A practical examination of computer presence in electro-instrumental music

Jessica Aslan

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Abstract

This thesis explores the following questions: What is the influence of algorithmic software on the composition process? How can spectromorphologies be manipulated in search of coherent and lucid coupling in electro-instrumental (*EI*) music? What are the practical implications of the performance of *EI* music?

This thesis will unfold practicalities, creative approaches, and new directions for the practice of *EI* music, drawing together spectromorphological theory and instrumental techniques. Framed around a body of work for solo instrument/ensemble with computer, I will assess each aspect of my musical process. Musical vocabularies, grammatical organisation and collaborative performance practices will be discussed.

Specifically, my research breaks down components of composition into context, materials and an attempt towards categorisation and grammatical organisation including spectral and algorithmic techniques. With the knowledge that the computer has influence on the music making process, I identify and discuss some of its key contributions. Additionally, knowing that the tools and spaces that facilitate performance also impact the music, I seek to understand how these tools and environments contribute in order to get the best musical responses from them.

Collaboration is a key theme, and throughout the thesis I pay attention to performer presence in the music making process. This thesis should be read in conjunction with my submitted portfolio for relevant case studies and musical examples.

Acknowledgements

First thanks go to Josh, who has been a constant support throughout this four year journey. To my supervisor Michael, whose guidance and encouragement beginning with my masters and carrying on through the rest of my education has been immeasurable. To my partner in crime, Emma, who I met at the office and managed to forge an incredibly fulfilling musical partnership, and more importantly friendship. To my parents, Nicola and Jeremy, whose unwavering encouragement through my education meant that I managed to get this far at all. To the crew at Alison House, notably Kev the master of all things tech and Martin my second supervisor, who somehow manage to create an an environment that's both incredibly friendly and incredibly professional. To Lauren and Frieda my trailblazing sisters who are a continuing inspiration. To anyone that's been kind enough to programme my music, particular thanks go to Manoli Moriarty for your enthusiastic programming of KUBOV, where I learnt so much! And finally to the many people I've worked with, particularly Marij van Gorkom with whom I started this journey and who offered me amazing opportunities that no one else would have done, and the ISON quartet who patiently helped me through my final project.

Declaration

I declare that this thesis has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a degree. Except where states otherwise by reference or acknowledgment, the work presented is entirely my own.

Jessica Aslan

Contents

List of creative works submitted

Three Pieces for Violin and electronics

- **Duration**: 22 minutes
- **Instrumentation**: Violin and electronics
- **Names of Performers**: Emma Lloyd and Jess Aslan
- **Dates of performances**
  104 first performed at Soundproof festival, Forest café (January 2013)
  104, Mechanica and Softly Softly performed at Reid concert hall (May 2013)
  104, Mechanica and Softly Softly invited for performance at Bloc bar, Glasgow (September 2013)
  104 invited for performance at Sonorities Festival, Belfast (April 2014)

KUBOV: Invisible Soundscapes

- **Duration**: 35 minutes
- **Instrumentation**: Violin and electronics
- **Names of Performers**: Emma Lloyd and Jess Aslan
- **Dates of performances**:
  Metanast festival, Manchester (April 2014)
  Invited for performance at Science festival, Edinburgh. (April 2014)
  Invited for performance at Metanast, Bangkok bar, Manchester (May 2014)
  Invited for performance at Sounding Objects Conference, Edinburgh (May 2014)
  Invited for performance at International Computer Music Conference, Athens (September 2014)
  Invited for performance at Metanast, Athens (September 2014)
  Invited for performance at Metanast, Media City (September 2014)
  Invited for workshop Impulse academy, Graz February 2015
  Invited for performance Ifimpac conference, Leeds March 2015

Labyrinths with the ISON quartet

- **Duration**: 35 minutes
- **Instrumentation**: String Quartet and electronics

- **Names of Performers**: Emma Lloyd (violin), Julia Lungu (violin), Alexandra Martha Usarche (viola first recording), Fiona Murdoch (viola - 1st recording), Laura Sergeant (cello) and Jess Aslan (electronics)
- **Dates of performances**:
  Reid Hall Concert Hall, closed performance. 17 - 18/04/2015
  Noisefloor studio, 24/04/2015

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Cantor Dust

- **Duration**: 9 minutes
- **Instrumentation**: String Orchestra
- **Names of Performers**: Edinburgh University String Orchestra
- **Dates of performances**:
  Reid Hall Concert Hall, Emre Araci String Orchestra Competition, 12/04/2014

The Confines of Light and Shade

- **Duration**: 7 minutes
- **Instrumentation**: Flute, Clarinet, French Horn and Electronics
- **Names of Performers**: Jane's Minstrels
- **Dates of performances**:
  Colourscape Concert, London. 20/09/2014

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Chapter 1

Chapter One

1.1 Introduction

When I formally started this research a little over three years ago I had a definite idea of the music I wanted to make, and some idea of how to do it. As time progressed I realised that to develop the skills for a coherent type of electro-instrumental (*EI*) music articulating the clarity that I desired, I would have to unpick what I'd previously developed. What I didn't realise was that the route to understanding and rebuilding my methods and techniques was going to be through their very disassembly.

This thesis sets out to explain my work through each stage of the creation of *EI* music. Starting from the algorithmic development of material, through the programming of reactive software to the staging of individual performances, I aim to address some of the key issues in the field. These include the collaborative generation of material, flexible ways to programme realtime computer software, and the practical implications of performing *EI* music.

When I refer to electro-instrumental music, I am defining the music by two key traits:

- There is at least one musician present playing an acoustic instrument at the performance
- There is some form of electronic presence contributing to the performance

Every element of my portfolio is encapsulated by these two features, however this broadly defined practice holds many more distinctions, which I reflect on throughout the thesis.

The central concern of my research is the presentation of a united musical form between computer and instrument. Exploring this topic calls for versatile strategies and my portfolio contains both fixed and improvised music, arguably a necessary undertaking in order to fully understand computer presence in *EI* music. Sometimes I use fixed and notated music to explore my musical questions, at other times a more improvised environment is appropriate.

1.2 *EI* music: What are we looking for?

When I began it seemed to me that some of my music was *lost in translation*, specifically the interaction between the computer and instrument was superficial and the music reflected this. So I began by analysing my previous work and looking for the culprits, key contributors to this superficiality that I could examine and amend.

Loose questions formed with regard to my method. I began with reflection on my existing work with a view to forming critiques of my own processes step by step . My most important observations were:

1. I was writing music, or instructions at that point, dictated by the reactive software.

Certain styles of music - sparse 'gestural' type material - made the software 'sing' and I had not departed from this narrow aesthetic.

2. I was avoiding any real exploration of pitch, a fixed meter and high density of notes. It was easy for me to hide behind a minimal aesthetic - when I started throwing more notes at the page, and exploring more conservative rhythms and harmonies the software interaction I had programmed was exposed and collapsed (as I will show).

3. I had not developed efficient methods of communication and collaboration with musicians and sound engineers, regarding the representation of the software interaction. This was making each performance highly limited and the process of performance was not contributing to the future development of the music.

Reflecting these observations, my thesis is divided into three core chapters to reflect these observations. I demonstrate methods for the generation of material, followed by the translation of this material to reactive software and concluding with an assessment of performance practice and materials.

Examining my work processes has allowed me to rebuild my musical practice, as I will demonstrate in this thesis. What has resulted is a far more flexible approach to different musical circumstances. This flexibility is focussed around collaboration and supported by knowledge of my own techniques and those of other critical thinkers in the field.

1.3 Contents of chapters two, three and four

Christopher Small's position of musicking (Small, 1998) as a process, not as an object but as a series of actions and interactions, shifts emphasis on the way we think about music and our reflections on it. Music is something we *do*, not a product or object. This notion underpins my research methods. However, to practice music we do need to create a series of objects that feed the overall process; we interact with each other through the technology we create.

In this thesis I balance action with method, examining why and what it is we are doing and how we are doing it. I am interested in the overall process, music as action through the detail of the tools, and more importantly my relationship to them. This thesis is not a document to justify why I'm undertaking this research, rather my discoveries through musicking and techniques I have developed in response to practical situations.

Each of the following chapters documents the dialogues innate to each stage of the musical process. I should emphasise that discourse through collaboration in various guises is present throughout. My writing will continually seek to redefine the objects I present - code, scores, stage diagrams - in terms of their matrix of relationships. The relatively broad spectrum of ideas that I'm hoping to present in this thesis draws from technical, historical and musical theory.

1.3.1 Chapter two

In chapter two I focus on the examination of *Computer Aided Algorithmic Composition (CAAC)*. I use Ariza's catch all term (Ariza, 2005) to clarify that the material examined in this section is both generative and computer assisted. I have based my research around Michael Edwards' software environment *slippery chicken*(*sl-c*)[1]. The material that I'm generating is instrumental; I use theory as laid out in chapter three to create my own reactive computer software.

[1] slippery chicken is an open-source Common Lisp environment for declarative or generative algorithmic composition building on CLM, CMN, CM, and Lilypond for score, sound file, and/or MIDI file outputs and the integration of these into closely aligned hybrid acoustic-electronic pieces of music. (Edwards, 2015)

Key points that I will address are:

- A brief account of the software *slippery chicken*, and its position relative to different approaches to *CAAC* and *algorithmic composition*.
- My process of exploring this software, including analysis of portolio works through the paradigm of *Degrees of Interpretation* of material (Aslan, 2014a).
- Outcomes of this process and how they feed into the development of new work.

In this chapter I'll be tracing my 'whitebox'[2] examination of *sl-c* from my initial experiences through to later use. The interaction I will be focussing on is that of musician with software designer, the idea of this process being a combination of the musical will of the user and that of the software itself (or the musician behind it). Informing this is a larger general contextualisation of others' approaches and experiences with algorithmic composition (Anders and Miranda, 2009; Ariza, 2005; Collins, 2009; Edwards, 2011; Essl, 2007; Koenig, 1978, 1983; Monro, 1997).

I introduce a paradigm, *Degrees of Interpretation (DoIs)*, a method of analysis that I use to explain the stages at which I have overridden software through interpretation in the process of composition (Aslan, 2014a). I use these *DoIs* to try to look for patterns of output that transcend formats[3]. Here I'm trying to separate the software's musical language from my own in order to be able to influence it more effectively. The point of this is to demonstrate the feedback loop that tends to manifest through the experimentation and refinement of techniques when using this type of software. Ultimately, my process of investigation allowed me to understand which bits of the software I wanted to accept, and those I wanted to reject in order to assimilate my own aesthetic into the software designer's

[2] White-box testing (also known as clear box testing, glass box testing, transparent box testing, and structural testing) is a method of testing software that tests internal structures or workings of an application, as opposed to its functionality (i.e. black-box testing)(Wikipedia, 2015b)

[3] Formats here means output medium, for example a score, audio file or MIDI file

work.

Crucial to this interrogation is the symbiotic relationship between material and form, not how instrumental the technology is in steering the final aesthetic product but how the software actually musically *manifests*. I'll be looking at writing by Collins (2009), DiScipio (1998), Thoresen (2007), regarding form specific to algorithmically generated computer music, contextualised with some more general understanding on our perception of musical form (Cook, 1987).

1.3.2 Chapter three

In chapter three I look at the space between instrument and computer and the interactions that fill it whilst musicking through realtime software. I examine what it means to aim for a 'successful' presentation of an *EI* work, my definition of successful being the presentation of a united form between computer and musicians, with clear perceptual links between the two. Perceptual in this case means the disparate elements of the music are perceived by a listener as having organisational links between them. This chapter focusses on research around strategies and techniques that can be employed at the compositional stage. Chapter three draws together literature in an analytical way, and focuses on the perceptual over the technical. That is, what we might hear and experience rather than a purely digital flow of data.

Key points include:

- Examination of some of the roles and sound world the computer can inhabit in an *EI* work
- The analysis of algorithmically generated instrumental material contextualised through existing electroacoustic approaches and terminology

- Translation of analysis in point one to the reverse practicalities of point one to create perceptually informed realtime computer software using *Max/MSP*[4]

In this chapter emphasis is on translation, an attempt at normalising the exchange that occurs between instrument and computer, with sound as the interface[5] . This can be considered on a multi-dimensional matrix, with elements belonging to multiple forms of interaction.

As I am looking at translations between instrument and computer my practice analyses algorithmically generated instrumental material in terms of documented paradigms of acousmatic music (such as Denis Smalley's spatial archetypes (Smalley, 2007)) in order to find connections. The assignment of spatial as well as temporal dimensions of music, as largely expanded through the analysis of acousmatic music, allows me to interrogate my decisions more critically, and navigate each interaction mapped through theoretical assumptions of how the music might be perceived as a whole.

Beyond translation, perhaps at the core of this chapter is the idea of transplantation. I analyse instrumental material in ways developed for the analysis of acousmatic material, and compose computer responses as appropriate. The computer is surveyed in many different guises, and its role as music-maker laid out in a multi dimensional spectrum of behaviours (Frengel, 2010; Croft, 2007; Emmerson, 2007; Bernadini, 2002).

First I look at the qualities of note units, identifying how these qualities can either be supported or offset by the reactive software I design. Which decisions are made after these analyses are to some degree academic. What is important here is an explanation of instrumental actions alternate to those traditionally found whilst seeking form in a musical

[4]A visual programming language combining possibilities for the realtime processing of audio and visual data.

[5]*Sound as interface* means that activating the realtime software is largely reliant on information gained from the sound feeding a microphone input. This ranges from amplitude thresholds, to certain pitches to the brightness of the sound.

score, for example, by identifying a harmonic structure through the pitches of notes. An electroacoustically informed analysis of instrumental material ranges from interrogation at a note unit level to longer musical phrases contributing to a larger scale form.

Above all lies an emphasis on what I hear as a composer rather than what I know to be structuring processes. Schaefferian theory of reduced listening (Schaeffer, 1952; Chion, 2009; Kane, 2007) somewhat contributes to this, though I contextualise it by a more encompassing view of musical perception. Key contributors to theory held in this chapter include Atkinson (2007), Clarke (2005), Deliège (1989), Smalley (2007), Windsor (1997), Bregman (1994), Thoresen (2007), Waters (2007), Houtsma (1997), McAdams (1989), McAdams (1999), Nelson (2011), Pasoulas (2011).

Moving between interactions in solo performances to those found in ensemble music necessitates a shift in accentuation. In ensemble music the score holds parallel layers of note objects and phrases of certain qualities. These contribute to a more complex musical surface. Understanding the way that this surface is constructed through its deconstruction helps pragmatically to feed the computer/instrumental responses. Growing numbers of strategies for electroacoustic analyses have given rise to a number of different lenses through which we can begin to unpick instrumental ensemble material. This ranges from different conceptual spaces (Smalley, 2007), to the way we actually hear things day to day (Bregman, 1994; Windsor, 1997; Clarke, 2005). Understanding algorithmically generated material in these terms allows us to construct realtime interactions more rigorously and make informed decisions through the disassembly of the material. Finally, I demonstrate the practical methods that I use to communicate computer behaviour and what is actually heard and how this is achieved through software design.

1.3.3 Chapter four

Chapter four presents the front end of the process, the event of presentation and interaction between the people that make the music happen. I choose these words carefully as performance does not imply finality. Each piece of music is open-ended to some extent and refinement is always possible. I find the constant struggle between ideas contrasted with the practical reality of performance situations a source of particularly rich information: this musical process iterates continuously.

Key points include:

- The representation of electronic processes for communication via score-based or screen-based media
- Hardware and software involvement in performance
- The impact of physical and social space on the reality of performance

In this chapter I will be demonstrating effort contributing to the act of performance and the dialogues that need to happen to ensure - or at least attempt to ensure - a satisfying musical experience. There are many people involved in this process. Chapter Four will document communication between composer and musician (if this dichotomy exists), musicians and venue, musicians and sound engineer, patch operator and composer and so on. These aides can either be visual, verbal or aural, and each situation will most likely illuminate new and appropriate methods for true understanding of the musical intentions.

Information about the software interaction - what is going on inside *Max/MSP* - is crucial for musicians to be able to understand quickly what will actually happen when they play. Of course aural interaction, practise, is the most effective way to achieve this. However, due to the current climate of commissions, short rehearsal time, and increasing demand on university spaces, it is in everyone's interest for the computer part to be in some way represented to the musicians before rehearsal. At present there is no unified language to achieve this, although there exists a lot of theory surrounding potential methods of visually representing electronic sound (Thoresen, 2007; Blackburn, 2007; Smalley, 1994, 1997; Patton, 2007).

Over complexity can be detrimental to the clarity of a score. Often non-graphical representations in the form of cues are more effective for the rapid information absorption that is necessary to read a score. To meet this need I will lay out a series of collaboratively developed additional material that allows those involved a fuller understanding of the computer part to be assimilated through practise before the action of performance. I also explain how and why this information will need to vary from musical situation to musical situation.

Necessary information extends to parties other than musicians directly involved in the playing of the piece. The second half of this chapter details various documents for different stakeholders and experiments with different forms of information exchange (Aslan, 2014b). I am interested in the architecture of the venue, both physical and social. These have the greatest implication on performances and can reflect material in different ways given different circumstances. Two way communication early on in the generation of the music gives each party an idea of what will be asked of them and how situations can best be managed. Implicit here is the understanding of performance as a flexible ecosystem (Clarke, 2005; DiScipio, 2011; Waters, 2007; Green, 2008, 2013; Mulder, 2010b,a). The final part of this chapter unfolds experiences of the performance ecosystem and compositional methods that prompt certain actions helping to ease the stress of performance situations.

Understanding what is happening in your own music and then communicating this to the sound engineer and musicians involved is a crucial part of this process. Whether a commission by a third party or an improvised event each performance carries with it information that will have enormous bearing on the presentation of the work. I therefore draw on chapter three, my own understanding of the musical interactions I have created, to examine ways to distil this information with the appropriate level of detail for each individual involved.

1.4 Chapter five

Chapter five contains greater detail regarding the portfolio submission. These are referred to through the previous four chapters and different pieces of music emphasise different elements of the thesis.

1.4.1 Three pieces for violin and computer

These three violin pieces (*104, Mechanica, and Softly, softly*) were formed early on in my research. They explore different ways of generating and presenting material collaboratively. The intricate nature of these works demonstrates how Emma Lloyd and I explored instrumental material as sound objects - looking at different qualities of different notes and how best they could be presented alongside a computer part, as will be shown in Chapter Three. *Mechanica* also contributes to my exploration of algorithmic composition via a form of hybrid composer mediation, as described in Chapter Two.

1.4.2 KUBOV: Studio album

KUBOV is an improvisational duo that I formed with violinist Emma Lloyd. Over the course of my research I have been developing Max patches that are not built around a single piece. They require a more flexible instrumental approach. None of the material found in this part of the portfolio was generated algorithmically, and this work is largely unrelated to chapter three. Where the work offers interest is with reference to perceptual decisions and software behaviour (found in Chapter Three) and via the practical exploration of venue architecture and communication materials (found in Chapter Four).

1.4.3 *Labyrinths* for string quartet and computer

Labyrinths for string quartet and computer is a three movement work generated algorithmically. The material for the instrumental part has been generated largely using a set of wraparound classes for slippery chicken, which will be detailed and explained. These methods pertain to chapter two. In forming the computer part I demonstrated different methods adopted using the perceptual theoretical grounding in chapter three. This looks at the ensemble as an acousmatic landscape and considers performance of *EI* music beyond solo work. Experiences of workshops, performances and supplementary documents relate to chapter four. *Labyrinths* demonstrates the most comprehensive effort that I have made to draw together all the theories I have developed during the course of my research.

1.5 Appendices

1.5.1 Publications

- Degrees of Interpretation in Computer Aided Algorithmic Composition as found in the proceedings of the International Computer Music Conference, 2014. (Aslan, 2014a)
- From Input to Output: Harnessing Software for mixed music as found in the proceedings of the CIM conference in Interdisciplinary Musicology, 2014. (Aslan, 2014b)

1.5.2 *Cantor Dust* for string orchestra

Cantor Dust. This is a string orchestra piece, algorithmically developed. This piece is a demonstration of the flexible input and output formats that algorithmic composition can offer.

1.5.3 *The Confines of light and Shade*

This piece was developed algorithmically using slippery chicken. The piece was commissioned by the *Colourscape* festival and first performed on 21st September in a *Colourscape* dome. It demonstrates later use and development of my wraparound techniques (documented in Chapter Two), perceptual translation (found in Chapter Three) and dealing with commissions and communication with a patch operator (found in Chapter Four). It also explores performances in unusual venues.

Chapter 2

Creating music with *Slippery chicken*

A significant amount of my portfolio was developed using Michael Edwards' algorithmic composition software *Slippery Chicken (sl-c)*. This has become one of my principal tools for composition. The following chapter will describe the software and my use of it, attempting to pinpoint and examine some crucial points of musical influence. Peter Hoffman's PhD thesis, '*Music Out of Nothing? A Rigorous Approach to Algorithmic Composition by Iannis Xenakis*' (Hoffmann, 2009), provides a useful framework for exploring many key issues surrounding this type of composition.

2.1 *Slippery Chicken*

Edwards describes the software as follows:

> "a new open-source algorithmic composition system, which enables a top-down approach to musical composition" (Edwards, Edwards)

First let's discuss his description of the software.

1. *Open-source*. The code is open for the user to examine and modify.
2. *Algorithmic*. The system encompasses an overall composition method[1].
3. *Top-down*. The user can control the musical output from a global perspective, as opposed to structuring generated material from smaller building blocks.

In Edwards' primary introduction to the software (Edwards, Edwards), it is significant that he chooses these three qualities as the principal descriptors; qualities that best encapsulate the *sl-c* environment. They deserve further discussion because each trait highlights a relevant and polarised possibility within the practice loosely labelled *Computer Aided Composition* (*CAC*) (open/closed source, manual/algorithmic, top-down/bottom-up). Interrogating these positions in terms of my practical software application provides an ideal circumstance for focussed examination of *sl-c* in context of the general practice of *CAC* .

Edwards describes *sl-c* as an initially specialised composition software that has gradually morphed into a more general set of tools. *sl-c* was primarily created to enable Edwards' own compositions. Much of the musical thinking found in its fabric embodies solutions to his own compositional goals. In his words "it offers a structured method as opposed to a composition software library" (Edwards, Edwards). This being said, the open source of *sl-c* nature means users are free to extract and augment any number of its functions; much like a library. This flexibility means user methodologies can vary greatly. Therefore *sl-c* presents an interesting tool for examining the presence of a software developer's inbuilt musical preferences combined with user intervention.

The nature of *sl-c*'s top-down approach characterises its output as globally as well as locally organised. This means it outputs large scale structures created directly through the

[1]Monro's definition of algorithmic, (Monro, 1997)

recombination of pitch and rhythm sequence palettes[2], Edwards pays close attention to transition between sections in particular. See Edwards (Edwards) for a detailed description of some transitional features. Because of this top-down approach, *sl-c* ostensibly avoids Nick Collins' pitfall regarding much algorithmic composition software; "stuck in a static moment form, able to abruptly jump between composed sections but unable to demonstrate much real dramatic direction" (Collins, 2009). In fact, the musical forms that *sl-c* creates are perhaps one of the most defining properties of the software. A great deal of attention is given to transitioning through subsequent sections often calling on pseudo-natural processes such as *L-systems* and *Fibonacci* numbers in contribution to the coherence of long term forms.

Over the past three years I have developed a number of different ways to survey this composition software in order to understand and extend it to suit my needs and create my own compositional tool. These activities raise a number of questions fundamental to the use of the computer in composition:

- How active is the computer's involvement in composition?
- How compliant am I when it comes to accepting what it delivers?
- How is a software designer involved in my compositional process?
- To what extent am I present at all?

[2]Pitch and rhythm sequence palettes are lists of user specified harmonies and rhythms which are navigated through and recombined using the main *make slippery chicken* function. More on this can be found in the software's manual, here http://www.michael-edwards.org/sc/

2.2 Active presence: A working definition of *Computer Aided Composition*.

> "There is an increasing trend...towards the use of the computer for tasks beyond music typesetting, recording and production, which is to use it as an active creative partner in the actual compositional process." (Miranda, 2009)

Seeking to define *active* computer presence in composition raises a number of overlapping and contradicting terminologies. It is important to set out some clear boundaries for these terminologies from the outset in order to discuss practical matters with clarity further on.

Computers as a general tool pervade every aspect of our lives, in both benign and active roles. In line with this, musicians are certainly adopting computers as more than just neutral assistants for meaningful tasks. This elevates certain compositional processes to where the computer is said to be more *active* and pushes these methods into the realm of the *Computer Aided*.

When Hoffmann questions "Is the present text a 'computer text' only because I use the computer to type it?" (Hoffmann, 2009), he highlights the potentially infinite number of compositional practices that could be labelled *Computer Aided* if we choose blindly to interpret all computer use as fundamental. This all-inclusive term would render its meaning unhelpful. Including the word *active* as a qualifier allows us to exclude certain musical activities that feature a computer seen merely as an agent to carry out tasks for the composer in a master/slave dichotomy. *CAC*'s requirement for creative contribution perhaps stems from the position that without it we are not embracing the technological epoch of programming far enough. For example, using the computer to format a score is something that could feasibly be fulfilled using the technology of writing. In other words the computer isn't adding anything of its own qualities into the resulting music.

But how can we qualify what it means to be *active*? The word implies some type of participatory engagement on behalf of the computer, for its behaviour to be in some way *autonomous*. *sl-c* is certainly an active partner in my creative process, in that it makes decisions beyond those that I take, so thus far I feel confident labelling my work as *Computer Aided*. But is there a more specific description of my practice? Am I practicing *Algorithmic* or *Automatic Composition*?

Edwards labels his own composition with *sl-c* as *Algorithmic* on the strength of Monro's distinction (Edwards, Edwards). Monro's words seem to conflict with other working definitions of the term *Computer Aided* in failing to find a middle ground between computer as assistant, and music that is created at the touch of a button :

> "I distinguish between computer-aided composition, where the composer constructs the piece directly while using the computer as an assistant, and algorithmic composition in the strict sense, where a whole piece is generated at the press of a button." (Monro, 1997)

I find both these definitions too narrow to define my practice accurately, and so do not find them appropriate for my compositional activities. This is because at many points in my work there has been a significant amount of composer interpretation after the touch of the button, yet my work can't accurately be described as manual.

The activity of interpretation supports the fact that I am practising *CAC*, something Anders and Miranda state as being half way between manual and automatic composition (Anders and Miranda, 2009). However, this doesn't mean to say that *Automatic composition* might not be the *ideal*; a touch of a button is certainly more efficient. Can practice morph from being *Computer Aided* to the more extreme *Automatic* further on down the line as it becomes more seamlessly folded into my compositional process? If this is the case this definition seems to seek to revise the context from which the software came. To clarify, I identify my use of *sl-c* to be in between *Computer Aided*, as distinguished above, and *Algorithmic* or *Automatic* composition. This is because whilst I do mediate the output material I tend to leave the form assembled by *sl-c* intact. Further on in this chapter I categorise the grey area of my practice into *Degrees of Interpretation* (see subsection 2.4.2).

2.2.1 *Slippery Chicken* in practice: Functionality and usage

What is *Slippery Chicken* (*sl-c*)? *sl-c* is an open-source, non real-time process model that features a text-based (LISP) language interface. It offers a wide variety of options for material input and a largely open formatted output, and is ostensibly what Ariza describes as "plural idiom affinity...[it] allows the production of multiple musical styles, genres, or forms." (Ariza, 2005), and features full extensibility to the user with some LISP programming skills. I will first provide some basic information surrounding *sl-c* by giving a brief summary of its core functions. After this I will carry out a more detailed interrogation.

Input requirements and output possibilities

Here is a basic description of the input and output formats, which are necessary in order to carry out the procedures found in *sl-c*. All elements must be specified by the user, athough instruments have a large number of standard default options that are built around existing acoustic instruments. Edwards introduces the fundamental components of the software in his manual as follows:

1. The instruments: ranges; transposition; chord selection function (if applicable); microtonal potential; any notes (especially microtones) that the instrument can't play etc.;
2. the instrument changes for individual players (e.g. flute to piccolo);
3. the set (harmonic) palette that the piece will use;
4. the rhythm sequence palette;
5. the rhythm sequence map: sequences onto instruments;
6. the set map: sets onto sequence progressions;
7. the tempo maps/changes;
8. the set limits: for the whole piece and/or instruments (these are curves that form restrictions on the lowest and highest notes selectable from any given set; they are used to control global instrumental and ensemble pitch height/width development)." [3]

...The output of the program is in the form of MIDI sequences [9.] (generated by CM's[4] MIDI interface and containing all the tempo and meter information that facilitates reading into notation software such as Sibelius), postscript score files [10.] (generated by interfacing with CMN[5], and thus allowing the algorithmic use of arbitrary symbols, note heads etc.), LilyPond[6] files [11.] (with similar advantages to CMN), and sound files [12.] (using samples driven by a custom, multi-channel CLM[7] instrument). "

(Edwards, 2015)

sl-c does not have a graphical interface. To show what the software looks like in action I have included an annotated version of the first tutorial from the manual, affixing each numerical input and output value to its place in the code. Of course, to get a proper grasp

[3] List of functions, found in (Edwards, 2015)

[4] Common Music is a music composition system that transforms high-level algorithmic representations of musical processes and structure into a variety of control protocols for sound synthesis and display.

[5] Common Music Notation is a simple little hack that can create and display traditional western music scores. cmn is intended as an adjunct to Heinrich Taube's Common Music and my CLM (Sjostedt, Sjostedt)

[6] Lilypond is a text based score formatting software

[7] CLM is Common Lisp Music is a music synthesis and signal processing package in the Music V family(Sjostedt, Sjostedt)

of the system it would be better to install it and explore it first hand. Figure 2.1 shows code with numbers identifying the elements described found in the first tutorial piece, *Primary Disposition* (Edwards, 2015).

On its basic level we have a number of input combinants, hard-coded internal processing (for example *make-slippery-chicken*[8], the algorithm for recombining pitch and rhythm palettes) and a number of output formats for interpretation. As we can see even with the most basic use, *sl-c* leaves a vast number of options open to the user. Here you can see that each defined instrument moves through its own combination of rhythm sequences whilst pitches are selected from a collective harmonic progression. This selection can be shaped further by *set limits*, meaning that you narrow down the register options available to an instrument at any time.

The input material is simultaneously generalised and specialised. You can input harmonies and rhythms of any character you define, moving between them as you stipulate, though there are some provisos. These are largely to do with list and duration lengths. Set maps and rhythm maps, the maps through which you navigate the pitch and rhythm palettes, must be the same length. Furthermore due to the combinatory nature of the algorithm, every rhythm sequence selected for every instrument at any one time must have the same duration. Another constraint is that the harmonies must change at the same time as the rhythm sequences. These are perhaps the most prescriptive elements of the software and if treated without thought by the user/interpreter can lead to musical output of a fairly definable character. For example, jumping through unrelated harmonies for bars of equal length can be an obvious signpost to internal processes.

In terms of the contents of each palette, the user is free to define their choices as they wish, either by hand or generatively. The software becomes more interesting when the

[8] This is the function that will be used most often to ”put it all together” (Edwards, 2015)

```
(in-package :sc)
(in-scale :chromatic)
(make-slippery-chicken

   '+primary-disposition+
   :title "Primary Disposition"
   :instrument-palette +slippery-chicken-standard-instrument-palette+
   :ensemble '(((flt (flute :midi-channel 1))
                (clr (b-flat-clarinet :midi-channel 2))
                (vln-one (violin :midi-channel 3))
                (vla (viola :midi-channel 4))
                (cel (cello :midi-channel 5))))
7  :staff-groupings '(2 3)
   :tempo-map '((1 (q 84)))
   :set-palette '((set1 ((fs2 b2 d4 a4 d5 e5 a5 d6)))
                  (set2 ((b2 fs3 d4 e4 a4 d5 e5 a5 d6)))          3
                  (set3 ((cs3 fs3 e4 a4 e5 a5 e6)))
                  (set4 ((fs2 cs3 e4 a4 b4 e5 a5 b5 e6))))
   :set-map '((1 (set1 set1 set2 set1 set2))
              (2 (set2 set2 set3 set2 set3 set2 set3))
              (3 (set3 set2 set4 set2 set4 set3 set4 set4 set2 set3 set4))     6
              (4 (set4 set1 set4 set1 set4 set1 set1)))
   :set-limits-high '((vla (0 b4 100 b4))
                      (cel (0 f4 100 f4)))          8
   :rthm-seq-palette
   '((seq1 ((((4 4) - 16 16 8 - { 5 - 20 10 20 20 - } { 3 3 6 } )
             ( - s s s s - (s) - s s s - - +e. s - q))                  4
            :pitch-seq-palette (1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9)
            :marks (mp 1 a 1 s 3 slur 1 3 a 4 slur 4 7 s 9 a 10 slur 16 18)))
     (seq2 ((((4 4) - e e - - s s s s - (s) s (s) s { 3 - te te te - } )
             ( - s s s - (s)  { 3 - te te - (te) } q \+8 (e) ))
            :pitch-seq-palette (11 10 9 11 10 8 7 11 10 6 5 11 10 9 8 7 11)
            :marks (mf 1 s 1 2 a 3 slur 3 4 a 5 slur 5 6 s 7 s 8 a 9
                       slur 9 11 a 12 slur 12 14 s 15 16 a 17)))
     (seq3 ((((4 4) { 3 - te te te - } - e e - - s s s s - (s) s (s) s )
             (- s s s s - - s s s s - { 3 - te te te - } { 3 - +te te te - } ))
            :pitch-seq-palette (1 2 1 2 3 1 2 3 4 5 6 1 2 3 5 4 4 4 2 7 5 4 5
6)
            :marks (f 1 slur 1 3 a 4 s 4 5 slur 6 7 slur 8 9 s 10 11
                      slur 12 13 slur 14 15 a 16 slur 18 19 slur 20 21 a 22
                      slur 24 25)))
     (seq4 ((((4 4) - s s (s) s - - s s - (e) - e s - (s) { 3 - te te te - } )
             ( { 5 - 10 10 20 - } - +s s s s - (e) - e+32 32 s s s - ))
            :pitch-seq-palette (4 5 4 4 5 4 5 4 7 13
                                17 15 14 15 11 12 13 4 5 7 8)
            :marks (ff 1 slur 1 2 s 3 slur 4 5 a 6 slur 8 10 s 10 a 11 s 11
                       a 12 s 12 slur 13 15 slur 16 17 a 18 slur 19 22))))
   :rthm-seq-map
   '((1 ((flt (seq1 seq1 seq2 seq1 seq2))
         (clr (seq1 seq2 seq1 seq2 seq1))                5
         (vln-one (seq1 seq1 seq2 seq1 seq2))
         (vla (seq1 seq2 seq1 seq2 seq1))
         (cel (seq1 seq1 seq2 seq1 seq2))))
     (2 ((flt (seq1 seq1 seq2 seq1 seq2 seq1 seq2))
         (clr (seq1 seq1 seq3 seq1 seq3 seq1 seq3))
         (vln-one (seq2 seq2 seq3 seq2 seq3 seq2 seq3))
         (vla (seq2 seq2 seq1 seq2 seq1 seq2 seq1))

         (cel (seq3 seq3 seq2 seq3 seq2 seq3 seq2))))
     (3 ((flt (seq1 seq1 seq2 seq1 seq2 seq1 seq2 seq2 seq1 seq2 seq2))
         (clr (seq2 seq2 seq3 seq2 seq3 seq2 seq2 seq3 seq2 seq3 seq3))
         (vln-one (seq3 seq3 seq4 seq3 seq4 seq3 seq4 seq4 seq3 seq4 seq4))
         (vla (seq4 seq4 seq3 seq4 seq3 seq4 seq3 seq3 seq4 seq3 seq3))
         (cel (seq4 seq4 seq2 seq4 seq2 seq4 seq2 seq2 seq4 seq2 seq2))))
     (4 ((flt (seq4 seq3 seq4 seq1 seq4 seq1 seq1))
         (clr (seq3 seq2 seq3 seq2 seq1 seq2 seq1))
         (vln-one (seq2 seq1 seq1 seq1 seq2 seq1 seq1))
         (vla (seq4 seq3 seq4 seq2 seq1 seq1 seq1))
         (cel (seq2 seq2 seq2 seq1 seq2 seq1 seq1))))))

   (midi-play +primary-disposition+ :midi-file "/tmp/primary-disposition.mid")   9

   #+cmn ;; <-- that means only run the next Lisp form if that CMN package is
         ;; available                                                      10
   (cmn-display +primary-disposition+ :file "/tmp/primary-disposition.eps")

   (write-lp-data-for-all +primary-disposition+ :base-path "/tmp/")      11
   ;; (lp-display +primary-disposition+ :base-path "/tmp/")

   ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

   ;;; EOF primary-disposition.lsp
```

Figure 2.1: Piece 1, *Primary Disposition* labels associated to Edwards' list of functionality (Edwards, 2015), table 3.

user delves into its potential generative aspects. It is arguably here that *sl-c* becomes most *active* in its collaboration. As *sl-c* is open-source, Edwards invites us into its mechanisms, and as this specialist software has been released for more general access, the user is able to repurpose it for their own specialist aims beyond the prescriptions of the tutorials provided[9].

