Transfunctionality:
A compositional approach for expanding the horizons of acoustic instruments

by
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This thesis is the candidate's own work and has not been submitted for another degree, either at University College Cork or elsewhere.

Signed: _____

Richard Molloy

Table of Contents

Table of Figures

Digital Media

This thesis is accompanied by a USB drive that contains copies of the Scores, Recordings and EIS software that I have created as part of my studies. This material is an integral part of the thesis and should be treated as such.

However, a few notable exceptions should be accounted for:

- *Glyph* and *The Gate* are unfinished, meaning their associated recordings are just demonstrations.
- For the same reason, *Glyph* does not have a score or an associated EIS.

  The score for *Alba Rosa* is included to illustrate a point. The piece was not fully realised.

Some pieces include extra software in addition to their associated Max/MSP files. These can always be found in the folder marked ‘other’ within the relevant ‘EIS Files’ folder.

Examples include:

- The Synapse application required to perform *Arianna.*
- The Logic Pro X Session required to perform *Boidsong.*
- The SoftStep 2 Software Templates required to perform the *Epochs* suite and *Perpetua.*
- The TouchOsc template required to perform *The Gate.*

Acknowledgements

I would like to start by thanking all the staff at UCC who supported and guided me during my PhD study: my co-supervisor Dr Jeffrey Weeter for getting me started, Eithne, Celena & Christine for their patience and John Hough for being a lifesaver in general. I should also give special thanks to Dr Yvon Bonenfant and Professor Michael Alcorn for the sincere and constructive manner in which they conducted my Viva Voce. To Mr John Godfrey, I owe even greater thanks. His unlimited reserves of insight, optimism and inspiration allowed me to finish a project that I, at many times, thought impossible.

To my family and friends, I am most grateful. My parents, Helena and Richard have helped and encouraged me through every step of my life. Words cannot express my gratitude for all that they've done for me. I'd like to thank my sisters, Deirdre & Evelyn for their constant support. My friends have kept me happy and perhaps even sane, especially Thomas & Jessie through their solidarity. To my girlfriend Ellen: You are the best. I couldn't have done this without you.

Thanks to everyone dear to me. I'm truly lucky to have you in my life.

Performances & Credits

Boidsong, Winter 2015. Performed by Maria Mulcahy.

Epochs, Spring 2016. Performed by Ilse de Ziah at the Village Hall, Cork.

Glyph, Winter 2016. Performed by Tosh Molloy.

Perpetua, Spring 2017. Performed by Tosh Molloy at ISSTA Dundalk.

Creidhne, Winter 2017. Performed by William Lang at The Lilypad, Cambridge, MA.

Hō-ō, Spring 2018. Performed by Scarlet String Quartet at O'Riada Hall, UCC.

The Gate, Summer 2018. Performed by HIVE Choir at SARC Belfast.

Arianna, Autumn 2018. Performed by Emma Power at UCC. Illustrations by Ellen Fogarty.

Abstract

This PhD in music composition explores a compositional approach referred to as 'Transfunctionality', where traditional acoustic instruments were paired with 'Expanded Instrument Systems' (EIS). These technological peripherals allow performers access to sonic expression in a live setting that would be inaccessible by other means. I've sought to classify such performance technologies not as 'add-ons' or 'performance elements', but as integral parts of that which is considered to be the 'instrument'. This aesthetic consideration has led me to work closely with musicians to create EIS that offer musically meaningful live interactions.

Writing music for EIS is labour intensive, niche and a challenging musical balance to achieve. This convergence of the classical musician and performance software is perhaps unduly rare in today's concert halls. While seeing my work through to completion I've found myself pitted against barriers of both practicality and perception. The interplay between software and acoustic instrument can be fascinatingly varied, with both elements potentially serving to inform the other. This thesis consists of a written dissertation, audio recordings, scores and performance technology.

Chapter 1 - Introduction to Transfunctionality

1.1 Background

From the moment I began to pursue a PhD in composition, two things were made very apparent: That I would need to write music that would lean on my musical strengths; and that I would need to address the looming spectre of 'originality' that hangs over all composers, especially within academia. Describing myself as a technologist would be the simplest and most common way to categorise my expertise. I find this term inaccurate, however, as I believe it both understates my familiarity with classical theory, instrumental performance and non-electronic music, while potentially overstating my abilities as a programmer or engineer. I have always felt that to best represent myself musically, I should create music that sees established compositional concepts and music technology meeting on equal terms. These core beliefs about my musical identity have moulded my pursuit of composition from the earliest days of my third level education.

After receiving my training in the techniques of classical composition at undergraduate level, I decided to pursue my longstanding passion for music technology at master's level. Here, I was particularly dedicated to the study of electroacoustic music and audio engineering. Ultimately, the culmination of my earliest composition practice manifested in a thesis piece containing electroacoustic elements and a number of classically orchestrated ensemble sections treated with effects processing. While undertaking this project I began to realise I was working in a field that I knew nothing about. I was very familiar with both electronic and 'art' music but not any style which merged aspects of the two. It was this seemingly unlikely lack of knowledge that eventually spurred me to pursue a PhD in composition. I set about broadly investigating music innovators who paired acoustic instruments with technology in an attempt to evaluate the practice as a whole, identify a niche and address the concerns of 'originality' that might hinder my academic progression.

In an effort to make up for lost time, I embarked on a listening spree through all manner of modern composers within my newly chosen field but became disappointed with what I heard. Instead of a new genre that would expand my understanding of what music could be, I found a mere amalgam of older styles. To my ears, nothing is more unsatisfactory than a loosely bound 'fusion' of genres. I believe that different styles of music hone in on particular aspects of the musical palette and value a chosen set of musical devices over others. If a piece of music was to explore every compositional device to the n^{th} degree, it's likely the music would have too much content to be pleasingly dissected by the human ear. If you were to listen to the heavy 'djent' music of Meshuggah looking for melodic interest,

they might disappoint, while even Mozart's renowned masterpieces mightn't satisfy the rhythmic needs of a djent connoisseur. If any music that could be considered a 'fusion' is to appeal to my ears, it must either satisfy the aural demands of its component styles adequately or prove distinct enough to offer a new musical experience. For these reasons, I wasn't drawn to fusions of acoustic instruments and fixed media. In my opinion, the sounds of the longstanding electroacoustic and Western Art Music practices carry a certain weight and significance that are extremely difficult to pair successfully. I have however, found some of the distinct practices & philosophies of Pauline Oliveros to be an essential guidepost for directing my very particular compositional curiosity.

Upon discovering Oliveros, her contemporaries and musical successors, I uncovered a lineage into which I aimed to incorporate myself. Reading through her associated journals and musings allowed me to reconceptualise the relationship between instrumental performance, composition and technology. Specifically, I was inspired by her 'Expanded Instrument System'. It highlighted some valuable ideological distinctions that would guide the course of my studies over the following years and more crucially, clear a sonic space for me where I could envisage technology and acoustic instruments intersecting to provide a distinct musical experience.

Oliveros, like many composers of her day, began composing pieces for early tape and electronics setups, but after some time began to wonder how electronics could contribute to her live performances. In particular, she sought to exploit 'space' as a musical parameter that she could have control over:

"As my experience of numerous performance spaces accumulated, I began to wish for the possibility of changing the acoustic space while performing. I also wished that I could hear as if I were in the audience while I was performing for it. With the advent of signal processors and sophisticated sound systems, it is possible to tamper with the container of music in imaginative ways." [1]

This 'wish' or idea in itself is hardly revolutionary, especially to a musician like myself who has never lived in a world without music technology, but the distinct ideological expansions Oliveros builds upon this unassuming foundation are far more evocative. It is the level of control she seeks to gain over musical space that I think is most striking. Even today, the distinction that reverbs can be changeable musical entities rather than simulated static architectures may be a minority opinion.

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[1] Pauline Oliveros, "Acoustic and Virtual Space as a Dynamic Element of Music." ***Leonardo Music Journal 5*** (1995): 19-22. Accessed March 21, 2017, doi:10.2307/1513156.

