolve after the initial seeding of the cells, the interaction between player and computer is constantly reseeding the automaton with new cells, which leads to a considerable degree of indeterminacy and iterative feedback.

The cellular automaton in *Whitewater* is in effect a complex filter acting discretely on the partials of the input sound. This approach appears to differ from previous implementations of cellular automata in music, which mainly fall into two large paradigms: (a) note-to-cell mapping which focuses on localised pattern variation in midi/note-based music; (b) Granular synthesis implementations, focusing on stochastic pattern variation and swarm effects in timbre-based music. For a more detailed history of cellular automata implementations in music, please refer to the article by Burraston and Edmonds titled 'Cellular Automata in Generative Electronic Music and Sonic Art: A Historical and Technical Review'.[147]

For *Whitewater*, neither of these earlier approaches were suitable. Because *Whitewater* uses spectral definition and discrete frequency content rather than quantised pitch-values, I wanted to avoid implementations which were based on the mapping of graphical cells to

[147]Burraston, D., Edmonds, E., 'Cellular Automata in Generative Electronic Music and Sonic Art: A Historical and Technical Review', Digital Creativity 16/3, (2005), 165-185.

fixed pitch values. Similarly, the swarm-effect paradigm doesn't allow sufficient control at the frequency level. Rather than controlling stochastic distributions of frequencies, I needed to be able to manipulate individual partials (frequency/amplitude pairs) which change over time.

My initial idea was to take the partials of a sound and treat them as though they were cells on a cellular automaton grid. This idea was refined by Pierre Alexandre Tremblay who suggested replacing the unworkable grid concept with a frequency continuum—an approach which fits much better with my compositional language in general. In this approach, the cell's neighbourhood is defined as a musical interval. Thus, applying the same rules as above, if there are either three or four partials alive in the neighbourhood then the partial being tested remains alive, otherwise it dies: for example, if the neighbourhood chosen is a major 2nd, then if there are three or four partials within a major 2nd of the partial being tested then that partial is not filtered out. This mechanism was coded by Dr Tremblay as the *spectralConway* object; in the *Whitewater* patch *spectralConway* is used in its javascript version and further references in this document to *spectralConway* will always mean the javascript version—see $$$$*Appendix X* for the complete javascript code.

The Max/MSP patch contains a javascript object that is emulating the cellular automata, while Max/MSP itself is only doing two relatively simple tasks: pitch analysis is carried out by the *fiddle~* object, and the resynthesis is handled by two *ioscbank~* objects that process alternating pitch sets and overlap each other in time to ensure there is no break in the sound. The pitch analysis happens in two sections:

1. The raw spectral data is constantly being filtered through *sprintf* into a *coll.*
2. *Fiddle~* registers an attack then (after a 10ms delay to bypass the attack transient) sends three 'dump' messages to the *coll*, with 1000ms delays between each after the first. *Fiddle~* is configured to read the 15 strongest partials in the signal but often only finds six or seven. The three dumps method ensures that enough partials are sent from the *coll* into the *spectralConway* javascript engine

Once the data is sent into *spectralConway* then the javascript takes over.

1. A temp array is created to handle the incoming frequency/amplitude pairs and these are sorted by frequency.
2. The index of dead and alive cells is checked and if there is at least one dead cell then that is replaced with the next new frequency/amplitude pair from the temp array. This process continues until all the dead cells have been replaced or the temp

array is empty.

3. The new array of live cells is output into Max/MSP as frequency/amplitude pairs to be rendered as audio by the *ioscbank~* objects.

The cellular automata in *spectralConway* will continue to run as long as the 'evolve' message keeps being sent from the Max/MSP patch. The 'evolve' function in *spectralConway* runs steps 1-3 above and processes a new generation of cells in the automata. The purpose of the automata is to vary the spectra from the live sound and provide a foil for the live improviser, and if there was only a single sound played live then the automata process would tend towards its states of silence, chaos or periodicity. Each time there is new input from the performer then the automata is being reseeded with new data, thus the computer part is constantly being interrupted by the player. Equally, the player's attempts to form phrase-level objects are interrupted by the computers evolving harmony. This relates to the form of *Lorenz* in that the different agents are impeding each other, and from this struggle arises the form.

The basic mapping of the multiphonic onto the cellular automaton is the beginning of the evolution process. The cellular automaton is itself an indeterminate process (dependent on hysteresis and sensitive to tiny changes in input) inside the web of indeterminate processes and feedback systems that make up *Whitewater.* The computer part begins as a sonic near-match to the live multiphonic and then follows an indeterminate path to several possible states; including the extreme states of silence and chaos. However, the most likely end state is a periodic oscillation between a small set of pitches or timbre complexes.

The computer's output then becomes an element in the live player's text process. Because the live player is trying to create beats with the computer part, there is an internal feedback loop that pulls the player back to the pitch of the computer. But the interaction with the computer is a component of the computer's own feedback loop which modulates its partial set with the most recent live pitch. This could be a static process but for the indeterminate nature of both agents' responses. The live player will deviate slightly from the computer's pitch in order to create beats, and this deviation will in turn become multiplied through a frequency modulation process. Whatever is generated from this frequency modulation process will then be filtered by the cellular automaton—which is indeterminate in itself—before being returned to the live player who starts the process again. To add a level of complexity, the computer patch inserts an extra frequency modulation process as an internal feedback process between the live input and the filtering cellular automaton. The filtering process is continuous, while the frequency modulation happens only when there is an input, thus the computer part tends to vary in cycles related to the activity of the live player. This is one of the main sites of vertical indeterminacy in the piece. The player has a level of control over the multiphonics and pitches but their evolution is dependent on a multivalent feedback process with several rule-sets operating simultaneously.

In Whitewater, spectral modelling is performed by the computer by analysing the real-time input of the solo performer. The computer takes the multiphonics of the player and 'breeds' eccentric variations before resynthesising them from sine waves and playing them back. The breeding process is performed by a cellular automaton acting as a filter that removes partials according to a proximity-based rule system; the rules favour small clusters separated by large intervals. Because the cellular automaton only removes partials, the computer patch includes an internal feedback system which adds extra partials derived by modulating the incoming partials against the most recent pitch played by the live player. As was seen earlier, a high degree of pitch material in multiphonics is derived from modulation and this extra process adds to the material in an indeterminate way which is dependent on the immediate pitch context as it evolves—which happens as some partials are filtered out and others added in. The evolution of this material is entirely dependent on both the text process in the score and the computer patch.

2.1.8.2: Bounded Improvisation and Performance

Whitewater takes the principles of bounded improvisation and interaction in *Primes* one step further by giving the computer part complete agency. This is achieved by allowing the computer to vary its own material via a cellular automaton. The feedback model described for *Primes* is essentially the same, but increased in complexity as the computer part is now undergoing spontaneous transformation: the ventriloquist's dummy takes on a life of its own, making the ventriloquist speak in tongues.

The bounded improviser playing *Whitewater* may use any stable multiphonic and its constituent single pitches (and intonational variants on these) as material. The phrase level ordering is not prescribed other than that long notes must be used: as is largely the case in *Primes,* this is both aesthetically pleasing and allows the computer time to react. As in *Primes*, the improviser is using the computer part as a duet partner, but here the partnership is more evenly balanced as the machine has its own agency. In *Primes*, the player could stop providing input and the patch would continue to play, giving the impression of agency. But in reality this would only be the randomly generated partials sounding, the trackers would simply maintain the last pitch they detected. *Whitewater* on the other hand can continue indefinitely without input (apart from the initial seeding). The piece would then be subject to the whim of the automaton's life-like processes, but it would still be evolving and 'performing'.

This raises the question of why bounded improvisation is necessary at all: why not simply write a fixed score for *Primes* and *Whitewater*? For it to be necessary, the improvisation must be doing something extra and unique. On a practical level, the improvisation is a way to deal with the inequities of the patch's response to the live input. There are both deliberate and accidental elements of unpredictability inherent in these patches, the only way to respond to these is to have an equally unpredictable live part. More importantly, the feedback loop which is central to these pieces needs this constant evolution to keep going, and to maintain the tension of repetition against variation. Without the feedback loop, the live player may as well be soloing karaoke-style over a tape part.

There's also the social element, that a piece like these requires the player's total commitment; these pieces cannot be sight-read, they require immersive learning before they can be performed. This is about making more of the experience for the player, to take the time to have true ownership of a piece, if it is what interests them. As the American painter Georgia O'Keeffe said:

> Nobody sees a flower, really — it is so small — we haven't time, and to see takes time, like to have a friend takes time.[148]

Bounded improvisation and free notation leave temporal decisions in the hands of the performer. The indeterminacy in these pieces is tempered by what the performer brings to the piece in terms of their own voice and performance reflexes both positively and negatively. On the positive side, each performer's version explores a different area of the piece's phase space (the set of possibilities within the boundaries defined by the score), ultimately enriching the piece. On the negative side, the performer may bring too much from other music and end up applying forms inappropriate to the pieces. There is no stricture against this in the score because the specifics are unforseeable; it is a risk that I accept, and can be mitigated against in practice through rehearsal and careful choice of performer. As an example of this, I took the piece to bassoonist and free improviser Mick Beck, who specialises in the manipulation of multiphonics. While the initial few runs went well, it soon became clear that the player found the piece's limitations to be too stifling. The piece can only support long sustained pitches, and this became aesthetically tiring for the player. We tried some variations where short notes were used and this was fine as long there was a lot of space between them, but any attempt to play melodic or gestural

[148]O' Keefe, Georgia, 'Quotes', (No Date), <http://www.georgia-okeeffe.com/quotes.html>, accessed 15/08/08.

music into the patch was unsatisfactory as the computer could not respond in kind. We considered the option of using a footswitch to occasionally cut off the input to the patch so that the player could improvise in whatever way they chose without affecting the patch's output. This would allow an improviser to take more control but it would also destroy the feedback loop between player and computer: it would turn the computer into an accompanist.

As with *Primes*, the score for *Whitewater* defines the interaction from the bottom up without defining an overall structure. The piece's form emerges from the interactions being always different but the same. *Whitewater* has a robust identity due again to the limited soundworld. The flexibility of the form means that it can be performed as a concert piece or as an installation. In the past *Whitewater* has almost exclusively been played as a solo concert work, but recently there has been a very successful version with three simultaneous players who moved through a space with multiple microphones and speaker arrays. This is something that has a lot of potential for the future of this and other pieces.