2.3 *CAC*: What can an *active* computer presence mean to the composer?

> "When the composition process is realized through a process of dialog between Man and Machine, where the machine's actions cannot fully be predicted, the classical notion of the composer must be changed from the picture of an almighty master to that of a cooperative collaborator who is ready to engage in open-ended processes of exploration."
> (Hoffmann, 2009)

Now some of the functionality has been addressed, it's possible to pursue a deeper aesthetic exploration of *sl-c's* influence on my composition. Hoffmann identifies the difference between the all-controlling master of manual composition and the composer who accepts that elements of a piece of music might succeed, even if out of their control. What is the impact of the computer as an active musical partner?

[9] For full manual, tutorials and papers on *slippery chicken* please consult Edwards (2015)

2.3.1 A dualistic paradigm

Much of the literature surrounding *CAC* alludes to its "dualistic" (DiScipio, 1994) nature, a reference to a division between the abstract and the concrete, a division perhaps exemplified in the historically opposing schools of *musique concrète* and *Elektronische Musik* (Emmerson, 1986). DiScipio describes this as the " unavoidable - but too often evaded - dialectic between the conceptual and the perceptual in the musical experience" (DiScipio, 1995).

The dual facets of the music, "the poietic and esthesic dimensions of musical experience" (DiScipio, 1994) , help us to position the algorithm crudely as conceptual and abstract, with its output format being its perceptual counterpart. This duality is Koenig's *strategy* versus his *proposed goal* (Koenig, 1975), Essl's "structural variant and concrete form" (Essl, 2007), Sandred's "cognitive dualism of sound and structure" (Sandred, 2009). Emphasising this dualism is a useful paradigm for analysis in *CAC*, allowing us to examine the influence of computer presence on music in more manageable parts, in particular to shed light on how the abstract building blocks have formed the concrete structure.

For Collins the interest lies not in these separate constructs of abstract and concrete, but in the relationship between them, the examination of which he describes as a *fundamental aim* of *CAC* analysis (Collins, 2009). DiScipio also ascribes importance to this relationship, labelling it "a novel analytic category" (DiScipio, 1995). He talks of the mechanism by which composers assemble their palette of tools, their *techné*, a term which imbues these tools with their original context and means of creation, rejecting technological neutrality altogether. DiScipio describes *techné* as "the realm of techniques and technology captured in the creative process of music composition" and proposes it as a fundamental analytical starting point for the understanding of *CAC* (DiScipio, 1995). Far from being neutral, tools are embedded with social context and historical artefacts from their creators and these factors can be discovered through examination of the tools themselves:

> "A composer's conception of sound and the way she/he relates sound to the overall musical structure can be analysed in his/her téchne. There one finds traces of the way in which a composer explores, extends, and models his/her own experience."
> (DiScipio, 1995)

Thoughout his extensive investigation into *techné*, DiScipio labours the idea that the clues to a composer's working process are held in their 'task environment', specifically the tools that they use to create. He proposes that the tools themselves can say much about the person that wrote them. In other words through this *novel analytical category* we can learn not only about the music but about the *techné* and therefore the user that constructed them.

2.3.2 Designer involvement: Collaboration through algorithms

Accepting that a designer's knowledge is crystallised in our chosen software, can we now say that a composer's chosen *techné* is also a composer's chosen collaborator? This is a strong shift in emphasis from the concept of computer as mere assistant and acknowledging designer presence in software takes into account the context and social relationships captured within the code itself. By using algorithms we are, in fact, engaging in dialogue with other human beings.

Hoffmann burrows further down this rabbit hole:

> Consequently, a composer who enters a feedback loop with a system of which he has actively participated in developing establishes a dialog with his complex self. The master-slave relationship in the classical use of the computer is replaced by a more cooperative approach of interaction,

> challenging human intelligence by contributing genuine computational elements of unpredictability and surprise." (Hoffmann, 2009)

Not only are we engaging with a third party, we are engaging with an algorithmic version of our former musical selves. Technology having been regarded as a sometime vehicle for movement from A to B, a "silicon assistant" (Anders and Miranda, 2009) now becomes far more - the formalisation of an approach, a vessel for individual musical values documented in code. From this stance it is easy to perceive an *active* collaborator in computer music, an "alter ego" and working with a computer becomes akin to "conversing with a clever friend" Hoffmann (2009) quotes Laske and Chadabe. The algorithm suddenly becomes much more animate.

This should and already has changed the way that we approach the use of code - particularly other people's - in our art. From functioning as a set of neutral tools that execute tasks that we fully understand, our technology has morphed to *techné*, an animate partner in music making, creating loops of interaction that combine knowledge captured in code with realtime human disrupters (the user). As the computer's role transforms to one of determined unpredictability (Hoffmann, 2009; Edwards, 2011), understanding the consequence of technological choices means we might then have also moved ourselves away from the blind acceptance of an algorithm's authority. DiScipio calls this the *Heretical Use of Technology* (DiScipio, 1995).

2.3.3 Compliance and non-compliance: User as heretic

Rather than using technology to solve a problem, DiScipio describes the *Heretical Use of Technology* (*HuT*) (DiScipio, 1998) as a way to challenge already existing solutions.
He explains:

> "... heretical notion observes that any particular piece of technology involves a particular body of knowledge and stems from someone's beliefs, wants and theories about the domain of application." (DiScipio, 1998)

The *HuT* therefore allows us to question the hegemony of code by acknowledging that there are people behind its design and it is our right to question and disrupt their values, in fact it is our responsibility to do so. Our wilful use of the software challenges its authority.

sl-c is Edwards' heretical use of Common Lisp. Though in some ways generalised, it is, in Edwards' own words, a specialised piece of software laden with his specialised solutions to his specialised musical problems (Edwards, Edwards). Therefore, to explore it creatively it was necessary for me to use it heretically; In order to question his solutions in pursuit of my own. More detailed elaboration on this can be found subsection 2.4.2 on page 41.

2.3.4 Material, Form and Interpretation

> "One main issue in the field of algorithmic composition is the relationship between the algorithm and the final musical structure" (Hedelin, 2008)

If we have established a way of using and understanding our tools, it should also be debated that our tools, our *techné*, will remain in the music as 'musical artefacts' (Eckel, 1998), even when the output becomes concrete and physically detached from the software of its making. By examining input to, and output from, an algorithm it becomes easier to establish where these artefacts might dwell in the music.

Discussing *Projekt 1*, Koenig suggests that the work itself - the essence of *Projekt 1* - exists inbetween the input data and output format. In other words the form of the work is a combination of the chosen input material and the processes contained in the encoded 'strategies' (Koenig, 1992). Through this approach, we choose material and we also choose which processes to enact upon it. Unsurprisingly then, the idea of form for Koenig shifts from the traditional perceptual qualities to objective strategies. This is something captured in the code, not necessarily an element to be perceived. This is particularly interesting seeing as he reserved the right to interpret his musical results, as discussed by Hoffmann (2009).

Koenig also points to a conflict for the composer interpreting another's software as lying between these two different perceptions of form (Koenig, 1983), blaming the 'elimination of the composer' during production as the root of this conflict. He maintains that for a composer without implicit knowledge of the codified rules, the relationship between the input and output is opaque, and it is therefore difficult to make meaningful employment of said rules. He is talking, of course, about composers using other software designer's systems. For him it seems, the shadow of the *techné* dwells in the demonstrable relationships to be found in the output material; if you don't understand these inner processes you risk a composition necessarily riddled with someone else's values. However, this conflict in interpretation can be mitigated through a robust exploration of the processes involved, diminishing this crucial void through education.

DiScipio describes strategies and processes as "immaterial and purely potential" (DiScipio, 1995). Looking beyond Koenig's assessment of code as objective form, one could take a step further and describe the potential of code itself as musical form; the form as an abstract projection of instructions. Taking this route we need not create the output at all. The composition lies in the code - the processes themselves are the aim of the composer, a stance many live coders might not wholly disagree with (Collins, 2008; Magnusson, 2009). An example of this, is the "shift in focus" from product to system, discussed by Anders and Miranda (2009) in their description of *Automatic composition*. Where composition itself lies in the composition of tools.

In my practice, however, this is a limited view, because it disregards the idea of composer as interpreter and dismisses the effect of input and output format on a piece of music, the concrete element. Davismoon (2009) refreshingly levels the argument to a more pragmatic perspective:

> "Whilst it is certainly true that most, if not all composers utilize symbolic manipulation to some often quite large extent, perhaps the best ones do it with what might be described as an interlinked musical, cultural and sonic intelligence." (Davismoon, 2009)

Certainly the instructions in the code are a significant aspect of musical form, but it is not always helpful to consider them without context, often dramatically shaping the activity of composition from the outset.

2.3.5 Algorithmic composition as pedagogy through *white box* exploration

> "His programs did not only serve to compose music but also, as it were, to instruct composers about what it means to compose." Hoffmann (2009), discussing Koenig

Koenig's potential 'elimination of the composer' could be construed as a bleak warning. However, by reversing the argument, exploring someone else's code could mean that a composer finishes writing a composition furnished with more musical ideas than he started with. Far from a void, the composer now dwells in a 'new dimension of musical ideas' (Koenig, 1975). As software designers leave something of themselves, their musical values are trapped in their code, we can therefore view the algorithm as a source of knowledge waiting to be tapped, something to be learned from. This of course refers back to the idea of algorithm as collaborator.

> "A good CAC system invites the composer to stop being user and take part in the design of the system in a participatory manner." (Hoffmann, 2009)

Naturally, it is a difficult task to learn from software that is locked to the user. This is known as *black box exploration*. The most instructive software is always that which allows the user to see every part of their mechanics, and furthermore adjust them (*white box exploration*). Here we go beyond understanding and even 'predicting' the algorithm (Collins, 2009) to the idea of *influencing* it. Arguably to a point where the software user begins to author their own task environment. Open source code invites modification and extensibility, allowing the composer to influence and adapt its mechanism. Openness in code allows the user to challenge hegemonic authority exerted by some more general pieces of commercial software 'imposing' their choices upon us (Assayag, 1998). This is *active* dialogue, with the computer allowing full view of its mechanisms in order to invite heretical use.

2.4 Exploring *slippery chicken*

2.4.1 Bending the rules

> "...a prerequisite for a creative use of technology is that artists invent new techniques of using it. Any application of established industrial and standard techniques would mean that the artist, instead of controlling technology, would him/herself be controlled by technology." (Hoffmann, 2009)

I have now reached the core of my chapter; my experiences in using Michael Edwards' software *slippery chicken*. I started learning the software through the manual, beginning with fairly standardised input combinations and output formats. However, being unwilling to relinquish complete control, I cobbled together various algorithms in order to form a piece, using *sl-c* more as a means to generate material rather than an active partner in composition. I was unwilling to learn from the technology. Rather than experimenting with the *top down nature* of the software I was cherry picking and rearranging material, working in ways familiar to me rather than developing new ways to create music. I have a recording of a piece which in my opinion simply doesn't work, (found on USB */Appendix/Cache*). It sounds fragmented, between aesthetics and unsure of itself. A concrete form that belies the lack of cohesion behind the processes by which it was made. This makes sense at a material level since I attempted to piece together fragments of code to create the overall form, rather than exploring form-building algorithms in *sl-c*.

After the performance of *Cache* I analysed the piece to discover what the problem might have been with my use of *sl-c*. The conclusion I reached was that I wasn't fully understanding what was going on in the inner mechanisms of *sl-c*. I had unwittingly fallen into *Koenig's void*; *Cache* was laden with conflicting values. Both those embedded in *sl-c* that I didn't completely understand, and my own. The natural way to regain my footing seemed to be to push the system with the things I did understand - the ways I was combining my input data and how I was choosing to interpret output data - and to look for similarities in behaviour. This, combined with all the source code helped me to understand the inner mechanisms of the software, validating the *white box* approach. I could then decide which elements of the code I wanted to accept, those I wanted to reject and those I wanted to modify or extend.

In response to this experience I created two pieces: *Mechanica* for violin and tape, and *Cantor Dust* for string orchestra. Both used the software in a heretical way. Heresy in this case means the augmentation of output format from those described in the manual tutorials, something I will discuss in more depth later on. Both also feature post-generation adaptation.[10] I decided that what marked these pieces out was the amount of artistic license

[10] A term Edwards uses for sections of code that adapt the music *after* the algorithm has generated it, hence

I had employed when feeding the software and interpreting the results. What followed was that I returned to using the software in a more conventional way, most desirable for reasons of efficiency, but equipped with a working knowledge of the inner procesess acquired through my heresy[11].

2.4.2 Degrees of Interpretation

In order to understand my user influence on the concrete interpretation of the algorithm, I am classifying my case studies into *Degrees of Interpretation (DoIs)*. These are indicators of composer mediation related to the output format of *sl-c*. *Low-degree interpretation* indicates unmediated output. The algorithm remains untouched post-generation for interpretation by a performer, with the polarity harbouring *Automatic/Algorithmic* composition. *Mid-degree* indicates hybrid mediation: I have manipulated some aspect of the output before performance but some 'touch of a button' elements remain. Finally, *High-degree interpretation* indicates complete user mediation of the output format, there is *no digital trace* from input material to output format.

These simple distinctions shed light on the flexibility of *sl-c* as a compositional tool but also bear witness to its influence on structural organisation. This documentation of my user experience will show areas of the software's flexibility but also musical qualities that can potentially persist through any degree of user mediation, in particular *sl-c's* unusual potential for global organisation. This is the element of the software that I have chosen to emphasise in my pieces.

By presenting a user assessment of *sl-c*, rather than a developer's explanation I hope to

bypassing the initial algorithm

[11]Heresy is defined in this case as interference with the output of the algorithm, therefore viewing *CAC* as heresy

illuminate previously undocumented aspects of the software and shed light on the means of "aesthetic integration" (Koenig, 1978) in *CAC*. With this in mind I will begin to assess the relationship between my own subjective decisions and those made by the fabric of the algorithm in order to track the musical traces of *sl-c*. Through varying *DoIs*, I am aiming to clarify levels of mediation that existed in the act of creating each case study in order to evaluate *sl-c*'s contribution to my compositional process.

I will now describe my use of *slippery chicken*, examining pieces in terms of their differing *degrees of interpretation*. The descriptions are in chronological order to demonstrate distinct stages of learning in *sl-c*. All pieces were written with musical and performance collaborations in place, opportunities that guided my use of the algorithm. I will contextualise each piece before I explain my implementation of each algorithm.

2.4.3 *Mechanica* for violin and computer (2013): Mid degree interpretation

Musical Opportunity

I started working with Emma Lloyd in 2012, beginning with three pieces exploring different timbral techniques for violin. *Mechanica* is the second of the three movements. Though nominally my compositions, the work towards this musical output was highly collaborative, and we involved the studio and computer at many stages of our work. A detailed description of the generation of material and implementation of live electronics in *Mechanica* can be found in section 5.1.2.

Software Output

Fixed media audio

Processes behind *Mechanica*

Mechanica comprises two core elements. The first is a fixed media tape piece, generated as explained in section 5.1.2. The fixed-media element of *Mechanica* is *low-degree interpretation*. After input of material the piece can be compiled as it will be performed. I do not amend the output in any way. The instrumental part, however was created through my intervention. Taken from the tape part, which was comprised of seven consecutive musical threads I transcribed a single melodic line to form the instrumental part - which Emma plays live alongside the fixed-media. Though the structure of the work and the rhythmic qualities all arise through the algorithm, the instrumental part was borne of my ear, my compositional intervention. This element of *Mechanica* therefore exhibits *high-degree interpretation*, with the tape part inspiring the instrumental material.

Mechanica as a combination of these two elements: the untouched tape part and the highly composed instrument part, can therefore be considered as *mid-degree interpretation*. In this piece I don't fully transform the material output from the software, with the formal structure of the piece being preserved.

Acquired knowledge

With this piece I began to understand the values that Edwards had placed on the structural integrity of the output. These turned out to be elements of the code that I wanted to embrace rather than undo, confirming that piecing together musical elements as I had with *Cache* is not the way I would consciously choose to use the software.

This composition largely fed theoretically to subsections 2.3.2 on page 34, and 2.3.5 on page 38 , the sections related to software programmer's involvement in the music making process and software as pedagogy. Without working in the *sl-c* environment I would not have explored this particular strategy for the unfolding of form and rhythmic placement of material; moreover *Mechanica* would not exist. Edwards had an influence on my composition, although at no point in the compositional process did we ever discuss this piece of music in terms of code and algorithms. The code became a medium for communicating musical ideas, ideas that I was then free to adapt and contribute to.

2.4.4 *Cantor Dust for string orchestra*: High degree interpretation

Musical Opportunity

The university runs a string orchestra competition each year. I thought this would be a good opportunity to develop an algorithmic work for amateur orchestra. The ensemble determined the difficulty level of the piece.[12]

Software Output

1 tape piece, which I then transcribed to string orchestra.

[12] Score and recording for *Cantor Dust* can be found in the appendix section of this thesis, and appendix folder of my USB */Appendix/CantorDust*. This is because I felt this material was useful to frame theory around but not suitable for my submitted portfolio.

Processes behind Cantor Dust

The second piece that I will examine is *Cantor Dust* for string orchestra. This piece uses *sl-c*'s *L-systems* algorithm to digitally augment a traditional Bulgarian folk tune (see figure 2.2). I began by recording the tune on the piano and processing it using the *CLM* branch of *sl-c*. As the title indicates, self similarity is the central focus, with particular emphasis placed on parameterised *digital signal processes* (*DSPs*).

Figure 2.2: Original folk tune

Cantor Dust is an example of an *L-system*. I used a method of self similarity to navigate the different *DSP* processes, the code of which can be seen in code listing 2.1.

```
(lfl (make-l-for-lookup 'l-sys
                               '((1 (( .1)))
                                 (2 (( .2))))
                               '((1 (1 2 1)) (2 (2 2 2))))))
```

Listing 2.1: Code for *Cantor Dust* L-system

Cantor Dust is another example of *sl-c* functionality in conjunction with *CLM*. To create a multi-layered fixed-media part from this fragment I processed eighteen different streams of the same 6 second recording. Each were assigned 6 separate *DSP* parameters: low-pass filter frequency, high-pass filter frequency, transposition, duration, start position in file. These streams began at different frequencies, and progressed through the *L-system* at different rates. What resulted was a dense cloud of static sound. A fixed piece formed through the layers of evolving musical strands.

Here I interpreted the algorithm through audio transcription. I divided the piece into instruments and notated in detail each prominent frequency and its trajectory through the piece. As the melody was linearly processed, each had a fairly logical direction and as such the fixed-media has a persistent character. This gave me the skeleton of the piece, which I then metamorphosised into a slightly more familiar harmonic form whilst maintaining voice leading and simplified rhythmic relationships.

In performance there is no element of the work implemented through algorithm that I have not actively transformed and reconfigured in some way. Therefore this piece exhibits *high-degree interpretation*, akin to Essl's notion of an "inspiration machine" (Essl, 2007). The quality of the software processes most embedded into the final work is the evolving nature of the different musical lines, in particular the pacing and temporal organisation. However, the work is filtered through my ear, my choices made with a very personal background and musical training. What endures is the global architecture, which seems to be highly consistent between each piece I have examined.

Acquired knowledge

Experimenting with *CLM* rather than MIDI output allows a lot of immediate sonic depth, which I was then able to transcribe and orchestrate. Inspiration for the piece came as much from the bi-product of the recording and processing as it did from the algorithm. It showed me that textural organisation was of as much importance as pitch and durational organisation, introducing me to self-similar processes, which I use throughout my portfolio.

2.4.5 *The Confines of Light and Shade*: Low degree interpretation

Musical Opportunity

I was selected for a commission called *Colourscape*. The remit was to write an eight minute piece for wind trio and electronics. This commission was to be performed by *Jane's Minstrels* in the *Colourscape* pod. Given the specificity of the space I decided that my piece would be textural in order to try and fill the nooks of the space, with the shape of the structure changing the quality of the material from one place to another. Being a short commission with limited rehearsal time, I kept the material and electronics very simple.[13]

Software Output

Score alone

Processes behind The Confines of Light and Shade

Musical interest in this piece lies in the textural changes in the instruments with instrumental lines shifting between various spectral parameters of 'light' and 'shade'. This featured very simple harmonic and rhythmic palettes. Material shifted through different techniques at different paces for each individual instrument. Table 2.1 on page 48 shows the parameters and their ranges from *light* to *shade* held in a number of envelopes:

[13] Score and recording for *The Confines of Light and Shade* can be found in the appendix, and a recording can be found on the portfolio USB, */Appendix/TCLS* as I felt this material was useful to frame theory around but not suitable for my submitted portfolio.

Parameter	Range
Register	
Acts on *set-limits*	Flute - ((1 a5 a6) (2 a4 g5) (3 c4 g4))
	B-flat-clarinet ((1 d5 c6) (2 d4 c5) (3 e3 c4)))
	French-horn ((1 a3 e6) (2 fs3 bf5) (3 c3 f4)))
Dynamics	
Added by *Marks*	(pp p mf f)
Noisiness	
Changes note heads	Trianglehead - cross head - Normal note head
Filters	
HP and LP	For computer part. High to low.
Harmonies	
Set palette	Wide to closed.
	Harmonies also transposed between + min 3rd and - min 3rd.

Table 2.1: Tabular summary of varying spectral parameters.

These parameters were selected algorithmically along their separate axes, using a combination of the *procession*[14] algorithm. These envelopes were assigned to each instrument's separate parameter. The harmonic palette was chosen from only 3 distinctive harmonies:

```
((1 ((G3 A3 C4 D4 E4 G4 A4 C5 D5 E5 G5 A5 C6 D6 E6 G6 A6 C7 D7 E7 G7 A7 C8 D8 E8)))
 (2 ((G3 AF3 C4 EF4 G4 AF4 C5 EF5 G5 AF5 C6 EF6 G6 AF6 C7 EF7 G7 AF7 C8 EF8)))
 (3 ((G3 A3 CS4 EF4 G4 A4 CS5 EF5 G5 A5 CS6 EF6 G6 A6 CS7 EF7 G7 A7 CS8 EF8))))
```

Listing 2.2: Harmonic palette for *TCLS*

Acquired knowledge

With knowledge previously acquired from my preceding compositions, understanding the idiomatic 'cutting' processes through which *sl-c* transitions material allowed me to create

[14] A function taken from the larger *Rhythm Chains* method to 'Generate a list of a specified length consisting of items extrapolated from a specified starting list. All elements of the resulting list will be members of the original list. function and user defined envelopes.' (Edwards, 2015)

a slowly evolving and subtle musical texture using instrumental timbre and playing techniques. This was the first successful performance of a *low degree interpretation* composition. The score required little to no interpretation for public performance.

2.4.6 *Labyrinths*: Low degree interpretation

Musical Opportunity

In 2014 I began working on a long term collaboration with the *ISON* quartet, with whom I decided to write a three movement piece for string quartet and computer. In *Labyrinths* the acoustic elements were exclusively composed in *Slippery Chicken*. The three movements were initially named after three different short stories, as the generative algorithms began by being guided by some mathematical paradigms Borges represents in words. A detailed description of the generation of material and implementation of live electronics in *Labyrinths* can be found in section 5.4.

Software Output

Score.

Processes behind Labyrinths

Labyrinths features three movements all drawn from the same harmonic palette (please see listing 2.3 on page 50). All movements are structured using the same *sl-c* internal processes *(remix-in, L-systems and procession)*. Where they differ is their textural and rhythmic palette, alongside the specific ways they are structured by these same processes. All movements feature different algorithmic growth processes in the 'procession' algorithm, carried out on unique input material. Notes are all thinned by a combination of random and precise note filtering.

```
(sp  (loop for i in
            '((c2 e2 fs2 c3 c4 e4 bf4 c5 fs5 af5 cs6 e6)
              (fs2 d3 ef3 f3 fs3 d4 ef4 f4 fs4 d5 ef5 f5 fs5 d6 ef6 f6)
              (e2 fs2 gs2 cs3 e3 fs3 gs3 cs4 e4 fs4 gs4 cs5 e5 fs5 gs5 cs6)
              (f2 a2 d3 f3 a3 d4 e4 f4 a4 d5 e5 f5 a5 d6 e6)
              (d2 bqf2 d3 e3 f3 bqf3 e4 f4 d4 bqf4 e5 f5 d5 bqf5 e6 f6)
              (f2 as2 ds3 f3 as3 ds4 f4 g4 as4 ds5 f5 g5 as5 ds6 g6)
              (af2 b2 cs3 af3 b3 cs4 fs4 af4 b4 cs5 fs5 af5 b5 cs6 fs6)
              (ef2 f2 df3 ef3 g3 df4 ef4 e4 g4 df5 ef5 e5 bf5 ef6 g6 df7 ef7 )
              (d2 eqf2 e2 b2 d3 eqf3 e3 b3 d4 eqf4 e4 b4 d5 eqf5 e5 b5)
              (gs2 a2 cs3 fs3 gs3 a3 cs4 fs4 gs4 a4 cs5 fs5 gs5 a5 cs6 fs7)
              (fs2 as2 b2 fs3 as3 b3 fs4 as4 b4 fs5 as5 b5 fs6 as6 b6)
              (cs2 fs2 b2 cs3 fs3 b3 e4 cs4 fs4 b4 e5 cs5 fs5 b5 e5)
              (c2 d2 fqs2 c3 fqs3 c4 d4  fqs4 g4 d5 g5 c6 d6 fqs6 g6 d7 g7 )
              (e2 c3 a3 e3 c4 a4 e4 c5 a5 e6 c6 a6)
              (ds2 f2 as2 ds3 f3 as3 ds4 f4 as4 ds5  f5 g5  as5  ds6 f6 g6 as6)
              (f2 g2 d3 e3 f3 g3 d4 e4 f4 g4  a4 d5 e5  f5 g5 a5 d6 e6 f6 g6 )
              (cs2 gs2 cs3 gs3 cs4 gs4 cs5 gs5 cs6 gs6)
              (c2 e2 bqf2 c3 e3 a3 c4  d5 e4 bqf4  c5  d5 g5 e5 bqf6 c6  d6 )
              (g2 b2 d3 fs3 g3 b3 d4 fs4 g4 b4 d5 fs5 g5 b5 d6 fs6)
              (d2  fs2 d3 e3 fs3 d4 e4 fs4 d5 e5 fs5 d6 e6 fs6)
              (bqf2 c3 cs3 gs3 bqf3 c4 cs4 gs4 bqf4 c5 cs5 gs5 bqf5 c6 cs6 gs6)
              (f2 g2 bf2 c3 f3 g3 bf3 c4 f4 g4 bf4 c5 f5 g5 bf5 c6)
              (b2 cs3 fqs3 b3 cs4 fqs4 as4 b4 cs5 fqs5 as5 b5 cs6 fqs6 as6))
            and j from 1
            collect (list j (list i))))
```

Listing 2.3: Harmonic palette for *Labyrinths*

Acquired knowledge

Having explored many different *sl-c* functions, *Labyrinths* gave me the opportunity to focus on one or two of them and examine the output of a variety of input materials. What resulted was a selection of movements with very different characters, but all linked both by the same harmonic palette and the same way of moving through material.

What results is a full work with character highly dependent on my choices of harmonies and textural decisions. This is combined with the continuity of the *procession* process, a contribution that could only be facilitated by this particular piece of software. What was most interesting for me was how unsuccessful my attempts to generate material with LISP were. Surprisingly, the flexibility that *sl-c* offers the user when allowing them to input compositional building blocks, rather than note seedlings, allowed me to construct my own algorithm with well defined ideas. This demonstrates the feedback loop when working; my initial ideas were shaped through my prior knowledge of the software. In other words, I knew what would work and created material accordingly. This early selection processes meant that I had little need for post-generation editing later on and that these movements were all only interpreted to a very *low-degree* if at all.

2.5 Summary

The chapter explores *Computer Assisted Composition* with *slippery chicken* in detail. Examining metholodological approaches to *White Box* exploration, I explain some of the mechanics of the software and my experience of using it. Aesthetic as well as technical implications of using another musician's *bespoke* software are also discussed and software is explored as a means of communicating values important to the software designer. Awareness of this hegemony is raised and subsequently challenged with reference to DiScipio's notion of the *Heretical use of Technology*, whereby a user deliberately bends the intended use of software to counter our benign acceptance to the hegemony of its design. Additionally, with the presence of the software designer acknowledged in the code, I explore the idea of software as a pedagogical tool. The chapter finishes with a detailed examination of some pieces included in my portfolio (with some in the appendix). I explain the musical situation that prompted me to write the piece, algorithmic methods for each piece's creation, and finally the knowledge that I acquired from the process of composition and how this relates back to the theoretical offerings earlier in the chapter.

Various conclusions can be taken from these analyses. First, as noted from the outset, using computer software to assist and steer musical composition means that your music will be shaped by the tools that you choose. This inevitable impact can be seen as negative *if the tools aren't properly understood*, largely because the musical result can sound confused and unfocussed, like the musical situation it has arisen from. However, if the software user takes the time to understand the compositional processes that the software invokes, they can simultaneously guide the software towards their own aesthetic preferences whilst learning musical methods from the tools themselves. In this way, the computer provides a rich resource for furthering musical education through analysis of instructions through code rather than a written score.

Chapter 3

Translating material: the computer in performance

3.1 Perception of *EI* music

> "That two sounds are produced and heard in the same place and close in time is no guarantee of a 'live link' being established in the mind of the perceiver" (Emmerson, 1994)

Emmerson's words still resonate strongly in *EI* music today. The presence of a loudspeaker on stage, making noise, is no guarantee to its acceptance as part of the music. What precedes this rejection seems to be a complex combination of factors leading to a translational gap between instrument and loudspeaker, a lack of idiomatic synchronicity that is then reflected in the music. In this case, even if present, the 'live link' is simply buried too deep to be found.

This chapter documents my research surrounding the 'live link' as a potentially elusive quality through my pursuit of an idiomatic interchange between instrumental material and *Max/MSP* software in performance. I have applied existing research rooted in auditory perception to the design of my software, seeking digital responses that will cohere perceptually with the instrumental material I work with. Beyond this, I also use tools originally formed to analyse electroacoustic music to examine the instrumental situations that will be feeding my software. The theorists that I rely on to drive my analysis are Schaeffer (1966); Chion (2009); Kane (2007), Emmerson (1986, 1994, 1998, 2007), Smalley (1986, 1994, 1997, 2007), Bregman (1994) and Frengel (2010).

Some of the material in my portfolio is notated, whilst some of it is improvised. Because it is more direct to demonstrate visually communicable material in a text-based thesis, the majority of the examples that I give in this chapter are formed from the notated element of my portfolio. I have, however, applied the theories equally to both types of output. Rather than providing a full technical document of my software in this chapter, I will explain reasons behind the technical decisions that I make, focussing on my search for potential vocabularies and grammatical responses in reactive software. As some analyses are more appropriate to solo works and others to ensemble, I have applied case studies to two pieces: *104* for solo violin and computer, and *The Garden of Forking Paths (TGOFP)*, movement II from *Labyrinths* for string quartet and computer. Full analyses for all portfolio compositions can be found in chapter five, alongside technical descriptions of my *Max/MSP* patches.

I will present my analyses in three distinct phases:

- *Phase 1* examines instrumental material in its smallest units, independent of source and using Schaeffer's own *solfège* (Schaeffer, 1966) as a guidline
- *Phase 2* looks for musical elements in terms of *Form Bearing Dimensions* (McAdams, 1989)

- *Phase 3* approaching the material as *Acousmatic image* (Smalley, 2007).