"The walls of an electronically created virtual acoustic space can expand or contract and assume new angles or virtual surfaces. The resulting resonances and reflections, which change continuously during the course of a performance, can be used to create spatial progressions, much as one creates chord progressions or timbre transformations by changing the tone quality of an instrument while performing a single pitch."[2]

Oliveros puts space firmly into the hands of the performer and into the realm of instrument, rather than that of 'effect', 'sound treatment' or 'architecture'. In some ways this distinction might seem meagre or inconsequential, that is until the true ramifications are explored. Here, Oliveros has added technicolour to the musician's palette and expanded their artistry into the world of the virtual. It is thoughts like these that spark a movement easily traceable into today's music. Her subsequent compositional work took full advantage of these added musical elements in instrumental performance. The scope of what could be considered her 'instrument' would soon be altered as she began to incorporate live electronics into her accordion rig.

"The premise of the EIS back in 1965 was to challenge myself as an improvising performer. I felt that I could handle more musical information than I was able to perform without the extension of electronic feedback."[3]

The Expanded Instrument System (EIS) is the manifestation of Oliveros' wish to gain performative control over musical space. It was initially enabled by analogue tape reels, but more recently has been transferred to the digital realm via Max/MSP for accessibility and expansion. Through a series of foot pedals, Oliveros could use physical interaction to control ‘spatial’ sound elements like reverbs and delay. The naming of this rig is indicative of her philosophy of extending the musical scope of what her 'instrument' can achieve. As music technology advanced over the years, it became possible for Oliveros' once convoluted analogue rig to be managed entirely within the digital realm of Max/MSP. Software environments like Max allow for flexibility, affordability and remote distribution of advanced music software that can be coded individually by skilled users. Today, the Max Community Forums are a hotbed of innovation frequented by technically minded composers and music software designers alike. This forum has become the birthplace of many of the 'systems' for modern EIS movements.

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[2] Oliveros, "Acoustic and Virtual Space as a Dynamic Element of Music."
[3] Oliveros, "Acoustic and Virtual Space as a Dynamic Element of Music."

Of course, there has been much work in the field of music technology twinned with acoustic instruments since Oliveros' pioneering work, and many modern examples shall be discussed over the course of this study. I do, however, find her philosophies and methodologies to be prerequisite knowledge to engaging with my specific studies. I was so compelled by Oliveros' work that I embarked on a mission to create modern EIS(s). I have, over the course of my PhD studies, examined, critiqued and refined this process into a compositional approach I call 'transfunctionality'. This particular compositional methodology has placed specific demands upon every EIS and composition I've made within the past 3 years. My aim is to create a clear compositional rubric for a modern, technologically expanded style of live acoustic performance. As Oliveros commanded control over 'space' in her live performances, I aim to imbue all manner of acoustic instruments with new dimensions of live performance.

1.2 Defining 'Transfunctionality'

Having essentially been inspired by a compositional ethos, I set about conceptualising a personal philosophy that might see me avoid what I perceive to be the pitfalls of many contemporary movements. With a desire to modernise the EIS approach, I examined what the trends of the past could teach me about technology's effect on musical styles, while also trying to address my qualms with more contemporary works. I see technology as an almost guaranteed source of innovation, with untold potential for reshaping Western Art Music practices. There is a large pool of talented performers who would be well capable of expressing themselves through well-designed musical peripherals if only more were forged around their needs. I have no doubt that there is further room for technology to shape the repertoire of the modern 'classical' instrumentalist through more efficient methods of integration. Eventually, through thought, discussion, listening, composition and the self-evaluation of my work, my methods for attempting to achieve these lofty goals were distilled into seven basic tenets.

I will now speak to each of these in context while highlighting them particularly in bold. Technology has been widely integrated into popular recorded music from almost its beginnings. My experience as a music engineer opened my ears to the changing use of technology in recording settings over time and the trends that arise from these changes. Perhaps what is most compelling to me is technology's potential as a transformative force. Within popular music spheres it is easy to connect emerging music technologies to the development of new genres; whether it be delay effects enabling reggae's transition into dub, or distortion seeing rock & roll evolve into heavier styles. These examples pinpoint the transformative function of technology as it propagates into specific styles, often changing them substantially in the process. It is this property that I see in Oliveros' work, continuing into the work of a select few composers in academia and the Max community.

Rather than juxtaposing diverse soundscapes in a 'fixed media and acoustic performance' setup, I believe further integration is needed, perhaps even demanded at this time. I aim to create music that views technology as a catalyst for change rather than a source of 'fusion' (to which I am averse). The conceptual foundation of the EIS is built on this basic idea: **Technology can grant musical instruments new capabilities.**

Of course, not all 'new' capabilities are created equally, with some wielding more transformative potential than others. Ideally, a new capability would change the way an instrument could react. If this change were great enough, one would assume its best musical use would require an alteration in playing style, approach or musical focus. I believe any substantially effective EIS will, almost by definition, lead to new musical styles and results. By now, composers have examined a nearly exhaustive range of ways to score for or perform on the various instruments popularly used in Art Music circles. It is not unreasonable to use a string instrument as a percussive devise by adjusting performance techniques and scoring methods. Thus, it might be useful to classify minor ability changes that don't present new enough musical opportunities as unimportant for this study. That is to say that **when an EIS grants an instrument a new capability, it is important that the same results could not be achieved by non-technological means.** Often, the boundaries of this distinction might appear subjective, but the purpose of this stipulation is to ensure that an EIS unlocks more new musical material than a simple change in scoring could.

Equally, expanding instruments via physical alterations is possible, but should also be excluded from this methodology. Although the 'augmented instruments' movement is a popular means of reimagining the roles of acoustic instruments it does raise a number of substantial practical issues. Firstly, this method excludes both composer and performer from distributing their art efficiently. Instrument building and alteration is a delicate craft that is not only difficult and rarely practiced, but also expensive and impractical. Secondly, since this composition style draws largely from Western Art canon, it would be beneficial to utilize the instruments most widely incorporated into that tradition. In addition, the player bases associated with these longstanding instruments are an invaluable resource for composers. Even the addition of expensive peripherals, sensors or physical add-ons should be limited where possible for much of the same reasons. With all this in mind, it is paramount that **the structure of any acoustic instrument used is unchanged.** Additionally, since the sound of these instruments is heavily tied to their identity, the instrument's **natural sound should be incorporated in a performance as primary source material.**

Now that the basic technical requirements have been extrapolated, there must be some discussion regarding the musical direction of the EIS(s). What is already evident about a successful EIS is its ability to extend the range of musical control that a performer can exhibit. That is to say that the instrument can now perform a new musical task formerly outside the capabilities granted by its unchanged physical form. These changes could exist in the domains of pitch, timbre, polyphony, texture and space, amongst others. As discussed, a great enough expansion will lead to new musical opportunities not previously available to the performer. To define this success criterion more accurately it might be helpful to state that a modern EIS **should grant an instrument a performance role functionally different from the norm.** This functional change could require new playing styles, scoring techniques or musical concepts being mapped to the instrument in question. Essentially, the performer might find themselves in unfamiliar musical territory or even musical roles often reserved for other instruments. This stipulation is of particular importance since it best communicates my personal philosophy concerning technology's transformative potential. In the examples to come, I will explore the ways in which I've transformed the musical function of longstanding musical instruments as part of my compositional practice I now refer to as 'transfunctionality'.

Lastly, I must make the distinction that **the new capabilities an EIS grants must be exhibited in a live setting.** Since EIS(s) deal with acoustic instruments, devices constructed for live performance, they should be designed with live performance in mind for them to be considered true expansions of their associated instruments. Many signal processing techniques could be suitable for a studio or electroacoustic setting but prove cumbersome or impractical in a live environment. In addition, **the performer must have meaningful musical control over the technology.** This is to ensure that the technology has been fully integrated into the world of the instrument. This factor cannot be understated since a musician's connection to an EIS will be through musical interaction. The effectiveness or appropriateness of this interaction must be evaluated to ensure an engaging and musical experience for the EIS performer.