The first few performances required that a loose score be prepared for the player. This was mainly so that the performer could be confident that they were playing the piece 'correctly'. Using a fixed score creates a performance problem, because the computer's response cannot be predicted from version to version (the patch is sensitive to initial conditions), the performer would become disoriented when they are following a score which the computer is not referring to: this leads to the computer making decisions that the performer must react to but which bear no relation to the score. Hence the piece only truly works with improvising players, a score is fundamentally incompatible with the piece but is acceptable as a learning tool. However, the piece is also problematic for improvisers due to its limitations. As was mentioned above, the player has infinite possibilities within a small area, but the simplicity of this in some ways reduces them to the machine level of decision making. Players who come from certain free improvising traditions can find this stifling and become disinterested. This piece works best with players who can strike a balance between reacting to an ever changing context and not straying outside its boundaries.

2.1.9: For Garrett Sholdice (2007)

Oboe, violin, piano: 6 minutes

This piece is one that I enjoy but do not consider a successful piece simply because the soundworld and construction betray the influence of Morton Feldman too strongly:

Feldman is omnipresent in my musical thinking, his methods and aesthetics are echoed in much of my music, but this piece actually sounds like Feldman and this is a step too far for me. Once I had realised how much Feldman was in the piece I decided to title it in the manner of Feldman. Garrett Sholdice is a young Irish composer whose work I greatly admire, the decision to title the piece for him came after hearing an excellent work of his which reminded me a little of Feldman, and activated my feelings of being too close to another composer's sound.

The most Feldmanesque element is the piano writing with its softly arpeggiated chromatic clusters across several octaves. Feldman made great use of such distended clusters in his music, especially the late piano works such as *Triadic Memories* where many of the harmonic configurations come from displacing the individual notes of a cluster by one or more octaves. Feldman often created ambiguity between subsequent events by slightly altering their rhythmic profiles—especially where the pitch content stays largely the same from event to event—so that the level of change was on the edge of what can be perceived.

In *For Garrett Sholdice*, the same type of ambiguity is explored through repeating the same ascending arpeggio gesture for long periods and subtly altering each iteration. With each iteration the pitch set changes slightly, the pitches do not appear in the same register in subsequent bars, and each arpeggio is always in a crotchet rhythm but the length of the bars—and by corollary, the number of pitches in each arpeggio—changes from bar to bar: see *illustration 20.* The oboe and violin contribute to this same ambiguity through very slight alterations to their respective intonations.

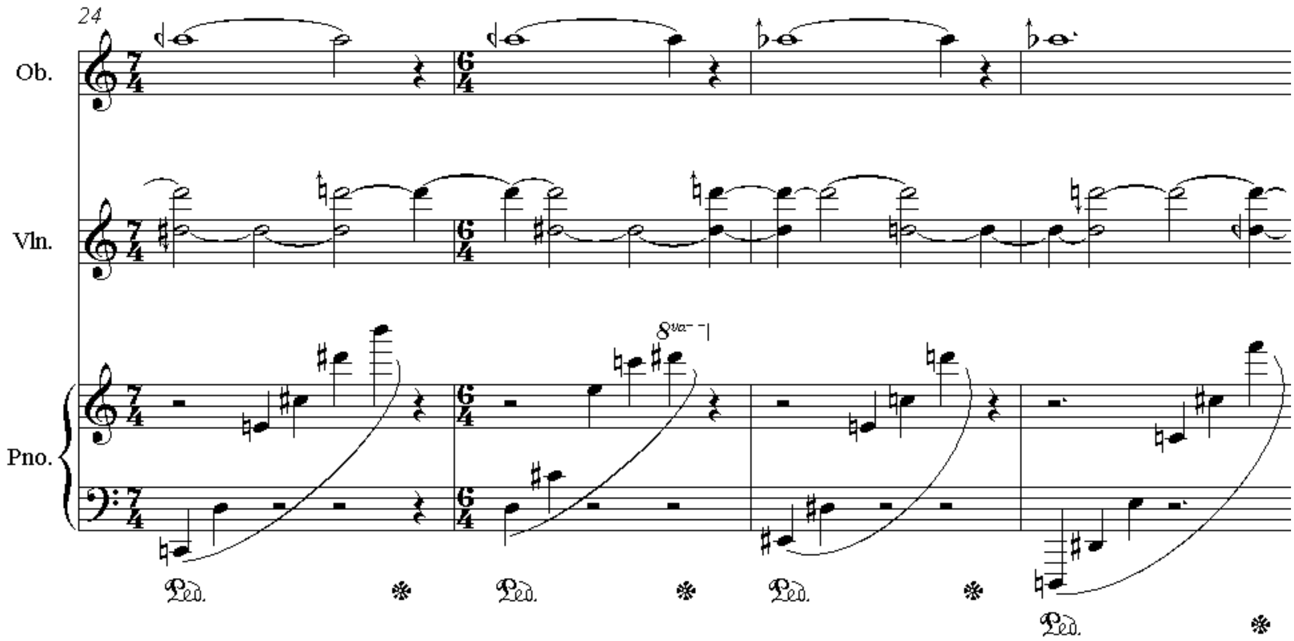

Illustration 20: For Garrett Sholdice, ambiguity created through subtle variation.

Small amounts of indeterminacy are present in this piece. The piano part in some sections is left rhythmically free and uses time-space notation: this looks forward to the synthesiser part in *Marx* which uses the same technique. More importantly, the oboe and violin use notational imprecision throughout the piece to again create ambiguity as to the harmonic identity of each event. This is sometimes used locally to unsettle a series of harmonies, and sometimes it used across a whole section as a trajectory: for example, the oboe between mm.19-29 moves slowly from A5 to A♭5(but slightly sharp), sometimes repeating pitches and sometimes making imperceptibly small alterations.

The piece's block structure and simple repetition also stem from Feldman (among other influences) and look forward to the repetitions of *-Intra* and to a certain extent also to *Nano*. Formally, the piece is a dialectic between two sets of material, the repeated and the sustained. The repeated material is the previously discussed arpeggio figures based in the piano, and the violin. The tendency of the oboe towards sustained notes is amplified in the opening gesture where the oboe slowly overblows a minor ninth interval (on the same fingering): the slow overblowing means that for a brief but glorious moment the oboe is suspended between D4 and a very flat E♭5. During this long note the piano is playing a free arpeggio and violin assumes its role as arbiter between arpeggio and sustained notes. The two types of material move between states of stable identity ambiguity, often the state is only clear when one type of material interrupts the other.

2.1.10: *Bifurcations* (2007)

Clarinet quartet: 8 minutes

This piece takes a structural idea from complexity theory[149], where a bifurcation is a sudden phase state change occurring at a point in a steadily changing parameter. *Bifurcations* begins as a single chord, which slowly pulls itself apart until the chord bifurcates into two chords, upon which the process begins again with these two chords which subsequently bifurcate into four. The piece stops after this third section as it wasn't practical for four clarinets to maintain eight chords simultaneously without departing significantly from the sustained texture.

Clarinets are ideal for this piece due to their almost unique ability to begin and end a note in silence, this lends the surface a gently undulating smoothness as the instruments overlap each other. The harmony changes within each section are at the level of 25¢ to 50¢ per alteration because I am aiming for imperceptible change, while the sectional breaks are the opposite, violent events that reset the material.

Indeterminacy is only a marginal concern in Bifurcations; before playing, two of the four clarinets detune by approximately a quartertone in order to increase the probability of beats between the close parts. The four players each follow a linear trajectory in descending or ascending eighth-tones that covers about 130¢ to converge on two clusters over three minutes. The detuning is largely a practical concern in this piece as it ensures that the student players—whom the piece was written for—can play very tight clusters without having to use difficult or awkward fingerings. The third section also benefits because the strongly perceived pitch of the multiphonics are mostly in twelve-tone equal temperament, thus the detuning increases the friction between them. This is even more acute when the same multiphonic is played simultaneously by more than one player, as shown in *illustration 22*; this final chord aims for maximum cluster density. While the first and second sections could have worked just as well with more complex fingerings, the third section would be much less dense and interesting without the detuning as it is almost impossible to use the embouchure to bend the multiphonic out of tune without the sound becoming unstable.

[149] Wolfram, Stephen, 'Complex Systems Theory', (1984), <http://www.stephenwolfram.com/publications/articles/ca/84-complex/2/text.html>, accessed 07/08/08.

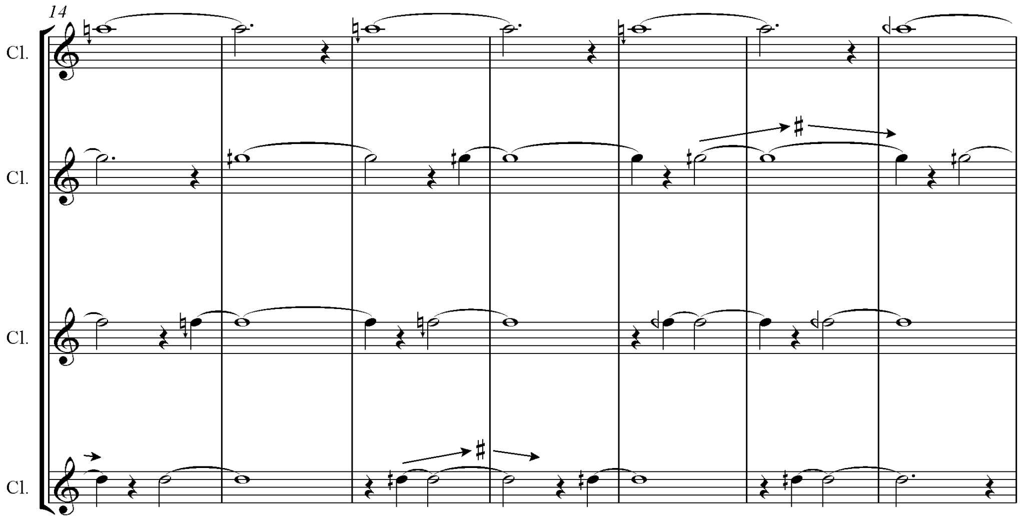

Illustration 21: Bifurcations (mm.14-20), detail of linear descents and ascent (clarinets 2 & 3 are tuned ¼ tone flat: example above is at written pitch)