Each of these phases provides a different angle from which to view instrumental material, and provides information that can be assimilated in the design of interactive software.

3.1.1 Beyond technical innovation and *intrinsic* organisation

> “The idea of interaction is seductive; it is also understandably attractive in an arts funding environment which favours a superficial and naive notion of ’innovation’. But the material result rarely measures up the appeal of the idea.” (Croft, 2007)

In this statement, Croft appears to be taking issue with an inherently *intrinsic* and *non-musical* approach. Although realtime interaction is present, it does not necessarily contribute musically in any way. He challenges the notion of innovation for innovation’s sake and is outwardly in opposition to the notion of ’Composition as Research’ (Croft, 2015). His basic tenet is that music composition should require the same criteria for study as scientific projects; our compositions need not prove technical innovation in the same way that scientific research must. With this in mind, my chapter doesn’t present technological innovation, rather a drive towards aesthetic interrogation of *EI* music.

> “The heritage of twentieth-century formalism and the continuing propensity of composers to seek support in non-musical models have produced the undesirable side-effect of stressing concept at expense of percept” (Smalley, 1986)

Smalley, treading a similar line of thought, was talking about the perception of *acousmatic* performances 30 years ago. This formalism, however, also extends to (and lingers in) performance with reactive software today. Arguably with these *non-musical models* extended to include mapping between instrument and computer. *Intrinsic* organisation in music with live electronics can be found in a situation where the 'live link' is only composed rather than audibly accessible to performers and listeners. Here, the so-called *formalism* lies in the method of realtime 'triggering'. This method means that the computer software may be reliant on certain events in the instrumental part but this isn't necessarily felt by any party involved in the music.

I am interested in avoiding this form of intrinsic organisation through the design and composition of interactive tools built around our perception of sound. Consequently my focus is to understand what's happening on the surface of the music, using this knowledge to compose coherent interactions between instrument and computer. Fortunately, to date there's an expanding pool of research in sound and music that interrogates how we might comprehend music that doesn't necessarily adhere to a culturally agreed form. Studies into how we hear pieces of music, rather than analysing notation for the musical organisation, have gained momentum, largely perhaps because music offers a useful test bed for experiments in auditory perception[1]. This is significant to my practice, because in order for *EI* music to maintain a sense of unity in performance, it's important to examine what qualities materials might have in the *concrete* rather than the *abstract* domain, and how these might be picked up by a performer or listener.

3.2 The role of the laptop

Before analysing instrumental material for translation it is useful to know what the analysis will be translated to. What is the musical role of the laptop in *EI* music making? What are

[1] Notable contributions to this field include (Windsor, 1995; Bregman, 1994)

the audible outcomes? The laptop certainly exists as a multiplicity of musical partners that the composer and programmer must define. For me its sound world should be considered alongside that of the musical material, rather than secondarily.

There are many proposed roles that the laptop can take, where the word 'role' implies that the laptop is behaving in a certain way. These roles are documented in the growing amount of literature surrounding interactive music, much of which is applied and helping to solidify mechanisms and guidelines around which *EI* music can be framed. Croft (2007), Emmerson (2007) and Frengel (2010) have all written in a highly practical way about the laptop's role during the performance of *EI* music.

Croft's and Frengel's papers both offer important insight into the translation gap between instrument and computer output, defining methods for compositional questions that simply didn't exist before the advent of interactive music. In table 3.2 on page 57, Croft sets out to define broadly variables of computer behaviour in live electronics. These categories help to to forge compositional parameters via interaction between instrument and laptop. For example, if one chooses that the computer will respond consistently with a *backdrop* category then there are already many implications on the decisions made surrounding the computer sound. In this instance, the paradigm set out suggests that it is unlikely that the computer will be louder than the musician for any sustained length of time.

Croft's analysis of existing methods of software programming is certainly helpful, though on greater inspection it appears fairly restrictive. For one, as he acknowledges, the laptop rarely occupies a single category within each piece (Croft, 2007). From this position these terms when considered as fixed compositional points prove limiting through their discrete nature. It is more useful to place them all on a multi-dimensional continuum, thus providing them with more gravity regarding actual sonic behaviour.

Frengel explores such behavioural continuua with more depth by offering many more

Paradigm	Summary
Backdrop	Electroacoustic sound functions as background. Non causal points of contact. Doesn't necessitate *L.E* - computer part can be concurrent and unrelated
Accompanimental	Computer accompanies in more traditional sense Use of sound analysis to link computer directly to instrumental material
Responsorial/proliferating	Antiphonal relationship to material
Environmental	Electronic creation of various acoustic environmental characteristics Will generally involve resonance, filtering and reverberation
Instrumental	An attempt to create a composite instrument The relationship between a player and instrument extended to include the live electronics

Table 3.1: Tabular summary of Croft's 5 behavioural paradigms (Croft, 2007)

behavioural categories, which he calls axes. Here the translational element of the composition is seen as having nine flexible continuum, many of which can run alongside the timeline of the piece. A visual representation of this can be found in figure 3.1 (Frengel, 2010). Like Croft's paradigms, Frengel's axes offer a salient method of navigation through different elements of computer behaviour. Additionally, they are diverse and flexible enough to represent laptop activity with a higher degree of accuracy. Though unlikely to be practical for musicians to read in a score. This information is helpful for a composer during the process of realtime software design. As well as being an indispensable framework for realtime software design, a multi-dimensional representation of the interactivity also provides useful information to musicians before rehearsal so they can understand a bit more about what is happening in each piece[2].

[2]Please see multi-dimensional tables for all my portfolio contents, *Three pieces* in table 5.2.4, *Invisible soundscapes* in table 5.3.4 and *Labyrinths* in table 5.5.4

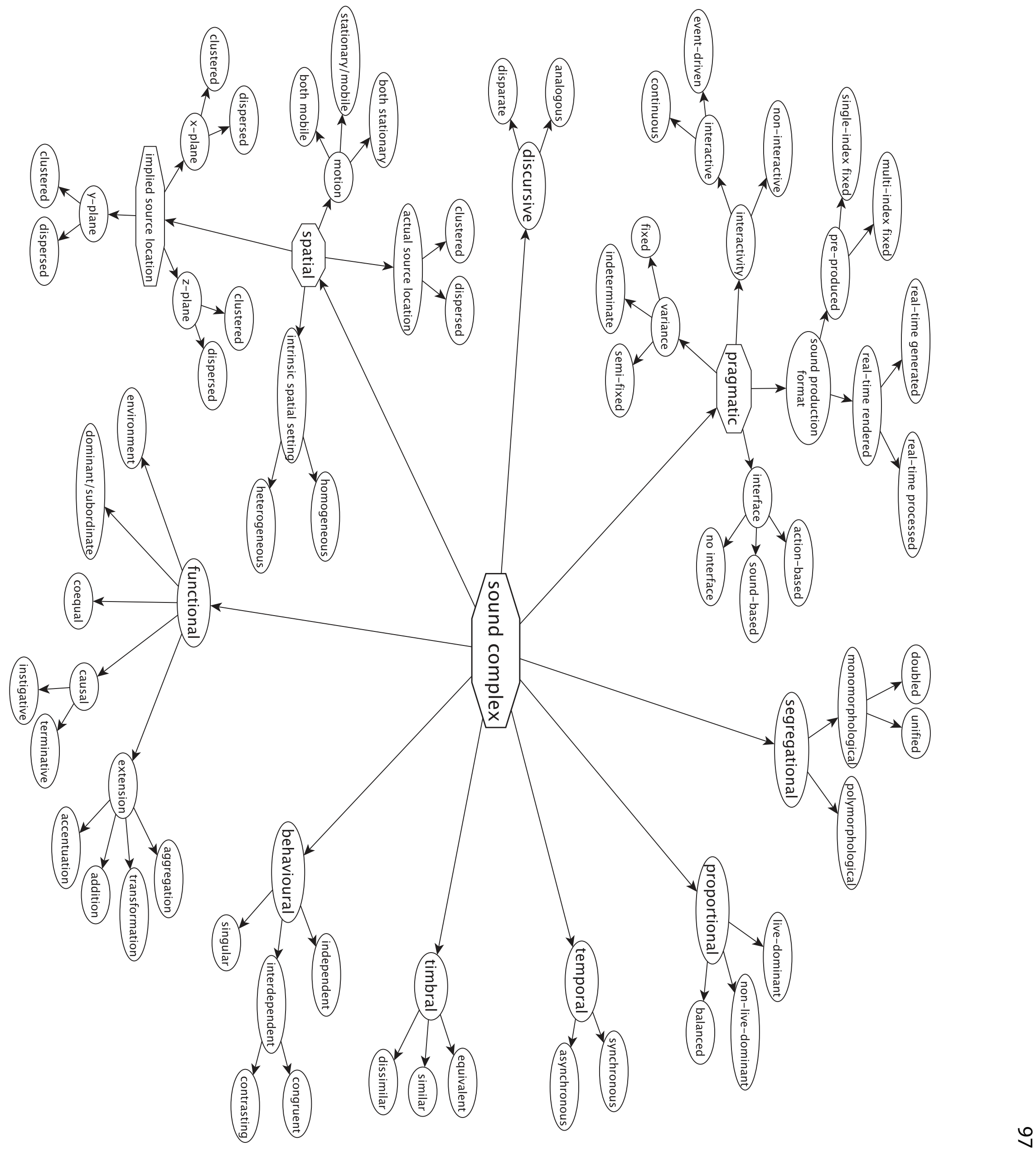

Figure 3.1: Frengel's multidimensional axes (Frengel, 2010)

3.3 Analysis of instrumental material

There are many approaches to analysis, although not all are appropriate for understanding what might be heard. Abstract structural points composed in a piece may not actually inform a performer or listener of their presence. Although process *can* be perceived in form that doesn't mean it necessarily *is*, or needs to be. In other words, conceptual tools for the organisation of material may be completely shed in various performance contexts; compositional navigation points may differ from performance ones. Physical analysis tools can also mislead - a sonogram can present a scientific account of the music without necessarily presenting what is actually heard. The point here is that there isn't a singular way to understand each individual's sonic experience; composers seeking to navigate instrumental material benefit from a multiplicity of analyses to inform their software.

Is it possible to analyse instrumental material in electroacoustic terms? Computer music as a relatively new pursuit doesn't appear to have a culturally agreed form of extra-musical communication, nor does it necessarily need it. Yet within at least one particular strand of electroacoustic performance, *acousmatic* performance, studies seem to be converging through the analytical tool of *spectromorphology*. Literature documenting musical descriptors draws a fairly linear trajectory of analysis techniques, from Pierre Schaeffer's offerings (Schaeffer, 1966; Kane, 2007; Chion, 2009), through to the *spectromorphological* analyses of the present day (Smalley, 1997, 2007; Blackburn, 2007; Thoresen, 2007; Patton, 2007). Schaeffer's contribution, refuted by many regarding its self-contained approach to psycho-acoustical processes, still provides abstract taxonomies that serve as useful starting points for encapsulating the translation of instrumental material to reactive software.

3.4 Sound objects (and their taxonomies)

> “The sound object is the meeting point of an acoustic action and a listening intention.” (Chion, 2009)

Categorisation of electroacoustic sound using Pierre Schaeffer’s *solfège* is a useful method to analyse the building blocks of instrumental music related to listening intentions:

- Listening - Through the intermediary of sound aiming to identify the source, sound as sign.
- Perceiving - Level of perception, how we are taking in the sound.
- Hearing - Showing intention to listen, choosing from what we perceive what particularly interests us in order to make a description of it.
- Comprehending - grasping a meaning by treating the sound as a sign.

(Kane, 2007)

There is, however, a scepticism surrounding these intentions. This is largely because two out of four of these modes (*perceiving* and *hearing*) specifically require the divorce of sounds from their origin. As Kane remarks:

> “His solfége is not just based upon the rejection of sound’s relationships with musical systems, but on a deeper rejection of their relationship with the world. It is in this sense that Schaeffer recapitulates the intrinsic biases of music theory.”
> (Kane, 2007)

Considered in this way, employing Schaeffer’s *solfège* as an analysis tool seems paradoxical to the aim of understanding instrumental material away from intrinsic organisation and on a perceptual level. As I will discuss, our search for a sound’s origin is at the very core of our perception of it. Indeed, this stage of analysis - considering instrumental material as a string of 'sound objects' - does have bias towards the acoustic event in isolation. In particular, the listening modes of perceiving and hearing. However, despite this apparent recourse to intrinsic relationships, embracing Schaeffer's more controversial listening modes does allow for the consideration of sound units in terms of concrete typologies. His taxonomy of sounds provides a comprehensive amount of analytical detail regarding potential physical sonic shapes with a glossary that permits easy reference for composers (Schaeffer, 1966). This provokes decisions on software design with regards to the physical attributes of the sounds, even if these typologies are only a part of the bigger picture. If approached as a compositional parameter rather than as psychological mandate, then his *solfège* still provides a rich matrix for composition.

3.5 Characteristics of sound objects and structures

3.5.1 Phase 1 analysis: Note units

> "If we wanted to be not only more rigorous but nearer the reality of music, we should use the concept of *planes of reference*, which emphasises the development of the note itself, in addition to notes in relation to one another." (Schaeffer, 1952)

At the beginning of my research Schaeffer's approach to *note development* was a good starting place to inform my work. For the most part I worked with solo musicians and dissected note units as single entities to be classified for translation into the computer music world. This first type of analysis gave me concrete parameters around which I could design my software's audible responses; more so if we are provided with the tools to interrogate the auditory characteristics of different instrumental techniques.

In 2011 I began a collaboration with violinist Emma Lloyd. In order to consider possible interactions we began by using Schaeffer's taxonomies to examine some of the violin techniques we were exploring. On the most basic level, understanding the qualities of a note object allowed us to consider what qualities might be appropriate in the laptop's material, whether it be similar or contrasting. At the core of our work together was a deep consideration of the fundamental materials that we were working with. With this in mind we explored three very different types of material - harmonics, percussive timbres and sub-harmonics – with a simple but structured analysis (see section 5.1 on page 124 for detail related to how we constructed the pieces).

3.5.2 Phase 1 analysis of *104*

104 is comprised of harmonics and bowing techniques that give the surface of the piece a continuous texture, lucid pace and glassy veneer that lend themselves well to combination with live electronics. Looking at the shapes of the individual notes more closely using some of Schaeffer's terminology allowed us to decide how best the computer might react to this type of material beyond this superficial assessment. Taking a single sample typical of the piece, found on the USB *examples/104note*, we first analysed it using Schaeffer's main criteria of sound characterology. This analysis is illustrated by five categories with a number of *criteria* on three planes.[3]

As can be observed in figure 3.2, an average note representative of the majority of musical notes in *104* is:

[3] See (Schaeffer, 1966) for a full glossary and terms and diagram of his sound characterology criteria.

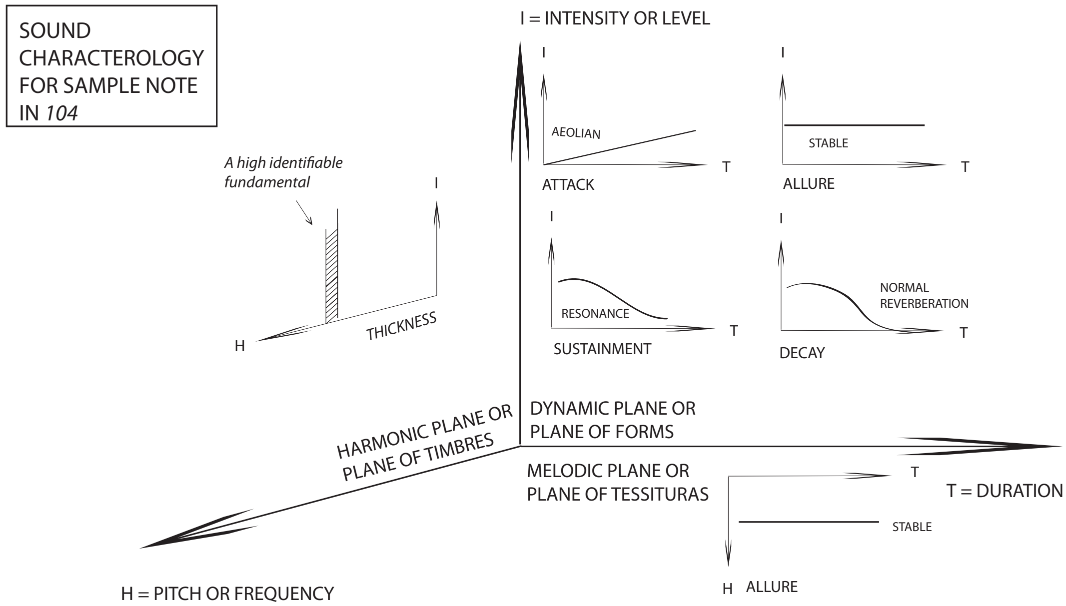

Figure 3.2: Schaefferian sound characterology of *104*

- Thin and high in register;
- Of fairly simple harmonic content and bright colour;
- Has a slow attack, stable allure and resonant sustain;
- Reverberates in a 'normal' fashion.

Representation of the notes using these sound characterologies gives a useful template for the design of the sound world and informs the aesthetic of the realtime software I design. Each category leads to a distinct set of decisions, forming compositional parameters between instrument and computer. Figures 3.3, 3.4, 3.5 and 3.6 and 3.7 shows each separate category and choices that I decided between at the note level (or gestural level) of *104*. The technical response that the software exhibits was taken around the aesthetic choices.

Possible realtime responses

Information harnessed by these analyses prompts building of the realtime *Max/MSP* software around these criteria. For example, with the knowledge that the violin notes are fairly thin and high, we might choose to ’bulk’ out the piece through the electronics. This can be achieved either by harmonically thickening the notes or by adding in some lower register. Alternatively we may wish to complement the notes with a similar texture, or, as is more likely change the computer response as the piece progresses to shape the composition.

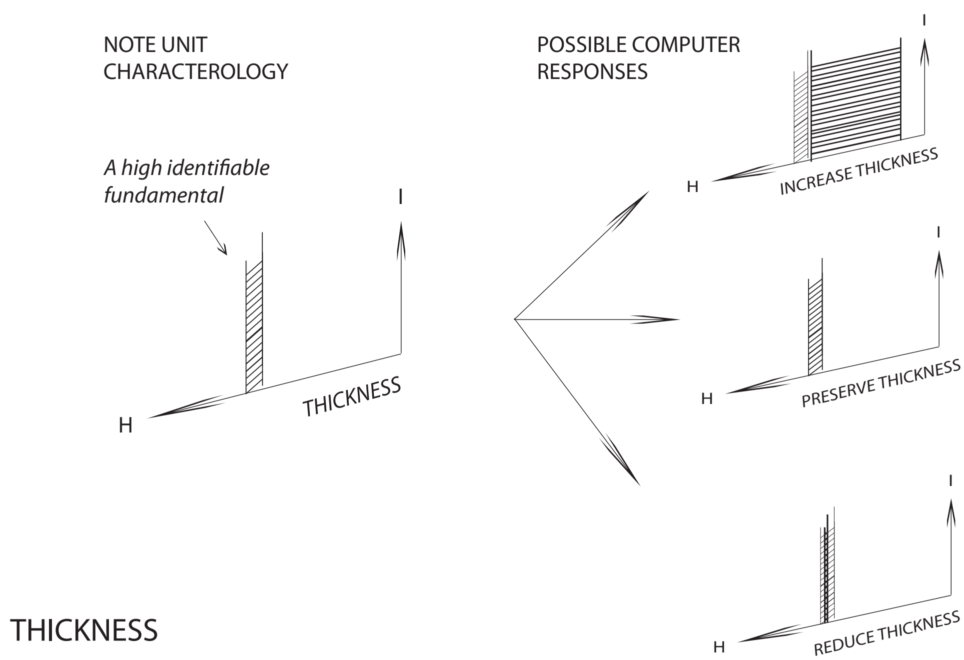

Figure 3.3: Some options for thickness

The responses that the composer chooses will directly instruct the way the software should be programmed - for example to make the violin sound thinner, you could filter some live signal. To extend the decay you could add a reverb object and so on. In the case of *104* the decision that we took with the software response was that it would enhance the shape

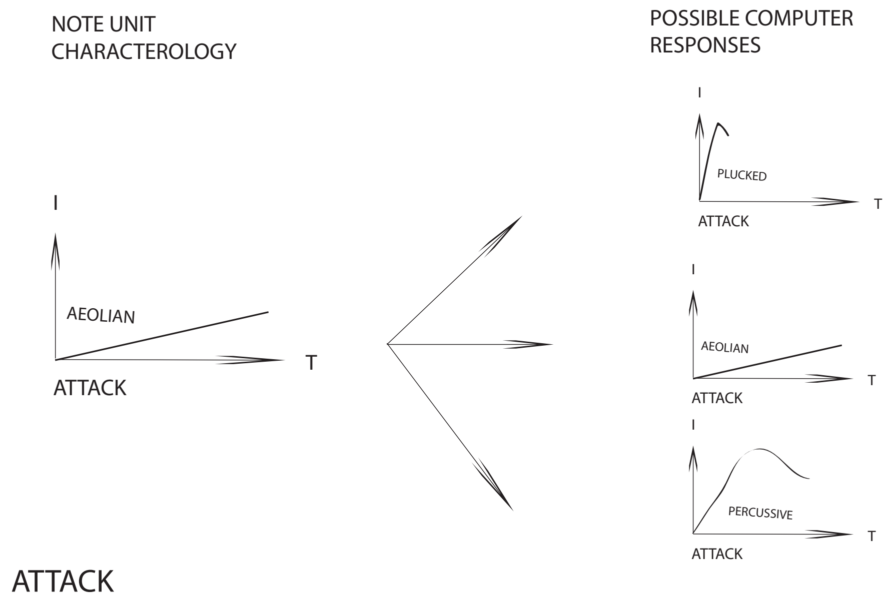

Figure 3.4: Some options for attack

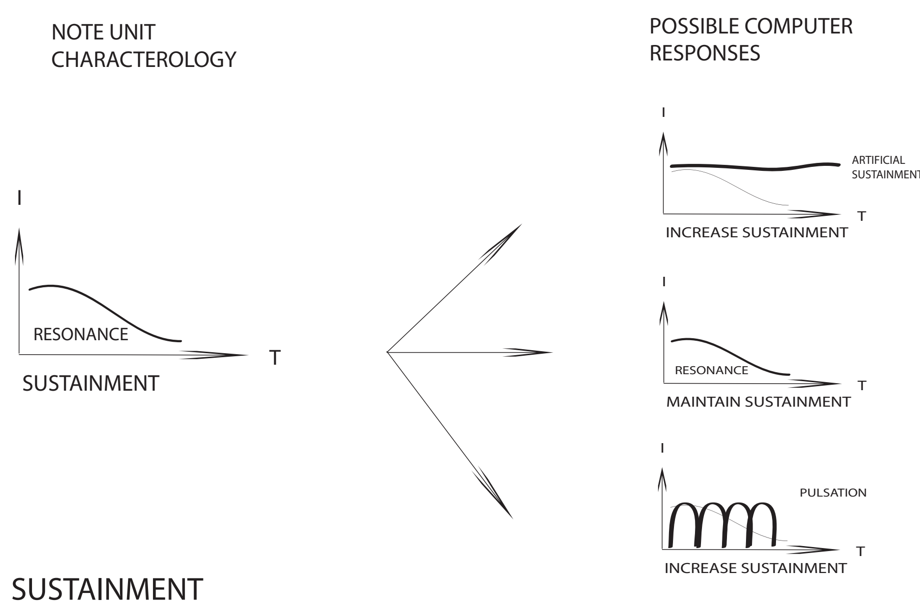

Figure 3.5: Some options for sustain

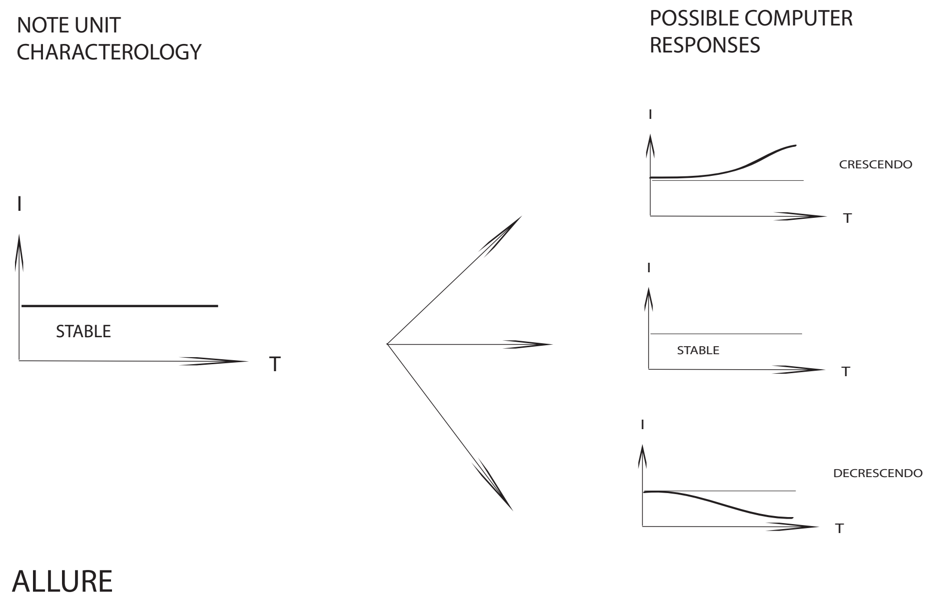

Figure 3.6: Some options for allure

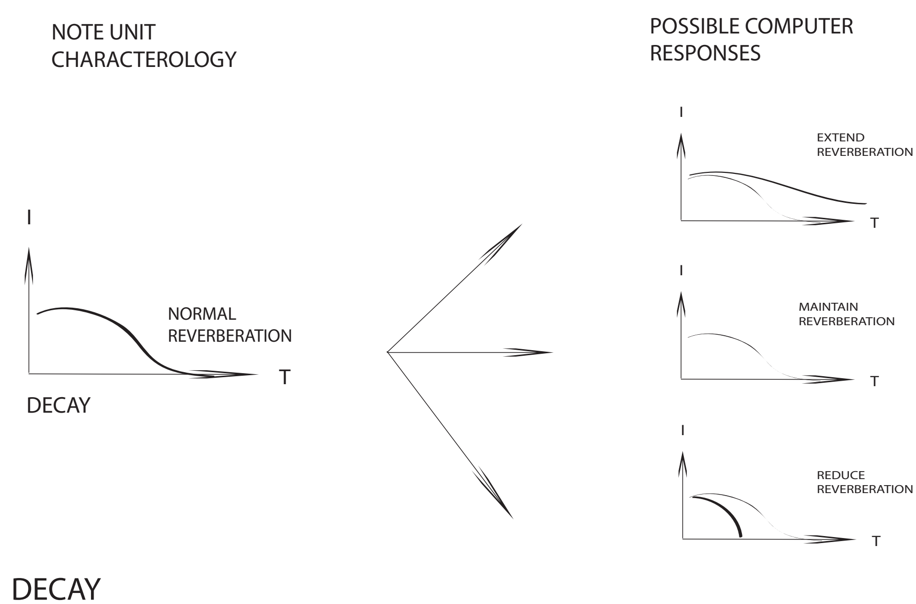

Figure 3.7: Some options for decay

of the notes further by extending them through a programmed digital sustain[4]. We also used these notes as a further extended backdrop to bulk out the thickness of the music as a whole.

3.5.3 *TGOFP* Analysis: Note units

Later on in my research I created a three movement string quartet in collaboration with the ISON quartet. These three movements leant themselves well to analysis at a phrasal building block level, again in order to compose an appropriate digital interaction.

In *104* each individual note unit is not only clearly heard but important to the surface of the music. This is contrasted with ensemble voicings, of which some might be in support of other, more dominant notes. In *TGOFP* there are 3 different types of building blocks:

- Small light arpeggiations
- Longer duration swells
- Pizzicato notes

Clearly not all of these blocks are comprised of single note units, nor are they often heard individually. These building blocks can be analysed separately, potentially leading to different responses in the programmed software. This might mean that the software will also need to be programmed to have awareness of certain events. This prompts certain reactions when confronted with specific types of material

Figure 3.8 on page 70 shows a representation of these three types of material mapped out over a grid. Each horizontal grid block represents a bar of music. The faded colours represent distance of transposition from original harmonic palette (from 1 to 5). Bright

[4] This module persisted in our work with KUBOV, find description in sub-section 5.3.4

green blocks represent plucked material and bright red blocks represent ’swells’, the distinct structural markers. These red blocks were the points that I decided to exaggerate.These are the points within the piece where a new element of the electronics is triggered. This contributes to the growth form as the occurance of ’swells’ increases as the movement moves on.

The previous description demonstrates the influence that the analysis of instrumental material can have on aesthetic and technical decisions for the computer part. The sonic qualities of the swells are considered on the *plane of reference* with other notes and deliberately enhanced by the software I designed.

3.6 Phase 2: Form bearing dimensions and *EI* music: Some notional research

> “A dimension can bear form if configurations of values along it can be encoded, organised, recognised and compared with other such configurations...The *utility* of a dimension as a form-bearer, however, depends on some additional factors. A dimension that affords a greater number of perceivable configurations is more valuable to a composer than a dimension along which only a small number are possible.” (McAdams, 1989)

The trajectory that the studies into the analysis of electroacoustic music have taken suggests that the material can display rather more evidence about itself than simple note qualities. Music is far more than the sum of its parts. When note units are organised into more complex structures we begin to hear the relationships between them as well as - or over and above - the qualities of the notes themselves. These relationships manifest in phenomena

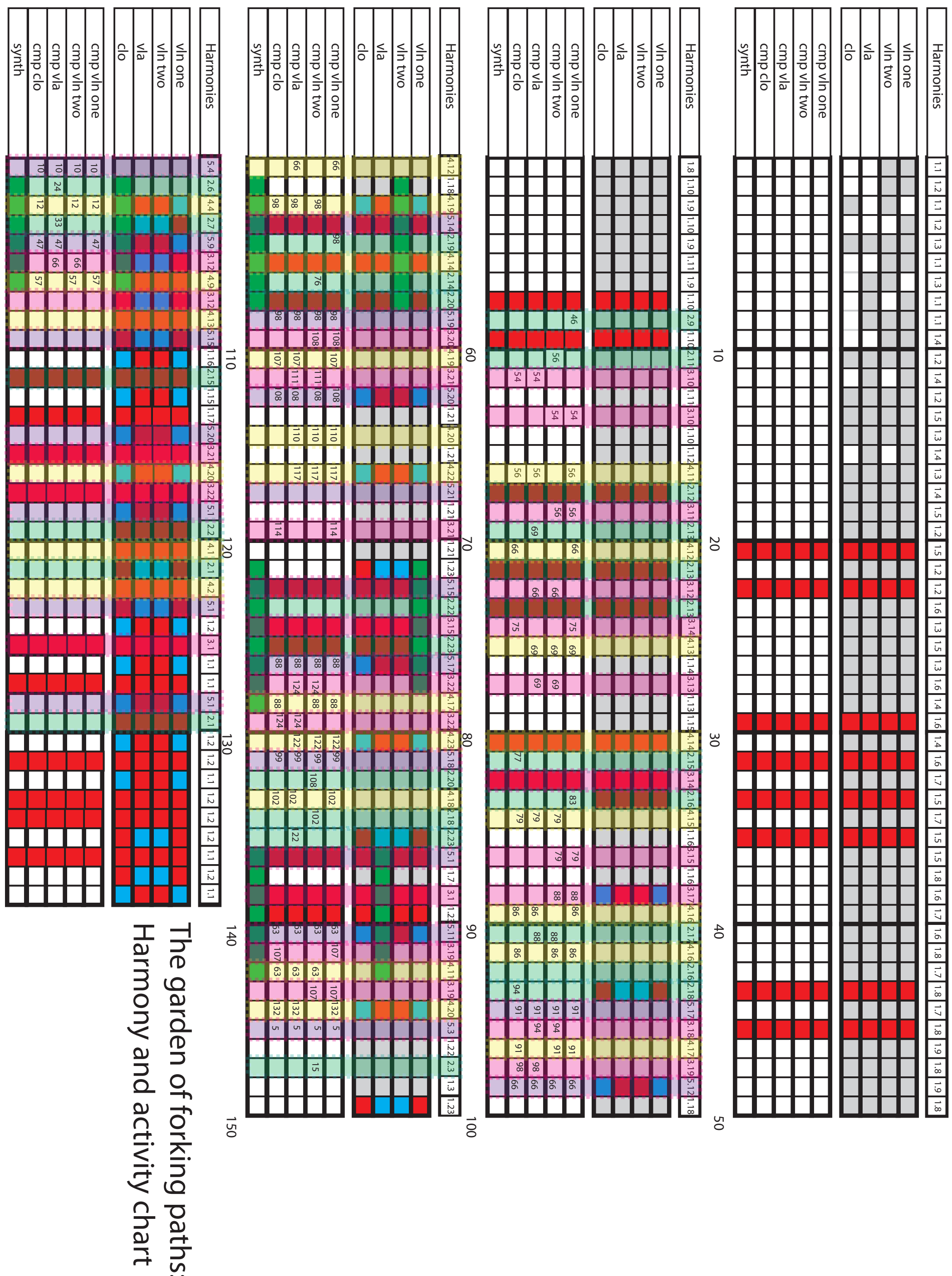

Figure 3.8: *TGOFP* computer grid

such as rhythm and harmony, and can also contribute to a more complex timbre. What potential effect do the 'utilities' of various dimensions in larger structures have on our perception of any 'live link'?

Psycho-acoustic research gives an indication of surface elements of music that are potentially more readily perceived than others. These are what McAdams calls *form-bearing dimensions* (McAdams, 1989). He sets out to analyse how we as listeners might receive and organise a matrix of musical qualities, even providing research into hierarchies of these particular dimensions. In other words, he offers some useful evidence related to the types of qualities that might dominate when one plays or listens to a piece of music. These can be referred to during the software programming stages.