The seven basic stipulations of transfunctionality have been now been introduced and are summarised on the next page. This basic outline will serve as a working template for the transfunctional pieces presented in this thesis since meeting these requirements is a prerequisite to creating transfunctional music. A more detailed discussion of this template through the example pieces to follow will allow me to outline a useful key for evaluating the effectiveness of individual works and informing the future direction of compositional energy.

'Transfunctionality' is when:

- Technology has granted an instrument new capabilities.
- These new capabilities can be exhibited in a live setting.
- The same results could not be achieved by non-technological means.
- The structure of the acoustic instrument is unchanged.
- Its performance role is functionally different from the norm.
- The instrument's natural sound is primary source material.
- The performer has musically meaningful control over the technology.

Transfunctionality is a compositional style that has arisen from a particular set of environmental factors. The style is also a manifestation of certain aspects of my musical outlook. To fully evaluate the content of the chapters and commentaries to come, I believe some important clarifications need to be made.

Chapter 2 - Regarding my Compositional Approach

2.1 The Instrument

My decision to work with acoustic instruments was certainly not made out of necessity or even convenience. Rather, my reverence for the instrumental tradition and 'Western Art Music' in general spurred me towards my own potential contribution to the canon. I aim to contribute to the slow attrition that the technological tide has been enacting upon Art music.

Many of the instruments associated with Western Art Music have been immortalised in popular culture thanks to their consistent appearance in musical settings over hundreds of years and relatively unchanged physical designs. I perceive my compositional practice to be part of a tradition and so, I must respect certain longstanding cultural monoliths. I previously eluded to the practical reasons for avoiding physical alteration of the various instruments I might employ, but equally there is a spirit or ethos that guides my design choices. I seek to expand instruments in a manner that integrates with their existing performance culture. Any technological peripheral I design should coexist with the performance norms and techniques already associated with each instrument. In this way I hope to assimilate each EIS into the conceptual realm of its associated instrument. That is to say, I want both 'viola' and 'EIS technology' to be considered components of the same 'instrument'. Over the course of this study I will continually evaluate my own work in order to assess where future work will be carried out. Although the seven-point rubric of transfunctionality is invaluable, my personal ethos regarding the nature of what an 'instrument' is, is also of crucial importance. I do not believe the qualities of what makes technology suitably 'instrument-like' is quantifiable in the strictest sense. Even so, the major contributing factors often revolve around musically meaningful control, playability and compelling interaction.

Meaningful control is covered within the compositional rubric that has already been outlined. In certain cases, however, control that could be considered technically valid may not be apparent to the performer. It's possible to create an EIS system that gives user input control over crucial elements of the eventual sonic product, but this control is so abstractly connected to the physical actions of the performer that they do not perceive the connection. Sometimes it is difficult to anticipate what exactly can be perceived as an 'instrument' while using only a written set of criteria. I think the ultimate arbiter of these potentially fine distinctions should be the individual composer of transfunctional music.

Playability is a factor that has derailed many potential projects of mine in the latter stages of their development. Sometimes it is not only obligatory that musically meaningful control can be perceived by the performer, but also that this control is practical within a performance setting. There is a fine and subjective line where an EIS does more to hinder a performer than enable them. Since EIS are augmentations of instruments which on their own require a high level of adeptness to play effectively, any additions must be considerate and worthwhile. This is to say that performance instructions given to a musician should be as reasonable as possible and the EIS itself should produce musical results that are worth its inclusion in the first place. In short, I aim to create EIS that are musically fulfilling. Creating EIS in the first place has personal, musical meaning that ideally would be transmitted to the performer. I've always found instruments to be fascinating objects that are individually beautiful, inviting and endless in their potential. Instruments, and by extension EIS should require an infinite amount of time to fully master. This widened concept of the instrument could be equated or reduced to 'good design principles', but I believe this wouldn't capture my overall ethos aptly.

2.2 Max/MSP/Jitter/Gen

The software created in this study, unless stated otherwise, was created in the Max 7 environment. Max is the obvious choice for working in my discipline for numerous reasons. Primarily, the versatility that DSP software provides is unmatchable via other means without great expense. Max allows me to take direct control over the EIS design process. This means every aspect of the eventual performance has passed my personal scrutiny. Since the creation of each EIS is central to my compositional style, it is crucial that I can sculpt them as I see fit. In addition, the musicians and ensembles I aim to work with often receive music remotely in the form of scores and recordings. Since my EIS designs are primarily software-based, they can be sent electronically through the internet, eliminating a plethora of potential practical barriers which would place my music at a disadvantage to other styles.

Lastly, there are creative benefits involved with using Max as a compositional device. Being familiar with Max gives you access to a common logic that encapsulates all manner of DSP techniques. Increasing my knowledge of Max allows me to better understand the current possibilities and limitations of music technology. This alone is a creative driving force. Often, I stumble upon new compositional ideas or approaches simply while practicing my Max programming abilities. Failing this, I can rely on Max's extensive online bank of resources, innovators, musicians and educators to inspire my work from time to time. Thanks to the generosity of some creators, I sometimes have access to software far beyond the realms of what my own proficiency will allow me to produce.

2.3 Influences & Contemporaries

It is my understanding researchers often embark upon a 'literature review' during the early stages of their PhD studies. This helps them better integrate their work within the wider landscape of contemporary research within their chosen field. As discussed previously, I engaged in a similar activity by performing a wide listening survey of earlier and more contemporary works in my perceived field of composition. In the chapters to come, however, I will not refer exclusively to musical works of a contemporary nature or even within a particular genre. Although many of my citations and influences will inevitably involve modern innovators within the EIS community, I will not shy away from unveiling the rather more disparate set of influences that inform my compositional decisions.

In today's interconnected world, music of all origins is available to just about any web-user and I have found that listening to a wide palette of musical styles suits my needs best. Personally, I think this increase in accessibility has made an impression on composers and the music they create. In days gone by, a composer might insert themselves into a compositional style by employing certain techniques or modes of thought. In my opinion the current trend, perhaps inevitably, is the personalisation of the compositional approach. One of my favourite works, *Liminal Highway* by Christopher Cerrone[4] is illustrative of this trend. This piece could easily be classified as transfunctional and I could therefore spend time emulating its instrumental or DSP techniques before scouring the web for similar works. I would contend however, that the charm and even the success of this piece stems from Cerrone's personalised approach whilst composing it.

"The issue of resonance and how it relates to the process of memory is a central preoccupation in much of Cerrone's music… Cerrone took the title for his new work from a poem by the Canadian indie rock musician John K. Samson, which begins with the premise "when you fall asleep in transit."… Written for flutter-tongue piccolo throughout, the first movement is made of delicate layers and loops. Cerrone remarks that he bought himself a $50 flute from Amazon: "As with almost all my solo work, I try to learn the instrument I'm writing for, so I ended up learning how to play the flute.""[5]

[4] Christopher Cerrone, "Christopher Cerrone – Liminal Highway for Flute and Electronics (2016)", Accessed December 29, 2018, https://www.youtube.com/watch?v=aOsYb6UgvHY

[5] "Christopher Cerrone – Liminal Highway for Flute and Electronics (2016)",

I believe making comparisons between modern EIS performances or dissecting pieces technically will have limited benefits for my compositional innovation. Conversely, I maintain that drawing from a wider set of musical influences and sources of inspiration will allow me the best opportunity to succeed in creating ‘original’ music. I will, however, make specific reference to contemporary works within similar fields of composition to my own on a chapter by chapter basis. I do this to contextualize my technical and aesthetic approach rather than to argue for its originality.