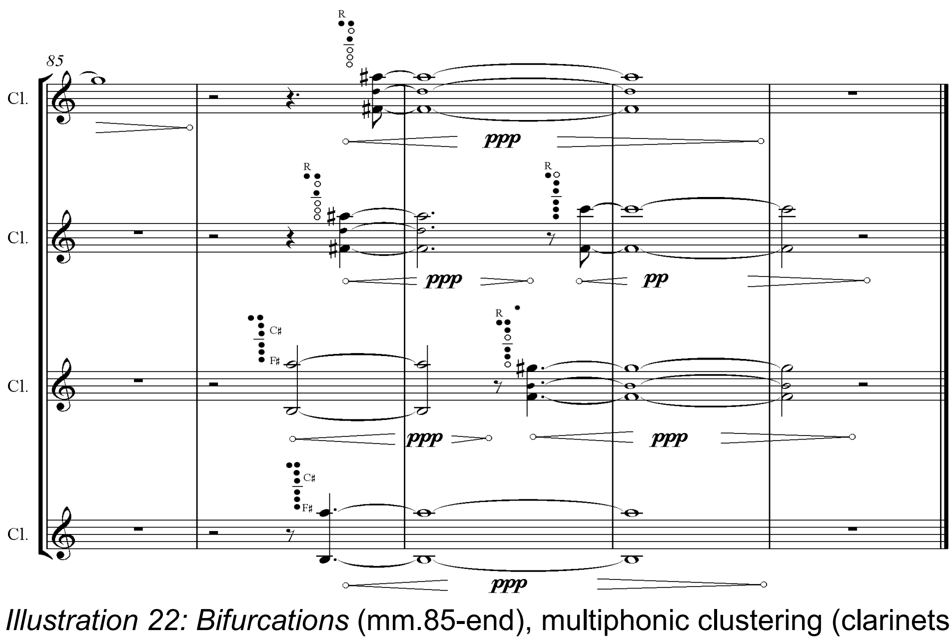

Illustration 22: Bifurcations (mm.85-end), multiphonic clustering (clarinets 2 & 3 are tuned ¼ tone flat: example above is at written pitch)

Formally speaking, *Bifurcations* is modelled on the bifurcation phenomena, where regular change in a single parameter results in period-doubling. The piece uses this idea as a macroform, creating three sections which divide from one chord to two chords to four chords.

The sections themselves each have strict teleological processes within them. For example, section-I begins as a single chord of four pitches which gradually separates out into two distinct clusters. The evenly spaced chord (D, F, G, A) narrows to two microtonal clusters around D♯4 and G♯4 (see *illustration 23*), with perceptual focus shifting from a single chord to two beating sound complexes.

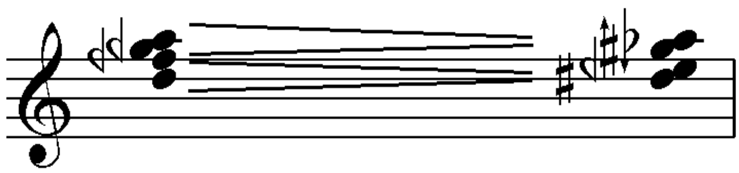

Illustration 23: Bifurcations section-I harmonic *motion*

Section-II has a similar process but without any memory of the first. This new process has different pitches and register—separated as it is into two distinct chords—and a slightly different morphology in that the lower chord inverts itself through an 'X' pattern rather than simply narrowing to a cluster: see *illustration 24.*

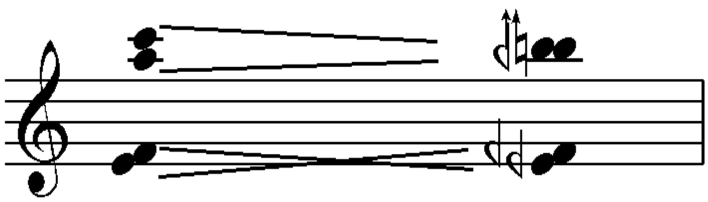

Illustration 24: Bifurcations section-II harmonic motion

The global teleology of the piece is to bifurcate again and again. For practical reasons the piece is truncated after two bifurcations, but this teleology would doubtless be clearer if it were possible to continue the process for longer; I have considered a longer version of the piece that would explore more sections of the bifurcation model and make clearer the global teleology, but this would require larger instrumental forces. This global teleology is separate from the local teleology at work within each section. Each bifurcation point starts the work again with twice the amount of lines, so each section is treated as a *tabula rasa.*

As with the pieces discussed already, each section in *Bifurcations* is an instance of the piece's main idea. In this case though there are two ideas: the teleological processes within each section, and the macro-formal process of bifurcations.

In the piece's originating metaphor these two processes inform each other; the macro-formal bifurcations being an emergent property of the system under the continued morphology of one parameter. This aspect has been metaphorically transformed here so that the parameter undergoing change across the piece is a metaphorical topological constant controlling the changing identity of each sectional instance with reference to the ur-object (the central sound idea). In this way the strange attractor is invoked inside the bifurcating system in slow motion: where each bifurcation brings up a new point on the attractor.

2.1.11: Torsion (2007)

Eighth-tone trumpet: 4 minutes

A short piece for Steven Altoft's eighth-tone trumpet: a standard trumpet with a fourth valve added to allow quartertone divisions, the eighth-tones are achieved by using the tuning slides. I had great difficulty writing a piece for solo instrument, because there is no possibility of harmony.[150] There was always the option to include tape or some sort of automated drone but I wished to see the challenge of writing a monophonic piece through.

In keeping with my work on ambiguities, I devised a simple process to take advantage of Steve's ability to play eighth-tone divisions. There is a four-note cell (F4, A4, G♯4, F♯4)—conforming to one of my standard models, the ambiguous minor-major cell—that over the length of the piece is slowly compressed into a single G4 pitch. This cell has a counterbalance in the form of a single sustained G5 that sounds after each of the four-note cells, but isolated in registral and temporal space. Across the piece this G5 slowly becomes as G♯5 so that by the end of the piece we are left with the minor ninth G4-G♯5 between the upper and lower voices. The counterpoint is also between the motion of the four-note cell with its quasi-lyrical contour—a simple rhythmic permutational process ensures that each iteration of the cell has a different temporal shape—and the single high G5, static in space.

[150] *Torsion* was begun before *Nano* and it is possible that the difficulties in writing *Torsion* contributed to the conception of *Nano*. Perhaps I needed to try and write a notated monophonic piece before I could consider other approaches.

2.1.12: *Nano* (2007)

Clarinet: 15 minutes or more

Nano is a text piece that simply repeats a single gesture in as many possible versions as the performer can generate. The gesture is defined as descending scale passage that is rhythmically regular and completed in a single breath, always in the upper register, and whose constituent intervals must be smaller than a semitone (though not necessarily evenly sized).

The piece has a robust identity due to the simplicity of the gesture, but also an infinite number of possible realisations of each gesture due to pitch being a continuum. Playing intervals smaller than a semitone opens up the almost limitless set of possible intonational variations that can be produced by embouchure and fingerings. As the piece progresses, memory begins to play a structural role as it becomes difficult to tell when and to what degree the elements are different.

There is a perhaps an inverse relationship here with Satie's *Vexations*. While in *Vexations* the variation is an unintentional inevitability of performance which becomes perceptually exaggerated over time, in *Nano* the variation becomes perceptually smoothed out over time as the differences become less obvious.

In my portfolio, *Nano* is both the simplest and most extreme example of the dichotomy between local and global teleologies because it exhibits clear local teleology, in contrast with a non-teleological macro-form that is an emergent property of the piece's bottom-up construction. Each event is a descending scale and thus has a clear teleology; the precise pitches may be unknowable in advance but the trajectory is clear. At the phrase-level though there are no reasons for one event to follow another. The only instruction is that events must be 'different'. Given that there are four variable parameters (starting pitch, tempo, number of notes in event, interval size between notes), and that most of them are bounded continua rather than sets of discrete size, the number of possible different events is very large indeed. Even if one takes into account perceptual limitations such as the practical impossibility of choosing a different tempo between 91bpm and 91.5bpm, or pitches which are less than the Just Noticeable Difference, the set of possible 'different' events is large enough to ensure that each of the successive events will be different.

It is possible for the player to work against this principle by creating phrase-level teleology, such as linearly increasing the tempo or linearly increasing the starting pitch for each event across the piece, but the practical limitations mean that the other four variables will still be in flux. The stable variable will become informationally less relevant due to its predictability and the listener will focus instead on the variables exhibiting most change.

The structural ambiguities of *Nano* are not especially suited to the concert hall, the games that it plays with memory are better suited to an installation context where there is no beginning or end and the listener is free to leave after they have reached a point of saturation, or stay to see what effect over-saturation will have. On the other hand, in the concert environment the piece has a definite beginning that may fool a listener into thinking that the opening gesture is some sort of theme to be varied. A listener attempting to listen to the piece in this way should generate for themselves a whole new layer of ambiguity in relation to this as they attempt to hold one particular instance of the gesture as the 'theme' and relate other instances to that. As their memory of the 'theme' erodes then they will eventually—if the piece does not end first—have that sudden sense of confusion associated with the realisation that one is truly lost.

2.1.13: *Intra-* (2007)

Violin and prepared guitar: 13 minutes

The title '*Intra-*' points towards aspects of being 'inside'. The violin part here is generated from spectral analysis of the prepared guitar part and as such is always vacillating between attempting to be inside the guitar sound and the impossibility of this. The guitar is prepared by attaching blue-tack to the strings; this increases the ratio of string-mass to string-length to increase the string's inharmonicity, resulting in a sound like bells or gamelan. *Intra-* is structured in three main sections: a disjunct first section, a continuous final section, and a middle section which is three miniatures for solo violin derived from the outer sections.