Much of the research surrounding *form bearing dimensions* has been carried out in the quest to understand the perception of long term form[5]. The perception of global form is not my chief concern. My main aim is that the form appears consistent and instrument and electronics feel coherent. However, I do find studies related to global form useful to be extrapolated to the design of reactive software. This is because it can be assumed that if a musical dimension is considered form bearing then it is most likely contributing to the shape of the surface of the music. This musical surface is something that the reactive software is also intended to contribute to and become part of. The 'rules' that McAdams et al offer will be useful in the attempts of making auditory streams of instrument and software cohere. In other words, I am not looking for the perception of large-scale form. I am seeking clarity of interaction, the markers of which are potentially subject to the same perceptual activities.

Each musical dimension can be crudely described in terms of duration, interval and space. However, there will be a multiplicity of dimensions occurring at any one time.

[5] Some good introductory discussions on this topic can be found in (Deliège, 1989; Cook, 1987; Tillmann and Bigland, 2004)

Each with a multiplicity of values. This means that although we can anticipate certain things about sound and its perception, we should also hold a healthy scepticism to formulaic approaches to music. This leads us to believe that that multi-dimensional axes will still create unexpected outputs.

3.7 What we hear

> "It is argued that most existing theories of acousmatic music are closely tied to prescriptive rather than descriptive concerns, and concentrate upon intrinsic aspects of acousmatic music to the detriment of its extrinsic potential."
> (Windsor, 1995)

Windsor points to the still prevalent activity of privileging intrinsic structural relationships over perceptible form (Windsor, 1995)[6]. He analysed *EA* music in terms of how it is perceived rather than how it was built. This resonated with the *EA* community and some highly practical literature in the analysis and composition of *EA* music can be traced to this thesis (Smalley, 2007; Waters, 2013; Green, 2013).

Windsor avoids analysis developed alongside notated music because he believes that it isn't appropriate to *EA* material, the building blocks are simply not the same: "Electroacoustic gestures and textures cannot be reduced either to note or pulse." (Windsor, 1995). Though, as we will discover, it is foolish to over-trivialise the notion of 'note' or 'pulse' in our reception of *EA* music. It does seem logical to look for extra-material building blocks to flesh out our analyses. Windsor's extrapolation of psychological-acoustical research on how we survey, group and experience auditory space provides some very useful models

[6] Windsor's PhD, focussed on debunking the status of intrinsic relationships, privileged by notated western notation, was pivotal in the field of analysis in *EA* music because it connected psychological research to music in a way that hadn't been properly explored (Windsor, 1995)

for analysis. This bears further examination.

3.7.1 Auditory Scene Analysis

> "Music has evolved out of the way we hear" (Bregman, 1994)

Windsor extensively cites Bregman's *Auditory Scene Analysis* (Bregman, 1994) as a key point of research. Presently, many theorists propose that we hear music in the same way that we experience everyday listening[7]. In other words we are always searching for the extrinsic meanings of sound, what made it, what it might mean and how we can construct our environment through our perception of this information. Bregman's book attempts to dissect some psychological explanations for the way that we analyse auditory scenes, based on our understanding of primitive grouping organisation.

Bregman gives the composer the analytical tools to zoom in and out of different structural levels of the music. This is drawn from psychological research on the way humans group and process events (Bregman, 1994). Key elements are an analysis of how we blend timbres, process the pitch continuum, perceive duration and how relative duration allows us to group events. Furthermore it allows us to think about music as a weave of vertical and horizontal lines that we can unpick.

How this is particularly useful for the design of *Max/MSP* software is that it provides transferable information on where, when and why a computer might be designed to support different types of instrumental material. This information can be related to structure, for example, and knowledge of specific structural points can point us to areas of the music that are important to the form. To return to Emmerson's 'live-link', an analysis of instrumental events from a perceptual perspective means that the composer can use information about

[7]Clarke (2005) for example explores some interesting points of discussion.

how music is heard to form this link. Conveniently, the majority of the distinctions that Bregman draws in his analysis are encompassed in Frengel's dimensions (Frengel, 2010). By categorising decisions using this matrix they provide a useful checklist for analysis in terms of perceptual and practical realities.

3.7.2 Relativity of dimensions

> "Cues play an essential role in the perception of the fundamental articulations of a musical work. Once extracted, they acquire value as reference points for strategies of comparison; they enable structures to be identified and filed."
> (Deliège, 1989)

Before looking for Deliège's cues, it's useful to reiterate why they are important at all to *EI* performance. If, as Deliège suggests, cues play a crucial part in our mental organisation of a piece of music it might be extrapolated that these are things we notice in music, things that strike our ear. Therefore these cues might be either exploited to draw together instrumental and computer part, or noted to avoid a clash. This could be anything from metrical coherence, to ensuring a stable amplitude balance (within reason) between instrument and electronics.

Where can these cues be found? As previously discussed, literature to present day, notably Bregman (1994), has tentatively offered divisions, scales and hierarchies that allow us to identify cues and convergence points in music. This research is highly practical because it allows for the dissection of instrumental material with relation to these potential hierarchies. What follows is a brief summary of four major dimensions I have extrapolated from this research. Afterwards I show how I search for these dimensions in instrumental material in order to locate musical 'cue points'.

Duration

> "The relative lengths of silence between moments of sound will be an important determinant of the groupings" (Bregman, 1994).

Duration and silence are directly contributory to our perception of groupings, Bregman's illustration clearly demonstrates this in the visual realm:

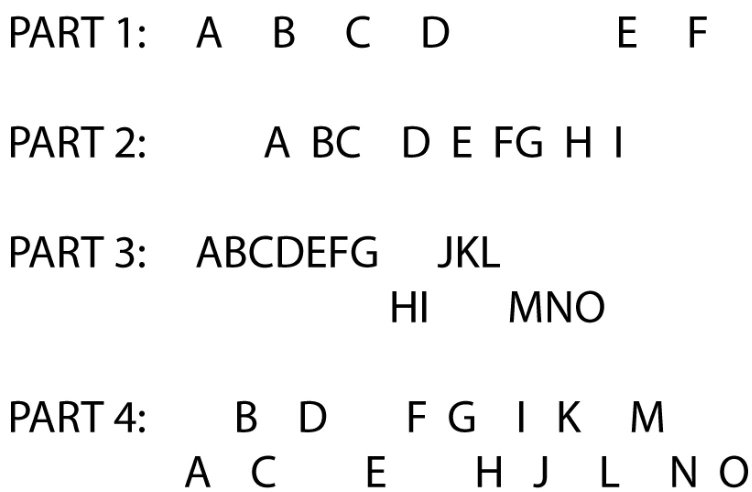

Figure 3.9: Importance of relative durations in grouping (Bregman, 1994)

We group members depending on how they are spaced relatively. This is important because it allows us to manipulate a listener's focal point and cohere two independent sound streams via spacings between musical events. Figure 3.9 shows how space is a direct influence on our perception of grouping.

Consistent patterns in duration (meter) are also strong contributing factors to our perception of groups with a sense of expectation. Analysis of both durations and overall temporal structure appears in Frengel's multidimensional axis as a strong decisive factor to the coherence of computer and instrumental material.

> "Musically significant grouping can, of course, be strengthened by the rhythm of the music. The existence of a repetitive pulsation in the music causes the sounds to group around the pulses, and to be segregated sequentially from one another." (Bregman, 1994).

This means that adherence to a mutual timeframe could be a practical way to ensure the functional coexistence of instrumental and computer parts. However, Nelson proposes that our perception of relative duration in contribution to a musical ecosystem might be a little more complex than the "dull shackle of entrainment to a beat" (Nelson, 2011).

Where I have found the analysis of the temporal dimension particularly useful has been with regard to highly metrical material where I have found it difficult to form a structural link other than timbrally. Tightening the computer material to the instrumental part in terms of meter allowed me more liberties with regard to the electronic material. As such I was able to introduce more abstract material such as synthesis, whilst still presenting a unified sound body. Examples of this include *Mechanica* and *Death and the Compass*.

Pitch

> "Intervallic pitch, if obviously present, will be the prime focus of attention for most listeners." (Smalley, 1997)

Our prolongued exposure to the western tonal system directs our ears towards certain intervallic relationships over others. In fact, the presence of any intervallic relationship at all might be privileged over a timbral scale, for which there is less of a quantifiable continuum (McAdams, 1989). Basic intervallic analysis of the material leads to an awareness of potential contrasts and similarities in the separate media. This draws attention to intervals that might dominate the surface of the music.

Fundamentally, an awareness of the horizontal and vertical activities of each musical line in an ensemble will allow for the decisive employment of consonant or dissonant pitch choices in the computer part (if relevant). Turning points in pitches might also be considered as cue points to emphasise in the electronics.

Timbre

The notion of timbre ostensibly absorbs many other dimensions whilst still encompassing a quality of its own; it is certainly a difficult dimension to quantify[8]. Simon Emmerson states its importance in *EI* music as a way to naturalise our interaction with acoustic instruments:

> "It is thus in the field of timbre that the only link between the true 'live" and real-time can be made, not that of a spurious 'syntactic' analysis, not that of Midi events, tracked, sensed, analysed and coded - impoverished entities without substance." (Emmerson, 1994)

This statement perhaps exaggerates the importance of timbral coherence in electronic music. Indeed we have discussed strategies for incorporating more abstract timbres to *EI* performance, such as temporal coherence. However, Emmerson highlights the importance of timbre as an area of multiple contact points for mapping between instrument and computer, rather than one to one event triggering. This reflects the fact that even single instruments don't maintain a singular timbre throughout their range (Bregman, 1994). Such a singularity would therefore probably be detected as unnatural in a computer part.

[8]Literature related to timbre in both instrumental and computer music is vast, though Boulez (1987), Saariaho (1987), and Bregman (1994) offer a robust starting point.

What is useful here is understanding how the instrumental material changes timbrally in relation to other dimensions - such as register - which gives us information that can then be used to create more depth and synchronicity in the computer part. For example, an increase in instrumental register could lead to a corresponding increase in brightness in the software output. This fuses instrumental and computer material reinforcing a 'live link' through timbre. This was the case in the *Max/MSP* patch for *104*.

Bregman also weighs into the discussion on timbre showing that contrasting types of material close together can also be perceived as different groups. He demonstrates this visually:

xxxx////xxxx////

(Bregman, 1994)

This shows that different timbres in instrument and computer parts could be perceived as segregated even if positioned alongside each other, unless bound by another dimension. Of course, Bregman concedes that what happens in the visual realm may not be analogous to our perception in the auditory realm. However it is still another useful angle from which to approach software design.

Timbral dimensions in interactive music are highly relevant not least because of the technical affordances offered by live sampling. This in itself provokes a timbral palette that shares at least some qualities of the instrumental material that can be used to help link musical behaviour. However, with other more quantifiable dimensions also playing a role, timbral interactions can be perceptually overshadowed. This is largely because timbre itself is often formed by them - so changes in onset and duration, for example, can effect the coherence of the timbre in *EI* music.

Space

Research is growing around space as a form bearing dimension. It is particularly relevant as *EA* composition offers high levels of control over this parameter. With regards to musical 'segregation' Bregman remarks, "...if the soloist can manage to be placed in a position in space that is separated from other performers this will assist the segregation" (Bregman, 1994), thus indicating that spatial distribution of musical elements can have a profound effect on our perception of the music. Smalley (2007), in particular, has written extensively on the musical impact of space in acousmatic music. This will be discussed in more depth further on in the chapter.

In each of the pieces I created the physical distribution of the sounding bodies is stipulated in the technical documents, intended for various stakeholders (see the diagram in figure 3.10 page 79).

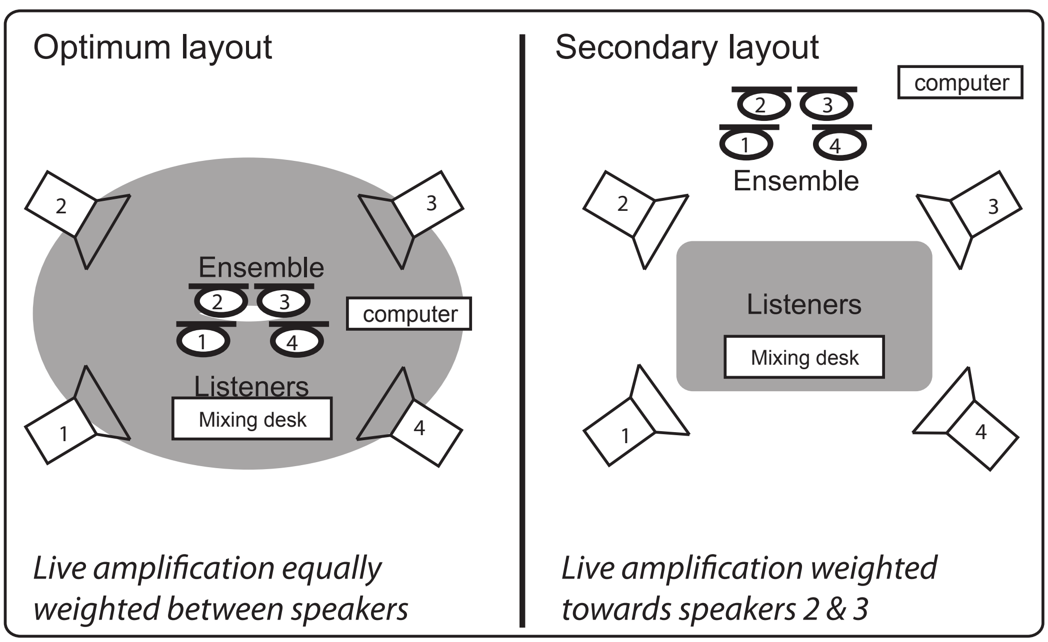

Figure 3.10: Stage setup document

Although stipulations for hardware setup aren't always honoured, as will be discussed in more detail in chapter four, thinking about the diffusion of the music in this way ensures that physical space is at least considered at some point in the compositional process. Imaginary space is also a contributing factor, and again I used this in support of structural points. For example, in *The Circular Ruins*, the growth of the computer part is manifested in registral, amplitude and also spatial growth in the quadrophonic image.

Like timbre, however, space as a form-bearing dimension is also at risk of being overshadowed by other more configurable dimensions. “We cannot, therefore, arbitrarily structure an available physical dimension such as spatial location and still expect it to be comprehended” (McAdams, 1999).

3.7.3 Using these dimensions

Moving through these four qualities individually allows me to examine the instrumental material I’m working with at an extrinsic level. Rather than approaching a score or improvisation with inside structural knowledge it ensures that I read or listen to the music with fresh ears. In other words I can analyse what might be perceived and have a concrete document to work from when programming my software in order to avoid an *intrinsic* approach. I find listening to a MIDI rendering of a piece can suffice, if a full recording isn’t available.

Crudely dissecting these relationships may seem like obvious and elementary qualifications of musical dimensions. However, the speculation of potential hierarchical relationships between them helps us to support coupling between instrument and software. In fact, it dispels the idea that any relationship may be perceived equally by the listener.

Therefore, assuming that spatial or timbral form will necessarily be perceived, even if as simple as a left right distribution, is dangerous when there are potentially more 'ear catching' relationships. This is crucial when designing *EA* components alongside instrumental material because painstaking work to make the timbral dimensions of the music coherent could be overshadowed by conflicting decisions related to pitch.

3.8 Phase 2 Analysis, and software response of relative dimensions in solo and ensemble pieces

What follows are analyses of my two case studies in terms of their relative dimensions.

3.8.1 *104*, Phase 2 Analysis and software response

Duration

Notes have loose durations and are not temporally synchronous, with groups of phrases providing shape to the music. The computer part, if functioning as gestural and environmental is not likely to conflict with these melodic shapes.

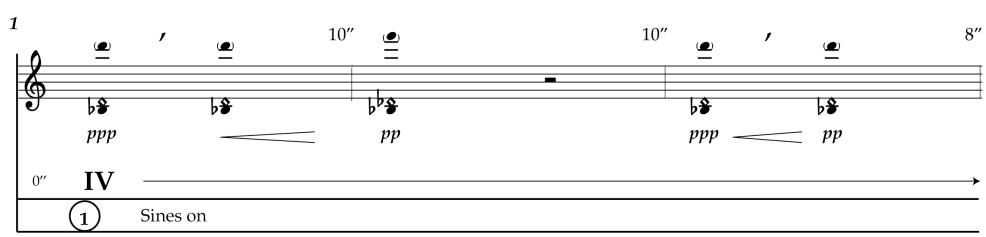

Figure 3.11: Score example of *104*

Intervallic

The fact that this is a solo piece and that notes aren't metrical as well as being quite sparse means that though intervallic relationships exist, these won't be as strong as with other pieces featuring sharp harmonic movements. This having been said, the computer part is providing an environment for the instrumental gestures to sit and will therefore provide a harmonic context for the piece. As live sampling is used to construct the environment the software will follow the horizontal intervals of the violin line, building up its own vertical harmonies. The lengths of these can be chosen by the computer operator with options to trigger additional layers - and hence add to the harmony - as well as fade each layer in and out.

Timbral

As discussed earlier, the quality of the instrumental notes leads to a light and glassy timbral veneer, which will be supported by the electronics. Readings of note brightnesses will further support the timbral movement in the instrumental part by filtering computer material in parallel to these changing parameters. Live sampling also enhances the timbral link.

Spatial

The violin is at the centre of the PA, to enhance the central role of the instrument, see figure 3.12.

Spatial activity within the electronics will move between different points with the spatial

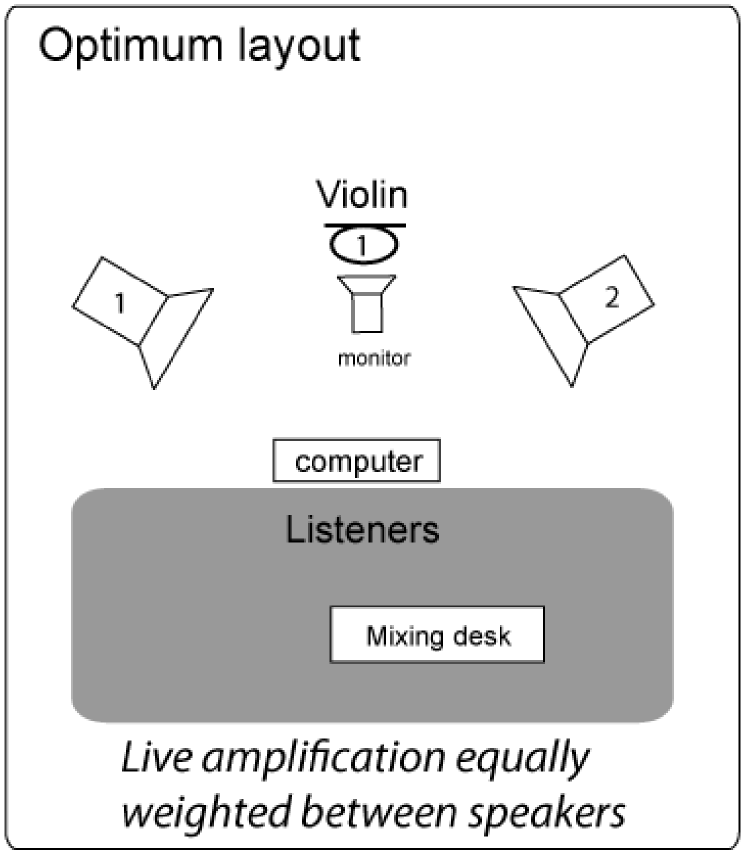

Figure 3.12: Stage layout for *104*

points widened at higher amplitude. This ties space to the instrument at another dimension.

Choices after analysis

The material that forms the electronics exhibits the following qualities:

- It is gesturally synchronous to notes chosen by Emma;
- It samples and processes material in realtime and is harmonically and timbrally synchronous with the instrumental material;

- It is not temporally synchronous;
- Live sampling persists for long periods of time for a textural element;

3.8.2 *TGOFP*, Analysis and software response of relative dimensions

Duration

There are three types of phrases: Arpeggiated phrases, held swells and pizzicato notes. Each individual's arpeggiated phrases are never at the same time, however swells occur together, becoming strong focal points. The piece is metrical, reinforcing the grouping between the ensembles. The swells had the potential to disrupt the flow of the piece if not treated with care in the computer part, and as discussed above, I use these as cue and trigger points for the electronics.

Intervallic

There is a strong harmonic vertical movement in this piece, which could lead to potential dissonance between computer and ensemble. This quality might be desired, but it is most likely to be useful to stipulate which arpeggios are being live sampled and layered into the computer part at which point. This is easily done via some triggering with *Antescofo*[9].

[9] Antescofo is a modular polyphonic Score Following system as well as a Synchronous Programming language for musical composition. The module allows for automatic recognition of music score position and tempo from a realtime audio Stream coming from performer(s), making it possible to synchronize an instrumental performance with computer realized elements. The synchronous language within Antescofo allows flexible writing of time and interaction in computer music. (IRCAM, 2015)

Timbral

There are three strong types of material here, as described above, all of which can be supported and linked through live sampling. As the piece is metrical and quite strongly defined harmonically, options for timbre are varied.

Spatial

The ensemble will be at the centre of the quadrophonic PA. The instrumental phrases are designed to move between instruments to create a spatial hocket effect, focally drawn together by the swell material. The PA can be used to enhance this by throwing back live sampled material in a similar exchange and by accentuating the enlargement of the space with the swells, both through panning and reverb/resonance. This should create a united space for both forms of media to exist.

Choices after analysis

The material that forms the electronics exhibits the following qualities:

- It is temporally synchronous to the triplet arpeggiation material;
- It samples and processes material in realtime and is therefore harmonically and timbrally synchronous with the instrumental material;
- It features additional synthesised material;
- It appears at the strongest structural cue points.

Although editing was required after the initial design of the software, the analysis of these dimensions provided a good technical starting point for performance.

3.9 Phase 3: Instrumental material analysed as acousmatic image

> "A listener needs time to progress from an initial listening encounter with the soundscape to a state of engaging actively and fully in scanning and exploring the spectromorphological and spatial properties on offer." (Smalley, 2007)

I found *EA* analysis appropriate for use in parallel with the analysis of note relationships in my instrumental material. As discussed in chapter two, it is easy to get lost in the abstract relationships formed between notes. So much so that one can lose sight of the perceptual level of the music, particularly when the number of instruments grows. Looking at the surface of the material as a *spectromorphological* and *spatial* construct allows me to hear the material with new ears and discover more areas for exploration with the computer part. Additionally, as *spectromorphology* is the most defined tool for analysis in *EA* music, it provides a convenient bridge between instrument and computer, allowing the instrumental material to be represented in acousmatic terms. Again, this can help to shake off the pitch/duration paradigm in instrumental music when required.

Smalley has formed and continually refined the definition and practice of *spectromorphology* in his theoretical work. He states, "Spectra are perceived through time, and time is perceived as spectral motion." (Smalley, 1986). Both, he says, are bound to the spaces that they occur in. In his significant written output he has offered a number of different approaches to the analysis of the *EA* sound palette, through motion analogies (Smalley, 1986), surrogacies (Smalley, 1986), dimensions of space (Smalley, 1994) and a functional distinction between *gesture* and *texture* (Smalley, 1997). Through his output he has maintained the essence of his original ideas whilst augmenting them to track his theoretical and practical advances.

I found a more recent paper, *Spaceform and the Acousmatic Image* (Smalley, 2007), as the most relevant to my work in analysing instrumental material on *EA* terms. It offers the fullest theoretical approach to space in performance, focussing on physical, musical and social space. Analysing instrumental material on these terms provides yet another set of tools to consider the organisation of notated material and arrange software accordingly. I find this method particularly useful for the examination of ensemble material.

Smalley describes a number of different forms of metaphorical spaces, beginning with his auditory description of the *Orbieu* landscape, a natural landscape he is seated in. The spaces he proposes to dissect are the auditory landscape, providing useful terminology to refer to in analysis and composition. They include:

- Zoned space - noise of an individual;
- Proximate space to Distal space - space nearest to and furthest from listener;
- Perspectival space - the relations of spatial position, movement and scale, viewed from the listener's vantage point;
- Vectorial Space - the space traversed by the trajectory of a sound;
- Panoramic space - The breadth of frontal space, extending to the limits of the listener's peripheral view;

(Smalley, 2007)

These different types of space can be paralleled through *EI* composition, combining both instruments and computer part with an active consideration of these various zones.

As well as spectromorphological space, Smalley takes recourse to social space. This is also something that Emmerson discusses (Emmerson, 2007). For Smalley, this theory is largely based on Edward T Hall's *Proxemic Theory* (Hall, 1966) in which Hall describes different types of space that we interact in, and their implications on our coexistence. Smalley analogises the different types of zonal space that Hall proposes into useful terms such as *microphone space*, *arena space* and *ensemble space* that invoke novel compositional parameters from these different spatial types[10].

3.10 Case study: The string quartet as acousmatic image: Analysis of *Labyrinths*

What follows is a case study of an analysis in terms of Smalley's criteria for *sound spaces*. This is followed by a subsequent functional application to inform the design of interactive software. Through my analysis of each movement of *Labyrinths*, that will show characteristics of each contrasting movement and the decisions I've made for them.

Vantage point: *Labyrinths*

Initially, I need to hypothesise as to my vantage point alongside the notated material that I am analysing. In this analysis I will place myself in the centre of the string quartet because decisions regarding spatialisation in the computer part will translate to this vantage point.

[10]See (Smalley, 2007) for a full description of these zones

Figure 3.13 on page 89 shows the hypothetical vantage point.

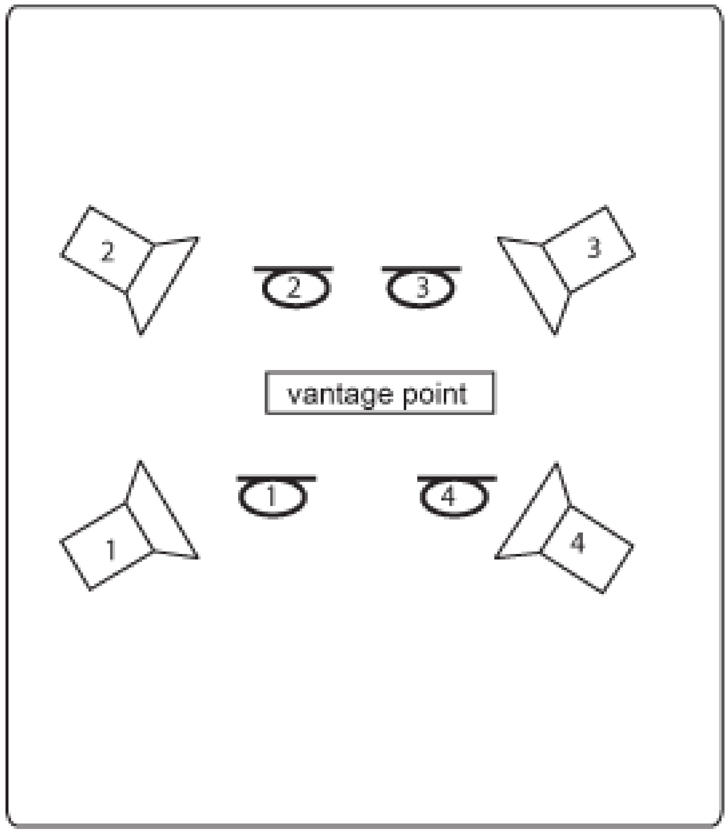

Figure 3.13: Vantage point

Ensemble behavioural space

From my central vantage point a number of key elements can be extracted from the landscape of the ensemble. Each of the four instruments has its own *gestural space*. It is possible to discern spatially as well as timbrally where each instrument is emanating from. However, it is also possible to consider the ensemble itself as a zone. Therefore we can consider this piece to have multiple zoned spaces. The ensemble's zone space is also a *behavioural space* because of the spectromorphological similarity of the string instruments themselves.

3.10.1 Material as landscape *The Garden of Forking Paths*

In *TGOFP*, the *proximate space*, considering a central vantage point, is uniform between the instruments. What changes this space is a different type of material - unison swells - which disrupts the uniform layer of the ensemble's *behavioural* space. This happens through an increase in dynamic and change in time signature. This changes the *proximate space* of the material, arguably invading my *personal space* more than the more uniform arpeggio material, and standing out through the disruption of the repetetive nature of the arpeggiations. This is supported by Bregman's grouping theory as pointed out early in the chapter, (see section 3.7.1).

What further disrupts this perspectival space are pizzicato notes that permeate the musical surface. These aren't like the swells, which occupy more space and are more invasive. Rather their contrasting texture and spectromorphological profiles serve to draw the ear to that particular instrument. Drawing the different types of space with the hypothetical listener vantage point can show the different types of perspecitval space that different types of material can occupy. This information is useful for either enhancing or contrasting with material in the *mediatised* performance space, which can change as the piece continues.

The interruptions of the continuous arpeggiation material also have the effect of gravitation towards or away from the spectromorphological plane. This is particularly conspicuous for the swells. Again, knowledge of this can allow for action in the computer software to support these diagonal forces.

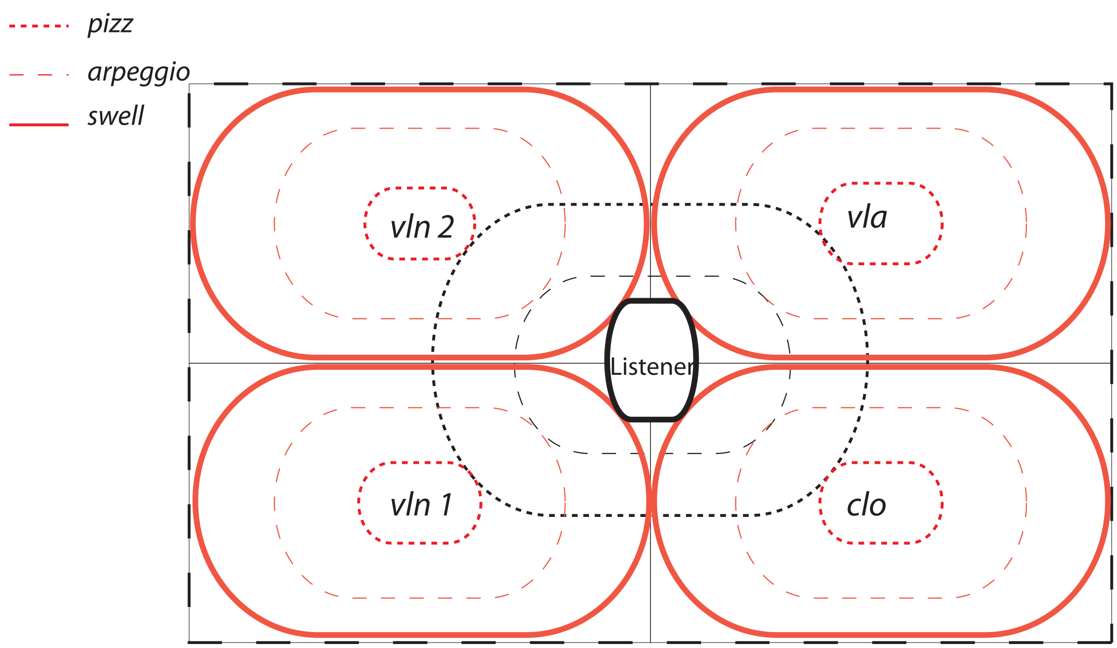

Figure 3.14: *TGOFP* behavioural space

Diagrams of the different types of technological space are also useful, both at the compositional stage and later at the performance stage, which will be discussed in more detail in Chapter Four (see section 4.7).

3.10.2 Adding to the landscape: *The Garden of Forking Paths*

Simple decisions taken with this information in mind could include:

- Enhancement of the 'hocket' type material through spatial distribution in the computer part;
- Changing resonance at points of the swells;
- Pulling the listener's ears towards the isolated pizzicato situations by spatially reinforcing the material;

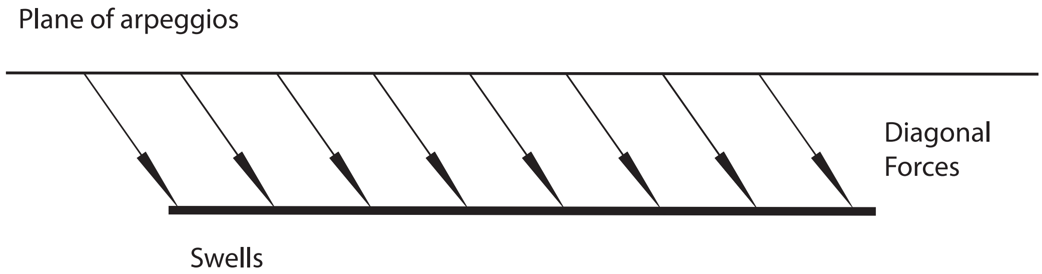

Figure 3.15: *TGOFP* behavioural space

3.10.3 Material as landscape: *Death And The Compass*

As with *TGOFP* in *DATC* each instrument has its own gestural space, however the nature of the material is very different, both in its sonic qualities and the musical surface that the notes form. As I discussed above, the quartet itself - and the PA setup around it - is comprised of multiple zoned spaces. The *behavioural space* of the instruments is on the one hand individual, but also united. In *DATC* what changes the fixed spaces as the music moves on is the quality of the material that is being played.

DATC is comprised of percussive material, again with interspersions of arco notes, intended to permeate the musical texture. However, unlike with *TGOFP*, where *proximate* space was encroached on by the unison swells, the arco material in *DATC* serves only to provide textural change rather than physically pervading the listener's space. This is because the score specifies that the arco notes remain at the same dynamic as the percussive material. The effect of this is that the notation presents a fairly consistent and flat landscape to the listener, with the increasing number of notes as the piece moves on seeming to complete the puzzle of the landscape. This is opposed to pushing through to another musical plane. It is an increase in activity that slowly shrinks the *proximate* space.

What draws the ear is the appearance of meter. The more notes that are heard, the more the meter appears, as if the musicians are unfolding the mechanics of the piece as it is progressing. Again Bregman's repetetive grouping theory comes into play and as listeners we are striving to find beats in the initially uneven appearance of the notes. Arguably the most compelling element of this piece is the eventual opportunity for the listener to make rhythmic groups in the landscape.

Due to the percussive and sparse nature of the material, the harmonic palette is fairly disguised and doesn't strongly inform the listener's groupings of the material. This also contributes to the 'flat' quality of the musical landscape. The ear isn't clinging to the harmonic phrasing and shape, so therefore attention is driven more to rhythmic phrases and sonic qualities.