2.4 Overall Approach

There are two intrinsic thought processes involved in creating transfunctional music: technological thinking and acoustic thinking. It is the interplay between these modes of thinking that ultimately leads to a musical performance. I consider my technological and sonic thought processes to be inseparable at this stage in my development, with both contributing to my creative voice. Both modes of thought provide me with inspiration at different times. For example, I might have a sonic texture in mind and find myself unable to execute this sound adequately through pure acoustic orchestration. In this situation I may look towards software to alleviate this limitation. Conversely, I could find myself stumbling upon a new DSP technique or patching technique. I've found that interesting DSP often pairs well with deliberately designed audio and so, I find myself writing music to complement the software I've created.

My compositional approach can be viewed as a process of design and resource collection in many ways. Generally speaking, once I've begun composing I tend to have a timbral soundscape or set of textures in mind. I can use this as a template to work towards as I select the necessary acoustic and digital techniques required to realise this sound. Although I am exclusively presenting my transfunctional work in this study, I do make an effort to compose across several different genres in my spare time. I've noticed that no matter what style I might decide to write, this timbral/ spectral way of composing acts as a common thread. Even in purely acoustic writing I will ask myself what I feel is missing from the overall timbre at any given point before answering with perhaps a countermelody or rhythmic device. As I attempt to forge the beginnings of a compositional niche with transfunctionality, I find this timbral approach to be an anchor point between many very different pieces.

2.5 Tracking Development

Shortly after defining what transfunctionality was to be as a musical style, I selected four specific areas of research and reflection that I would use to compartmentalise and assess my progression as a composer. I titled these Subversion, Control, Design and Performance. I wanted to see marked improvements in each of these areas before I could deem my research successful. These four subjects guided my research hours between compositions allowing me to develop new concepts and design philosophies.

Subversion refers to whether or not my music holds the subjective quality of subverting the functional norms an instrument or performer might have. This mode of thought is a useful tool for inspecting the nature of an acoustic instrument and identifying compositional limitations that technology could alleviate. Subversion also speaks to my ability to write and theorise music for instrumental settings as unusual as EIS. As my knowledge base expands and my experience heightens, I would like to become increasingly comfortable with this process. I consider it to be the primary force to be grappled with at the earliest stages of each piece's development.

Control is an important research element of EIS and requires ongoing research and awareness of the ever-developing technological landscape. There is an entire spectrum of options available for the control of EIS. I have set a personal challenge to explore as wide a range of controller peripherals as is practical during this study. A controller can be as rudimentary as the press of a button or as intangible as an advanced gesture tracking device. These options and everything in between present unique challenges, positives and negatives within an EIS design context. By incorporating a wide range of control mediums, I can at least begin to expose myself to some of the variety on offer. Ultimately, each EIS will be assessed as the sum of its constituent parts, but I do think that each instrument has its own distinct demands for control surfaces.

In addition, aspects of EIS design and composition should be tracked and revised at every major juncture during my research. Due to the wide variety of sonic forces I will be making use of, I should take care to communicate my ideas as clearly as possible. Each new EIS may require different scoring elements and methods of interfacing. It is important that I make effective use of the sonic palette that I select for each piece and learn how best to transmit my thinking through the medium of paper.

Lastly, all contributory elements are superseded by considerations involving the eventual live performance. I aim to create a substantial and varied portfolio of performances that will see diverse EIS approaches take the stage. Anticipating the intricacies of a live performance is a difficult task. I endeavour to write music that is engaging both to play and to listen to. As important as my technical criteria for composition are to this research, I believe I am ultimately answerable to the quality of the music I produce. I will now examine the music from my portfolio in a series of commentaries, each dealing with a distinct form of compositional focus.

Chapter 3 - Self-accompaniment in *Boidsong* & *Creidhne*

3.1 Background

This first set of commentaries aims to address some of the most fundamental considerations transfunctional composition demands by evaluating the musical success of two pieces while concurrently examining their adherence to the aforementioned transfunctional rubric. While subsequent chapters will examine pieces in more rigorous detail, under numerous lenses, I believe these pieces can be critiqued both swiftly and precisely. For this reason, they will serve as a foundational benchmark for defining both successes and failures.

Boidsong (flute & electonics) and *Creidhne* (trombone & electronics) bear similarities in both approach and instrumentation, while differing greatly in musical outcome and artistic focus. Chronologically, *Boidsong* is the earliest composition included in this portfolio while *Creidhne* was composed after numerous pieces that are featured later in this thesis. The differences I perceive between these two compositions illustrate an artistic development and a narrowing of the definition of 'transfunctional'. Both compositions attempt to speak to one of my earliest wishes for my EIS; to allow the live performer to 'self-accompany'. On a basic level, some instruments already present performers with such opportunities. For example, if a right-hand piano melody is heard as a primary musical force, then a simple left-hand chordal part could be considered secondary in nature. Thus, if a pianist were to improvise a solo with their right hand and provide chordal context with their left they could be deemed to be 'self-accompanying'. In my opinion, this is a satisfactory fulfilment of self-accompaniment, but by no means the only such solution. We can also easily identify instruments where this faculty is not as available to the performer. Imagine also, if a drummer were to join this pianist, vamping with standard time while providing subtle variations as another layer of accompaniment. A musical dialogue could develop, seeing both performers reacting to the nuances of the other's playing.

We are still discussing accompaniment, but interestingly, it is now shared between two brains with the performers less able to anticipate all of the musical events to unfold. Clearly this isn't 'self-accompaniment', but technology could allow me to assimilate some of these performance relationships into a solo setting. In the earliest days of my doctoral composition practice, I wondered how best and how well I could incorporate these distinct aspects of accompaniment into any instrumental performance. This chapter examines the challenges and considerations of extending instruments in this manner; imbuing them with the ability to self-accompany on some level.

3.2 *Boidsong*

Boidsong was a formative piece in the development of transfunctional composition. Essentially, the technical and musical elements of this piece grew out of a thematic train of thought. Initially I had struggled with how best to marry my knowledge of Max/MSP programming with my compositional practice. Before this time, I hadn't created any such music for the live environment. I knew I wanted to create a layered and textured soundscape from a solo performance but was unsure how best to realise this goal through code. My reactive solution was to lean on my experience with studio and guitar equipment. I began to devise a system of delay lines that would each receive vastly different sound treatments before being heard. Within Logic Pro, I layered a multitude of audio effects across separate tracks. Once I achieved a sufficient level of timbral variety, I became concerned with how I would write for this system and even more pressingly, how anyone could reasonably expect to control such a long list of effects parameters. Thankfully, while pouring over a tome of theses from my department in the library I came upon some work that would answer both questions.[6] Although I have come to largely question my reasoning from that time, I also see how it began my formulation of the transfunctional method.

UCC alumnus Derek Foott's[7] thesis detailed his integration of Craig Reynolds' 'Boids'[8] algorithm into his digital compositions. This algorithm simulates the movement patterns of flocks of birds through a system of rules and input parameters. Coincidently, at the same time that I was reminded of Boids I was also listening to Messiaen's orchestral works. At this point I quickly set a thematic framework that would inform my approach to both the score and technology. I would use the individual movements of birds within a simulated flock to control effects parameters and create a collection of birdsong to serve as my musical inspiration. I selected flute as the instrument to be extended in this piece for its timbre and since I was familiar with its associated techniques. My intention was to transform a single line of birdsong into a soundscape of echoing melodies thereby creating a musical 'flock' from a single voice. The delayed nature of the recurring material could be considered akin to the dialogue bird species participate in through their chorus of songs.

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[4] Derek Foott, Exploring processes of indeterminate determininism in music composition, programming and improvisation, National University of Ireland: University College Cork, 2013.