The first section is a discontinuous succession of possible versions of a phrase: the phrase is musically simple in order to highlight contrast between versions. Rather than the classical notion of theme and variation that pre-supposes an objectively fixed and present theme. I prefer the idea of constant evolution where there is no theme, only change: points in a space rather than points on a line. The reference point for each phrase may be the previous phrase, or a phrase which hasn't happened yet: each phrase has characteristics from many other phrases. This form was influenced by Richard Dawkins' Biomorph application, which allows a user to 'breed' objects by selecting from a set of possible mutations in each generation.[151] *illustration 25* below shows the biomorph programme in action; the central pattern is the parent and the others are mutations. In each generation the user selects any of the possible patterns to breed with the parent, and the characteristics of both are selectively carried over to the next generation. The Biomorphs can be subject to a teleological breeding as the user can pick what mutations they like and guide its evolution. However if the mutations are chosen at random in each generation then the Biomorphs go on a strange journey through shapes different and the same; there is no clear pattern or direction but the observer cannot avoid the feeling that the same spaces are being traversed in many different ways.

[151] Matt Jones' Javascript implementation of Dawkins Biomorph. Jones, Matt, 'no title', no date, <http://www.codecarnival.com/svg/biomorphs.svg>, accessed 02/08/08

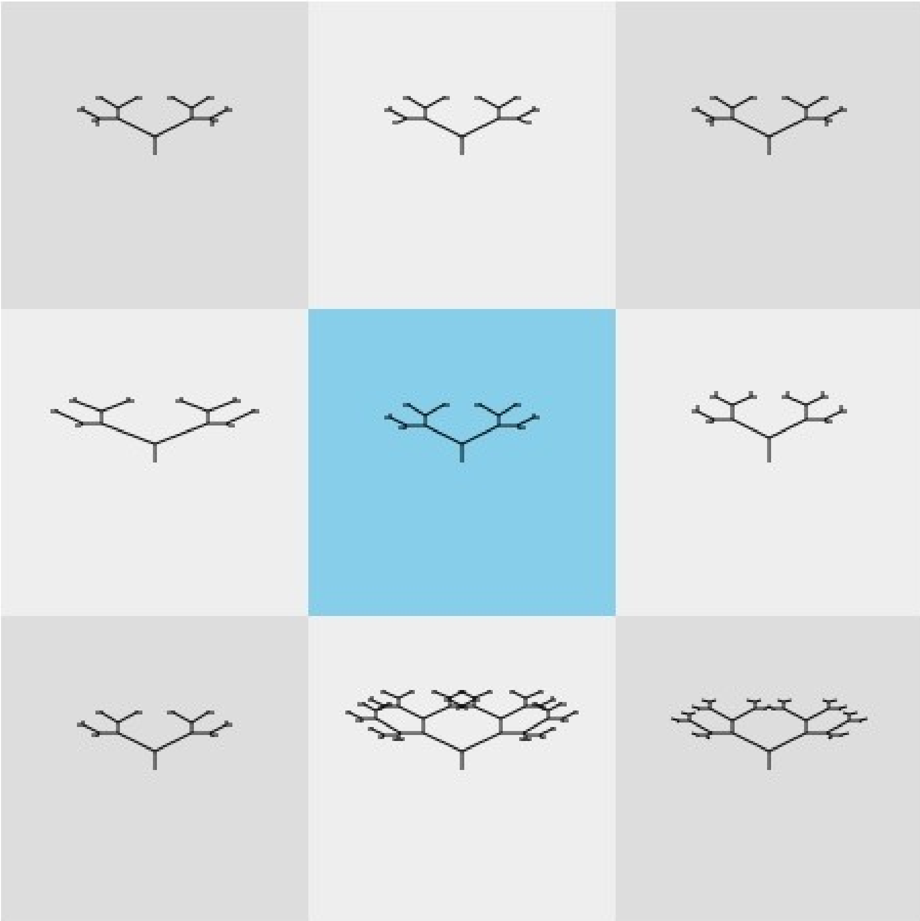
Illustration 25: a generation from Dawkins' Biomorph application

The second section is for solo violin, encapsulating the violin's gestures in three miniatures which are three different perspectives on the violin's material. The third section is more continuous, but continuously goes nowhere; the material is successively pared back to touchpoints.

There is a certain amount of pitch indeterminacy in the relationship between the violin line and the partials in the prepared guitar which it is shadowing. The violin, in attempting to get inside the guitar by playing along with its partials, merely causes the already fragile guitar timbre to to dissolve further. The other site of indeterminacy in this piece lies in the esthesic process, the blurring of identities in the listener's ear. The middle solo section is really a break for the ear, showing in simple one-dimensional terms what the prominent characteristics of the violin's gesture pool are. But the first and third sections are much more deliberately misdirecting the listener. The first section has such slight material that, even when the sectional breaks are made as clear as they are here, it becomes difficult to tell what aspect of it is repeating. As with the Biomorphs, the mutations in the violin and guitar part cross identities and characteristics in a manner which sounds at times random but within a definable identity. *Intra-* attempts to compose within the perceptual space of sound objects which may or may not be changing.

Intra- is the only fixed score piece in the portfolio to use spectral modelling. The guitar preparations create inharmonic sounds, the spectra of which are analysed and this data is used as the basis for the violin part. As each string is prepared differently, the partials of each string are differently altered, thus it is possible to play the same sounding pitch on different strings but have different spectra for the two notes: where both notes have a common strong partial but the rest of their spectra are perceptually different. *Table X* compares the analysis data from what in standard tuning would be fingered as E5 and F5 (1st string open, and the 6th fret on the 2nd string) with a hypothetical spectrum of their common partial if it were a standard harmonic pitch. This shows clearly the uneven stretching of the spectra with the preparations applied.

	2nd string, 6th fret	1st string open	Harmonic version
Fundamental	191hz (G3 -50)	191hz (G3 -50)	191hz (G3 -50)
Partial 2	266.1hz (C4 +35)	266.1hz (C4 +35)	382hz (G4 -50)
Partial 3	517hz (C5 -25)	484.4hz (B4 -35)	573hz (D4 -48)
Partial 4	934.6hz (A#5)	854.1hz (G#5 +50)	764hz (G5 -50)
Partial 5	1374hz (F6 -30)	1254hz (D#6 +11)	955hz (B5 -64)

Table 3: Comparison of string spectra with common fundamentals

The composition takes advantage of this by alternating two different spectra on the guitar part and writing the violin part to move between the strong partials of the two guitar spectra. *Illustration 26* shows a score example from *Intra-* with the violin part slowly glissading between the 3rd partials of the two guitar spectra while sustaining the common 2nd partial. The aim of these interactions is to produce acoustic beats between the two instruments, this follows from the metaphorical association of the title in that the violin wishes to be 'inside' the guitar part.

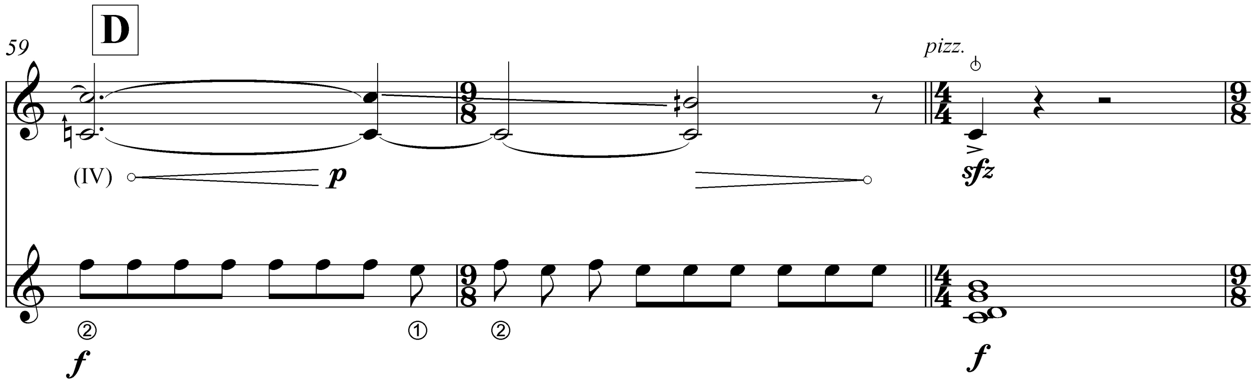

Illustration 26: Intra- (mm.59-61) showing guitar and violin pitch interaction.

While the multiphonic-based pieces generate their own clusters and beats, the prepared guitar instead creates stretched spectra with very little clustering. However, the combining of strings with different spectra as shown above produces its own clusters and the addition of a violin part interacting dynamically with this achieves plenty of timbral variation. During the writing of the piece, the preparations were tested on six different guitars and the resulting variation in guitar spectra was within acceptable limits. As a safety measure, the violin part tends to wander around the frequency area of the guitar's strong partials to increase the chances that their frequencies will cross at some point.

2.1.14: *Whitewater II* (2008)

8 or more saxophones: 8-10 minutes

Whitewater II is an attempt to create the soundworld of *Whitewater* using acoustic instruments. The form has been changed to that of a game piece which avoids large scale teleology but limits the amount of events in the structure. The players form a group whose only score is a fixed series of harmonic events, in each successive event players may sound any one of the given pitches. Events can be initiated by any player, once initiated all the players must follow: each player is limited in the amount and type of events they may initiate. Assuming no-one initiates a new event (they may overlap), members of the group may sustain an event indefinitely or allow it to fade into silence. These events continue until the player begins to run out of initiating gestures, which are limited by amount for each player (this also controls the length of the piece). As the piece goes on and the players begin to run out of events, they then begin to play an alternative sound (that has been predetermined by the group) such as air sound, whistle-tones, etc. The piece finishes on an agreed signal once all players are on their alternative sounds and no-one can initialise an event.

Indeterminacy in this piece entwines the vertical and horizontal. The text process sets up a situation with many variables, which is multiplied by the nature of a group of individuals where everyone is a potential leader. Once an event has been initiated the players must move towards it, and until the next event is begun they must remain in orbit. However, any one of them can take control of the piece at any time and begin a new event. This push and pull of agents with the same capabilities but differing personal sonic agendas is the driving force of the piece, and the indeterminacy is the mechanism.

Originally, this was to be a piece called *For N Homogeneous Instruments* in which these game rules would be applicable to any group of like instruments, but it became clear that the piece was too close to *Whitewater,* and too conceptually tied to the saxophone, not to consider it as an expansion of *Whitewater*. The generic game piece called *For N Homogeneous Instruments* will be written as a future project, with less specific harmonies and alternative sounds.