A key element that distorts the shape of the landscape is the lower frequency notes, which have the effect of pulling the canopy of the music downwards. This gives the music the feel of increasing gravity. Again, this is emphasised by the lack of discernible harmonic shape and is something that can be enhanced through the electronics.

3.10.4 Adding to the landscape: *DATC*

A decision I made at the beginning of writing this movement was the idea of maintaining consonance between the computer and instrumental material. As a result, all the decisions I make regarding programming are to support and emphasise the landscape as I analysed it. What follows is a summary of the key qualities and my chosen responses to them:

- *Flat, consistent landscape*

  Maintain consistency with this landscape. Live sample or playback samples should appear to be in the same space as the instrumental material, rather than further forward or backward. Therefore, attention should be paid to amplitude of the notes and also quality of the material chosen to maintain a perceptually consistent landscape. I chose sampled percussive notes and some additional samples with similar qualities.

- *Activity increases as the piece progresses*

  Activity increases in the electronics in parallel to instrumental material.

- *Meter and rhythmic phrases focus listener attention.*

  Ensure that the computer part is meter aware, and contributes to the consistency of the phrases to support rather than distort the rhythms that can be built out of the flat landscape.

- *Disguised harmonic palette*

  Notes can be sampled and played back without concern for distortion of the harmonic landscape.

- *Lower frequency notes influence gravitational pull on the canopy*

  Where lower notes are featured in the electronics can have a great effect on the overall feel of the piece and therefore be used as a device for shaping the form. In this case moving the notes downwards as the piece progresses.

3.10.5 Material as landscape: *The Circular Ruins*

As with the previous two movements *The Circular Ruins* (*TCR*) starts at a low point of activity. The crucial difference is that there is more focus on a united *behavioural zone*, with each of the ensemble's attacks occurring at the same time. This has the effect of focussing the listener's attention on the ensemble as a whole, rather than picking out some individual lines.

The notes all have consistent traits that evolve to flesh out the landscape of the piece. They all begin high and glassy, gradually decreasing downwards, becoming longer in duration, fuller in amplitude and more distorted in timbre. That they are acting collectively is fundamental to the perceptible landscape of the piece. The *proximate space* is effectively closing in on the listener at the same time as the *panoramic space* is enlarging. These are parameters that can be emphasised further in the electronics.

The meter of the notes is synchronous but not repetitive, which gives space to allow the other parameters to behave in a very predictable way with the overall sound still arriving at some unexpected points. The textures of the notes play an important role, and is where the *behavioural space* is most individualised for the musicians. The varying timbres are the elements that mark each instrument out from others.

The harmonic palette is well defined but doesn't feel like it has a linear macro-structure. Rather, there are points at which the harmonic phrasing sounds consonant to the ear, and others where the notes feel more unrelated.

3.10.6 Adding to the landscape: *TCR*

This movement starts with the balance weighted towards the ensemble. As the piece moves on the balance between ensemble and electronics equalises before finally the emphasis is passed over to the electronics. However, although the balance will be shifting between the two entities the general traits as shown in the landscape of the instrumental material will be reflected in the electronics. In a way, although the electronics are developing their own voice, they are still highly consistent with the musical material because they follow the trends of all the parameters.

These trends include:

- *Minimal activity to full activity*: Similar behaviour.
- *High register to low register, quiet to louder, shorter to longer, clear to distorted*: Similar behaviour.
- *Synchronous notes but not repetetive meter*: Similar behaviour.
- *Defined chords but not overly consistent movement between notes*: Note selection through live sampling or synthesizer sounds consistent with the harmonic palette.

3.11 Summary

This chapter demonstrates how analysis that evolved around *EA* music can be applied to instrumental music and subsequently used to form compositional parameters for the design of realtime software. Though each analysis isn't exhaustive, and I don't use all analyses for the design of all software, having a palette of approaches to access my material gives me time to assess and consider decisions for the music with extensive detail.

I began with analysis at a 'note unit' level - *phase one* - calling on Schaeffer's *solfège* (Schaeffer, 1966) as a guideline. This explores individual notes for their qualities independent of source, examining factors such as sustain, decay and allure of each note. When analysed on these qualities, rather than the qualities found on the printed page, the resulting information allows for design of a realtime computer system on terms that are easily translated to reactive software. I used case studies to demonstrate this practice.

Phase 2 zooms out from the note unit to examining the material on a more relative level. Crucial to this analysis is the notion of *form bearing dimensions* (Bregman, 1994). Not only where these might be but how they fit together and influence each other hierarchically (McAdams, 1989). I then presented case studies where I examined notated material in search of these dimensions and demonstrated how this information might also inform my subsequent software design.

Finally, in *phase three*, I entered more metaphorical territory, using landscape metaphors to extract information about the zoned activity of the instrumental material. This is largely based on Smalley's paper *Soundspace and the acousmatic image* (Smalley, 2007). Having described some of the key zones that Smalley highlights, I present case studies for all three movements of *Labyrinths*. I demonstrate analysis on *spatial* and *spectromorphological* terms and subsequent use of this information whilst building my realtime *Max/MSP* software. It is assumed that *phase one* and *phase two* analyses are folded into these final case studies when related to aesthetic and technical decisions in the reactive software.

The strongest conclusion I have reached whilst designing these different analytical *phases* is that the more vantage points from which you can look at instrumental material, the more information you have to hone the software responses. From my research into the auditory perception of sounds, what strikes me most is the *relativity* of each musical dimension. That each dimension relies on others for how strongly it is comprehended. Without taking into account all of these dimensions separately, it is difficult to build up a strong idea of what is going on in the music as a whole. With this in mind, building phases of analysis into stages of composition provides a full set of parameters to work with. This maximises the potential for ’successful’ interaction in a diverse range of musical situations.

Chapter 4

Performing material

> "Today's loudspeaker is a great anonymous pulveriser of sound that does not measure up to the means which have been developed to create a new sonic world."
> (Boulez, 1987)

Thirty years on and Boulez' words still resonate for a large number of *EI* performances. Perhaps though, the loudspeaker is now a scapegoat for more ingrained communication issues in the *EI* music community. As composers and performers we spend a considerable amount of time perfecting the inner nuances of software interaction and practising our instruments, attentive to minute details. Yet *EI* performances still so often appear *pulverised*, lacking in precise projection. Reflecting this is a comparative lack of literature surrounding its performance, particularly regarding the way that digital elements are relayed for precise sound projection.

With this in mind, this Chapter Four moves my narrative from the theoretical to the practical. Broadly, I examine the impact of the action of performance on theoretically developed material. The first question I address is how to communicate the computer's musical behaviour to another musician. What forms of representation tell another person what is going on efficiently, without swamping them in detail. How does this information change for different types of material? An example of this might compare scored versus improvised material. I follow this with an exploration of the musical impact of varying performance situations. Specific types of variation include differing hardware, spatial and social environments. Examining the nature of these in detail questions how best to communicate the technical requirements and aesthetic nature of the music to be performed.

Though it is helpful for everyone to have all the different forms of direction. Each stakeholder necessarily seeks detail in different places[1]. Crucial to this chapter is the division of information depending on the recipient. Providing information to performers in the score via simple symbols and extra audio files, references to tempo, meter and so on can be considered as separate from what a sound engineer may require. Therefore this chapter will show how I have been examining extra score material to provide to performers, sound engineers and gig organisers with as much mutual understanding as possible about the musical situation.

4.1 Presenting EI music

Whilst there isn't a huge amount of literature surrounding this type of performance, that is not to say that there has been no attempt at discussion. Recently there does seem to be more interrogation of the actual performance of computer music, with some more specialised discourse about *EI* music in particular. The notion of musical performance as an ecosystem highlights an area previously overlooked regarding physical space and

[1] Stakeholders in this chapter refer specifically to composer, musicians, sound engineers, stage technicians and venue management

hardware as embedded musical parameters. DiScipio (2003), Waters (2007), and Green (2008) survey this topic particularly well. A practical example is DiScipio's *Background Noise Studies*, which use feedback loops between microphone, space and loudspeakers as audible flag posts to their own presence. No longer is there the tacit assumption of neutral devices and a simple transplantation of music from one space to the next. Each space, stage and venue carries with it its own characteristics which are ultimately embedded in each performance.

With this in mind, I will dissect some of the issues we might encounter in the performance of *EI* music:

- First, we are dealing with live sound, necessitating microphones, loudspeakers and other diverse forms of software and hardware in between. All of these will colour and impact the performance, in fact all of these are the performance.

- Second, sound is emanating from *two different media*: acoustic instrument(s) on the one hand, and some form of loudspeaker setup on the other. We are presumably attempting to form a unified piece of music with them, yet the varieties of setup are far from fixed and therefore difficult to anticipate.

- Third, and most importantly, all these factors are bound to the physical spaces in which they take place. Each venue carries with it its own sonic hallmarks, its own layout, social conventions, possibly sound engineer and other architectural idiosyncrasies that can be impossible to predict until hours before the performance.

Understanding these issues returns me to the two questions I would like to address in this chapter and the practical examples I use to illustrate my responses. How can you first provide enough third party information for *EI* music to be realised to the best of your intentions? And how can the variances of particular venues be best allowed for in *EI* music? One answer to each lies in the flow of succinct and clear communication between *all parties* involved in the music. In other words musical collaboration through technological documentation.

In my portfolio work there are a number of different documents in various formats that I have developed in order to communicate musical intentions with clarity to every person involved in the act of performance. I begin with the representation of the computer part in a traditional score and ask what the best information is for the musicians to have, and how can this be distilled to clean up rather than clutter the page? I look at various attempts to classify visual symbols for electroacoustic sounds, going as far as to examine material beyond this such as mp3 mockups and demonstration of material. I also examine different possibilities for this type of representation in improvised as well as composed music. I then move on to the performance space, and its implications for the presentation of the music. I look at useful information to be relayed to each member of the performance relating to previous performances that I have undertaken.

Those interested in pursuing this topic in more detail should certainly consult Sebastian Berwick's PhD thesis, *It worked yesterday: On (re-)performing electroacoustic music* (Berwick, 2012), which gives a rigorous and methodical analysis of a number of pieces for interpretation by solo instrument and electronics. I believe that this a useful reference point for experience from the performer's perspective[2].

4.2 Not initially designed for interpretation

As I noted in the previous section, the computer led element of my submitted portfolio was not initially designed for interpretation by another electronic musician. This approach

[2] It should be noted that all pieces in my portfolio are not initially designed for interpretation and performance by another electronic performer. I have so far always been present at performances though some of my patches are available to share. This is further explained in section 4.2.

evolved through the experience of the musical events I curated, and took part in during my research. Specifically, my patches were designed to examine aesthetic and technical interaction with musicians.

Shaping the patches required a great deal of personal practice and the development of mechanisms in response to the musical situations at the time. As a result, all the pieces I have submitted in my portfolio feature me as attendant and performing in some way or another, rather than asking another musician to interpret my patches. This highlights a curious continuum between the notion of performer and composer in electro-instrumental music, by which composed patches become instruments through practice. The longer I worked with the patches, the more they became my performance instrument, leaving my portfolio as a combination of electro-instrumental composition and performance.

The first piece that I embarked on for this PhD was a collaborative composition for bass clarinet and electronics entitled *IKON*, which I composed with Marij van Gorkom. Here we worked as co-composers, both contributing aesthetically to written material, as the piece is completely notated. Marij continues to perform this piece herself, though we have never distributed the piece for performance by other bass clarinetists, and the electronics are free standing (Marij is able to perform the work, with electronics, on her own). To say that this piece is not intended for interpretation is wrong, since Marij interprets the performance each time she plays *IKON*. Perhaps then it is useful to identify that this piece is, in a way, personal; meant for interpretation or communication by us and between us. As neither of us were improvisers, the notes were a way for us to communicate between our two different media.

The development of the piece, rather than its creation, required notation to prompt a performance. Subsequent to this, I became more of a performer of electronic music than a composer. This way of making music felt infinitely more natural to me. What can be taken from this experience is that we created *IKON* as a reflection of our requirements and abilities at the time. This approach endured throughout the rest of my research.

Pertaining to my work with *KUBOV*, I would categorise my musical activity as completely performative and my patch as a constantly evolving instrument. This is perhaps reflective of the improvisational approach that Emma and I have developed over our time working together. In contrast, the computer element of the rest of the collection of my portfolio is transferable as a complete unit alongside the scores and is more composed than my work with *KUBOV*, maintaining the option for interpretation by another electronic performer.

Reflecting on the difference in using the various patches sheds light on two points. First, Emma and I have worked very closely together developing a semi-improvised sound world (see section 5.3), with each of our sonic materials linked through our experiences of practise and performance. Over the three years of our work together, the iterative cycle of practise to performance followed by analysis has folded our personal experiences into the *KUBOV Max MSP* patch. In this way, the patch holds, and also requires, our cumulative experience of working together. Our work is embedded in the patches for us to draw on, and the *KUBOV* patches developed into a personal instrument for this project.

The second point is that it is useful to consider the notion of embedding an individual musical idea into a patch, and that much of this depends on how fixed the instrumental material is in notation. The musical material in other parts of my portfolio is notated, therefore the ideas can be transferred much more succinctly to a third party. The notation naturally draws out specific elements of the accompanying patches, making the computer part more neutral and easy to understand. The instrumental notation sheds light on the action of the patch. In this way the patches associated with the notated elements of my portfolio are far more accessible to a third party electronic performer. Even this approach, however, is not without its difficulties.

The circumstances in which a person will be performing the patch have a great imposition on the ability of an electronic performer to interpret the piece. Thus, who will be interpreting the piece, and more specifically how long will they get to rehearse the piece with the other performers, will have a significant impact on how successful the performance of the piece is. Since my research focussed on interaction between performers, computers and performance spaces, adding in more layers of interpretation did not seem like a very succinct way to carry out my research. In other words, I reduced the number of variables in my portfolio in order to allow for a more balanced examination of the musical behaviour of the patches.

The practical impositions of curating an environment where another individual can successfully understand the music, interpret and perform a piece meant that, for the purposes of my research, I tended to avoid this by performing at every event myself. In my performances with *KUBOV* I am not only triggering sound, my *Max MSP* patch has become my personal instrument. I have developed my patch to behave in response to the way in which I choose to improvise with Emma.

So to understand that my patches were not initially intended for interpretation, it must be clear that they are borne of my personal practice and my individual choices as a musician. As I learnt to perform material with these patches, I was able to experiment and reflect in order to refine my musical output. This approach isn?t a musical dogma; it is, rather, a reaction to circumstances surrounding the creation of EI music, particularly the requirement for concentrated practice, the same as with any other musical instrument. To understand the musical behaviour I was trying to examine, my presence was a necessity. However, as circumstances adjust, future interpretation is welcomed.

4.3 *EI* Music: What are we communicating?

Before we dicuss how communication can be achieved, understanding what is being communicated is crucial. It should be noted that parts of my portfolio presented in this section, particularly the textual description of the interaction, are related to composed music. They therefore have the privilege (or curse) of quite specific temporal information, which can be used for informed trigger points. Improvisation systems require different treatment and analysis and are discussed later on in the chapter (see section 4.4.2 on page 109).

In Chapter Three I explored with some depth the ways that instrumental material can be treated in attempt at the elucidation of musical form. The key focus being realtime software that behaves in a perceptually coherent way. I began with solo instrument and computer, examining individual note qualities and their placement into a larger musical timescale. Particularly I looked at how meter, spatial location and harmony can all affect our perception of the whole (or its parts). I examined how reflection on *EI* music has increased, and how the role of the computer in performance has also emerged as another type of musical parameter with Croft (2007) and Frengel (2010) proposing fairly defined categories of behaviour. I then moved on to the consideration of the ensemble as *acousmatic landscape*, surveying the notes by ear through the lens of acousmatic analysis. Here perception of the whole was a major focus.

As well as forming compositional methodologies, these analyses can be succinctly communicated to a performer to indicate intended musical behaviour in advance of rehearsal. Why is this useful? Because they signpost behavioural traits programmed into the computer part, indicating what is going on musically. I provide a table such as Frengel's *Multidimensional approach* (Frengel, 2010) together with a verbal explanation of the different types of behaviour the computer will adopt in performance. This gives a good general overview for quick appraisal, for example whether the computer is behaving as a musical partner, providing a textural environment or adopting another role. In other words communicating technical choices and programming decisions can be enlightening to a performer, no matter what their technical ability relating to the electronics. Additionally more traditional forms of notation can also support this information, by providing in-score cue points for texture types, rhythmic and harmonic cues, dynamics and more.

With this in mind, what we are communicating seems to be an abstraction of prior knowledge related to the design of a system; a communication of musical intentions. This interaction, as with the software, often lies in the space between the two media, and the question of what to communicate can therefore be distilled as the illumination of potentially hidden processes in the realtime software.

4.4 How can we communicate?

This section surveys some different types of process illumination to instrumentalists. First via a fixed score, and second via a live computer link. It references some of the more useful practical solutions that I have discovered in other compositions, which have influenced the pieces that form my portfolio.

4.4.1 Material within a score

Audio effects and beyond

Although visual sonic representations of signal processes are far from standardised, communal understanding of what effect certain processes will have on a sound is far more consistent. If common processes are to be applied to a performer's sound (for example ring modulation), by far the most simple way to indicate what is actually going to happen at each particular point is via a quickly referenced textual signal (as opposed to an attempt at visualising them). See figure 4.1 and figure 4.2. When a performer is unsure of how a particular effect might sound, its implications can be researched and understood.

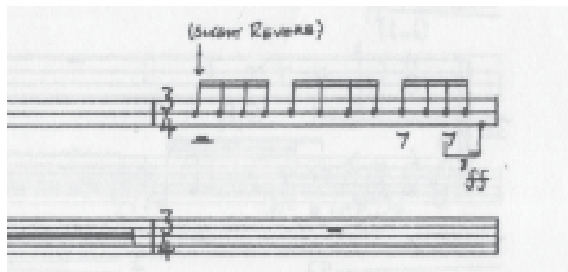

Figure 4.1: Edwards' marking of reverb amount (Edwards, 2009)

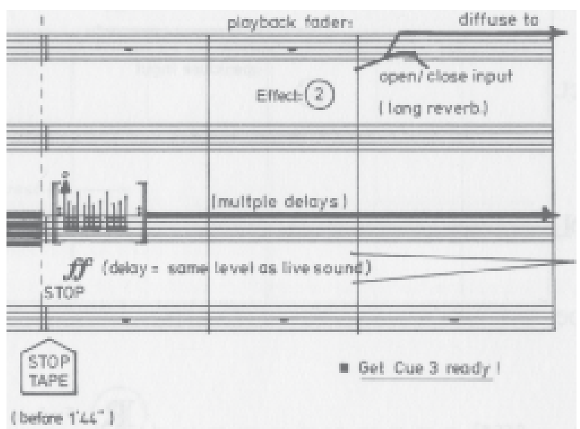

Figure 4.2: Montague also shows reverb length (amount) (Montague, 1989)

Textual notes in the score also serve as useful cue points and we can see them used by Saariaho in figure 4.3 on page 109. These cue points can also act as an aide for the electronic performer to synchronise with musicians. Additional sound files can be supplied with cue points ahead of rehearsal to give a clear idea of how a sound might translate from page to performance.

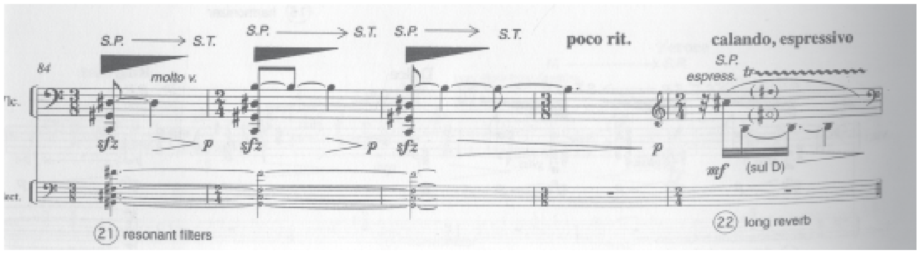

Figure 4.3: Saariaho labels cue points with processing directions (Saariaho, 1996)

Identifying more traditional musical features, such as rhythms and specific pitches, can also be particularly useful reference points, not least because the performer is not needing to learn an entirely new visual idiom that might not be as instinctive. See figure 4.4 on page 109 using more traditional notation in comparison to figure 4.5. The former shows very clearly how the electronics are rhythmically synchronised with the instrumental material, whilst the latter proves much less instinctive to follow.

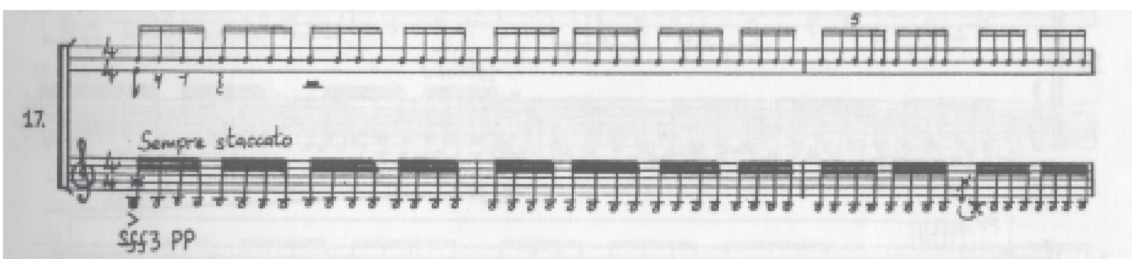

Figure 4.4: This shows very clearly how the electronics are rhythmically synchronised with the instrumental material (Edwards, 2009)

4.4.2 Communication when improvising: Realtime screen-based information

So far I have been examining non-realtime communication through a written score. However, I also work with violinist Emma Lloyd in an improvised environment, in our duo *KUBOV*. When in *KUBOV* and improvising, we also found that using visual

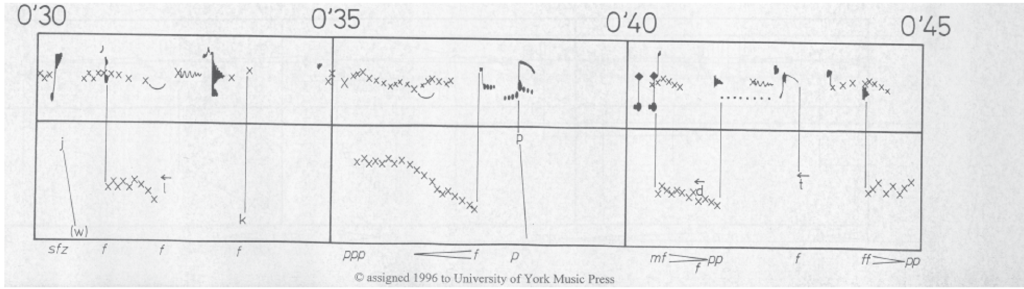

Figure 4.5: Visual description of notes is vague and less instinctive (Harrison, 1980)

communication to supplement aural communication was helpful in order to give Emma a clear idea of processes and modules I had activated. This has the additional benefit of supporting Emma if adequate monitoring wasn't provided for any reason, for example if feedback was an issue.

My reactive *Max/MSP* patch relies on readings of pitch and attack for the parameterisation of certain modules. This is key information that we decided could provide useful visual information for Emma, for reassurance as well as calibration. I also share realtime information as to which modules had been activated (please see section 5.3.4 on 141 for a detailed description of the modules) , certain parameters and relative amplitudes. A later addition was a text box that I was able to type messages into. This simple design proved very functional and, although Emma was relying as much on her ears and knowledge of the system as her eyes, visual communication provided an extra layer of support should it be needed.

An element that we didn't implement for our performances and album, but something that we will be exploring in future, is the two way flow of information. Namely this is designing a way that Emma can also send me messages. As her hands are holding her instrument we considered a foot-pedal system that could nudge the performance in certain directions. However, this is at its early stages. In reality, the practicality of this is questionable, as much of the material is lead by Emma's performance, the chosen style of her playing leads to a high level of control over the musical output.

4.5 Hardware and space

> "Musicians need to be able to communicate somehow their expectations of the gestalt if the engineer is to have any hope of arriving at a satisfactory balance."
> Green (2013)

This section relates to the characteristics of each performance venue and each characteristic's influence on the behaviour of the sound. This is all part of the *performance ecosystem*. There is a growing body of writing related to the loudspeaker as an "active" musical participant (Mulder, 2010b; Emmerson, 2007). There is also some particularly interesting research into its incorporation as a compositional parameter with the importation of acoustic properties of concert hall (via impulse responses) into the studio for a more informed compositional process (Pierre Alexandre Tremblay and Pohu, 2009).

Returning to music with scored notation, I have provided information for musicians on the forms of interaction that occur, types of sound that might arise and points at which this happens. However, this type of score embedded with details on interaction might not always serve as a particularly useful document for *all* stakeholders. Not least because information spread over 20 pages in one score can most likely be distilled into a much briefer record that is just as relevant to the projection of sound.

Green (2013) suggests that technological stipulations should be considered useful but perhaps not requisite. Whilst wanting your favoured setup to be as clear as possible, should it not be realised then unnecessary performance stresses can still be kept at bay by arriving at the venue equipped with some practical coping strategies. This is certainly an approach that I have adopted considering the different venues that I have performed at. Site visits are often not viable and Figure 4.6 on page 113 reflects a few of the varied performance settings that I've been presented with on the day of the gig. In other words, it seems that the idealism of a perfect layout combined with a healthy pragmatism regarding setups in a variety of venues is a robust starting point.

However, detail from the outset regarding specifications for a PA and setup remains important. Not necessarily because you will be guaranteed what you request, rather to give a full idea of the ideal approach to sound projection for each performance. That way the sound engineer can on the one hand work with what they have, whilst on the other have the best chance of projecting a a sound world as close to concept as possible. Likewise, notation regarding input of instruments, as well as signal flow in and out of the mixing desk is a highly evolved practice, with some established and accessible syntax, for example symbols of microphones and loudspeakers found in 4.9 on 120.

4.5.1 Performance and technical notes

A score for a musician, with notation related to each separate technique, is a document that can hold specific indications of the desired sound world. However, it is debatable that a document for a sound engineer need contain this level of prescription. There are alternative ways to communicate the quality of the sound world and how it changes through time.

Consequently, I have assembled a shorter collection of setup documents that contain relevant information about what seem to be the most important and recognisable qualities and interactions within the music, as found through research and experience. This goes beyond physical signal flow and speaker layout to more descriptive vocabulary about

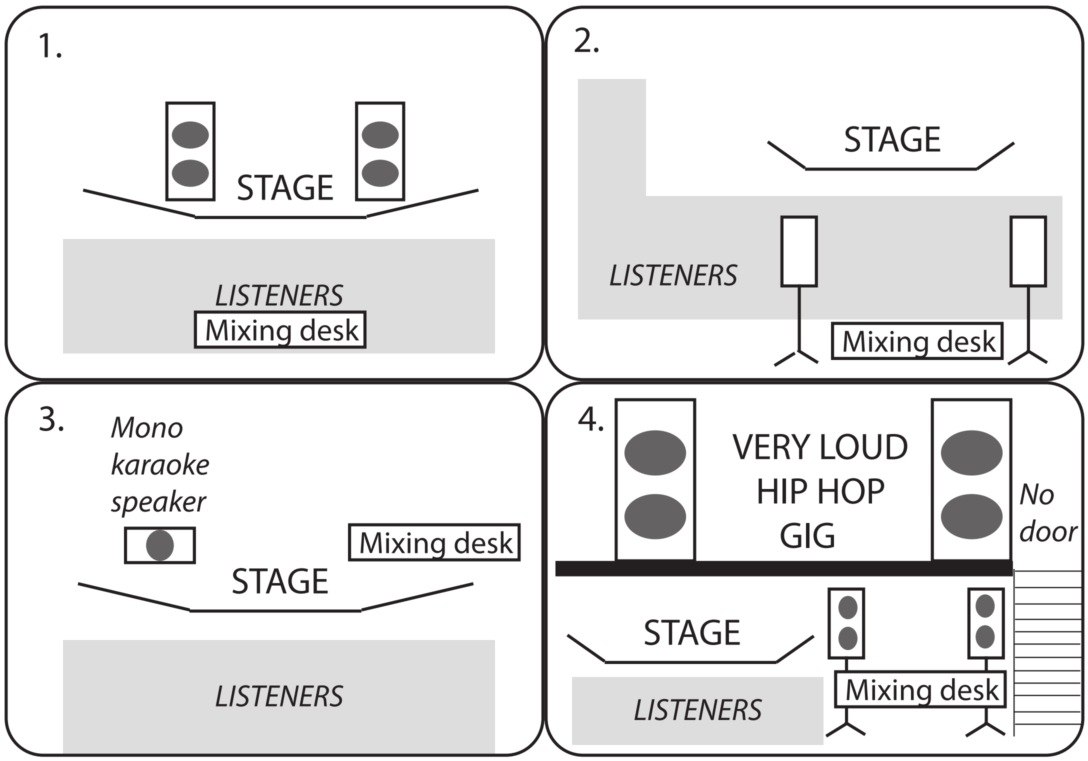

Figure 4.6: 4 Performance Situations

what they can expect as the music is performed, as well as my musical intention. I find this is particularly important with multi-movement works that shift greatly in character from movement to movement as it allows a sound engineer to treat the sound as they wish from a more informed perspective.

General setup

In scored *EI* music, composers frequently put together a number of technical notes for performance. Often more detailed notes are provided when the electronics themselves are to be interpreted by another musician, rather than performed by the composer themselves. In which case circuit and patch diagrams can also be included.

Generally, decent technical notes always include a spatial overview, technical specifications of hardware and software and possibly a signal flow (see section 4.7 on page 116 for examples and descriptions of these).

Additional Textual Description

Textual descriptions are also a valuable tool to help communicate the tome of your piece. These can be found to greater and lesser extents within musical material. For example, in much of the discourse surrounding *EI* music, there seems to be some collective pursuit towards an understanding of balance between amplified instruments and electronics. Arguably a prominent feature in textual information can be found in one of Frengel's axes, 'live weighting' Frengel (2010), which approaches the amplification of sound as a compositional parameter, similar to Mulder's *Levels of Amplication* as a musical function (Mulder, 2010b). This can be found on a continuous rather than discrete scale and a description of how this changes over time places can be an extremely efficient communication tool, effected in a single line of text (see Figure 4.10 on page 122). Emmerson (2007) has devoted a significant amount of his book *Living Electronic Music* to the question of balance in *EI* music.

4.5.2 Space and amplification

In his paper *Functions of Amplified Music* Mulder (2010a) draws attention to Theo van Leeuwen's (Leeuwen, 1999) ideas on how social spaces can be sonically encoded, in order to reflect on how microphones can transcend physical distance in performance. Related to this, physical responses to a space can also overcome problems with amplification. This was exemplified in our experience with a noisy neighbour (see Figure 4.6 on page 113, box 4), where we were unable to compete with another gig. This prompted the movement of the audience closer to us, shifting the listening space to enhance their experience of the music.

In the above musical situation, being unable to properly amplify the sound changed the social distances at play. The architecture of the venue forced a modification in the structure of the social space, allowing for some leeway in the strength of sound that the audience were able to hear. The listener's response in restructuring the environment at the time felt appropriate. In another performance space they may have felt too close.

This experience first emphasises the necessity for a dynamic software response to the architectural demands of the performance. More importantly however, it demonstrates the limitations of any document. Although information to a sound engineer before the event could flag up warnings to potential conflicts, often these situations don't arise until the performance of the music has begun. No set of performance documents is infallible.

4.6 The venue and its social architecture

The architecture of the venue isn't only physical and awareness of where responsibility for different elements of the music lies can lead to the most efficient communication documents. Splitting information into sections such as technical rider, separate layout, signal flow documents, and finally an aesthetic description means that venue management, sound engineer and musicians can quickly understand the particular demands of the music *on them*.

Two way communication is necessary for a mutual understanding of the exact performance context. Prior knowledge of what is to take place will give the venue manager the opportunity to flag up any potential issues. However, this level of investment into the music isn't always guaranteed and what is clear is that when communication within the venue is clouded, the performance often suffers for it.

4.7 Setup document: Case Study, *Labyrinths*

Having previously established the requirements of various setup documents I will now discuss one of these in detail. *Labyrinths* is a three movement piece for string quartet and computer, featuring live electronics through a set of bespoke Max/MSP patches. Each movement has its own flavour and forms of interaction, the role of the computer and sound qualities are quite distinct. I formed the computer part based largely on Albert Bregman's perceptual theories as described in Chapter Three, specifically how we group sounds (Bregman, 1994). The proposed interaction is loosely based on Michael Frengel's *multidimensional axes* for *EI* music Frengel (2010).

4.7.1 A general description

Target stakeholders: Venue management, sound engineer, musicians

Labyrinths, for string quartet and computer is a three movement work exploring different musical spaces inspired by the short stories of Jorge Luis Borges. The preferred listener's vantage point is from within a quadraphonic speaker layout, either surrounding the ensemble or with a more usual stage and listener setup (see technical manual of Labyrinths *for layout). The intention of this is to engulf the listener in each environment, with light amplification of each instrument and light processing creating tricks of perception as to which voice each sound belongs. Instructions regarding the mood of each movement can be found later on in this document, as variable amounts of reverberation, delay and compression are intended for each differing movement.*

This paragraph - though technically vague - gives each stakeholder a feel for some general intentions for the piece, whilst also explaining why certain requirements (e.g. A quadrophonic speaker setup) are important to the fabric of the piece. This makes sure that emphasis is placed on the most important aspects of the music.

4.7.2 Technical requirements, Fig. 4.7

Target stakeholders: Venue management

Technical riders, perhaps the most general requirement for technical communication when it comes to gigs can often appear patchy and incomplete. As discussed above, detail - even if not realisable - can at least provide a good idea regarding overall intentions for the sound projection. Even going into the level of detail such as types of connections will preempt any problems with missing equipment on the day.