[7] Foott, Exploring processes of indeterminate determininism in music composition, programming and improvisation

[8] "Boids", Last modified December 3, 2018.http://www.red3d.com/cwr/boids/

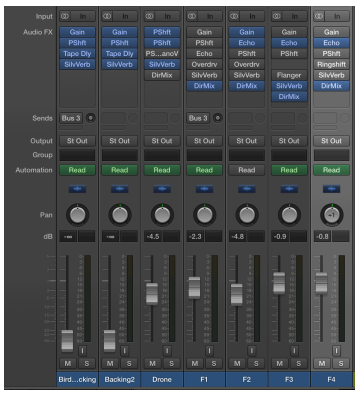

Figure 1:
A view of the original Logic file, with the four rightmost tracks being the delayed signal chains

I would categorise this form of self-accompaniment as lying somewhere between the analogies of the solo pianist and the improvising duo. Although all material featured is played by the same musician, its reoccurrence is somewhat randomised while under the control of the flock of Boids. In a sense, the performer could be considered to be interacting with another musical entity or mind of sorts; namely the computer. To me, this troubling element of indeterminism although a valid musical force, seemed to be outside the acceptable realm of 'instrument' even in the expanded sense that I was coming to understand. The patch was operated purely through sparse mouse-clicks and is primarily autonomous from the performer. This early experience led me to consider elements of control that I might afford to both myself as a composer and the performer through the EIS as I moved forward. In addition, the ratio of input to the patch's output is such that a short melodic phrase from the flautist can amount to a myriad of sounds being created shortly after. I consider this relationship to be less than ideal, as it further compounds the issue of separation between the performer and what should be an extension of their instrument. Finally, the score itself doesn't do much to remedy this issue since much of the material isn't intended to interlock specifically with the echoes of earlier ideas. On a side note, this score serves as a pictographic representation of my ability to present material at the earliest stage of my thesis. I have not altered it as I believe it is illustrative of my progression.

In summation, I would concede that this piece doesn't serve as a benchmark for self-accompaniment as much as an example of expanding the texture of a solo performance. I do not discredit its validity as a study nor as a soundscape, but I was especially certain at the time I composed *Boidsong* that I should pursue greater levels of performance-based control and more unique transformations of functional norms. This piece in particular highlights the importance of the 5th and 7th stipulations of transfunctional composition. Although the majority of the criteria have been met, there is a clear deficit in changes to 'performance role' as well as insufficient interaction between performer and EIS.

3.3 *Creidhne*

Creidhne was composed in late 2017 for the Boston Microtonal Society's Call for Scores. The competition afforded composers an opportunity to write for experienced trombonist William Lang. My personal fascination with microtonal music stems from an interest in unconventional chords and unusual intervallic beating. When tuned in just intonation, chords can take on an entirely new timbral character. I quickly realised that in order to avail of these techniques within a solo trombone performance I would have to revisit the theme of self-accompaniment, but by this point I was much more knowledgeable and technically skilled in my field. It was clear to me that I could create a rich chordal texture by recording and layering a solo performance.

By learning from the shortcomings of *Boidsong*, I realised that if I were to carefully time and subdivide a performance's content I could then store and recall specific elements with the aid of software in order to gradually layer a solo performance into something texturally akin to an ensemble piece. To achieve this, I first devised a unique microtonal scale that redefined the tuning of each note on the stave (Fig.2).

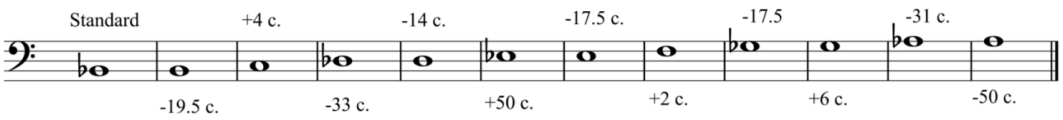

Figure 2:
The amount of deviation in cents each scale tone differs from Equal Temperament

I then composed a structural progression of chords that the piece would follow. My primary challenge when doing so was to limit the number of new pitches introduced in each chord. That way, I could record and store each individual pitch as it was played so that it could be used in upcoming chords that require the pitch in question. My way of achieving this was to allow the performer to set the length of each 'bar' in seconds. Since each bar on the score contained only one pitch, these could be stored separately in the computer's memory. As new notes are being performed, earlier bars are being replayed through speakers to create a chord. This simple yet effective approach speaks directly to perceived weaknesses of *Boidsong*'s Max patch. Now, the score clearly communicates the relationship between each bar and its predecessors. Although the individual bars tend to only feature one pitch, a chord symbol is included below to communicate the context of each pitch (Fig. 3). The performer now engages in a very particular fashion with the material emanating from the software. Since there is very little rhythmic and pitch information on the score at large, I decided to focus my compositional energy on the dynamic balance and timbre of every individual note and by extension, every chord created by the patch. All bars contain either dynamic, timbre or pitch related instructions

that when layered produce an ever-changing microtonal landscape. The interlocking nature of these instructions should become the performative focus of the trombone player as they react to the accompaniment provided by the recycled system of recorded bars.

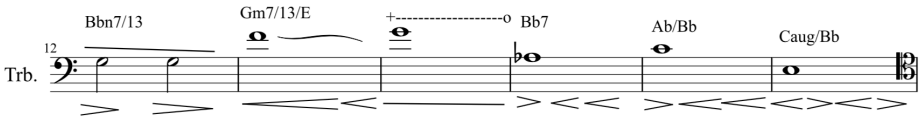

Figure 3:
An illustrative excerpt from the score of Creidhne

I believe the qualms I expressed with *Boidsong*'s eventual form are directly responsible for my approach to *Creidhne*. I attempted to expand the chordal breadth of an acoustic trombone performance into the realm of an ensemble piece. I also would claim that the score attached to this piece better bridges the gap between instrumentalist and software, since the performer is more informed about and directly involved in every musical event that comprises this piece. On the other hand, the greater level of performance rigidity required for this composition is not without its drawbacks. Since the recording and reoccurrence of every event in this performance is predetermined and unchangeable, the patch itself effectively only facilitates this specific piece or any others that bear a remarkable resemblance to its overall structure. The new capabilities granted to the trombone by this particular EIS are musically significant, but also quite specific in their application. In that way, this EIS does lack in the realm of versatility and may not align with many people's conception of what an instrument should do. Of course, future versions of this code could allow for increased flexibility. However, I propose that this style of patch is best suited to notated performance as opposed to improvisational settings, unlike the patch featured in *Boidsong*.

3.4 Contextualisation

Both *Creidhne* and *Boidsong* follow a similar dynamic and textural profile to *Industry*[9], one of Michael Gordon's most influential and my opinion greatest works. I think this comparison does well to place these two pieces of mine in both an aesthetic and developmental context. Within *Industry*, the level of distortion steadily increases, changing the timbral landscape with it. *Boidsong* is much the same in that the number of channels and effects at play increase throughout. I would contend that the greater integration of score and technology in *Industry,* however, yields far more musical results. The very particular, minimalist scoring approach creates a fascinating interplay between the changing level of distortion and the beating of harmonic dyads. While *Boidsong* might conceptually resemble *Industry* in some ways, the score is written to interact with the software in a more general fashion.

[9] Micheal Gordon, "Industry", Last accessed August 5, 2019, https://michaelgordonmusic.com/music/industry

Creidhne on the other hand, sees technology and score become intrinsically linked. While Gordon's score relies on technology to achieve the desired timbral effects, *Creidhne* is dependent on technology to realise its intended harmonic form. This technical distinction is one of many useful ways to better conceptualise the practice of transfunctionality. By definition a transfunctional piece will see an instrument perform a musical function it is not normally associated with. As a result, the music written for this EIS will tend to take advantage of these new functional roles. In other words, transfunctionality often sees technology facilitate unusual scoring techniques or arrangement styles. In this case, a solo trombone piece becomes primarily concerned with chordal arrangements and microtonal relationships. This conceptualisation is central to the aesthetic foundation of transfunctionality and further integration of technology into the instrument.

3.5 Further Reflection

Both of the EIS approaches featured in this chapter exhibit particular strengths and weaknesses that have informed my compositional work ever since. *Boidsong* directly lead to the musical pursuits detailed in the coming chapter, while *Creidhne* informed some of my decisions when later writing for string quartet. On a philosophical note, these two pieces raised important questions regarding the nature of transfunctional composition. From the earliest days of refining this process the first four tenets of my method were already identified and established. The remaining three concerning performative role, the use of natural sound and the need for musical control, were not yet solidified however. Their inclusion came only after a long process of trial and error regarding what approaches breed successful EIS and what live digital elements integrate best into the realm of the EIS.