Whitewater II is all about mass effects, of performer choice, and of intonation. The same detuning technique that was used in *Bifurcations* is applied here with greater cogency by devising a text process which would take full advantage of the detuning. The aim of the text process in vertical terms is to create sound complexes rich in beats and inner life. To maximise the possibilities and richness of beats generated from this harmony, most of the players detune by a random amount (up to 50¢) before playing. This ensures that should two or more players choose the same written pitch in any given event, the possibility that they will all play precisely the same frequency is massively outweighed by the probability that they will form a tightly packed cluster; even if they did all play precisely the same frequency, that note is unlikely to be present in the pitch set of each different family so there will be at least one other pitch in the chord. Also, because each event has a main pitch and many subordinate pitches, under the right circumstances any close-tuned intervals (those close enough to cause beats) should fuse together as a single percept; in some cases the entire chord may fuse.

Another layer of vertical indeterminacy in *Whitewater II* involves the type of notational imprecision seen also in *Five bells for Elliott Carter* and *For Garrett Sholdice* where accidentals other than the standard twelve-tone equal temperament and quartertones are not defined. The players all detune their instrument by approximately a quartertone before the piece begins, and are instructed not to tune to each other but instead play their part independently—choose their own intonation—while attempting to create beats with the other parts. This all leads to a degree of mistuning which is much higher than would be expected if these accidentals were found in a score with a fixed intonation. Earlier scores of mine such as *Tracheids* and *The Lady with the Hammer* use the same notation but with cent values attached but this was before I understood that me language was developing towards timbral and pitch ambiguity rather than clarity.

Whitewater II uses spectral modelling to create the series of basic harmonies which acts as the main structural line of the piece. The harmonies are derived from spectral analysis of saxophone multiphonics and split into parts according to the range of each of the different saxophones in the ensemble; players independently choose a pitch at random from the set to create a sustained chord. *Illustration 27* shows the pitch set from the original multiphonic analysis at sounding pitch, and the transposed parts for the instruments of the saxophone ensemble. To help with perceptual fusion, the strongest partials from the analysis of each multiphonic are translated as accented pitches in the score. Each event begins with an accented pitch which is attacked strongly and sustained loudly so that the others become a cloud around it and hopefully some pitches fuse together.

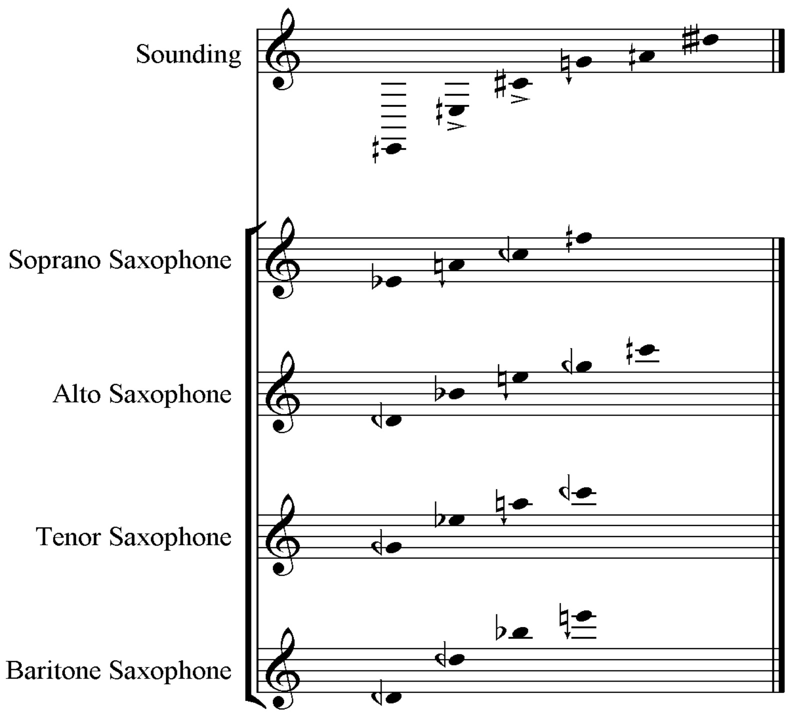

Illustration 27: Whitewater II pitch-set partitioned by instrument range.

The form of *Whitewater II* uses the genotype/phenotype evolution model but with the added complication of group decision-making. As in *Nano*, the score gives instructions on how a single event is constructed and each individual instance are controlled by independent decisions made by each player, contributing to a group effect.

The piece maintains synchronisation by using a strict ordering at the phrase-level. The score defines the order of events as chords from which players choose pitches. The events may be any length as they may be instantly interrupted by the next event or they may be sustained indefinitely. The indeterminacy here is based on the agency of players to alter the course of the piece. This works on a first-come first-serve basis (whoever plays first in each event controls the event) and is further limited by the requirement that each player has only a limited number of times in the piece when they are allowed to take control; decided before performance. Once all the players have used up their allotted amount then the piece moves into an end-game sequence of sustained noise before finishing. The amount of times a player may take control is also an indication of how long the piece will last on average.

2.1.15: The Well-Tempered Prism (2008)

Clarinet and piano: 6 minutes

This piece was an unsuccessful experiment in that it demands that the performers execute rhythmic events with an accuracy that is probably outside human ability, and the failure to play these rhythms accurately and smoothly will undermine reception the piece. Again, this relates not to the sonification of a process but simply that I want the listener to hear the relationships set up in the music, without these relationships it is only a series of events, without meaning.

Each section of the piano part is a rhythmic palindrome made from interlocking prime-numbered durations; such as 19:17, 23:29 etc. Each section has a fundamental pitch, two partials of that fundamental are played as a rhythmic palindrome where the ratio of the palindrome is the partial numbers. For example, in the opening section the fundamental is G♯2, the ratio is 19:36 so the palindrome is the 19th and 36th partials, B6 and A♯7 respectively. In the rhythmic palindrome these two pitches have durations inversely related to their partial numbers, so B6 (19th partial) occurs every 36 demisemiquavers and A♯7 (36th partial) occurs every 19 demisemiquavers: see *illustration 28*. This structure is a simplified model of the harmonic series, with higher partials occurring more frequently.

While writing the piece I came across James Tenney's *Spectral Canon for Conlon Nancarrow*, a piece with a similar structuring idea, although realised quite differently to my own piece. In Tenney's piece the first 24 partials of a harmonic series on A enter in canon (beginning with the fundamental) and the durations of each note are proportional to their partial number: so the 2nd partial is twice as fast as the fundamental, the 3rd partial is three times as fast and so on. The player piano used for this is also retuned so that the partials are all at the correct frequency.[152]

Rather than retune a piano, for *The Well-Tempered Prism* I returned to an idea that I used in *Prisma* (2005) for violin and piano, where the piano acts as an equal-tempered filter on the spectral material. In *The Well-Tempered Prism* the partials are offset so that in any given ratio the two partials are within 10¢ of equal temperament. *Table X* shows the pairings of partials that are offset from equal temperament by the same amount, these partials are tuned to the nearest tempered pitches on the piano and the rest of that spectrum is offset by the same amount. The clarinet part is generated as the difference tone of the two piano pitches—in *illustration 28*, the difference tone generated from the 19th and 36th partials is the 17th partial A6. The generating partials are always tuned to equal temperament to fit the piano but the clarinet can play any microtonal difference tones that are then generated by this offsetting. The tempos of the sections are also related to their respective sectional fundamental, but not as strictly as in *Tracheids*: the tempos are in relation to each other but are not derived from a subaudio fundamental.

Fundamental (midi note)	Ratio				Difference Tone generated
	Partial no. + midi note		Partial no. + midi note		
38	17	87.05	19	88.98	50
51	17	100.05	27	108.06	90.86
42	17	91.05	36	104.04	92.98
37	17	86.05	43	102.12	93.41
39	19	89.98	24	94.02	66.86
39	19	89.98	27	96.06	75
48	19	98.98	32	108	92.41
47	19	97.98	34	108.05	93.88
44	19	94.98	36	106.04	93.05
38	19	88.98	43	103.12	93.02
43	23	97.28	41	107.29	93.04
36	23	90.28	29	94.3	67.02

Table 4: Partials offset by the same amount (within JND).
Ratios and difference tones (grouped by no. of lower generating partial).

152Maher, Ciarán, 'Spectral Variations by James Tenney', <http://www.rhizomecowboy.com/spectral_variations/> accessed 21/11/08

In performance, there were great difficulties in achieving an acceptable level of timing accuracy and the sense of their being a strict relationship between the pitches and their temporal ordering was, in my opinion, obscure. I am greatly attracted to the relationships that I have explored in this piece but the only way forward for using these relationships that I can see would involve some manner of computer performed rhythms: there is of course always room for performers to overturn this perception should they wish to take on the challenge.