Tech Rider:
Labyrinths for String quartet and computer

Supplied by musicians:
4 x DPA 2060 microphones
All firewire and MIDI cables
1 X RME Fireface
All MIDI interfaces (if needed)

Speaker position:
Please see attached layout

Venue must supply:
1 x table (12ft x 4 ft) for computer
5 x chairs
4 x music stands (with lights)
12 x XLR cables
2 x 4 way power supply
PA (EAW system favoured)

Loudspeakers		4
Subs		1
Stage Monitors		2
Ensemble microphones		4 (supplied by us)
I/O	Mixer ins	1 - 4: 4 x DPAs from Quartet 4 - 8: 4 x TRS from Computer
	Mixer outs	1 - 4: To PA 4 - 8: Quartet DPAs To Computer 9 - 10: Monitors 11 : To sub

Figure 4.7: Tech rider for *Labyrinths*

4.7.3 Setup document: Stage setup, Fig. 4.8

Target stakeholders: Venue management, sound engineer

A lot of detail can be placed into a graphic representation of the physical space. This includes direction of speakers, position of listeners, musicians, mixing desk, position of onstage power, DI boxes, and types of microphone. There are also some standardised graphics to represent different forms of hardware, such as graphics related to microphones, loudspeakers and mixing desks.

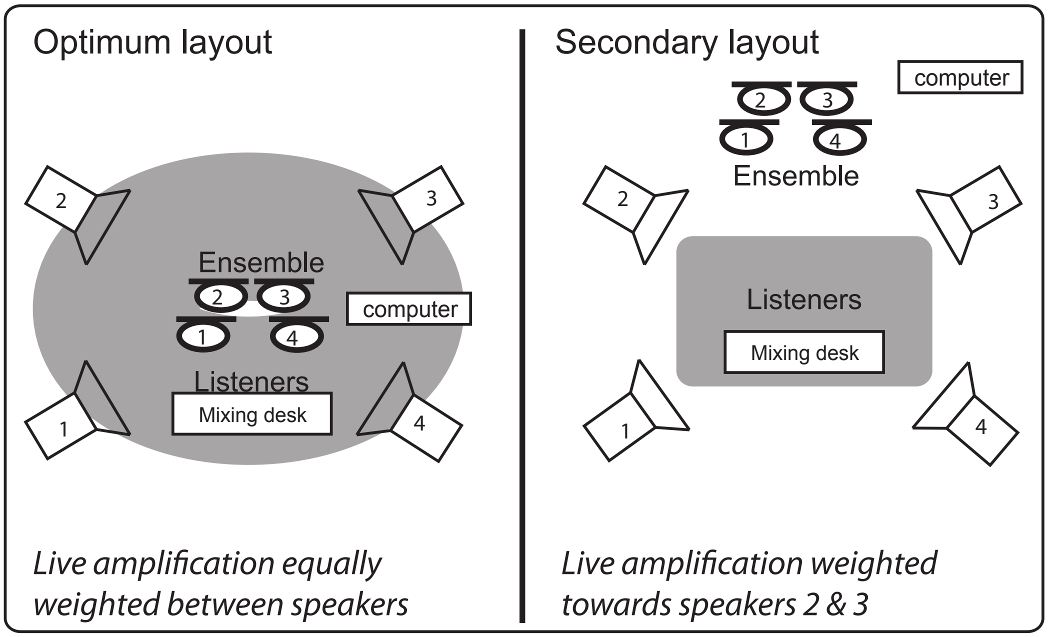

Figure 4.8: Stage setup document

4.7.4 Setup document: Signal flow, Fig. 4.9

Target stakeholders: Venue management, sound engineer

A separate document related to the signal flow of the piece clarifies any doubt over what you intend to project and where it should be sent. References to instrument reinforcement and monitoring can also be located here.

Signal flow from within the mixing desk also ensures further precision.

4.7.5 Textual information, Fig. 4.10

Target stakeholders: Sound engineer, musicians

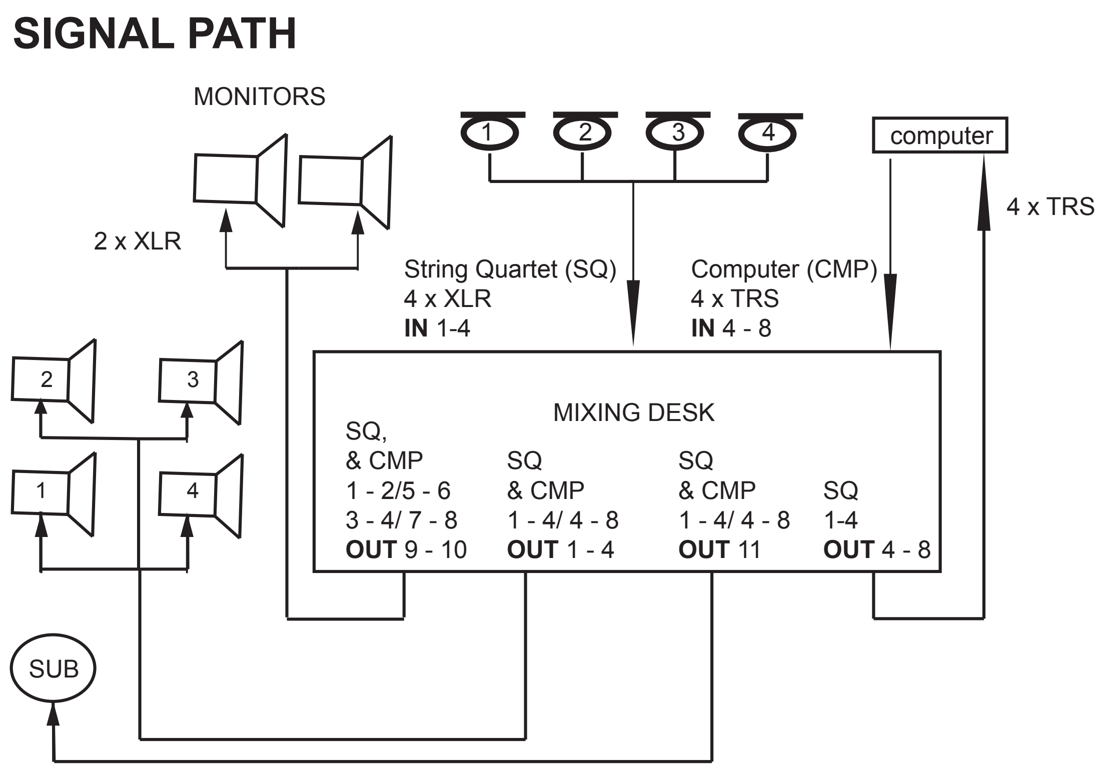

Figure 4.9: Signal flow for all movements

This is where the more detailed information documenting modes of interaction and aesthetic preferences can be found. The information in this document can be drawn directly from decisions made at the beginning of the composition process. In my case based around Frengel's multidimensional axes. Information can be extrapolated from this and communicated in a clearer textual form. In Figure 4.10 on page 122 I have chosen to highlight certain types of information. First, I state what type of material will be heard in the computer part, in order to stop disparate musical elements being confused for "mistakes". This could include, for example, a synthesiser sounding like feedback. I document where the balance lies between instrument and electronics from movement to movement, which isn't always static. I include information regarding whether the patch is tempo synchronous or not and what role the computer is inhabiting. Finally, I indicate intended dynamics and quality of the sound.

This sort of information is important because if there are points in the music where it isn't clear that the musicians and computer are meant to be interacting in a certain way[3], then the sound engineer may take unnecessary steps to counteract this specific intention. Explaining what you are expecting to hear gives the sound engineer the freedom to focus their skills on bringing out the best in the music, rather than spending their time guessing whether something is meant to be there at all.

4.8 Summary

Methods for the communication and staging of *EI* music will always be in a state of development. Each performance will throw up a variable that differed from the last. However, I have attempted here to cover eventualities that I am able to foresee through

[3]For instance with the computer part becoming louder than the amplification of the instruments in *The Circular Ruins*.

MVT I - THE GARDEN OF FORKING PATHS

Live sampling and processing
Balance - Towards unprocessed live sound
Tempo synchronous (score following)
Singular behaviour - patch reliant on musicians
Computer role - Insruments extended for musical emphasis (eg addition of extra reverb at certain points by patch)

MID RANGE DYNAMIC. CLEAR ARTICULATION

MVT II - THE CIRCULAR RUINS

Live sampling and synthesizer
Balance - Live sound moving to computer
Not tempo synchronous
Singular behaviour - patch reliant on musicians
Computer role - causal from instruments moving to coequal and finally independent to instruments

VERY QUIET TO VERY LOUD. SMOOTH BLEND

Figure 4.10: *Labyrinths* Movement I and II, textual information

research into other composers' work and collaboration with sound engineers regarding the best ways of presenting information. I have done this through a set of documents containing general textual description, tech riders, stage and hardware layouts, signal diagrams, and a brief description of aesthetic intention.

Understanding that music is a finely balanced network of many different activities, including factors completely beyond compositional control, helps to manage to identify certain types of problems. The documents presented in the chapter demonstrate my response and rationale to these issues, including varying levels of detail for the different parties involved in the performance. It should be stressed that this often boils down to individual preference. Indeed, some people I consulted suggested more detail, and some less in the documents. For me the crucial points are clarity and flexibility - the documents are detailed with different levels of focus directed to different individuals. Coupled with this are some pragmatic software and hardware responses to a variety of situations.

What underscores all of this work is that the presentation of *EI* music is built on a number of dialogues between different parties. Without a shared understanding of what is to take place, the loudspeaker often unnecessarily remains a *great anonymous pulveriser*.

Chapter 5

Portfolio: Creation and analysis

5.1 Instrumental material: *Three pieces for violin and computer*

Three pieces for violin and computer were created for, an in collaboration with, violinst Emma Lloyd, with whom I later formed the improvisatory band *KUBOV* with (see section 5.3 on page 138). The process of composition was collaborative in many aspects. We set out to explore different technical approaches to violin material and involved the use of the computer for the generation of each part of these pieces [1].

[1]These pieces have been performed in a number of different spaces, and the submitted recording was filmed at their premiere concert in the Reid Hall, Edinburgh University

5.1.1 MVT I:

104

This movement is built around the technique of harmonics[2]. Whilst creating our first work together, Emma and I tried to be careful to avoid the ’box of tricks’ approach to composer/performer collaboration described by Fitch and Heyde (Fitch and Heyde, 2007), balancing techniques with the design of a collaborative sound world. At the time I was interested in a spectral approach to composition. With this in mind we involved recording and spectral analysis early on in the composition.

I wrote four phrases comprised of harmonics that we then recorded (see figure 5.1).

Figure 5.1: *104*, four ’seed’ phrases

I ran them through spectral analysis software *Audiosculpt*[3], arranged them in order and visually highlighted the most prominent harmonics that would then themselves become harmonic material that informed the piece. Therefore the spectral analysis formed the macro structure of the piece (see figure 5.2 on page 127). Following this I manipulated

[2]The name “104” relates to the 104 different harmonics initially analysed for the piece.
[3]AudioSculpt is a software for viewing, analysis and processing of sounds.(IRCAM, 2015)

the pacing and exact harmonics to suit my musical taste, adapting timings of attack and notated pitches.

I created a realtime *Max/MSP* patch alongside this movement, the responses of which draws from the shape and quality of the notes themselves, (described in Chapter Three). A detailed analysis of this can be found in subsection 5.2.2. The patch is triggered by Emma, with these realtime choices accompanied by a fixed evolution of the background texture. The harmonies of the patch were built to support those found in the instrumental material, to form stacks of minor thirds and minor sixths. Filtering was also applied to enhance the harmonic series in the harmonics themselves.

5.1.2 MVT II: *Mechanica*

Mechanica[4] was built in an entirely different way. This time we placed the initial focus on percussive violin techniques. We used a similar approach to the creation of *104* in the sense that I composed a set of 'seeds' that Emma then interpreted using different techniques, recording the seeds one by one (see figure 5.3 on page128 for notated seeds).

I had hoped that I would be able to put together the 'seeds' manually, in a coherent fashion, in order to form a tape part and instrumental structure. However, the material wasn't working this way so I took a different road, cutting up the seeds to create a palette of different percussive notes. It's most simple to imagine my subsequent arrangement of these as drum samples in a drum machine that can be triggered subsequently.

Again, different to *104* I used these samples to build up a tape piece using *slippery chicken*.

[4]The name "Mechanica" references the grid-like interactions found in Ligeti's method "patterns meccanico", with similar material phasing in and out of itself. For detailed information on this process, Clendinning (1993) gives a thorough survey

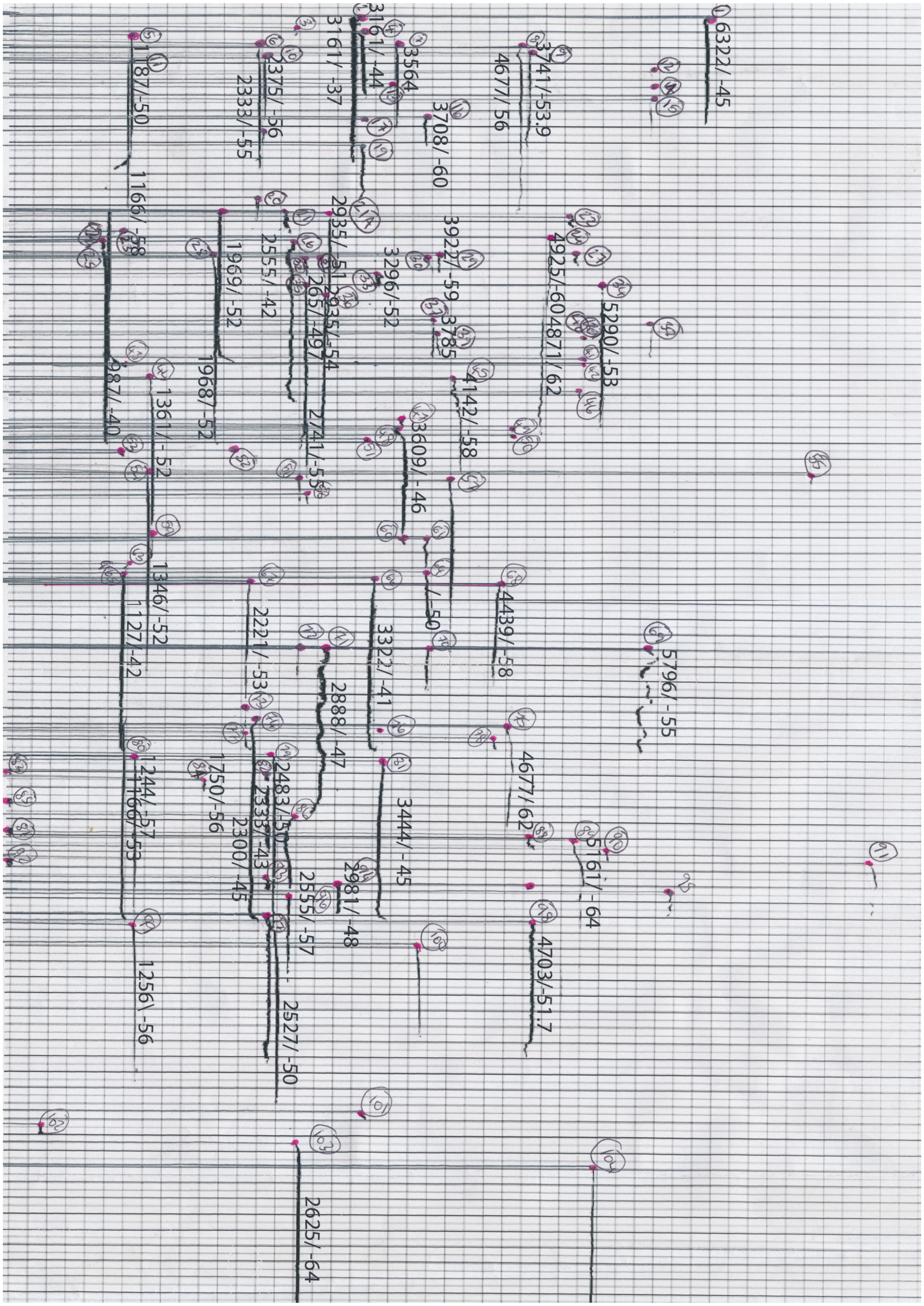

Figure 5.2: *104*, macro structure following sonogram

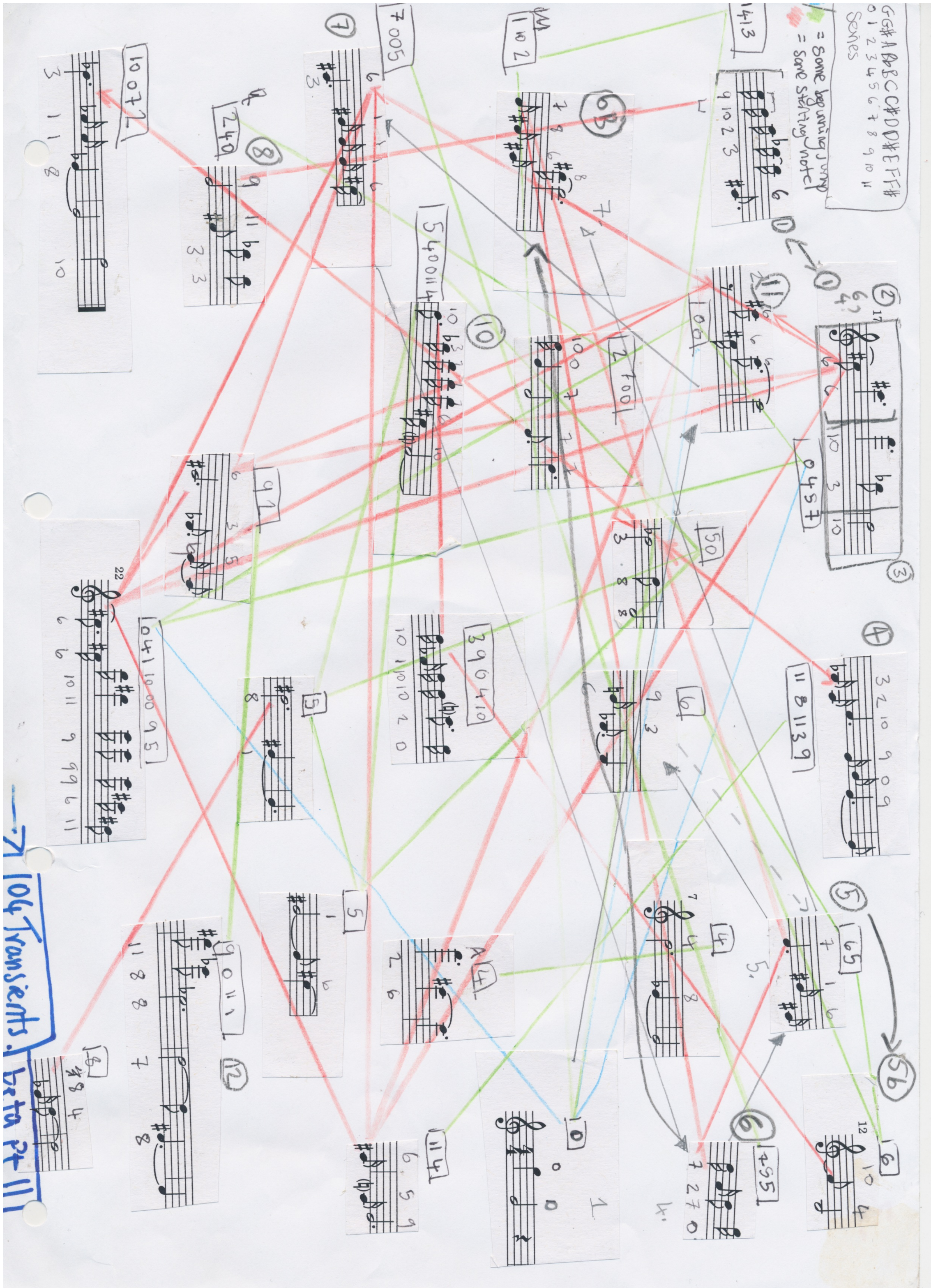

Figure 5.3: *Mechanica*, First recorded seeds

I used the *rhythm chains*[5] technique to trigger samples that created a six minute tape piece. Specifically, I put together 7 different rhythm chains, all comprised of the same code but temporally compressed, in order to create a gradually thickening and more detailed musical texture with self similarity. Self similarity in this case means that the kernals of each of the seven layers were the same, and the only different between them is the speed at which they unfold.

In Chapter Two I described *Mechanica* as exhibiting *mid-degree interpretation* because a part of the composition, the instrumental part, was created through my own ear rather than accepting material directly from the software. Listening to the tape piece, I transcribed what I felt was the most obvious melodic line that I could hear between the seven different tape seeds, displacing some of the earlier notes to form a more interesting dialogue between the violin and computer part. This seemed to work because the material that Emma was playing was weaving between the different elements in the fixed media, sounding consistent, yet independent, from it. We practised the two together and manipulated the material through these rehearsals to create the most interactive sounding dialogue. Building the instrumental part from this tape material, in a way working backwards, was challenging. This is largely because of the heretical approach to software output, and failing to find the most efficient route to my goals.

The *Mechanica* algorithm

Mechanica features a combination of algorithmic arrangement of sound files with a transcribed live instrumental line. The algorithmic processes used call on far more of the internal processes found within Slippery chicken, though the arrangement and subsequent

[5]The *rthm-chain* class provides a means of algorithmically generating two-voice *rthm-seq-palettes* and *rthm-seq-maps* that can be inserted directly into a slippery-chicken object. It creates the two voices by automatically assembling sequences of user-defined rhythmic fragments of either one, two, or three beats. (Edwards, 2015)

transcription is all done by ear. The essence of the piece does come from the rhythmic placement of each sample rather than evolutionary processes, though there are different structures holding different fixed elements for the parameters (for instance high transposition, short duration and so on). These structures can be thought of as different contrapuntal lines in the piece. Much of this functionality was for experimentation and isn?t used in the composition.

Mechanica features 7 different instances of the rhythm chains algorithm the only difference being the length. This means the exposition of the rhythm stipulated by the algorithm appears at different times, creating interesting counterpoint between the seven different wav files created by the algorithm.

7 different variables are created, all with a different number of bars held in separate slippery chicken objects. To associate these objects containing rhythms stipulated by the rhythm chains I moved the information of the position in the piece each note fell in seconds rather than bars and beats. That way each call to *CLM* can trigger an appropriate sound file at the correct time related to bars and beats within the piece. Other processing parameters specific to each call are adjusted related to values held in the relative structures.

Transposition of the soundfiles is related to the pitches held in each slippery chicken instance. Transposition envelopes are held in structures, as are the high pass filter envelopes, amplitude, start time and option to reverse of each soundfile. The result of these processes is seven separate soundfiles of different length that are then put together in a DAW to build up in density.

5.1.3 MVT III:

Softly, softly

This piece was created through Emma's work with subharmonics on the G string[6] . The instrumental material is a simple musical line, weaving between subharmonics and more traditional bowing techniques. The computer part was created through a realtime sampling patch that created a textural bed for Emma's line. Feedback, filtering and some sine tones push particular frequencies through and creating a harmonic base around the G.

5.2 Technical notes and analysis:

Three pieces for violin and computer

5.2.1 General technical notes

These three movements are presented in stereo with a third mono channel reinforcing Emma's dry violin signal for balance and localisation (see *Three pieces* technical manual for detailed information).

5.2.2 MVT I: Technical notes

The *Max/MSP* patch for this piece is built almost entirely on realtime sampling. It is triggered by a MIDI foot pedal, rather than reactive to sonic parameters, and Emma has a choice between three gestural 'sustain' pedals (see sustain examples 1, 2 and 3 in the examples section of the USB). These are triggered at moments of her choosing

[6]The name "softly, softly" is a tongue in cheek reference to the harsh and distorted material the piece comprises.

throughout the piece, I have noticed that she's marked particular points where certain modules are appropriate to emphasise phrasing, using the realtime patch to highlight particular parts of the structure. There is an additional textural element to the patch that builds from these triggered gestures - the patch picks up material from the gestures and extends them for longer periods of time to create an evolving environment through which the gestures permeate. Filtering and additional sinetones are triggered at certain points of the piece. These are harmonically related to the instrumental material (see figure 5.4 on page 134 for an annotated screenshot of the patch, which corresponds to the list below).

1. ADC in, main amplitude level of violin signal from DPA microphone;
2. Settings boxes for MIDI, general DSP settings, option to read or write presets;
3. Reset button to return patch to original state;
4. Gain sliders for modules 1, 2 and 3 triggered by Emma's MIDI pedal. These are triggered individually but can be activated in quick succession. They are not affected by the cue points.;
5. Turn on high and low sine waves. These are turned on and off and then automatically trigger sine waves. The frequency of the sine waves depends on which cue point we are at, harmonically consonant frequencies have been programmed at different points of the piece. These are turned off and on at different cue points.;
6. Turn on 1, 2 or 3 environmental layers. This are turned on and off at different cue points and may run in parallel. They sample material from modules 1, 2 or 3 and create a harmonic texture. Transpositions are harmonically consonant to different cue points of the piece;
7. Level of Haas delay to flesh out signal in performance;

8. Time code of piece and cue point. Point out how much time has elapsed and allows the patch operator to move the cue point;

MVT I: Score representation of computer part

The computer part of this movement is represented by cue points in the score. These mark out important sections of texture changes, filtering and sine wave appearances through the piece. These cue points are also a score for the patch, signifying changes in software state that move the computer material through a sequence of textural and harmonic changes (see figure 5.5 on page 138 to see example of a cue point).

5.2.3 MVT II: Technical notes

The computer element of this piece is largely comprised of fixed media computer material, with elements of triggered realtime sampling corresponding with the violin's later arco material. The piece is synchronised through the use of a click track sent to Emma, though I would not use a click track again is it is uncomfortable for performers. We are working on more creative ways to synchronise the piece, and have experimented with a visual click that will allow Emma to interact with the space in a more musical way although we have yet to perform with it.

MVT II: Score representation

The 7 tape seeds are condensed to a single musical line that indicate percussive rhythms and relative pitches to help Emma synchronise with the tape part (see figure 5.6 on page 138). Arco elements have directions to MIDI trigger the live sampling elements via a foot pedal.

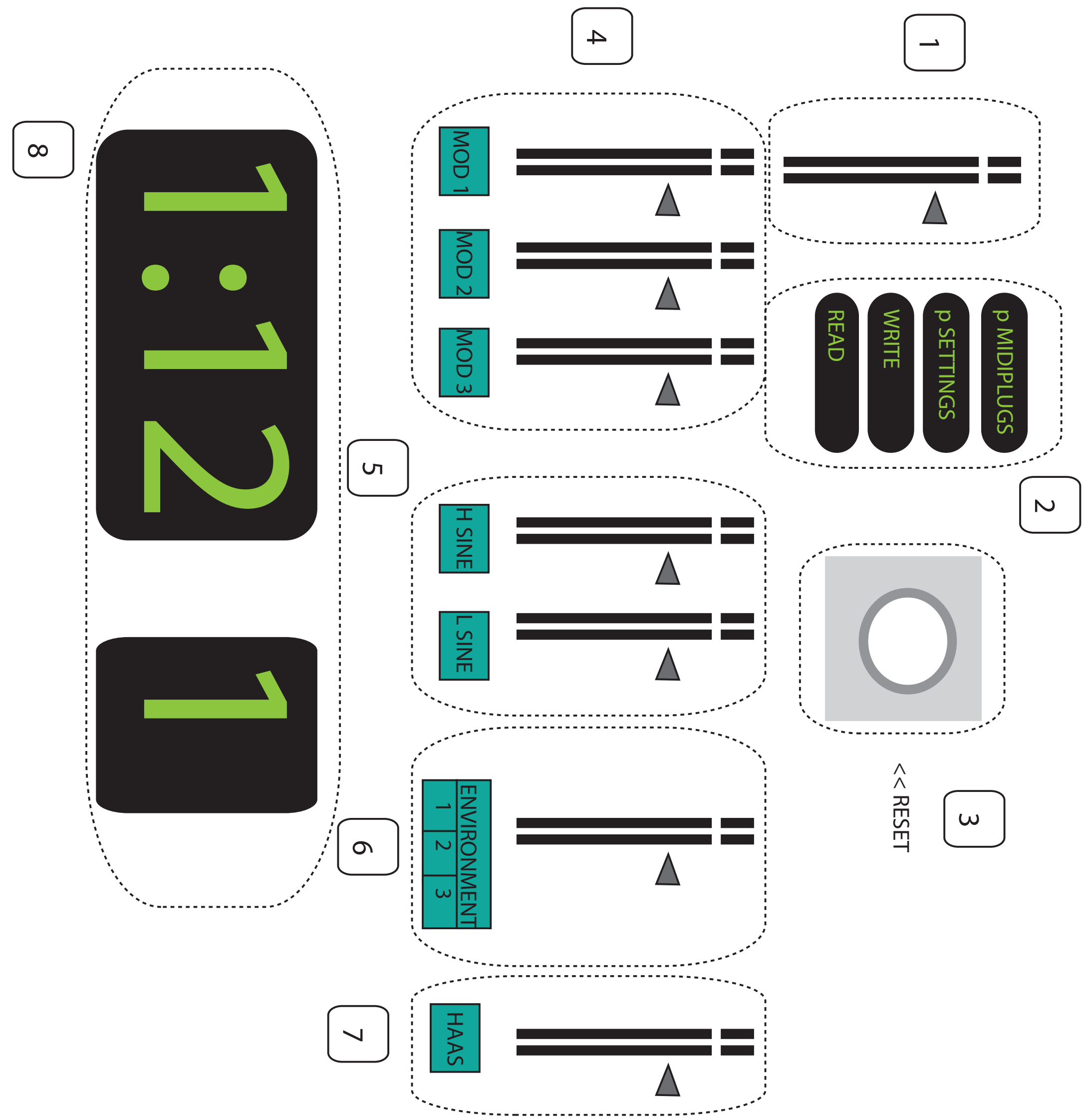

Figure 5.4: *104*, Annotated *Max/MSP* patch

5.2.4 MVT III: Technical notes

This piece is formed of a live sampling patch that works independently of instrumental material or any MIDI triggering. The live sampling is triggered by an internal clock, that triggers after a number of durations.

MVT III: Score representation

The live sampling patch is indicated in the general notes, and there are no markings for the computer part in this movement.

All movements: Detailed analysis of interaction

Please see PDF on the next page of a Frengel style multidimensional analysis of all three movments.

Axis	Type	Implementation (mvts I - III)
Segregational	Monomorphological: Unified	- Live sampling
	Polymorphological	- Processed recording and playback
	Monomorphological: Unified	- Live sampling
Proportional	Acoustic	- Gesture triggered from violin - Violin in foreground
	Equal	- Both from similar material - Behaving interactively - Both foreground
	Acoustic => Equal	- Live sampling - Texture builds along timeline - Instrumental foreground leading to equal balance
Temporal	Synchronous/Asynchronous	- Gesture triggering synchronous with attacks - Environmental 'picking up' of material not synchronous
	Synchronous	- All material synchronised by meter
	Asynchronous	- Granular synthesis not perceptually related to violin attacks
Timbral	Similar	Live processing and synchronous triggering make the computer material perceptually an extension of the instrumental
	Equivalent	The material is very alike but not exact. The electronics feature recordings of the violin but also other percussive recordings alien to the violin.
	Equivalent	The electronic material is live sampled, but processed and also not synchronously triggered so is considered equivalent rather than similar.
Behavioural	Singular	Reactive to violin MIDI triggering

	Independent	The computer element is mostly fixed, as is the instrumental material. Though the lines may sound related, they are in fact independent from each other.
	Independent	The electronics part is reliant only on a clock for activation, rather than any realtime triggering.
Functional	Extension/Environment	Live sampling, gesture triggering turning into environmental
	Coequal	Processed samples fixed into tape and notated part, both equally contribute to musical discourse
	Environment	Live sampling creating an environment for the gestural violin material
Spatial	Stereophonic image	See seperate layout sheet
Discursive	Gesture/Gesture&Texture	
	Gesture/Gesture	
	Gesture/Texture	
Pragmatic	See additional tech specs and layout documents.	

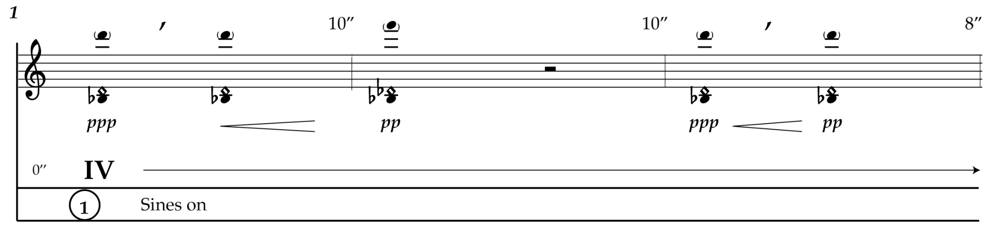

Figure 5.5: *104* cue point example

Figure 5.6: *Mechanica* Notated rhythm example

5.3 *KUBOV*: *Invisible Soundscapes*

Invisible Soundscapes[7] is the result of two years worth of collaboration with Emma Lloyd. In this time we have performed many improvisational gigs in a number of different settings. The collaboration features amplified violin, with reactive *Max/MSP* patch and Minibrute synthesiser. There is no notated material, although much of the material is solidified into its form through extensive practise.

5.3.1 Practice and development

During our gigs we worked from an improvisatory framework, loosely knowing the structure and timeframe that we would be working within. The patch and material that we worked with evolved through addition and refinement of what we performed. This meant that our gigs developed through practise, and each gig wasn't presenting an

[7]Each title is taken from one of Italo Calvino's *Invisible Cities*, reflecting the character of his fictional locations.

entirely new piece. Rather, a morphed version of the previous performance. In this way, we thought of each performance as an iteration of our process, rather than a final product (see USB drive appendix folder KUBOVICMC.mov and concoctsoundingobjects.wav for recordings of live performances).

5.3.2 The album

We felt that recording our album should capture something different to our live performances. The listening situation is different, and working without the visual element of performance requires more effort to make the disparate elements seem cohesive. We decided to analyse our performances and divide the material into different segments. We then weaved these into an eight track album consisting of eight unique sound-worlds and combinations of interactions (Frengel, 2010). In fact, we found that creating the eight different sound-worlds necessitated different types of interactions.

5.3.3 Overview of creative process

This section provides a description of our creative process during our research.