This chapter has discussed two contrasting approaches to expanding instruments that share the same end goal. These solo arrangements aim to achieve transfunctionality via the functional role of a self-accompanying performance, a context the instruments concerned don't normally feature in. A number of judgements have been made regarding the validity or effectiveness of these transfunctional digital systems. In general, this grading process has been informed by assessing whether the changes made align with the notion of what an expanded instrument might be. To clarify, successful acoustic instruments tend be centred around human interactivity, live musical control, ergonomics and of course sound production. I aim for my EIS to adhere to this ethos.

Chapter 4 - Chordal Extension & Technological Variation in *Epochs*

4.1 Background

"The composer (organiser of sound) will be faced not only with the entire field of sound but also with the entire field of time. The 'frame' or fraction of a second, following established film technique, will probably be the basic unit in the measurement of time." - Cage[10]

Following on from early investigations like *Boidsong*, more simple and intuitive means of interaction between performer and patch were sought in a bid to better satisfy the philosophical criteria of transfunctional composition. It became clear that more tactile methods of musical control were more aligned with traditional notions of the 'instrument'. These ongoing technical concerns set the compositional process for a suite of works in motion and would later inform a multitude of musical decisions.

Epochs is a set of pieces composed for string instrumentation and 'audio freeze' technology. The pieces were conceived as a means of enabling an instrument such as the cello to provide its own chordal backing without altering its traditional construction or replacing the standard bow. Although double-stops are achievable on a cello, for example, sustained chords containing five or more notes are unachievable due to both the curvature of the instrument's bridge and traditional four string design. Overcoming these physical constraints would allow the cello to provide a new sort of musical functionality separate from its predominantly melodic role. If this instrument's chordal palette were no longer limited by the tight physical boundaries of fingerboard practicality and bowing considerations a new musical vocabulary could be introduced. The inspiration for the technical components that would facilitate this new vocabulary came from Kurt Rosenwinkel's live performance of *Stella by Starlight*[11]. Here, Rosenwinkel uses the EHX H.O.G. Pedal (Fig 4.) to perform an 'audio freeze' on various chord voicings leading to the creation of an unusual tone as well as a harmonic backdrop to solo over.

[10] Richard Kostelanetz, ***John Cage, An Anthology***, New York, 1968.

[11] "Kurt Rosenwinkel - Stella by Starlight - H.O.G. Improvisation" Last modified December 3, 2018. https://www.youtube.com/watch?v=THFJw0-0Y_Q

Figure 4:
EHX H.O.G. Pedal

'Audio freeze' is a digital audio effect which involves performing a Fast Fourier Transformation (FFT) on an incoming signal. This FFT serves as a kind of timbral approximation of the audio source. The particular spectral characteristics of the inputted signal are stored in a matrix and 'resynthesised' before being outputted to the speakers. The effect is often experienced as a hazy, static recreation of the source timbre that can be sustained indefinitely. Much of our experience of timbre is shaped by the dynamic envelope of a sound. Many of these aspects are not incorporated into an audio freeze. An audio freeze is often discussed in terms of 'frames' which are the minute moments of sound only experienced over extremely short divisions of time. Although not analogous to a freeze, a video frame shows a visual scene at a specific moment of time. If one was to examine a single frame of a subway train frozen in time it may not always be possible to tell which direction it is traveling or even if it is moving at all. Similarly, much of the tonal dynamism of an audio signal is lost once frozen. That isn't to say that this sound is bland, rather, it is audio freeze's timbre and particular practical uses that have led to it being selected for use.

To begin, it was necessary to identify the most practical means of achieving an audio freeze effect within the Max/MSP/Jitter environment. Jean-François Charles was quickly identified as one of the key contributors in this field. His paper A Tutorial on Spectral Sound Processing Using Max/MSP and Jitter (2008) outlines the exact process of creating an audio freeze in Max. The particular tonal qualities of the audio freeze Charles achieves can be said to be both smooth sounding and true to the source audio. These qualities can be attributed to the following innovation:
"A simple way to freeze a sound in real time is to resynthesize one spectral frame continuously. I improve the sound quality by freezing several frames at once and then resynthesizing the complete set of frames with the stochastic blurring technique..." [12]

[12] Jean-François Charles, "A Tutorial on Spectral Sound Processing Using Max/MSP and Jitter." ***Computer Music Journal 32, no. 3*** (2008): 87-102, Accessed August 10, 2017. http://www.jstor.org/stable/40072649.

Charles' paper describes a 'stochastic blurring technique' which not only allows for a more accurate recreation of the source audio, but also facilitates 'blurring' between one or more sets of audio frames. Each audio freeze is comprised of eight frames which in turn are blurred together with artificial, synthesised frames. As the system transitions from one frame to another, new frames are created which become increasingly likely to exhibit more spectral characteristics from the next 'real' audio frame. This quality gives Charles' method an added functionality which is crucial to the final sound of *Epochs*. Now, not only do the individual freezes sound tonally interesting, but each frozen tone can be gradually 'blurred' into the next providing a smooth, musical transition between different sets of audio frames. The audible result of this technical approach is a more complex, evolving tone that can be blended at different rates as it transitions from one timbre to the next.

With these capabilities now established, the challenge of creating frozen chords remained. Although there were many potential solutions available, a pitch shifting solution was selected in an attempt to emulate Rosenwinkel's performance rig. Now any note which is frozen is duplicated and pitch shifted in order to build a chord (Fig 5.). The [*gizmo~*] object became the method of choice within Max/MSP thanks to its ease of use as well as its timbral consistency. Other more complicated pitch shifting methods either presented latency problems or harsh timbres while [*gizmo~*] complimented audio freeze excellently, perhaps due to the unmistakably digital nature of both effects.

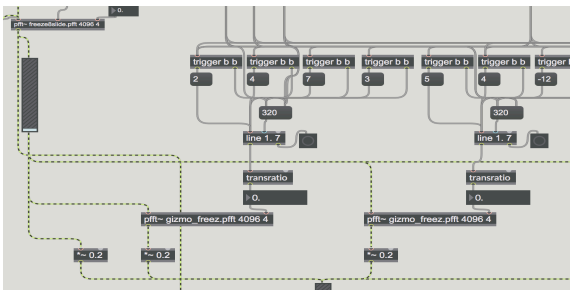

Figure 5:
Frozen signal is duplicated and pitch shifted

Finally, a method of controlling these pitch shifters in order to create different chord voices needed to be devised. Since a cellist's hands are often unavailable while pitches are being produced, a foot controller seemed the most appropriate means of enabling such control. Keith McMillen's 'Soft Step 2' (Fig 6.) is a versatile peripheral, which in this setting has been used to toggle the patch's various predetermined chords. A foot pedal seemed to be the most fundamental control surface to use at this phase of transition towards performer-controlled signal processing. As David Gamper says, improvised music necessitates a "minimal number of distractions caused by technical requirements. In order to have extensive choices when using this technology, one needs a clear, easily learned user interface.

Since most instrumentalists' hands are fully occupied with their instruments, their feet are often the most precise and expressive means of independently operating controllers."[13]

Figure 6:
Keith McMillen's Soft Step 2

4.2 Variations in software

In all, two different patch designs were created to accompany the three movements within *Epochs*. The first patch involves pitch-shifted chords and is used in the first two movements. The second patch uses multiple parallel freezes and accompanies the third movement.

The first patch (Fig. 7) created for this set of works was designed as a means of turning single notes into chords in order to emulate Kurt Rosenwinkel's performance. An audio signal from the cellist is captured by microphone and fed into the system. The performer uses the SoftStep to control freezes as dictated by the score. All buttons on the device trigger a freeze but a different chord is formed depending on which button in particular is pressed. The patch blends from each frozen timbre to the next at a rate which can be set by the performer via the user interface. In addition, the pitch shifters are programmed to gradually bend from one transposing interval to the next. Great care was taken to ensure that minimal amounts of change are needed for the system to transition from one chord to the next. For example, since many of the chords contain a fifth, one pitch shifter almost exclusively handles this interval. The sliding operation of the pitch shifters was incorporated as a means of masking the operation of the patch. Much in the way stochastic blurring masks the transition between freezes, the pitch shifters smoothen transitions between chords.