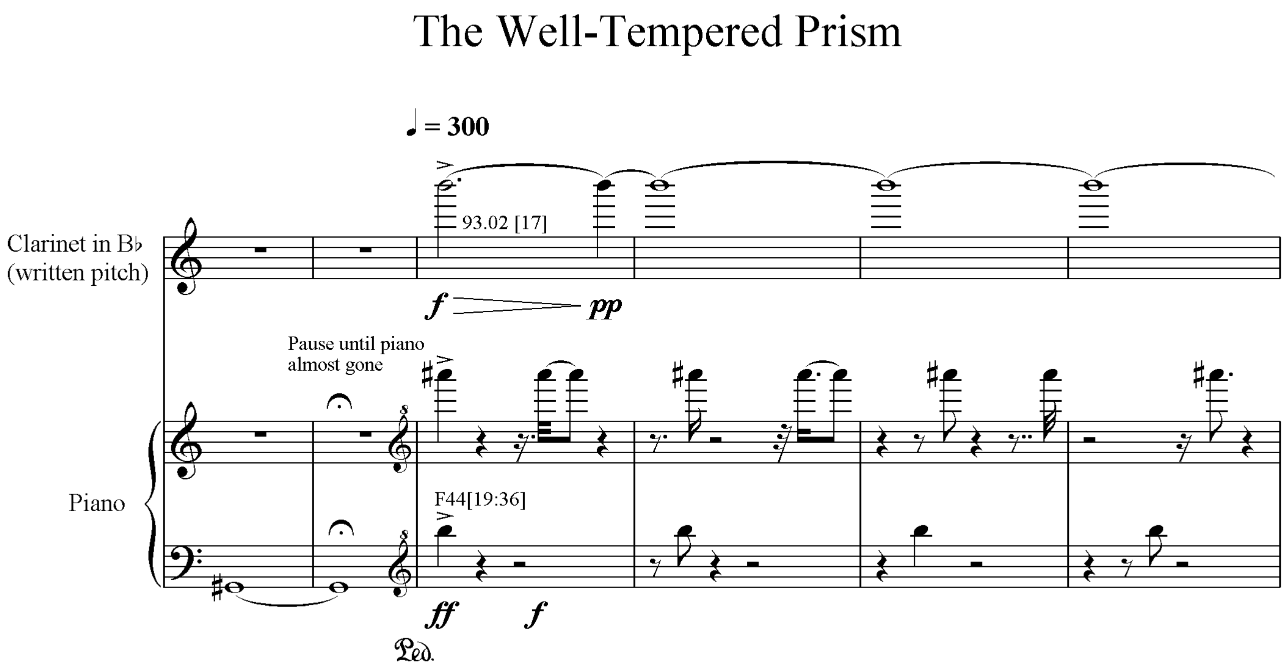

Illustration 28: The Well-Tempered Prism, opening bars

2.1.16: *Lorenz* (2008)

Saxophone and 3 or more string instruments: 10-12 minutes

This piece is named after the meteorologist Edward Lorenz, one of the first people to research strange attractors. These are present in systems whose behaviour is non-linear:

where rather than there being a single point to which all behaviour tends, instead there is a field of possible end states which may be infinitely deep in certain dimensions but bound in others. The metaphor is here extended to the infinite possibilities for intonational differences within pitches derived from saxophone multiphonics.

The saxophone pre-defines a set of 25 notes (including some repetitions) derived from a single multiphonic, the individual stable pitches playable from the multiphonic fingerings, and intonational variants of these using different fingerings. These notes are played as a series of long notes with rests, all subject to the saxophone player's control.

The string players have no knowledge of the saxophone's part, and must attempt, independently of each other, to match the saxophone pitches by ear. They are restricted in that once they commit to a note they must sustain it for a full bow length and may not adjust their intonation during that bow. If the pitch is incorrect then the next attempt may only be different by up to quartertone, but must be in a different octave to the last: if the saxophone's next note changes by more than a semitone then the strings may choose a completely new pitch, but subject still to the rule that pitches may not be 'fixed' once begun.

The percussion only acts as a breaker, any time the strings actually match the saxophone pitch then the percussion enters to further confuse the pitch. The percussion only enters when a string player 'wins' the game by achieving unison/octave with the saxophone pitch. This relates, unintentionally to the role of the percussion in Kagel's *Match for three Players* where a game of tennis between two cellists is umpired by a percussionist.[153]

The ultimate aim of the piece s to produce beats between the different instruments as a by product of a game process. As with later Nono works such as *No Hay Caminar Sonando*[154] or *Fragmente - Stille, An Diotima*,[155] the piece's interest lies in the journey rather than the goal.

Lorenz is an example of bounded improvisation used in a very limited way. The backbone of this piece is the saxophone line which is a sequence of 25 events, each held for one breath and with pauses of indeterminate length between them. The pause length is the crux of the indeterminacy here. The score sets an upper limit of two minutes on pauses, and advises that those greater than 20 seconds long should be used sparingly. The saxophonist's sense of time is guided by, but not determined by, the string players' performance: as they get closer to matching the saxophone's most recent pitch he must

[153]Kagel, Mauricio, *Match for three Players* (Vienna, 1964).
[154]Nono, Luigi, '*Hay Que Caminar' Soñando* (Milan, 1989).
[155]Nono, Luigi, *Fragmente-stille, an Diotima: per Quartetto d'Archi.* (Milan, 1980).

attempt to draw them away with his next pitch. The material and ordering of the saxophone's event series is devised by the player—because multiphonics are not standardised from instrument to instrument, this allows the player to use those most suitable to their instrument. The order may be fixed before performance or may be improvised.

Lorenz is topologically fixed, in that there are always 25 events in sequence. These events may be indeterminate in order, depending on how comfortable the player is with improvisation. The events are indeterminate in terms of duration and phrase-level construction because the player is manipulating the pause lengths in real-time to react to the the other instruments. The structure undergoes compression and dilation which rely on the players' listening skills: a game of cat and mouse for the ears.

This piece is the most literal adaptation of the strange attractor model in the portfolio. The saxophone part is derived from a single multiphonic by listing the stable single pitches in the multiphonic and any intonational variants of these (within a quartertone of the original). This provides a set of pitches which outline the multiphonic; a suitable analogy is of the multiphonic being a 2D shape and the single pitches as 1D points as in *illustration 29* .[156]

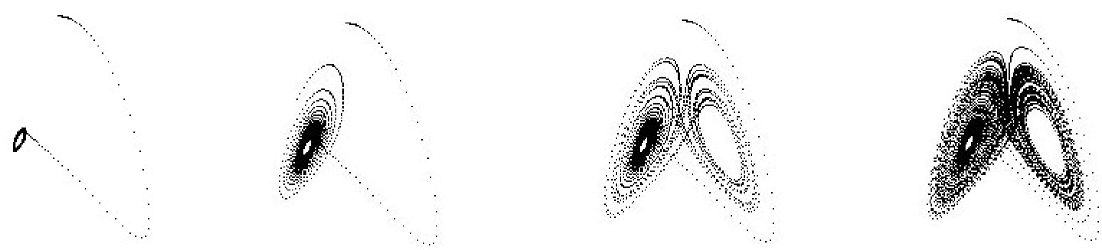

Illustration 29: Lorenz attractor as a 2D shape being outlined by 1D points.

The multiphonic is further outlined by the action of the strings, which have their own process—explained above—that uses the saxophone pitch as a variable. These limitations mean that the strings are converging on a the shape of the multiphonic in frequency-space as it is being outlined by the saxophone. As the strange attractor metaphor attempts to show, the text process is highly indeterminate but within boundaries set by

[156]The lorenz attractor is actually a 3D shape, of which this is a 2D representation being outlined by 1D points. But for the purposes of illustrating this argument it is accurate enough.

the multiphonic. The piece depends only to limited extent on the players' abilities and aural skills. The piece move sufficiently slowly for any competent musician to be able to fix on a pitch and home in on it. Analogously, it is as though the multiphonic were being viewed by microscopes of varying sensitivity, some allow higher resolution than others.

Lorenz also exhibits clear local teleology because the strings are always moving towards the saxophone pitch. The large-scale form of the piece is ambiguous though. The moving target of the saxophone pitch means that the strings are always re-initialising their 'search', so the piece is always starting again in mid flow; leading to a macro-form of pitch wedges that are constantly interrupted. The lucidity of this form to the listener is dependent on the player's ability to home in on the target pitch consistently. In versions where the saxophonist chooses to make their line more varied in pitch, it will be more difficult for the players to track the target and consequently the form will be more opaque. The percussionist's role is to shine a subtle light on the form. They only play when they perceive that a string player has achieved a pitch match with the saxophone. It is possible that the entire piece may pass without any pitch matches, but if there are any then the percussionist underlines this with a wide cluster.[157]

2.1.17: *Marx* (2008)

Mezzo soprano, viola d'amore, synthesiser: 13 minutes

I usually avoid writing for the voice, especially in a mixed ensemble, as it can be difficult to blend with other instruments because there is simply too much expression and humanity tied up in our relationship with and perception of the voice for it not to stand out of the sound mix. However, the opportunity to write for Trio Scordatura could not be passed up, so I elected to use the voice as both a primary pitch generator, and filter. The voice and viola sustain dyads together, these act as generating pitches in a ring modulation process, the results of which are played by the synthesiser (as clouds of sine waves). The voice is used compositionally as a crude bandpass filter by allowing through only those pitches which fall within the formant of the vowel is being sung at that moment; an idea which unbeknownst to me at the time had been explored by James Tenney in his pieces *Clang* (1972) and *Three Indigenous Songs* (1979).[158]

As with other pieces in this portfolio, *Marx* relies heavily on the structural device of

157 This should be a subtle hint to the listener rather than a cadential hammer-blow.
158 Wannamaker, Robert, A., 'The Spectral Music of James Tenney' *CMR* 27/1, Feb. 2008, 109.

evolution, where a sound object is repeated with successive alterations to different characteristics. In this case the object consists of an attack by the voice or viola, leading to a sustained dyad on voice and viola which is enveloped by a cloud of sine waves from the synthesiser. The compositional process of evolution owes a lot to Morton Feldman's memory processes. He describes this as a 'formalizing a disorientation of memory'[159] where he would compose a page of music and then try to compose the same again without looking back to see the detail; he mentions this specifically with reference to *Triadic Memories*[160] (1981) but processes of this nature seem to inform most of his composition from the mid and late periods. *Marx* and many other pieces of mine achieve similar results through indeterminate means. Form is achieved by repeatedly reformulating the sonic object to create local difference, and this stream of local difference creates large scale patterns from which form emerges.