Phases of Performance

This studio album represents a core body of work from over three years of collaboration. The way that we came to a point where we were able to dissect and record this album as separate studio pieces came from extended collaborative. These three years comprised a cyclical process of practice to performance followed by reflection. This reflection was then engaged in practice, leading to an evolution of performance and so on. What emerged over this time were what we came to think of as three distinct 'pieces' (*Absolute Zero, Concoct and Atual*).

Though these pieces weren?t as fixed as one might find with a notated score, our knowledge of each other?s materials and the framework indicated by these pieces meant that we had a lot of information absorbed and therefore at our fingertips in performance. In other words we knew where we would be at a particular point in the performance and also knew the direction that we were likely to take in future.

Each performance that we engaged in brought to light different issues for our collaboration, thewe were practical, as in a particular type of material had a tendency to feedback. But they were also aesthetic, for example we might have felt that remaining on a particular type of material meant that section of the piece started lacking in energy. Feedback from audience members, discussion between ourselves and most importantly revisiting any documentation we had recorded (videos, sound recordings), gave us even more insight into things we might change in future performances, and elements of the piece we felt needed more work. As this cycle continued we instinctively knew when we had successfully honed each piece. The urge to move on from material and shapes we felt we had performed multiple times is represented in the need for new material. In practise we no longer wanted to play this material as it didn't offer us anything particularly fresh. The shifting from one piece to another was therefore natural progression rather than an active decision.

The studio album presented in this portfolio is a re-contextualisation of our collaborative endeavors up to this point. When it came to making the studio album our working processes endured. What proved particularly useful were the documents that we had already taken. These were recordings that we listened to closely and picked apart to find distinct sound worlds that could be made into tracks. We felt that different attributes were required from a studio album over a live performance, with keen attention on the segregation of longer structures of the pieces into smaller segments. We rationalised that attention spans might be altered without the visual spectacle and listening forum of a concert. What lead to the studio album was a thorough reflection on all of our output over the three years. Having analysed our performances and dissected material that would be worthy of a complete track, we reassembled the tracks as they fit in this particular context. What follows is a technical and aesthetic description of our collaboration for each track.

5.3.4 The patch

The patch we used to perform on the studio album is the latest iteration of my performance patch (see figure 5.7 on page 143) for annotated screenshot of the patch. Below are the corresponding functions of each of the modules and accompanying audio file.

1. ADC in (signal and control gains) plus limiter activity
2. Drum pad trigger. The drum pad I use has twelve pads, each associated to trigger two different types of files. Each pad can be turned on and off, and either K, S or both K and S options are turned on to signify either K for Kontakt triggering or S for live sampled triggering.
3. Filter. Part of the violin signal is filtered and this biquad filter can be edited manually to change the filter frequency and type
4. This button object signifies when the threshold of the attack has been breached. This button triggers many of the live sampling modules
5. Background texture. There are four different options of background texture. Two are low transposition and two are high. The numbers directly below the gain for each module correspond to the length of the loop (default 8000). All background

textures can be turned on and off individually. There can be 8 voices of each background module, 32 in total. These are triggered one by one when the attack button is triggered. The length of these loops can range from 100 ms - 30000 ms.

6. Delay. This refers to my tampering with the delay creating a glassy effect that is responsive to input amplitude and pitch. This changes the parameters of the delay in realtime. It can be turned on and off manually. The delay does not need to be triggered, though only sounds when the parameters actively change, an action that opens a gate.

7. Sustain. Features the digital sustain pedal from the *104* patch. Can be turned on and off. There can be four seperate sustains held at any one time. This is triggered when the attack button is triggered.

8. Pitch shift. Uses an FFT pitch shift on the live violin signal. Can be turned on and off and the frequency is stipulated by the keyboard slider graphical object. This is active when it is on.

9. Gestural module. Samples very short buffers from the live signal and synthesised signal, that are then immediately retriggered. Can be turned on and off manually. This is triggered by the attack button.

10. DAC. Gives gain level out as well as optional reverb level.

Valdrada

This piece was created from the requirement for fast interaction between Emma and I. This particular aesthetic came about through our collaboration in Austria 02/15 with Bernardo Barros. His style of playing is much more rapid and fast moving than ours previously had been, but we had to develop a new method of interaction in order to

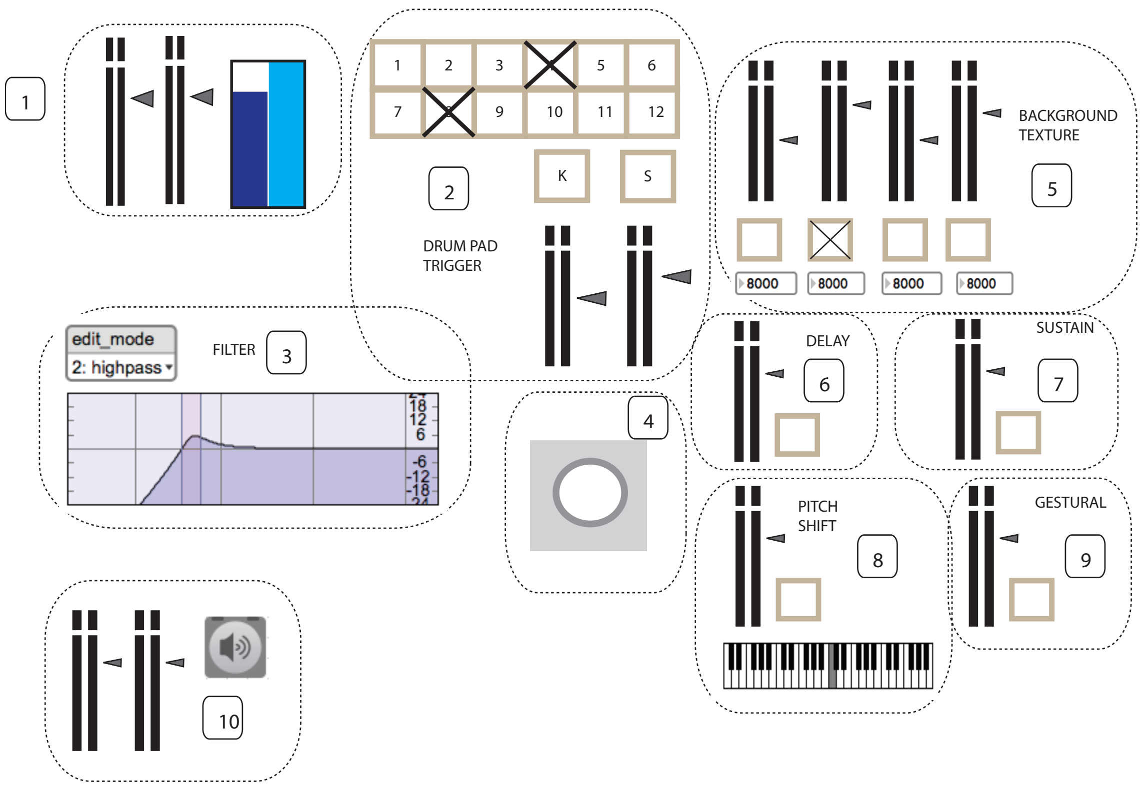

Figure 5.7: *KUBOV*, Annotated *Max/MSP* patch

collaborate effectively with Bernardo. The bulk of the material for Valdrada was developed after this collaboration, so was formed through our existing creative experiences being pushed by an external influence. Valdrada is quite unique in the album for this reason.

A fast paced and energetic movement, *Valdrada* consists of light and lively material in the violin that requires short response times from the modules. These form short phrase shapes in the high register with additional fast moving noisy material in the synthesiser. The dialogue between violin and electronics is rapid and responsorial - there are two musical personalities imitating each other within this track. Each contributes equally to the direction and flow of the music.

Zenobia

Exploring different technical material was something that Emma and I had covered quite extensively in the *Three Pieces for violin and computer*. Of particular interest to us in these pieces was how the re-contextualisation of repeated material can shed different light on that material, for example the emphasis of different harmonics in *104* telling us different things about the quality of the instrument itself. Zenobia is a natural extension of this approach, with Emma playing repeated notes with only subtle variations, and my choice of electronics extending these notes and emphasising the variations to carry the structure. The electronic material in this piece is typical of our earlier live performances which tended to be less dynamic and more textural.

Languid material consisting of plucked harmonics in the violin part and very slow harmonic movement supported by the electronics. The electronic material is dependent and reactive to the violin part, consisting only of live sampling and looping of material. The response times are long, creating a textural background for the foreground of the violin gestures.

Despina

The pacing of this is comparable to Valdrada, but in fact our development of material found in this piece can be traced to far earlier on in our collaboration (from the *Concoct* era). I have already described the division of our work into different pieces. What these names really referred to was improvisational structures framing different types of material that we were exploring.

Despina relates to our second iteration of performances. Once we had performed Absolute Zero enough times to be comfortable with the material in a live setting we changed gears, and decided to incorporate some pre-recorded samples into the performance. This shift in emphasis is the main source of material in the beginning of *Despina* (listen for the prepared piano samples), and the percussive nature of these samples forced a more energetic interaction than the extremely textural material we had been performing before. This track is representative of our dynamic of practise, perform, refine, practise approach to music making, marking not only a shift in emphasis but a consolidation of existing material (as heard in the latter part of the track).

A fast dialogue, with a similar pace to track one, this time with the incorporation of recorded *prepared piano* material, triggered like an instrument via a drum pad. Modules are set with short response times, and the electronics and violin are working very much as a duet rather than soloist with accompaniment. This track is in two parts, the second part with a deep bass like synthesiser drone accompanied by dry percussive material in a higher register on the violin. This is one of the few places in the album where the electronics material leads, at least for half of the track.

Zirma

Another example of re-contextualisation of material, this time using a variable delay object in the electronics. This piece demonstrates how both mine and Emma's material is mutually guided by the output of the other. In this instance I developed a very simple module for use in performance, and Emma discovered a way to exploit its sonic qualities that made it distinct from the other movements. This movement was one that we fleshed out for the studio album, and had not explored much in a live performance setting.

A short interlude, featuring single note instrumental material with a lot of vibrato and the delay line module in the electronics. Lead by the violin, the electronics paradoxically exhibit faster rates of change the more static the violin material is. The delay material is directly taken from the violin material. However, the settings of the delay also give it its own character, creating a musical partner. This time the electronics are as combative as they are collaborative.

Zora

Zora exemplifies Emma's practise with extended techniques to increase the sonic capabilities of her instrument. It came about through our third iteration of live performances at the latter end of our research. In terms of electronic material it features a new interface, a drum pad, leading to a more lively and responsive musicality. This movement really labours the idea of an absolute minimum of material, and as such had Emma and I thinking musically beyond the material we were both using and the interaction we were choosing to employ with it. The structure in this piece, rather than being defined by an evolution of material, is shaped by the harmonic content of Emma's chosen tuning forks. In this way the shape of our interaction is a bit more abstract than in other movements, providing a different type of movement and depth to the movement.

In this track, the instrumental material is most detached from the violin as we know it. Emma uses tuning forks to activate violin resonances that are then picked up and transformed by the patch. The patch is working with live sampling and retriggering with transposition, using both short and long response time to create a foreground and background that blend with the instrumental material. This track is slow paced, and largely moved on by the changing of tuning forks, which has the effect of progressing the harmony and structuring the piece. The reaction of the patch is quite static, although it feeds back on itself and thickens as the track progresses.

Isuara

Using another technique that brings unusual sounds out of the violin, this movement possibly best represents our first iteration of performances, a slow build up of crisp textures using looped live material (See absolute zero). In this way *Isuara* shows how Emma and I instinctively explored each others' sound to begin with: through slow evolution and textural build up.

Consisting of another advanced technique, the instrumental material in this track consists of crunching the hairs of the bow on the bridge to create a light and clean sound. This works particularly well when amplified. This is complemented by a line of similar material in the synth part and long response in the computer loop modules, building up to create a fluid like texture of multiple musical lines.

Argia

Material in this piece reflects the third phase of performing and the need for more dynamic response in the electronics. We developed this element of the album in the studio, and didn't perform this part of the patch many times before recording. The interaction that we favoured for this piece was that of matching and exceeding the other's strength. Collaboration in this piece then was more like competition, with the resulting aesthetic being ever so slightly beyond either of our control.

A second interlude. This time consisting of strong distorted material reflected in the patch which features live sampling, transposition, and filtering of the material in order to create a wall of aggressively distorting sound.

Octavia

The final track of the album sums together our many different phases of collaborative work. In terms of material you can hear much of what was present in even our very first performances: Emma's guiro bow and our textural built ups through looped electronics were present from the beginning. However, the track moves through a number of different phases with an ease that would not have been present in the initial phases of performance.

Another unusual instrumental technique, featuring Emma's design of a 'guiro bow' (horse hair wrapped around the wood of a violin bow) played alongside a normal bow to create the combination of light percussive phrases alongside bowed harmonics. The material in the synthesiser recalls the low drone material as found in track III, which is also feeding the looping patch with the long response times. The drones diminish, leaving a final instrumental effect to close the album: bowing on the tail of the violin, leading the ear seamlessly between the electronics and the violin.

Detailed analysis of interaction

Please see the table overleaf for a track by track Frengel-style table for multi-dimensional axes.

Axis	Type and Implementation (Tracks I - VIII)	
Segregational	I) Polymorphological	- Live sampling - Synthesiser
	II) Monomorphological	- Live sampling from violin only
	III) Polymorphological	- Live sampling - Recorded samples - Synthesiser
	IV) Polymorphological	- Live delay with shifting parameters
	V) Monomorphological	- Live sampling from tuning fork/violin only - Indistinguishable sound world between amplified instrument and software
	VI) Polymorphological	- Live sampling - Synthesiser
	VII) Monomorphological	- Live sampling
	VIII) Polymorphological	- Live sampling - Synthesiser
Proportional	I) Equal	- Gesture triggered from violin material - Gesture also triggered by synthesiser
	II) Violin dominant	- Violin gestures triggering electronics textures
	III) Equal	- Live sampling / synthesis later on - Texture builds along timeline - Instrumental foreground leading through equal balance finally to electronic foreground
	IV) Equal	- Live delay shifting, reliant on violin material but shifting parameters give signal voice of its own
	V) Equal	- Live sampling - Electronic textures manually triggered - Equally perceptually weighted between tuning fork and electronics
	VI) Violin dominant => Eletronics dominant	- Live sampling with synthesiser of similar material

		evolving to a denser texture where the electronics lead
	VII) Violin dominant	- Live sampling clearly lead by violin material
	VIII) Coequal	- Live sampling / synthesis - Texture builds along timeline - Instrumental foreground supported by loop and synthesiser drone foreground later on
Temporal	I) Asynchronous	- Triggering via reactive patch, so synchronised but not perceptually - Triggering synth manual
	II) Synchronous	- Triggering perceptually related to exact onsets, though timescale between 4 – 8 s
	III) Asynchronous	- Triggering via reactive patch and manual triggering. - Not perceptually synchronous
	IV) Asynchronous	- Module permanently on - Parameters not perceptually dependent on violin material (triggered by pitch reading)
	V) Asynchronous	Manually triggered, independent of each other
	VI) Quasi synchronous	Manually triggered and reactive, clearly coming from the violin with temporal synchronicity but not exactly reactive
	VII) Asynchronous	- Module permanently on - Texture created by electronics no clearly temporally related to violin material because of heavy processing
	VIII) Asynchronous	- Reactive module clearly related to synthesiser and violin material but not perceptually related to onset
Timbral	I) Similar & Dissimilar	Multiple layers weave between material, some live sampled and therefore similar gestures, some manually triggered

	II) Similar	The material is directly sampled and loop and not highly processed, only pitch shifted
	III) Similar & Dissimilar	Multiple layers weave between material, some live sampled and therefore similar gestures, some manually triggered
	IV) Dissimilar	Electronics takes on own characteristics, though fundamentally reliant on violin material
	V) Similar	The material is directly sampled and only pitch shifted with no other processing
	VI) Equivalent	Similar sounds sampled, synthesiser to blend
	VII) Similar	- Live sampling, only processing being filtering and transposition
	VIII) Dissimilar	- Synthesiser adds independent dimension to the sound
Behavioural	1) Interdependent	Instrument and electronics reliant on each other's material for subsequent triggering
	II) Singular	The computer element is entirely reliant on the violin material
	III) Interdependent => Singular	- Instrument and electronics reliant on each other's material for subsequent triggering - Later on violin relies on synthesiser for cue
	IV) Interdependent	Instrument and electronics reliant on each other's material for subsequent triggering
	V) Interdependent	Instrument and electronics reliant on each other's material for subsequent triggering
	VI) Interdependent	Sampled sound dependent on violin material but also synthesiser material and loop processes feeding into violin material
	VII) Singular	- Electronics relies on violin

		leading
	VIII) Independent	- Each line is clearly independent from each other, though musicians clearly work from what they can hear
Functional	1) Coequal	Live sampling, gesture triggering, lead by the violin weighted towards acoustic, but synthesiser and independent elements balance the weighting
	II) Causal	Violin material directly causes electronic material
	III) Coequal	Live sampling, gesture triggering, lead by the violin weighted towards acoustic, but synthesiser and independent elements balance the weighting
	IV) Causal	Violin material directly causes electronic material
	V) Coequal	Live sampling, gesture triggering, lead by the violin weighted towards acoustic, but synthesiser and independent elements balance the weighting
	VI) Coequal	Live sampling, material lead by both violin and synthesiser
	VII) Causal	Violin material directly causes electronic material
	VIII) Coequal	Live sampling, material lead by both violin and synthesiser
Spatial	Stereophonic image	See seperate layout sheet
Discursive	1) Gesture/Gesture	
	II) Gesture/Texture	
	III) Gesture/Gesture	
	IV) Gesture/Gesture	
	V) Texture/Texture	
	VI) Texture/Texture	
	VII) Gesture/Texture	
	VIII) Gesture/Gesture	

Pragmatic	See additional tech specs and layout documents.

5.4 *Labyrinths*: Instrumental material

This three movement piece examines different types of growth forms through three distinct instrumental techniques and their parallel reactive computer parts. Each movement is developed using composition software *Slippery Chicken*, each exhibiting elements of similarity and difference from the others. Similarities in processing include the jumping through layered matrices of rhythmic and harmonic material and structuring of the piece using regular movement using the *Procession* algorithm[8]. Each movement has a different number of transposed set palettes from the seed palette.

The rhythmic code for each movement is very simple, using little external algorithmic programming to create the material. In other words, the material is composed rather than algorithmically generated. Note-thinning and bar-thinning (filtering out a selection of unwanted notes) are used post generation to shape the density of the compositions, with the common trend being the gradual build up of material.

5.4.1 General functions

Note thinning and bar thinning either removes individual notes from a slippery chicken object (notes which are a pre-determined percentage, and at predetermined points of removal. Bar thinning stops the instrument playing for the entire bar. These patches are used throughout the compositions to shape the pieces.

Each of the movements moves through the same harmonic palette, though related palettes might be different number of steps away.

[8]The procession algorithm is purely deterministic; i.e., it incorporates no randomness. It starts with the first three elements of the initial list and gradually adds successive elements from that list until all of the elements have been added. The initial list must therefore have at least four elements. (Edwards, 2015)

5.4.2 The Garden of Forking paths

The intention of *The Garden of Forking Paths* was to create tension and release through highly contrasted musical surface tensions. On one hand there are predictable rhythmic semiquavers, and on the other hand the 3 eighth beat held swells punctuate the glassy musical surface. Set limits were used but it was also important to use the thinning algorithm after in order to shape the composition a little more as desired.

5.4.3 The Circular Ruins

Designed with a similar strategy in mind to The Confines of Light and Shade, in terms of shifting musical layers and the instrumental body being thought of as a mass of sound. Much is done to progress this piece through techniques marked in the score in text, for example OB means overbowed, with the idea of different instruments moving through the articulations and parameters at different rates of speed. As with *The Confines of Light and Shade* the rhythms are simple but not so simple as to be boring. The harmonies are drawn from the core labyrinths harmonic palette, with 4 additional palettes one semitone away and four semitones away (up and down).

5.4.4 Death and The Compass

This piece features a similar Patterns Meccanico approach to *Mechanica*, in terms of fitting together a mesh of individual sounds and increasing the texture as it continues. This time the rhythm palette is far more complex, and textures of the percussive notes play much more of a role. These are all selected using an l-systems rule. The rhythm sequences and harmonies are both looped through using a procession algorithm. Bar thinning is also applied afterwards to sculpt the composition even more.

5.5 Technical notes and analysis: *Labyrinths*

5.5.1 General technical notes for *Labyrinths*

This piece is presented with a quadrophonic speaker set-up.

5.5.2 MVT I: Technical notes

Death and The Compass uses score following via *antescofo*[9], a score following to detect the ensemble's position score and respond as programmed. Triggered responses via soundfiles at certain points have been created in advance using *Common Lisp Music* to create a flexible, yet statically responsive computer part. *antescofo* is tempo aware, but the triggered files are tempo locked. These will be heard in the monitors and allow the ensemble to sync naturally to the perceived tempo in the triggered sound files. The computer elements consists of a combination of realtime processed and non-realtime triggered files.

MVT I: Score representation of computer part

The computer part is represented as percussion on a stave, with the rhythmic responses being the most salient information to be communicated. Dynamics are static, and very little processing is applied to the instruments themselves. Accordingly nothing like this is mentioned in the score.

[9]Created at *IRCAM*, Paris, *antescofo* is a *Mas/MSP* object that is able to follow notes played by instruments in a realtime setting

5.5.3 MVT II: Technical notes

The garden of forking paths also uses score following via *antescofo*. Triggered responses at certain points have been created in advance using *CLM* to create a flexible tape piece. Again, *antescofo* is tempo aware, but the triggered files are tempo locked. These will be heard in the monitors and allow the ensemble to naturally sync to the perceived tempo in the triggered sound files. Most of the computer material has been created in advance, though realtime processing also occurs at particular points of emphasis in the piece.

MVT II: Score representation of computer part

The rhythmic nature and quality of the computer part is indicated via text in the stave.

5.5.4 MVT III: Technical notes

The Circular Ruins uses score following via *antescofo* to detect the point of the score and how to respond. The computer part features realtime sampling.

MVT III: Score representation of computer part

The quality, density and register of the electronics are all verbally communicated in the score.

Please see Table overleaf for a Frengel-style multidimensional analysis of all three movments.

Axis	Type and Implementation (mvts I - III)	
Segregational	Polymorphological	- Live sampling - Pre recorded triggering - Synthesis
Proportional	Acoustic => Equal	- Gesture triggered from quartet material - Electronics texture grows as piece unfolds
	Equal	- Both from similar material - Behaving interactively - Both foreground
	Acoustic => Electronics	- Live sampling / synthesis later on - Texture builds along timeline - Instrumental foreground leading through equal balance finally to electronic foreground
Temporal	Synchronous	- Triggering set to a meter via score following
	Synchronous	- Triggering set to a meter via score following
	Synchronous	- Triggering at unified onset via score triggering
Timbral	Equivalent	Live processing and synchronous triggering make the computer material perceptually an extension of the instrumental, but additional processing makes the soundworld distinct
	Equivalent	The material is very alike but not exact. The electronics feature recordings of the string quartet but also other percussive recordings alien to the their sound production.
	Equivalent	The electronic material is live sampled, but processed and morphing material into something different
Behavioural	Interdependent	Relative to metered timescale

		but reliant on score following within this meter for triggering
	Interdependent	The computer element is mostly fixed, as is the instrumental material. Reliant on score following for triggering
	Interdependent	Reliant on score following for triggering
Functional	Acoustic dominant	Live sampling, gesture triggering, lead by the ensemble, which are dominant throughout
	Coequal	Processed samples fixed into tape and notated part, both equally contribute to musical discourse
	Causal => Electronics dominant	Electronics fed directly by ensemble, but gather a life of their own towards the end of the piece
Spatial	Quadrophonic image	See seperate layout sheet
Discursive	Gesture/Gesture&Texture	
	Gesture/Gesture	
	Gesture/Gesture	
Pragmatic	See additional tech specs and layout documents.	

5.6 Summary

This chapter describes different methods used to generate my material, parameters that I have designed my realtime software around, and different materials I have distributed for performance. Each piece included in the portfolio contributes to a different part of my main thesis, each leading to different practical responses related to the composition and performance of *EI* music.

The pieces in this portfolio are functional stepping stones representing stages of process advancement in my music making. My first major work, *Three pieces* with Emma Lloyd, covered a huge amount of ground related to all three chapters of the thesis. *104* provided material for new forms of analysis as found in Chapter Three. We examined which software responses might be appropriate for the specific techniques that Emma was playing, extrapolating this theory for use in other pieces. *Mechanica* contributed largely to Chapter One and examining the generation of material using *slippery chicken*. In particular how to arrange material suitable to its specific qualities.

My work with KUBOV contributed mostly to Chapters Three and Four. It provided a robust testing sphere for realtime analysis of different types of improvised instrumental material. This was then fed back into the reaction of the software itself. The different tracks on the album reflect the different approaches to interaction. These are laid out in the multi-dimensional axis analysis. We knew when we began working with improvisation that we wanted to perform very early on. These performances informed much of the theory found in Chapter Four. Performing in so many different environments meant that we began to be able to predict problems before they arose. In other words experience informed and refined our practice.

Labyrinths didn't as much inform the theory, as demonstrate my most current position related to generating material, namely developing appropriate realtime software and communicating information succinctly for performance. It is an up to date account of the skills I have acquired using *slippery chicken*.

Chapter 6

Conclusion

This thesis has explored computer presence at various stages of creating *electro-instrumental* music. It demonstrates research happening in parallel with practice. The contents of the portfolio are vital to the knowledge acquired and demonstrated in each chapter. The motivation for both the theoretical and practical strands of my research was twofold. First, with the knowledge that software and hardware is not neutral I wanted to understand how the computer was moulding and influencing my musical output. Second, I wanted to use this understanding to shape my use of these various tools in order to create new music with a more conscious awareness of the processes involved in getting from A to B. Underpinning all my research efforts over the last four years is a highly practical approach to composition and performance. In other words, I didn't compose without the possibility for performing my work and the performance opportunity shaped the musical process from the outset.

6.0.1 My practice

My methods have lead me simultaneously to refine my composition with computer software whilst absorbing the realtime practicalities of performance very early on. This had the effect of carving out methodologies informed by both abstract and concrete approaches to music making, refining my working methods from two different vantage points. These two approaches gave my practical work a certain amount of rigour. On the one hand I have actively steered myself away from writing musical styles defined by what suits realtime software, thus avoiding music solely designed to feed the software with what it wants to hear. This was the sparse, textural material I referred to in my initial observations of my existing work, as (see section 1.2 on page 11) . On the other hand, I did not allow myself to enter a void of completely abstract relationships fuelled by algorithmic composition without the highly functional, and often sobering experience of performance. By examining the abstract and the concrete in equal measure I ensured that my ambitions with composition and performance were neither lazy nor unrealisable.

My situation as software user (rather than designer) is far from extraordinary. Yet the growing pool of research related to computer music still remains highly populated by technical offerings over analytical reflection. With this in mind, I find that the most original contribution of my thesis and portfolio to the research community is in examination of *relationships* at each stage of the musical process. I have looked at the gaps between highly evolved practices of algorithmic composition and realtime software design to understand the composer/software user experience of employing these systems. I have examined each of my portfolio works in terms of the matrix of relationships that I have had with different people in order to create the music I present. This type of analysis has had a profound effect on the way I make music. Therefore, it is in this gap, reflection and analysis, that I feel my work is most useful to others.

In Chapter Two, I examine the generation of material via my use of composition software *slippery chicken* in context of research into the field of *Computer Aided* and *Algorithmic* composition. The important element of analysis here lies in the transfer of musical ideas through the medium of code. Chapter Two interrogates the cycle of experimenting with different input and output formats, feeding back information gathered into another testing stage (a testing stage most likely equating to another compositional opportunity). My experience as a user rather than designer of software necessarily leads to the influence of the software designer's musical voice on my musical output. My analysis stretches beyond my working process to a reflection on how my compositional style is being augmented by the code itself. Understanding this rather than blindly accepting output as detailed in the software manual leads to values inbuilt into the code being folded into my own musical palette. This process of absorption means code acts as a teacher as well as facilitator.

Chapter Three makes use of a different type of analysis in examination of the design of appropriate electronic material for performance. Rather than communication between software designer and composer, I demonstrate how relationships can be forged between instrumental and electronic material. This transplants analysis that evolved out of electro-acoustic performance onto instrumental material. Applying this analysis using a parallel musical vocabulary makes it far easier to understand the material in an idiom more appropriate to electronic material later on. When deciding what actions to take, analysing instrumental material and then assessing the various roles the computer can adopt is another important step towards forging suitable compositional tools. Behavioural roles necessarily define some of the traits that the computer's material can take. This works by combining information on the qualities of the role with analysis on the instrumental material narrows down the vast palette of choice available to a composer. As I discussed in Chapter Two, information formed through the analysis of relationships - this time between computer and instrument - has driven and fed back into the overall musical process.

Chapter Four describes my experiences with performance and the flow of information between different people taking part in the music. In a way, it demonstrates the refinement of my practical and theoretical output by working backwards. Early experiences with performances shaped the material of my output. These lead me to existing research that explores the idea that the physical and social space in which the music takes place is itself a potential musical parameter. Analysing my output with regards to the problems I came across in performance helped me to identify where more tightly designed information could have pre-empted certain undesirable performance situations. This knowledge fuelled the later pieces in my portfolio, leading to a more efficient and appropriate approach to communication of extra-instrumental material. Working backwards from a performance in order to understand how to fine tune the next piece helped with my versitility, in terms of both the types of material I was performing (be it improvised or notated), and the spaces that I performed in (from karaoke bars to disused stock exchanges). What I took from this section of my research was how rich in information the concrete elements of the music process are, and how this information can feed the refinement of the abstract material earlier on in the composition process.

These three theoretical stages for my electro-instrumental performances are tightly intertwined, with changes in each element having a consequential effect for all other stages. This further supports the notion of the feedback process of music. Performance isn't seen as a 'final' stage of a particular piece, rather a stage that can furnish earlier compositional stages of future pieces with a great deal of relevant information.

6.0.2 General conclusion

My PhD is practice based and my own process is central to it. It is easy to draw personal conclusions on the impact that my research has had on my own practice, harder that this is how to extract more general conclusions relative to a wider population of musicians practising *EI* music.

What strikes me most about creating and performing *EI* music is that quality suffers for ease of creation. In other words the less 'manually' involved a user is in shaping their music the harder it is to create something that feels nurtured, as opposed to a random collection of notes. How we understand a computer's role in our process of creating music actually informs our use of it. For example, seeing it as a vehicle to carry out our intended musical tasks seems short sighted because fundamental to the proper exploration of other people's software seems to some extent to be the acceptance of their musical values. A fundamental factor that assists the user experience of other's software are its accessibility and flexibility. *Whitebox* exploration seems to be a key factor in learning the mechanisms of any software. However, willingness of the user to adapt their approach to the software's strengths also leads to more satisfying musical output.

6.1 Future work

Every new piece, realtime software patch and performance will lead to new information related to the process of making *EI* music. However, with each iteration of the cycle I am more equipped with information to tackle the next project. In this way, my future work will carry on much like it has so far and I will continue to tackle new and interesting performance situations, exploring new ways to generate, translate and present material.

In contribution to my own personal development, I feel that at this stage of my research I was pursuing rigid musical frameworks around which I was exploring theoretical ideas. Because of this, some of the propositions in the dissertation seem over simplified. The research needed this level of simplification for a thorough examination of the ideas I was fleshing out. Now these rules are in place I think that the theories would benefit further testing with the pushing, redesign or breaking of these rules. I intend to continue working in this vein. I hope that the proposition of these rules will lead to discussion with my peers in the pursuit of strengthening, augmenting or redesigning my ideas.

With particular reference to Chapter Three, the translation of instrumental material in coherence with computer material would benefit from another practical exploration, this time with a more creative and liberal attitude to potential software responses. This specifically relates to the measure of pitch and time and the rigour with which these qualities are pursued. In time, perhaps a more flexible approach to these potentially relative qualities might cohere instrumental and computer media further.

Chapter 7

Publications

Degrees of Interpretation in Computer Aided Algorithmic Composition

Jessica Aslan
Univeristy of Edinburgh
j.aslan@sms.ed.ac.uk

ABSTRACT

In 2012 Michael Edwards introduced his open-source composition system, *Slippery Chicken (sc)*. Since then I have been working with the software, experimenting with the possibilities and limits of its output and identifying its constants and mutations. In this paper I will analyse some of the different compositional methodologies that *sc* offers, tracing its digital fingerprint and examining its persistent presence through degrees of composer and performer interpretation. I will include a discussion of the broad spectrum of opportunities for the parallel generation of ideas and maintenance of each user's compositional voice, not only through choice of input material but flexibility of output formats from the software.

Summarising some current thought on Computer Aided and Algorithmic composition I will attempt to unpick some of *sc*'s design mechanisms, with particular attention to the relationship between form and process of composition when using the software. I will then examine case studies from my compositions with specific reference to *degrees of interpretation*. Firstly, I will present my experiences using the software in a *first degree* approach, which represents unmediated algorithms. Following this I will look at hybrid mediation, *second degree* usage. In this case study *sc* is still directly present through sound file organisation in a fixed-media part, however the notated score is created through aural interpretation of the fixed-media. Finally I will outline the compositional methodology in a *third degree*, fully mediated composition in which I place myself directly in front of the information flow between algorithm and score, meaning no digital (only a perceptual) trace of the software can be found.

1. INTRODUCTION

Slippery Chicken (*sc*) is "a new open-source algorithmic composition system, which enables a top-down approach to musical composition" [**?**]. Michael Edwards, its creator, describes it as an initially specialised composition software, that has gradually morphed into a more general set of tools. *sc* was initially created to enable Edwards' own compositions, and much of the musical thinking found in its fabric embodies traits common to his own compositional voice. In his words "it offers a structured method as opposed to a composition software library" [**?**], however its open source nature means users are free to extract and augment any number of its functions, much like a library. This flexibility means user methodologies can vary greatly, and presents an interesting tool for examining the presence of each software developer's inbuilt musical preferences combined with user intervention.