[13] Gamper, D. and Pauline Oliveros, "The Expanded Instrument System: New Developments and Implementations", ***Computer Music Journal, Spring 1998,*** (1998) 75-77, Accessed August 30, 2017, doi:10.2307/3681047.

After the frozen tone is duplicated and transposed according to the required intervals, the signals are recombined and processed via a common reverb. The particular qualities of this reverb can be adjusted via the user interface. Finally, the dry cello signal and wet chordal signals are recorded into separate channels of a buffer and combined before being outputted as a stereo mix.

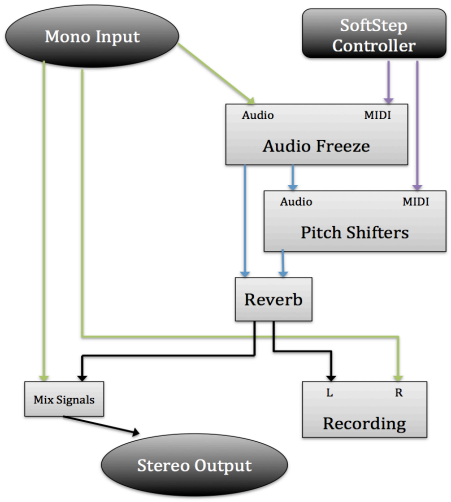

Figure 7:
First Patch Summary

In a bid to create a more flexible patch which wouldn't require separate programming for different musical settings, the idea of instantaneous chord production was discarded. Chords are built sequentially or note by note in this second patch. Instead of relying on a single matrix and pitch shifting, this patch allocates one freeze matrix to each foot switch. Now frozen notes are collected, overwritten and blurred within ten individually controlled signal chains. Essentially, pitch shifting is removed in favour of more freezing matrices. Although the patch ultimately demands higher CPU usage and doesn't provide an instant chordal backdrop, it does facilitate the juxtaposition of varying timbres, a wider number of chords and dynamic variations between chordal notes. Ultimately this patch is more flexible and widely applicable moving forward.

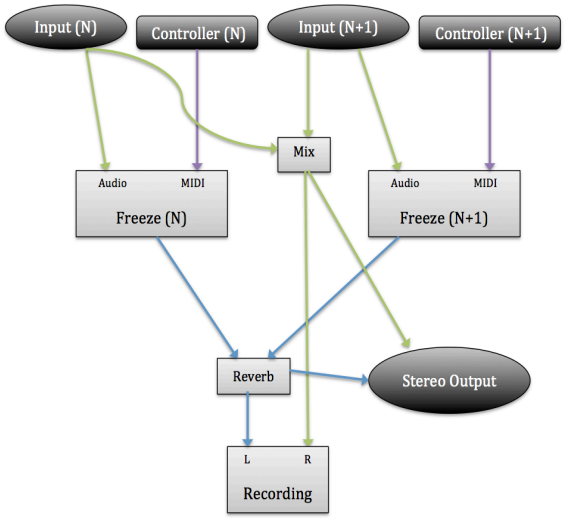

Figure 8:
Second Patch Summary

This process of revising and repurposing software strategies is central to transfunctionality's development. Although most of my compositional inspiration is derived from musical concerns and considerations, this technical exploration can provide impetus also. In this context, there is a definite interplay between musical concerns and technical design choices. A musical goal informed my initial patch design and a technical critique of this patch led to the formation of a new design. This design in turn gave rise to a new musical opportunity. Within the *Epochs* suite, the two freezer patches' musical applications are explored in a linear and logical fashion. Each movement marks a new compositional exploration.

4.3 First Movement

The first movement of *Epochs* highlights the timbral characteristics of the first Max patch. Ideally, this exposition of the patch's basic function and tonal output would serve to familiarize the listener with the capabilities and mechanics of the technology. If experienced visually, the causal relationship between the foot controller and tonal output is intended to become both apparent and perhaps even rewarding to an audience. The score denotes a series of pitches to be provided to the software by the performer with an increasing range of timbral variety (Fig. 9). The harmonic progression presented by this sequence of notes and button presses has a simple structure of fundamental intervalic jumps. In addition, many of the notes selected are easily available as harmonics on string instruments.

In all, only two chord voicings are used throughout the movement. Although these chords are within a similar register and are closely related, in the context of the piece they may seem like two very distinct worlds. In spite of the fact that transitioning between the two chords is achieved via semitonal movement, one is built upon thirds while the other is more quartal in nature. This allows for maximum contrast with minimal movement.

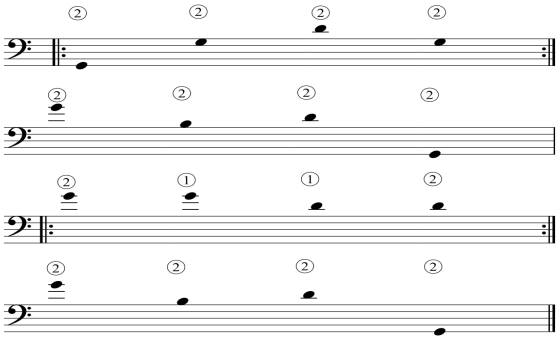

Figure 9:
Simple outline of pitches/ foot controls

In order to execute this performance as intended, the instrumentalist is invited to utilize a wide range of playing techniques that will in turn highlight tonally different spectral frames. For example, a frozen harmonic yields a glassy, focused sound while a roughly bowed open string can be reminiscent of a tremolo string section. Due to the huge variety of spectral frames contained within a single bowing of a string, no two performances of *Epochs* can be exactly alike. A major contributing factor to this variance is the relatively inaccurate timing of a human performer on a frame-to-frame scale. As a result, the actual timbre obtained from an audio freeze can sometimes be different from the intended timbre. The changeable nature of this performance setting requires a confident and resourceful musician.

4.4 Second Movement

The initial aesthetic which brought about the genesis of the original patch comes to fruition in the second movement. Simply put, this movement revolves around a chord progression and features melodic passages which are to be played over sustained chords, much like Rosenwinkel's performance. In reality, it differs from that performance since only single notes are provided by the performer and all chords are predetermined within the patch. Additionally, the stochastic blurring of multiple frames yields a more changeable timbre than the EHX Hog pedal. This technical advantage is reflected in the score via the varying treatment of the notes selected for freezing.

The transferral of these new abilities to the cello was not without its disadvantages, however. Firstly, the number of chord voicings available to me was limited by the number of foot controls available to the performer. Also, since these chords are synthesised from a single note, options are further limited. Pitch shifting downwards produces unappealing timbres which I aimed to avoid, with only strict exceptions. This stifled my melodic writing greatly since I was required to produce the lowest note of each upcoming chord during the sounding of its predecessor. This constraint meant that pre-emptive notes would frequently render my chordal progression either predictable or uneasy.

Nonetheless, I endeavoured to include as much harmonic content as possible. A careful preparation of chord voicings and structure led to the eventual progression which features all 12 pitches. As a result, I believe the second movement achieves its goal in serving as a technical exhibition of my initial transfunctional goal. Ultimately, the rigidity of my EIS patches up to this point was still a matter of concern for me.

4.5 Third Movement

The third movement was scored as a slow, thoughtful exploration of many fundamental intervals. As a musician I've always been predisposed to examining music in this intervallic way. Much of the piece involves comparing and contrasting different intervals over static drones and pedals. Although many of the melodic and harmonic jumps are quite straightforward, the less predictable musical moments are often arrived upon by whole-tone steps or transpositions. The opening of the B section clearly exhibits this technique and was inspired by a similar motive from the verse section of the jazz group Hiatus Kaiyote's *Mobius Streak*.[14] I was struck by the ambiguous nature of this particular suspension and the vocalist's ability to pair it with such a wide array of pitches throughout the piece. I thought this would be a good starting point that would inspire me to create an interesting sequence of chord tones.