In *Marx*, the synthesiser part is strictly generated through frequency modulation of the viola and voice parts. Depending on how close the original pitches are, frequency modulation can generate sets of sidebands with frequencies close to the main band, leading to microtonal clusters of pitches. The frequency modulation technique will be explained in more detail below, but as an example of clustering the first two sets of combination tone sidebands derived from modulating B1(61.7hz) and C2(65.5hz) are shown here in *Illustration 30*:

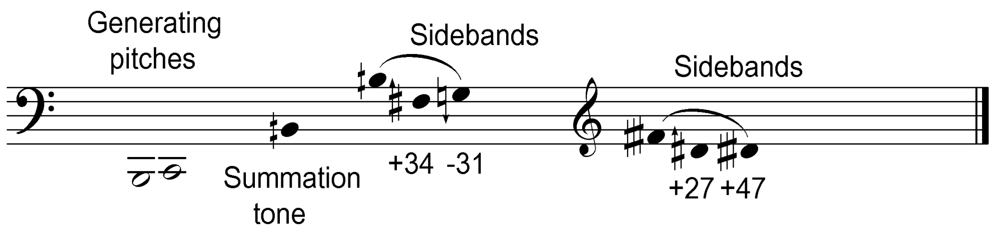

Illustration 30: Clusters and sidebands in frequency modulation

The psychoacoustic concept of masking, in which sounds are present but hidden because of our perceptual systems, presents a wealth of compositional possibilities; I wanted to make these phenomena audible, to focus on them and place them in the foreground. Early works of mine took a more literal approach to this idea. *AfterImages* (2004), attempts to sound the melody from the first movement of Schubert's B♭ piano sonata D.960 (1828) in difference tones (see *Illustration 31)*, but my inexperience meant that I did not attempt to limit the difference tones to those required to form the melody; with no filtering of any sort, simply stacking frequencies and hoping for a melody to emerge with no prompting of

159 Sani, Frank, 'Why Patterns? An Analysis of Morton Feldman's “Piano and String Quartet”', (2000), <http://www.cnvill.net/mfsani2.htm>, accessed 13/08/08.
160 Feldman, Morton, *Triadic Memories* (London, 1981).

the ear was doomed to failure.
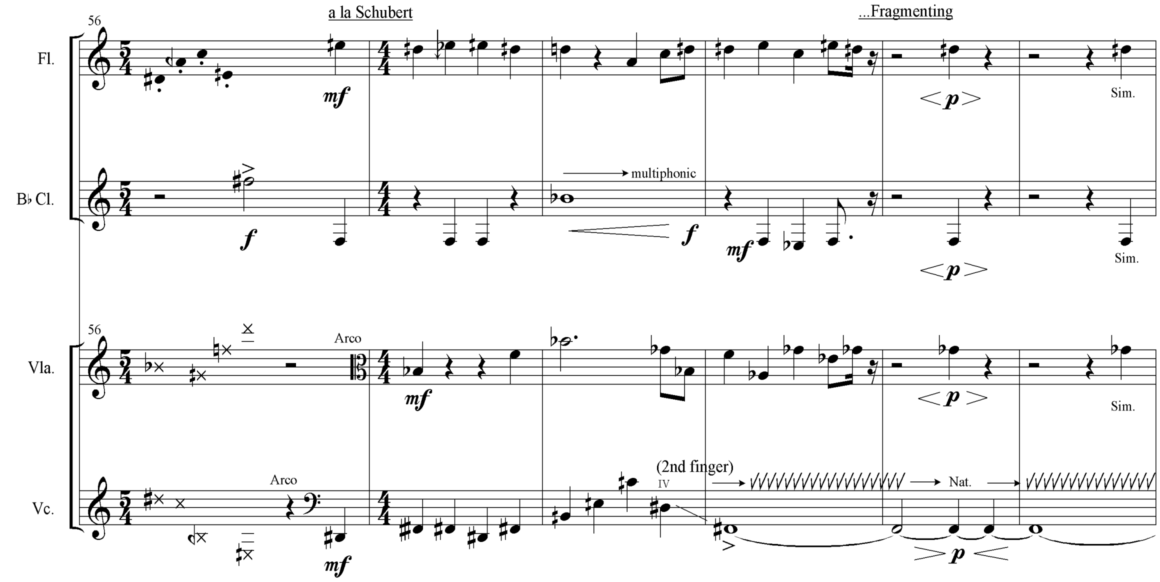
Illustration 31: AfterImages, spectral Schubert melody

Like *Primes*, *Marx* generates a level of tension through contrasting the intonation of live players with a synthesiser whose intonational purity is unrealisable by human player. Each event in *Marx* is a harmonic system where the voice and viola d'amore sustain an interval and the synthesiser part is generated from their heterodyning. Because the synthesiser part is fully precomposed, the viola and voice parts must be an exact frequency match with the synthesiser in order to generate the same pitches as those of pitches of the synthesiser part. In the real world, this level of accuracy is impossible to maintain, as well as being beyond the resolution of human hearing, making the voice and viola parts most likely out of tune relative to the synthesiser. Whether the voice and viola actually generate some of the combination tones which make up the synthesiser part is dependent on unforseeable acoustic factors such as room size and reverberation, but if they do, these will almost certainly be different to the ideal combination tones of the synthesiser. This may seem like an error in calculation but even in this piece the accuracy is not the issue. Any difference in combination tones will only serve to increase the density of the sound.

Marx's voice and viola d'amore parts are in standard rhythmic notation, while the synthesiser part uses stemless time-space notation; durations are to be inferred from a combination of notehead size, ties and position within the bar: see *illustration 32*. This is for two reasons: in practical terms there is no point being overly specific about relative temporal notation in the synthesiser because of its slow attack time—the synthesiser envelope is specified in the score—the part often demands more pitches than there are fingers available, it is up to the player to decide which of the pitches is producing the most interesting interaction with the other instruments in a given room. The synthesiser part is intended as a cloud of sine waves, and as there is no rhythmic element to this idea, it is unnecessary to impose one when an approximation under performer control will have the same outcome.

The metric order in *Marx* is not apparent to the ear and the rhythmic notation largely only serves to ensure that the viola and voice begin events together. The events are harmonically driven, with voice and viola forming a dyad whose pitches are used in a frequency modulation process to generate the synthesiser sine wave cloud. Once events begin, the constituent elements are quite amorphous and require no real co-ordination except in isolated cases of rhythmic interplay. Indeterminacy here is more a matter of simplification for the sake of practicality than aesthetic purpose.

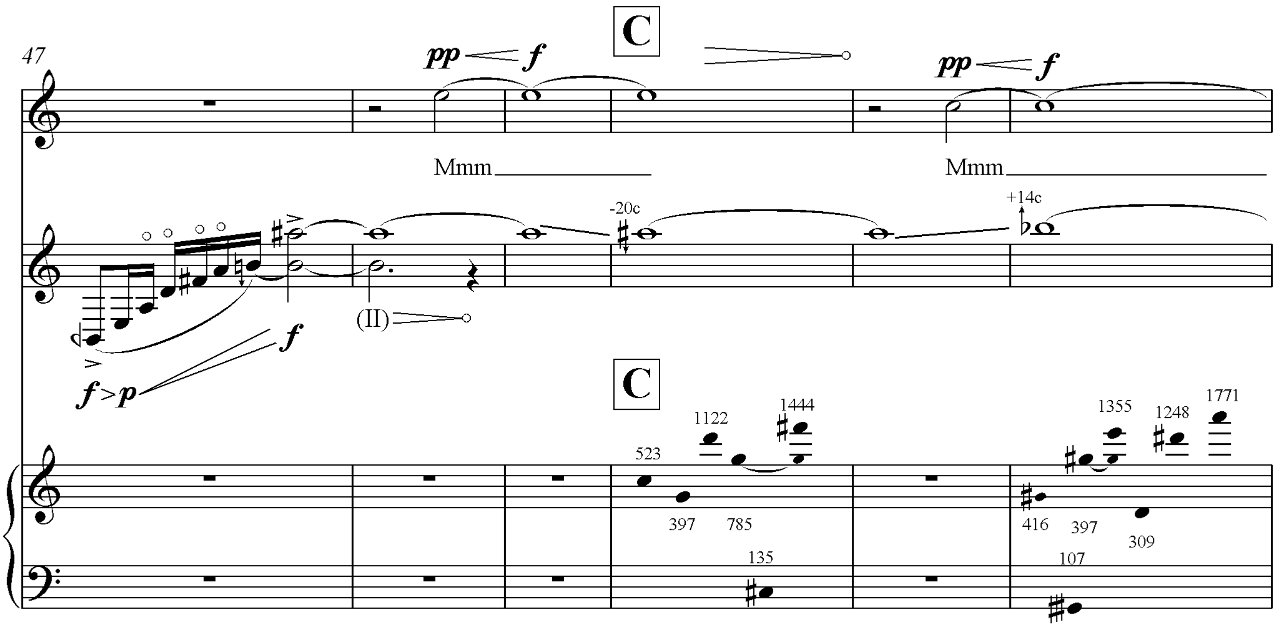

Illustration 32: Marx: synthesiser notation (staves 3 & 4).

2.2: Conclusions

> This is a grey area where the vertical and horizontal aspects interact in a non-trivial manner, similar to Feldman's statement about his own work; 'I began to compose a music dealing precisely with inbetween-ness [...] confusion between material and construction, a fusion of method and application.'[161]

2.2.1: The Supporting Diagonal

The works presented in this portfolio employ indeterminacy to varying degrees. I have split this into two categories called vertical, for the pitch aspects, and horizontal, for the temporal aspects. With this categorization I hoped to show the different ways of thinking involved, and how they have different influences and antecedents. What is missing from this is how the two sides must come together and support each other for the whole to function. This is the supporting diagonal, the strut which stops the shape from collapsing. The diagonal is the interaction between the vertical and the horizontal.

Some pieces do not work as well as they could because the two aspects do not relate properly. As we have seen in 2.1.7 (p.79), *Five Bells for Elliott Carter* is problematic because the horizontal method by which the players articulate their chords does not produce the perceptual fusion required to make the altered chords sound like bell spectra. The vertical aspect requires that all pitches be sustained for fusion to be possible; the alternating double-stops that they use provides the ear with too many cues that allow it separate the instruments into distinct percepts. The piece's initial concept is lost in the implementation, resulting in a different piece: the initial concept may return in a later work with the correct implementation.

The Diagonal is more clear in *Nano*, which for all its simplicity, combines in a single text process the vertical and horizontal aspects. Each event is defined both by its pitch content and register, as well as its temporal characteristics: tempo, duration and amount of notes. The two aspects complement each other by reduction of material to what is essential and by simplifying the interactions to the point where they can generate rich possibilities with the simplest of means. This is what chaos theory taught me, that the right kind of simplicity can lead to great complexity.

In *Whitewater* and *Lorenz* the vertical drives the horizontal and vice versa in a feedback process. The recursive process makes the players follow a pitch whose value is dependent on their own previous pitch, which was dependent on the other agent's previous pitch and

[161] Johnson, Stephen, *The New York Schools of Music and Visual Arts*, (London, 2002), 180.

so on into infinity. But within these processes are embedded non-linearities that add enough noise to keep the system just off balance.