Since its release, *sc* has been my principal tool for composition. In my time using the software it has been a primary concern that I maintain my own compositional voice, not only experimenting with input varieties (harmonic palettes, rhythmic character, recursive transitions and so on) but stretching the output formats that *sc* lends itself to. Edwards himself aligns his user of *sc* as "firmly in the algorithmic camp" [**?**] (in terms of Munro's [**?**] definition). As a user that often mediates algorithm and concrete output I associate my own practice of composition with *sc* alongside Ander's and Miranda's description of computer-aided-compostion "where composers manually shape certain aspects of the resulting music" [**?**]. Therefore, to avoid conflicting terminology I will refer to Christopher Ariza's hybrid expression, Computer Aided Algorithmic Composition (CAAC), which he employs to increase specificity to the often separated definitions of Algorithmic and Computer Aided composition [**?**]. This will allow me to circumvent any confusion between the two terms, however useful a distinction may be.

1.1 Slippery Chicken in summary

Detailing the idiosyncrasies of composition software is no easy task. Ariza [**?**] offers some useful descriptors to understand elements of functionality found in CAAC software, and it is useful to offer a short summary of *sc* with these qualifications in mind. *sc* is an open non real-time process model that features an intuitive text (LISP) -based language interface. It offers a wide variety of options for material input and a largely open formatted output, it is ostensibly a "plural idiom affinity...[it] allows the production of multiple musical styles, genres, or forms." [**?**], and features full extensibility to the user with some LISP programming skills.

When unravelling the effect of differing input and output material and interior processing, the idea of a plural affinity becomes more complex. Though *sc* is extensible and fairly open, its mechanisms are rooted in Edwards' compositional thinking - particularly when it comes to large-scale form. So though *sc* doesn't restrict the user to a singular approach, some of the inner operations for configuring a complete musical work are sonically quite distinct. Even with an attempt at simple affinity attribution, it is easy to see how definitions identifying traits in CAAC software are hard to secure.

1.2 Process and Form

Unpicking the software contribution to musical form is also tricky, particularly considering the contribution of context to musical perception [**?**]. In *sc*, user defined input and output are reasonably open, the material itself being the choice of the user, with the shape that it takes (pitch and rhythm sequence palettes, set maps) being determined. Please find more information in the online manual [**?**].The character of *sc*, latent within parts of the code more hidden from user view, manifests through processing on input material, the final combination consisting of initial user defined units that are processed within a fixed set of constraints.

The nature of *sc*'s top down approach characterises its output as globally as well as locally organised, with large scale structures created directly through the recombination of pitch and rhythm sequence palettes, with crucial attention paid to transition between sections (see [**?**] for a detailed description of some transitional features). Because of this *sc* ostensibly avoids Nick Collins' observation of much algorithmic composition software as "stuck in a static moment form, able to abruptly jump between composed sections but unable to demonstrate much real dramatic direction" [**?**]. In fact, the musical forms that *sc* creates are perhaps one of the most defining properties of the software. A great deal of attention is given to transitioning through subsequent sections often calling on natural processes (L systems, fibonacci transitions) in contribution to the coherence of long term forms.

Practitioners acknowledge varying levels of coherence between form and process - some placing more distance between technical means and artistic output than others. Authors writing on CAAC often use phrases like "piloting the vessel" [**?**] or employ descriptions of software as "a bicycle, offering mobility to a composer" [**?**]. These metaphors invoke an analogy of A to B, with the software as an aide to transportation to a final aesthetic object distinct from the means that took it there. For Koenig [**?**], however, form determines process and process determines form. Thoresen, elaborating on form in more general terms describes it as "The study of how identifiable smaller parts would integrate into greater wholes" [**?**], this integration, the mechanical processes acting on the smaller parts also making up the form itself.

Nicholas Cook takes care to highlight how intertwined material is with the formal proportions of a work:

> Thus, though compositions can certainly create the effect of being well or badly proportioned, this has to do with the qualitative as well as the quantitative aspects of the music; and this is why, when a piece's proportions are faulty, putting it right is likely to involve modifying its content rather than simply cutting out a few measures here or adding an extra beat or two there. [**?**]

The point he raises is that there are processes that are temporally appropriate to given material. The idea of a piece of music being well proportioned relies not only on abstract schema, but the natural transformation that its smaller elements lend themselves to. He takes this idea further by describing form as "defined by the listener's intentions", meaning that though internal schema may exist they may have little bearing on the perceived form of the final aesthetic object, not unlike Ariza's reference to context as crucial to the perception of form. In other words user material (input and output) has as much influence on the perceived form as the organising processes. Therefore by establishing modes of composer mediation in the process of composition, we can begin to examine formal elements of the work that are strongly influenced by input/output and those that rest more heavily on the software's internal schema.

1.3 Degrees of Interpretation

In order to understand my user influence on the final aesthetic objects, I am classifying my case studies into *degrees of interpretation* (DOIs), indicators of composer mediation related to the output format of *sc*. *First degree interpretation* indicates unmediated output, the algorithm remains untouched post generation for interpretation by a performer. *Second degree* indicates hybrid mediation - I have manipulated some aspect of the output before performance. Finally, *third degree interpretation* indicating complete user mediation of the output format - there is *no digital trace*. These simple distinctions shed light on the flexibility of *sc* as a compositional tool but also bear witness to its influence on structural organisation. A documentation of the user experience will show areas of the software's flexibility but also musical qualities that can potentially persist through any degree of user mediation.

By presenting a user assessment of the software, rather than a developer's explanation I hope to illuminate previously undocumented aspects of the software and shed light on the means of "aesthetic integration" [**?**] in CAAC. With this in mind I will begin to assess the relationship between my own subjective decisions and those made by the fabric of the algorithm in order to track the musical traces of *sc*. Through varying Degrees of Interpretation, I'm aiming to clarify levels of mediation that existed in the act of creating each case study in order to evaluate *sc*'s contribution to my compositional process.

2. FIRST DEGREE INTERPRETATION

I will examine first degree interpretation with two movements *Labyrinths*, for string quartet and computer, which I created in collaboration with the ISON quartet. Each of the movements draw from separate short stories by Jorge Luis Borges and explore some of the narratorial themes and mathematical paradoxes that he presented. I'll look at the first two movements, *The Garden of Forking Paths (TGOFP)* and *The Circular Ruins* and unfold each compositional process with reference to my mediation of *sc* output.

2.1 The Garden of Forking Paths

I created *TGOFP* through a LISP coded wraparound technique focussing on the multiplication of intervals, with the navigation of the subsequent tonnetz a nod to the literary representation of the infinite found in Borges' story. Here I frame the musical material - creating a function that facilitates the generation of *sc* friendly information. [1]

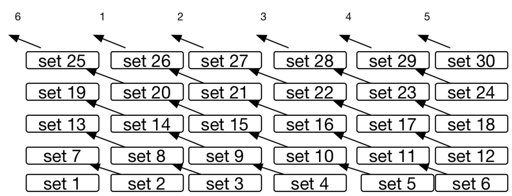

Figure 1. Tonnetz navigation. The harmonic progression infinitely forks to the left.

The harmonic wraparound is the only deviation from a) *sc*'s own code and b) usage as described in the extensive online tutorials and manual, and I did not interpret the output other than in the forms automatically produced so I am ascribing *TGOFP* as a first order *sc* composition. The material as it is played can be generated through a single compilation and I do not mediate the material . The *sc* algorithms specifically generated not only the temporal structure, but carried out the orchestration, and completely assigned all the associated rhythms and harmonies. I have not attempted to bend the output format in any way.

2.2 The Circular Ruins

The Circular Ruins, named after Borges' depiction of the phenomenon of the simulacrum, was formed using a different approach. The idea of the simulacrum and the environmental depiction within the story is important to the fabric of the material - I wanted to evoke an ever shifting instrumental texture through simple material and flexible sound shapes that consistently shift in terms of onset, continent and termination. The realtime electronics become the mirror of the instruments, before eventually engulfing the material completely. I often use spectromorphological analysis as a way to contribute to my understanding of formal coupling in mixed works, and these sound shapes are also a useful method of viewing ensemble material. I used my harmonic wraparound function to generate a new tonnetz (arbitrarily navigated in a circular fashion), and created a very simple rhythmic palette. The emphasis here was the textural change of the ensemble body rather than any particular rhythmic interest (the movement has no time signature).

The interest in this movement is in the timbre and dynamics of the notes, the texture of the ensemble. To harness Smalley's sound shapes I used *sc*'s lilypond graphical notation and added 26 sound shapes as potential articulation. Crucially, I assigned potential parameter changes to these shapes, developing an overall algorithm for the position of each note in the sound shape and their relative dynamics and articulation. For instance a sudden onset might indicate a pizzicato in the first instrument, with additional ensemble notes contributing to the sound body to reinforce each individual shape.

This composition is also first order: a single compilation of my code will create the score that you see below for interpretation by an ensemble, but in contrast to *TGOFP* I have incorporated my interpretation of sound shapes and augmented the software to suit my needs. In other words I altered the algorithm but *prior* to the generation of any notes.

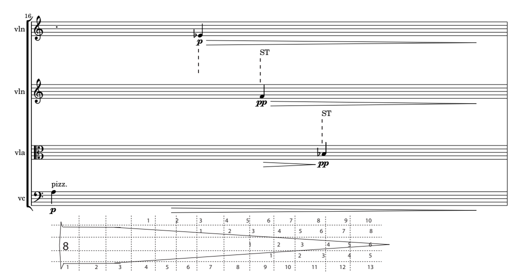

Figure 2. A sound shape and its algorithmically notated representation

Creating both of these works I took advantage of the extensibility of *sc*, an even extracted some of its internal functions to create my own compositional add ons. However, with both these first degree compositions some of the musical qualities found in its functions, particularly the *Rhythm Chains* and L-system transitioning through harmonic progressions are clearly identifiable in the works (musical examples will be presented). I classify both these works as unmediated because though the software may have been altered, the output is accepted without any further editing and the core of the software's mechanism remains intact.

[1] The harmonic material is pushed through a dense rhythmic palette, using the software's *Rhythm Chains* method. No post generation editing was carried out.

3. SECOND DEGREE INTERPRETATION

Contrasted with my relatively simple approach to generating material in *Labyrinths*, *Mechanica* for violin - Emma Lloyd - and computer, weaves a more complex web. This piece features hybrid mediation, a fixed-media part was produced by *sc* and the instrumental material was formed through composer intervention - a transcription of notes from within the fixed-media part. I am attributing *Mechanica* as second degree intervention.

3.1 Mechanica

Explaining the methodology in this work requires a side step from algorithm to authorship. *Mechanica* began through extraction of recorded samples from seeds of material that I gave Emma, which she then played in an array of unique timbres. This initial step was what gave the piece its clarity and overall character, something that the subsequent algorithm was built to emphasise. This collaborative process complicates the developer/user relationship further - input material is created by a musician and frozen in time through recording. The quality and grain of the work then has relied on the performer, and the resultant aesthetic object is therefore dependent on a third individual. However, as this paper is concerned with *post-generation* mediation, I won't focus further on this aspect.

Once divided and categorised, our samples became the fuel for a fixed-media piece consisting of seven parallel computer parts, consisting of different (though similar) material and made from seven different *Rhythm chains*. The data was exported to *Common Lisp Music* (CLM), an output format fully incorporated into *sc*. Again the foundation of this work is through the software's *Rhythm Chains* algorithm, the rhythmic tendencies perhaps similar to those of *TGOFP*, but masked through duplication. This work explores self similarity, the seven slippery chickens all use the same rhythmic information but are called at different speeds, in a canon.

The fixed-media alone is first order - after input of material the piece can be compiled in a single sweep. The instrumental part, however was created through my intervention. From the seven consecutive threads I transcribed a single melodic line - the instrumental part, which Emma plays live alongside the fixed-media. Though the structure of the work and the rhythmic qualities all arise through the algorithm, the instrumental part was borne of my ear, my compositional intervention. The output format is no longer intact and therefore the work is second order, as some algorithmic trace is present, but the piece also relied on output mediation.

4. THIRD DEGREE INTERPRETATION

The final piece that I will examine is *Cantor Dust* for string orchestra. This piece uses *sc*'s L-systems algorithm to digitally augment a traditional Bulgarian folk tune.

4.1 Cantor Dust

I began by recording the tune (see figure 3) on the piano and processing it. Again, much of the grain of the work comes from this initial step of recording and freezing certain acoustic attributes. As the title indicates, self similarity is the central focus, with particular emphasis placed on parameterised DSPs.

Figure 3. Original folk tune

Cantor Dust is another example of *sc* functionality in conjunction with CLM. To create a multi layered fixed-media part from this fragment I processed eighteen different streams of the same recording, each assigned 6 separate DSP parameters: low-pass filter frequency, high-pass filter frequency, transposition, duration, start position in file. These streams began at different frequencies, and progressed through the L-system at different rates. What resulted was a dense cloud of static sound, a fixed piece formed through the layers of evolving musical strands.

Here I interpreted the algorithm through audio transcription. I divided the piece into instruments and notated in detail each prominent frequency and its trajectory through the piece. As the melody was linearly processed, each had a fairly logical direction and as such the fixed-media has a persistent character. This gave me the skeleton of the piece, which I then metamorphosised into a slightly more familiar harmonic form whilst maintaining voice leading and simplified rhythmic relationships.

In performance there is no element of the work implemented through algorithm that I have not actively transformed and reconfigured in some way, therefore it is third order, akin to Essl's notion of an "inspiration machine" [**?**]. The quality of the software processes most embedded into the final work is the evolving nature of the different musical lines, in particular the pacing and temporal organisation. However, the work is filtered through my ear, my choices made with a very personal background and musical training. What endures is the global architecture, which seems to be highly consistent between each DOI.

5. CONCLUSION

> "If one focuses on transitions between mo-ments perhaps the global organisation - the form - also begins to make sense." [**?**]

Through separating my work patterns into DOIs I have in some way illustrated a level of distinction between the contribution of input (material) and mechanism (process) reflected in different compositional methods. The nature of *sc* means that in some sense the composer is also the primary listener, and thus able to assess focal points and able to shape the form in a more audibly concrete (rather than abstract) way.

The input and output formats of *Cantor Dust*, *Mechanica* and *TGOFP* are very different. However they are both largely grammatically organised by the *Rhyth-m Chains* method. The material they both consist of is unrelated, but the rhythmic tendencies on a micro level are arguably parallel, representing some consistency in compositional method - Edwards' own compositional disposition appearing. L-syste-ms and fibonacci sequences are transitioning functions that Ed-wards has developed extensively, and can be used to structure a work with ease. Regarding larger scale form, the pieces are also comparable in the fact that each exhibits the constant transitional evolution of the material, rather than jumping from moment to moment. This makes sense - the form arises from the context of the material, and the material's suitability in its context. *Rhythm Chains* is a consistent process and inevitably will leave some formal traces of its identity through its process.

The above analyses do indicate a general consistency encouraged by my use of *sc* regardless of input or output, which is its ability to macrostructure a work with logical musical coherence. This is clear when listening to the pieces - each demonstrating evolution of longer musical lines from small input fragments. Though each work entailed differing amounts of mediation, in each the top down structure of *sc* encourages compositional thought towards extended musical lines. The suitability of input material and consequent output format are largely responsible for the final pieces, the impact of innately programmed (in this case transition) functions in *sc* shapes the users' choice of input material - illustrating a continuous feedback loop between software and user. The level of composer mediation of course effects the final aesthetic product, but there are some elements of software that remain musically present even when there is no digital trace of the algorithm.

This paper represents the beginning of what will be a long process of navigation through this rich and powerful musical resource. Assessing future compositions on these terms will help me to understand, develop and share compositional methods, creating a a platform for communication regarding composer intervention in CAAC.

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FROM INPUT TO OUTPUT: HARNESSING HARDWARE IN MIXED PERFORMANCE

Jessica Aslan[1]
[1] *The Reid School of Music, University of Edinburgh*
Correspondence should be addressed to: j.aslan@sms.ed.ac.uk

Abstract: **At the core of this paper is the notion of hardware as compositional material and sound engineer as performer, specifically in the practice of electro-instrumental (mixed) performance. The key issues that I aim to examine are the practical matters surrounding the performance of mixed music, which information is best communicated prior to performance and how this can be done. I explore the impact of hardware and venue architecture on performance and remark on some existing communication issues regarding musical intention. I then present various case study documents, addressing some of the points that I have examined and exploring feedback from practitioners in the field.**

1. INTRODUCTION

> "Today's loudspeaker is a great anonymous pulveriser of sound that does not measure up to the means which have been developed to create a new sonic world."[1]

Thirty years on and Boulez' words still resonate for a large number of mixed performances. Perhaps though, the loudspeaker is now a scapegoat for more ingrained communication issues in the mixed music community. As composers and performers we spend a considerable amount of time perfecting the inner nuances of software interaction and practising our instruments attentive to minute details, yet mixed performances still so often appear "pulverised", lacking in precise projection. Reflecting this is a comparative lack of literature surrounding the performance of mixed music, particularly regarding musical elements are relayed for clear sound projection.

The presentation of mixed music is a tough discipline. First, we are dealing with live sound, held at the whims of microphones, loudspeakers and other diverse forms of soft and hardware in between. Second, sound is emanating from *two different media*, acoustic instrument(s) on the one hand and some form of loudspeaker setup on the other. We are presumably attempting to form a unified piece of music with them, yet the varieties of setup are far from fixed and therefore difficult to anticipate. Third, and most importantly, all these factors are bound to the physical spaces in which they take place. Each venue carries with it its own hallmarks, its own layout, social conventions, possibly sound engineer and other architectural idiosyncrasies that can be impossible to predict until hours before the performance. In this paper I try to examine how these musical situations can be successfully managed through clear and informed communication on one side, and a flexible approach to performance on the other.

Whilst there isn't a huge amount of literature surrounding this type of performance, it is not to say that there has been no attempt at discussion. Recently there seems to be more interrogation of the actual performance of computer music, with some more specialised discourse about mixed music in particular. The notion of musical performance as an ecosystem highlights an area previously overlooked regarding physical space and hardware as *embedded musical parameters*. DiScipio [2], Waters [3], and Green [4] survey this landscape particularly well, with Di Scipio's *Background Noise Studies* using feedback loops between microphone, space and loudspeakers as sonic flag posts of their own presence. No longer is there the tacit assumption of neutral devices and a simple transplantation of music from one space to the next. Each space, stage and venue carries with it its own characteristics which are ultimately embedded in each performance.

With all this in mind, two questions I would like to address in this paper are: how can you first provide enough third party information for mixed music to be realised to the best of your intentions? And how can the variances of particular venues be best allowed for in mixed music? One answer to each lies in the flow of succinct and clear communication between *all parties* involved in the music. In other words musical collaboration through technological documentation.

2. MIXED MUSIC: WHAT ARE WE COMMUNICATING?

Before we dicuss *how* communication can be achieved, understanding *what* is being communicated is crucial. It should be noted that the setup documents I present, particularly the textual description of the interaction, are related to composed music, and therefore has the privilege (or curse) of quite specific temporal information. Improvisation systems need further examination, and are not in the scope of this paper.

In previous presentations I explored with some depth ways that instrumental material can be treated in attempt at the elucidation of musical form, with a key focus being realtime software that behaves in a perceptually coherent way with this material. I began with solo instrument and computer, examining individual note qualities and their extrapolation into a larger musical timescale, how meter, spatial location and harmony can all affect our perception of the whole (or its parts). I then moved on to the consideration of the ensemble as *acousmatic landscape*, surveying the notes by ear through the lens of acousmatic analysis, drawing heavily from the work of Denis Smalley [5] and Albert Bregman [6]. Smalley's work draws acousmatic syntax away from the solely abstract organisation of material through the study of different spaces as musical parameters, with musical analysis extending to the physical characteristics of performances.

As reflection on mixed music has increased, the role of the computer in performance has also emerged as another type of musical parameter with Croft [7] and Frengel [8] proposing fairly defined categories of behaviour. Croft [7] proposes five paradigms that describe the relationship between instrument and computer, whereas Frengel introduces a *multidimensional framework of relations*, consisting of nine separate compositional axes. These extend to practical considerations on a *pragmatic axis*, with the inclusion of hardware and software choices as key musical decisions.

Axis	Type	Action
Segregational	Mono morphological	Light Processing
Proportional	Live Weighted	Reactive patch
Temporal	Synchronous	Metrical
Timbral	Similar	From Instruments
Behavioural	Singular	Score following
Functional	Instrumental extension	Musical emphasis
Spatial	Fig. 3	Quad speaker setup
Discursive	Analogous	Gesture/gesture
Pragmatic	Sound as interface	Reinforcement

Table 1: Frengel's Multidimensional axes template for *Labyrinths, Movement I*

Using these frameworks incorporates relationships between musicians, technology and performance environment into the compositional process. This is relevant to performance because it equips the composer with knowledge that can be usefully dispersed further on in the making of the music.

So to return to *what* we are communicating. In my experience, early compositional choices regarding interaction in mixed music have also become the most useful thing to communicate. In other words, the process by which these musical parameters have been reached are the best descriptors for behaviours to expect in a performance situation.

3. How can we communicate? Scores and additional performance materials

Whilst developing my practice I have been examining extra score material to provide to performers, sound engineers and gig organisers in order that we have as much mutual understanding as possible about the musical situation. Providing information to performers in the score via simple symbols and extra audio files, references to tempo, meter and so on can be considered as separate from what a sound engineer may require. Though it is most helpful for everyone to have all the different forms of direction, each stakeholder necessarily seeks detail in different places. *Stakeholders in this paper refer specifically to composer, musicians, sound engineers, stage technicians and venue management.*

As discussed earlier, a high degree of compositional precision regarding interactions between instrument and computer means the composer already knows how they have programmed the software to behave in performance, the aforementioned *what*. *How* this information can be exchanged changes from performance to performance. As I am focussing on music with scored notation, there is an assumption that there has already been a single translation stage at which performers are provided notes and the necessary information on the forms of interaction that occur, types of sound that might arise and when this happens. However, this type of score embedded with details on interaction often doesn't serve as a particularly useful document for *all* stakeholders - not least because information spread over 20 pages in a score can most likely be distilled into a much briefer record that is more relevant to the projection of sound.

A score for a musician, with notation related to each separate technique, is a document that can hold specific indications of the desired sound world. To this musician, information in the notation often relates to nuanced expression *involving their instrument*. However, it is debatable that a document for a sound engineer need contain this level of prescription. There are alternative ways to communicate the quality of the sound world and how it changes through time.

Consequently, I have assembled a shorter collection of setup documents that contain relevant information about what I deem to be the most important and recognisable qualities and interactions within the music. This goes beyond physical signal flow and speaker layout to more descriptive vocabulary about what they can expect as the music is performed, as well as my musical intention with the qualities of the sound. I find this is particularly important with multi-movement works that shift greatly in character from movement to movement, as it allows a sound engineer to treat the sound as they wish from this more informed perspective. Further media can also extend to audio demonstrations and pointers to previous performances.

4. Hardware as compositional parameter?

In the previous section I began to explore my first question, related to the provision of information to each stakeholder. The second relates to the characteristics of each performance venue, and their influence on the behaviour of the sound - all part of the oft referred to *performance ecosystem*. Again, there is a growing body of writing related to the loudspeaker as an "active" musical participant ([9], [10]). There's also some particularly interesting research into its incorporation as a compositional parameter with Tremblay et al [11] importing acoustic properties of concert hall (via impulse responses) into the studio for a more informed compositional process.

Detail from the outset regarding desired PA and setup is most important, not necessarily because you will be guaranteed what you request, but rather because you will give a full idea of the way you want to project your sound. That way the sound engineer can on the one hand work with what they have, but on the other hand have the best chance of projecting a a sound world as close to concept as possible. Likewise detail regarding input of instruments, as well as signal flow in and out of the mixing desk is a highly evolved practice, with some established and accessible syntax.

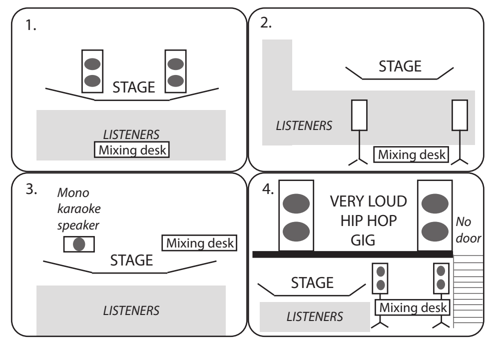

Figure 1: 4 Performance Situations

Green [12] suggests that technological stipulations should be considered useful but perhaps not requisite. Whilst wanting your favoured setup to be as clear as possible, should this not be realised unnecessary performance stresses can still be kept at bay by arriving at the venue equipped with some practical coping strategies. This is certainly an approach that I have adopted considering the different venues that I have performed at. Site visits are often not viable, and Fig. 1 reflects a few of the varied performance settings that I've been presented with on the day of the gig. In other words it seems that the idealism of a perfect layout combined with a healthy pragmatism regarding setups in a variety of venues is a robust starting point.

4.1. Textual Description

Textual descriptions are also a valuable tool to help communicate how you want the loudspeaker to sound. For example, in much of the discourse surrounding mixed music, there seems to be some collective pursuit towards an understanding of balance between amplified instruments and electronics. Arguably a prominent feature in textual information can be found in one of Frengel's axes, *live weighting* [8], which approaches the the amplification of sound as a compositional parameter, similar to Mulder's *Levels of Amplication* as musical function [9]. This can be found on a continuous rather than discrete scale, and description of how this changes over time places can be an extremely efficient communication tool, effected in a single line of text (see Fig. 5).

5. The venue and its social architecture

The architecture of the venue isn't only physical, and awareness of where responsibility for different elements of the music lies can lead to the most efficient communication documents. Splitting information into sections including technical rider, separate layout and signal flow documents and finally an aesthetic description means that venue management, sound engineer and musicians can quickly understand the particular demands of the music *on them*.

Two way communication is necessary for a mutual understanding of the exact performance context, prior knowledge of what is to take place will give the venue manager the opportunity to flag up any potential issues. However, this level of investment into the music isn't always guaranteed and what is clear is that when communication within the venue is clouded, the performance often suffers for it.

5.1. Space and amplification

In his paper *Functions of Amplified Music* [13], Mulder draws attention to Theo van Leeuwen's [14] ideas on how social spaces can be sonically encoded, in order to reflect on out how microphones can transcend physical distance in performance. Related to this, physical responses to a space can also overcome problems with amplification. This was exemplified in our experience with a noisy neighbour (see Fig. 1, box 4), where we were unable to compete with another gig. This prompted the movement of the audience closer to us, shifting the listening space to enhance their experience of the music. Being unable to properly amplify the sound changed the social distances at play; the architecture of the venue forced a modification in the structure of the social space, allowing for some leeway in the strength of sound that the audience were able to hear. The listener's response in restructuring the environment at the time felt appropriate, in another performance space they may have felt too close.

This experience first emphasised the necessity for a more dynamic software response to the architectural demands of the performance. More importantly however, it demonstrates the limitations of any document: though information to a sound engineer before the event could flag up warnings to potential conflicts, often these situations don't arise until the performance of the music has begun. No set of performance documents is infallible.

6. SETUP DOCUMENT
CASE STUDY, *Labyrinths*

Having previously established the requirements of various setup documents, I will now go through a set of these in detail. *Labyrinths* is a four movement piece for string quartet and computer, featuring live electronics through a set of bespoke Max/MSP patches. Each movement has its own flavour and forms of interaction, the role of the computer and sound qualities are quite distinct. I formed the computer part based largely on Albert Bregman's perceptual theories on the Auditory Organisation in music [6], specifically how we group sounds, and have documented the proposed interaction loosely based on Michael Frengel's *multidimensional axes* for mixed music [8].

6.1. A general description

Target stakeholders: Venue management, sound engineer, musicians

Labyrinths, for string quartet and computer is a four movement work exploring different musical spaces inspired by short stories of Jorge Luis Borges. The preferred listener's vantage point is from within a quadraphonic speaker layout, either surrounding the ensemble or with a more usual stage and listener setup (see Fig. 3 for layout). The intention of this is to engulf the listener in each environment, with light amplification of each instrument and light processing creating tricks of perception as to which voice each sound belongs. Instructions regarding the mood of each movement can be found later on in this document, as variable amounts of reverberation, delay and compression are intended for each differing movement.

This paragraph - though technically vague - gives each stakeholder a feel for some general intentions for the piece, whilst also explaining why certain requirements (e.g. A quadrophonic speaker setup) are important to the fabric of the piece. This makes sure that emphasis is placed on the most important aspects of the music.

6.2. Technical requirements, Fig. 2

Target stakeholders: Venue management

Tech riders, perhaps the most general requirement for technical communication when it comes to gigs, can often appear patchy and incomplete. As discussed above, heavy detail - even if not realisable - can at least provide a good idea regarding overall intentions for the sound projection. Even going into the level of detail such as types of connections will preempt any problems with missing equipment on the day.

Tech Rider:
Labyrinths for String quartet and computer

Supplied by musicians:
4 x DPA 2060 microphones
All firewire and MIDI cables
1 X RME Fireface
All MIDI interfaces (if needed)

Venue must supply:
1 x table (12ft x 4 ft) for computer
5 x chairs
4 x music stands (with lights)
12 x XLR cables
2 x 4 way power supply
PA (EAW system favoured)

Speaker position:
Please see attached layout

Loudspeakers		4
Subs		1
Stage Monitors		2
Ensemble microphones		4 (supplied by us)
I/O	Mixer ins	1 - 4: 4 x DPAs from Quartet 4 - 8: 4 x TRS from Computer
	Mixer outs	1 - 4: To PA 4 - 8: Quartet DPAs To Computer 9 - 10: Monitors 11 : To sub

Figure 2: Tech rider for *Labyrinths*

6.3. Setup document: Stage setup, Fig. 3

Target stakeholders: Venue management, sound engineer

A lot of detail can be placed into a graphic representation of the arena space, including direction of speakers, position of listeners, musicians, mixing desk, position of onstage power and DIs and types of microphone. There are also some standardised graphics to represent different forms of hardware, such as graphics related to microphones, loudspeakers and mixing desks.

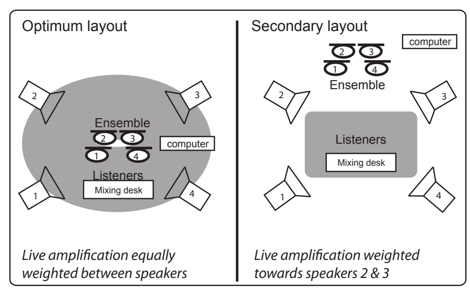

Figure 3: Stage setup document

6.4. Setup document: Signal flow, Fig. 4

Target stakeholders: Venue management, sound engineer

A separate document related to the signal flow of the piece clarifies any doubt over what you intend to project and where it should be sent. References to instrument reinforcement and monitoring can also be located here.

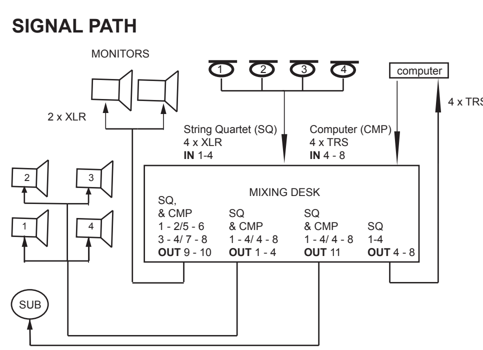

Figure 4: Signal flow for all movements

Signal flow from *within* the mixing desk also ensures further precision.

6.5. Textual information, Fig. 5

Target stakeholders: Sound engineer
This is where the more detailed information documenting modes of interaction and aesthetic preferences can be found. The information in this document can be drawn directly from decisions made at the beginning of the composition process, in my case based around Frengel's multidimensional axes, see Tab. 1.

Information can be extrapolated from this and communicated in clearer textual form. In Fig. 5 I have chosen to highlight certain types of information. First, I state what type of material will be heard in the computer part, in order to stop disparate musical elements being confused for "mistakes", for example a synthesiser sounding like feedback. I document where the balance lies between instrument and electronics from movement to movement, which isn't always static, whether the patch is tempo synchronous or not, what role the computer is inhabiting and finally a general indication of intended dynamics and quality of the sound.

MVT I - THE GARDEN OF FORKING PATHS

Live sampling and processing
Balance - Towards unprocessed live sound
Tempo synchronous (score following)
Singular behaviour - patch reliant on musicians
Computer role - Insruments extended for musical emphasis (eg addition of extra reverb at certain points by patch)

MID RANGE DYNAMIC. CLEAR ARTICULATION

MVT II - THE CIRCULAR RUINS

Live sampling and synthesizer
Balance - Live sound moving to computer
Not tempo synchronous
Singular behaviour - patch reliant on musicians
Computer role - causal from instruments moving to coequal and finally independent to instruments

VERY QUIET TO VERY LOUD. SMOOTH BLEND

Figure 5: *Labyrinths* Movement I and II, textual information

This sort of information is important because if there are points in the music where it isn't clear that the musicians and computer are meant to be interacting in a certain way, for instance with the computer part becoming louder than the amplification of the instruments in *The Circular Ruins*, then the sound engineer may take unnecessary steps to counteract this specific intention. Explaining what you are expecting to hear gives the sound engineer the freedom to focus their skills on bringing out the best in the music, rather than spending their time guessing whether something is meant to be there at all.

7. CONCLUSIONS

Methods for the communication and staging of mixed music will always be in a state of development. Each performance will throw up a variable that was different to the last. However I have attempted here to cover eventualities that I am able to foresee through research into other composers' work and collaboration with sound engineers regarding the best ways of presenting information. I have done this through a set of documents containing general textual description, tech riders, stage and hardware layouts, signal diagrams and brief description of aesthetic intention.

Understanding that music is a finely balanced network of many different activities, including factors completely beyond compositional control helps to manage if not specific problems, then at least identify certain types. The documents presented in the paper demonstrate my response and rationale to these issues, including varying levels of detail for different parties involved in the performance. It should be stressed that this often boils down to individual preference, indeed some people I consulted suggested more detail and some less in the documents. For me the crucial points are clarity and flexibility - the documents are detailed with different levels of focus directed to different individuals, coupled with some pragmatic software and hardware responses to a variety of situations.

What underscores all of this work is that the presentation of mixed music is built on a number of dialogues between different parties, and that without a shared understanding of what is to take place, the loudspeaker often unnecessarily remains a *great anonymous pulveriser*.

8. ACKNOWLEDGEMENTS

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