2.2.2: The Inbetween-ness Paradox

My doctoral studies began with works which were concerned almost completely with harmony, even to the detriment of time. However, as my work has developed I have found ways to work with time in the form of evolution through indeterminacy. Now I find myself trying to unite the two, and this is part of what Morton Feldman, in the above quotation, refers to as 'inbetween-ness'. The methods used to apply indeterminacy in the portfolio works are sometimes limited to one task, and sometimes they spill over to become what drives the piece. Later works such as *Nano* and *Lorenz* achieve this inbetween-ness by finding techniques and ideas that complement each other in a way that combines harmony and form into an organic whole.

The paradox of this inbetween-ness is that my work is influenced by opposing schools of thought. The conceptual works attract me by their elegance but I am not willing to lose control of the sound in order to free the concept; in this I am indebted to Lucier for using concepts based in sound. If the sound is so important to me then I could simply compose exactly the sound I want, but this forces me to abandon interaction and the resulting complexity; creating perfection is not as interesting as setting a complex and unpredictable system in motion. Perfect equilibrium is for crystals, dead patterns. There is a Zen saying that 'water which is too pure has no fish'; a living equilibrium requires an element of chaos to keep it interesting and this chaos is evident in my music in the constant evolution of the events.

Evolution proceeds by difference and is constrained only by the environment. Difference is generated by the indeterminacy which, like a strange attractor, never repeats the same path twice, because the variables are too complex. Difference casts into relief the essence of something, thus bringing us closer to an understanding, or, as Gilles Deleuze puts it:

> Difference and repetition: the simulacrum. Identities are produced by difference and repetition.[162]

If we equate Deleuze's 'identity' above with my 'essence' then a text piece's indeterminacies can be seen in the light of strange attractors. The boundaries of the score are sketched by the differences generated by repeating the event described in the score, thus each iteration takes us closer to an understanding of the piece's essence. Taking

[162] Deleuze, Gilles, *Difference and Repetition*, (London, 2004). 4.

Nano as an example, each repetition of the event highlights a difference with the preceding event by altering one or more parameter—or some point in its history when the altered parameter was last addressed—these differences accrue over repetitions and the accrued trace outlines the boundaries of the score. In a strange attractor, as time passes the seemingly random arrangement of points takes on a shape, often of great complexity and beauty. This shape is the attractor basin towards which all possibilities flow. Any single point on the attractor is simply a point, without meaning or context, its identity is defined relative to its neighbours. Difference defines identity, the choice lies in where to search for difference.

As a part of limiting my pieces to one soundworld, I allow the the mechanism to be visible on the surface—Feldman's 'confusion between material and construction'. The elements of the work which undergo evolution through indeterminacy tend to be clearly audible. The identity of each work is tied to both the singularity of the soundworld and the robustness of the mechanism, with the intention that no matter how flexible the piece is internally it will always be recognisable.

The conflict between the conceptual and the realisation in my work is a dynamical system in itself which hopefully does not resolve into chaos or order but maintains a lifelike balance between predictable and unpredictable.

2.2.3: The future

> The torch of doubt and chaos, this is what the sage steers by.[163]
> - Chuang-tzu

In future music I hope to explore further the possibilities of dynamical systems and indeterminacy. It seems to me that the works presented here are both an end and a beginning, in that the division of technique into vertical and horizontal is giving way to a more holistic approach. Like the observer effect in physics, the act of writing this dissertation has changed the techniques themselves and consolidated them into a set of tools. Thus making the concepts which are central to many of these works into the tools for the next generation of works. I hope that the ideas and the work continues to change, evolve and live.

[163] Chuang Tzu, cited in Radice, Thomas, 'Clarity and Survival in the *Zhuangzi*', *Asian Philosophy,* 11/1, (2001), 35

Appendix 1: Javascript code for spectralConway

```
inlets = 1; //nb of inputs
outlets = 1; //nb of outputs
//check arguments
if (jsarguments.length > 1)
{
post("¥Spectral Conway Error: arguments will be ignored\n");
}
//assistance
setinletassist(0, "stuff");
setoutletassist(0, "things");
//define the cell struct
newCell.local = 1;
function newCell(freq, amp, alive_flag, nb_around)
{
this.freq = freq;
this.amp = amp;
this.alive_flag = alive_flag;
this.nb_around = nb_around;
}
//define the array's sorting function
sortByFreq.local = 1;
function sortByFreq(a, b) {
ÊÊÊÊvar x = a.freq;
ÊÊÊÊvar y = b.freq;
ÊÊÊÊreturn ((x < y) ? -1 : ((x > y) ? 1 : 0));
}
//define the array of cells
cell_array = new Array();
for (var i=0; i<32; i++)
{
cell_array[i] = new newCell(9999999,0,0,0);
}
//define the life rules
var interval_factor = 2;
var min_rule = 0;
var max_rule = 0;
function list(a)
{
//test the number of arguments - NOT NEEDED ANYMORE SINCE NaN is taking charge of it
// if (arguments.length % 2)
// {
// post("¥Spectral Conway Error: odd number of arguments in list\n");
// return;
// }
//create the temp_cell_array
temp_cell_array = new Array();
//create temp delta
var prev_index = -1;
```



```
var index, delta, prev_delta;
//iterate the list
for (var i=0; i<arguments.length; i+=2)
```

```
{
//make sure arguments are numbers
if((isNaN(arguments[i]) + isNaN(arguments[i+1])) != 0)
{
post("¥Spectral Conway Error: NaN in pair #" + ((i/2)+1) + '\n');
} else
{
//fills the temp array
temp_cell_array[temp_cell_array.length++] = new
newCell(arguments[i],arguments[i+1],1,0);
}
}
//sort temp array
temp_cell_array.sort(sortByFreq);
//insert temp in main array, replacing the nearest dead cell
//find the first dead cell
for(i=0; i<cell_array.length; i++)
{
if(!cell_array[i].alive_flag)
{
prev_index = i;
break;
}
}
// if we have at least a dead cell
if(prev_index >= 0)
{
// for each cell to insert
for(i=0; i<temp_cell_array.length; i++)
{
//if we don't have an option, get out
if(index == -1)
{
break;
}
prev_delta = Math.abs(cell_array[prev_index].freq - temp_cell_array[i].freq);
delta = -1;
//search loop
while(1)
{
//find the next dead cell
index = -1;
for(j=prev_index+1; j<cell_array.length; j++)
{
if(!cell_array[j].alive_flag)
{
index = j;
break;
}
}
//if there is none
if (index == -1)
{
break;
}
//compute the new delta
delta = Math.abs(cell_array[index].freq - temp_cell_array[i].freq);
```

```
//are we getting further?
if(delta >= prev_delta)
{
break;
}
//increment and back in the loop to search further
prev_index = index;
prev_delta = delta;
}
//copy the last optimal
cell_array[prev_index] = temp_cell_array[i];
//go to next (might be -1 and we skip!)
prev_index = index;
}
//sort the main array (clean up if any change)
cell_array.sort(sortByFreq);
}
//garbage collection
delete temp_cell_array;
}
function life_rules(a, b, c)
{
//test for the validity of the arguments
if((isNaN(a) + isNaN(b) + isNaN(c)) != 0)
{
post("¥Spectral Conway Error: arguments to life_rules should be (interval_span,
nb_min, nb_max)\n");
return;
}
//test the quality of argument 1
if(a <= 0)
{
post("¥Spectral Conway Error: 1st argument to life_rules should be an interval in
semi-tones\n");
return;
}
//test the quality of arguments 2 and 3
if(b<0 || c< b)
{
post("¥Spectral Conway Error: 2nd and 3rd arguments to life_rules should be the
minimum and maximum rules\n");
return;
}
interval_factor = Math.exp(0.057762265046662108 * a);
min_rule = b;
max_rule = c;
}
function evolve()
{
var freq_max;
//reset the alive cell counter
for(i=0; i<cell_array.length; i++)
{
cell_array[i].nb_around = 0;
}
//count the number of cells alive within the interval
for(i=0; i<(cell_array.length-1); i++)
```

```
{
//compute the ceiling value
freq_max = cell_array[i].freq * interval_factor;
//iter through the list until the interval is out
for(j=(i+1); j<cell_array.length; j++)
{
//if within the interval
if(cell_array[j].freq <= freq_max)
{
//increment if the other is alive
cell_array[i].nb_around += cell_array[j].alive_flag;
cell_array[j].nb_around += cell_array[i].alive_flag;
} else
{
//if outside the interval, get out
break;
}
}
}
//decide if the cell should live or die
for(i=0; i<cell_array.length; i++)
{
if((min_rule <= cell_array[i].nb_around) && (cell_array[i].nb_around <= max_rule))
{
cell_array[i].alive_flag = 1;
} else
{
cell_array[i].alive_flag = 0;
}
}
}
function play()
{
// create a temp array
output_array = new Array();
//transfer the freq/amp pairs of live cells
for(i=0; i<cell_array.length; i++)
{
if(cell_array[i].freq == 9999999)
{
break;
}
if(cell_array[i].alive_flag)
{
output_array[output_array.length++] = cell_array[i].freq;
output_array[output_array.length++] = cell_array[i].amp;
}
}
//send the output
if(output_array.length)
{
outlet(0, output_array);
} else
{
outlet(0, 0,0);
}
//clean the array
```

```
delete output_array;
}
function clear()
{
for (var i=0; i<cell_array.length; i++)
{
cell_array[i].freq = 9999999;
cell_array[i].amp = 0;
cell_array[i].alive_flag = 0;
cell_array[i].nb_around = 0;
}
}
function print()
{
//test print
post("interval_factor = " + interval_factor + '\n');
post("min_rule = " + min_rule + '\n');
post("max_rule = " + max_rule + '\n');
for (var i=0; i<cell_array.length; i++)
{
post("cell_array[" + i + "] = " + cell_array[i].freq + ' ' + cell_array[i].amp + ' '
+ cell_array[i].alive_flag + ' ' + cell_array[i].nb_around + '\n');
}
}
```

Appendix 2: Scores written during PhD study but not included in portfolio

Appendix 3: Scores of Pieces written before PhD

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