Although the piece appears predominantly as a stream of individual notes, the duration of certain pitches is greatly extended through audio freeze. The score has been designed so that frozen tones are not silenced or turned off but rather overwritten. For example, a note stored in button six's matrix is sounded until it is replaced by a new note. This feature served as both a creatively challenging and guiding force during the composition of this piece. I didn't consider this stipulation to be creative hindrance, but rather a unique opportunity to write for a new instrument with unique scoring considerations. Much of the tension and release within the movement is created as direct result of transitions between chords and sections happening one note at a time.

[14] ***Mobius Streak,*** performed by Hiatus Kaiyote (2012, Sony Music Entertainment Inc.), CD/Vinyl/Digital.

4.6 Contextualisation

The EIS created for *Epochs* represents just one of the many technological methods that soloists can use to provide harmonic accompaniment to their performances. Rob Bentall's *Music for Nyckelharpa and Electronics*[15] demonstrates a wide array of the most common techniques for addressing the same compositional challenge as *Epochs*. Both pieces use the solo acoustic instrument as their sole source of input audio but achieve their goal in very different ways. Bentall's piece uses sampling, loops and granular synthesis techniques in combination to build its dense and unique textures. In my opinion, both strategies deliver a distinct set of advantages and disadvantages that must be considered when planning future EIS.

Firstly, the EIS from *Epochs 1/2* allows for more instantaneous harmonic movement than Bentall's piece which generally doesn't stray from its key centre. The patch from *Epochs 3* shares this shortfall but with significantly less set-up time required. These differences stem from a difference in technical approach. Since Bentall's patch replays musical moments, the harmonic backdrop that is created retains all of the dynamic, pitch and timbral characteristics of the originally played material. The comparatively homogenous characteristics of an audio freeze are offset by the timbre's distinct yet well blended sound in comparison to the source audio. Frozen sounds also respond well to pitch alteration since they are synthetic and as a consequence can germinate large amounts of material from small amounts of input. Choosing between these techniques depends on the musical intentions of the composer. Ultimately, the speed and smooth operation of audio freeze delivers transfunctional properties in a manner which aligns best with my compositional aesthetic.

4.7 Further Reflection

The patches created for *Epochs* allow an acoustic cellist to perform chordal pieces in self accompanying style that cannot be recreated in the absence of technology. It can be argued that this technological peripheral adds dual transfunctional properties. When paired with this EIS, the cello (or similar string instrument) gains harmonic and timbral functions it normally cannot attain. The extended cello can output sustained chords of any voicing or provide multiple layers of semi-static timbres to a soundscape.

[15] Rob Bentall, Music for Nyckelharpa and Electronics, Last accessed: August 5, 2019, https://robbentall.bandcamp.com/track/music-for-nyckelharpa-and-electronics

Audio freeze has a myriad of potential musical applications which have been partly explored within the context of *Epochs*. This repurposing of DSP techniques and EIS patches may be the most crucial facilitator of transfunctionality as a compositional approach in the long run. The compositions within my portfolio follow a clear path of conception, permutation and refinement. While audio freeze is featured again within this portfolio, other patches and techniques appear only once. Despite this, it must be highlighted that every work featured in this study is slated for alteration and further development with the creation of new works.

Chapter 5 - Playability & Functional Change in *Glyph* & *Perpetua*

5.1 Background

Having identified playability and musical control as key areas for further development and having had success in creating a versatile EIS for string instruments, I turned towards my own instrumental base for inspiration. I considered percussion to be particularly suited to the transfunctional method given the complexity of timbre produced by non-pitched instruments in addition to the more limited catalogue of solo percussion pieces found in the Western Art tradition. In my experience, complex source audio can facilitate digital signal processing in achieving a wider array of sonic outcomes. In this chapter, I will detail how a long process of experimentation led to a period of less fulfilling work before yielding arguably my most significant piece to date.

Early on in my investigation I was directed towards The Augmented Drum Kit[16] and some of the Max objects most often associated with percussion. The Augmented Drum Kit sees an acoustic drum performance married to digital synthesis.

"Various types of microphones are mounted around the instrument, feeding live audio and control data to bespoke software programmed in Max/MSP. The produced electronic sound and lights are controlled, shaped and directed in real-time through the physical gestures performed on the acoustic instrument, which now also becomes their control interface."[17]

This piece is clearly outside the bounds of transfunctional composition since the acoustic sound of the drum kit is not used as primary sonic material, but rather as a means of controlling a separate chain of synthesis. What was most appealing about this piece was the non-intrusive technology that didn't alter the form of the instrument. At this time, I had experience in working with the transfunctional method and had come to solidify the fourth stipulation of transfunctionality that addresses this consideration. Although the approach to tracking a drum performance highlighted by Sensory Percussion[18] was compelling, it was expensive, difficult to attain at the time and required the use of electronic triggers. I decided since I was now more limited in terms of harmonic and melodic writing in this context I would repurpose every measurable aspect of a drum performance in an attempt to attain a new functional role for the instrument.

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[16] Christos Michalakos, "The Augmented Drum Kit - Frrriction EP", Accessed September 27, 2018, https://cycling74.com/projects/the-augmented-drum-kit-frrriction-ep

[17] Christos Michalakos, "Christos Michalakos | Augmented Drum Kit | Trrraction", Last modified December 3, 2018, https://www.youtube.com/watch?v=FyjGaMLtT1Y

[18] Sunhouse, "Discovering Sensory Percussion", Last modified December 3, 2018.

[*bonk~*][19] is the Max external most commonly associated with percussive performance. Ostensibly, this object detects incoming attacks and outputs associated numerical data, but the mathematics involved in identifying these attacks creates some interesting by-products. In addition to recognising increases in signal intensities, [*bonk~*] also conducts spectral analysis that discerns much about the timbre of a signal. All manner of information concerning 'brightness, frequency bands, attack time'[20] is parsed, all while being compared to predetermined timbral profiles. In this way, [*bonk~*] can be used to differentiate between different elements of a percussion set and accordingly trigger events within a software environment. This surplus of information would lead to my first attempt at percussive transfunctionality.

5.2 *Glyph*

While devising my first piece I had two goals in mind; to transform the timbral output of a drum performance and to redefine the performer's interaction with the various surfaces of the kit. I foresaw the former of these to be the most challenging and rewarding aspects of this process. As a result, I spent months testing numerous combinations of software and percussive audio. I uncovered delays, feedback systems, audio freezers, playback scrubbers and signal degraders. Once I had chosen the best of these, I threaded them together into a single patch. Then, I set about mapping and scaling the information outputted by [*bonk~*] so that it might control these transformative forms of DSP. I devised a system of codes which would trigger changes in the patch's processing. These codes correlated to combinations and sequences of various elements from the drum kit. Other factors like loudness, rates of change and spectral brightness would help finely tune parameters. The result was a performance entitled *Glyph* which was named in light of the code-based thinking that inspired its creation. After a long period of testing and iteration I sat down to perform this piece. I started by feeding the patch some straightforward drum patterns to work with before setting the processing in motion. Once that had begun, I provided a slew of predetermined combinations and varied timbres. I repeated this process once more on a different setting before stopping, after which the patch continued to sound. It was at this moment I realised that this composition was unfit for performance. Even though I had designed the entire patch, I felt disconnected from its workings. If that was the case, how could anyone else be expected to do much more? To me it seemed that any set of input data could be substituted for my performance with little consequence.

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[19] Miller Puckette, "64-bit versions of sigmund~, fiddle~ and bonk~", Last modified December 3, 2018.

[20] **Computer Music Design**, "Bonk: More than attack detection - Part 1", Last modified December 3, 2018, http://www.computermusicdesign.com/category/maxmsp/objects-in-depth/

This perceived disconnect can be explained by this patch being insufficiently 'instrument-like' to be considered an effective EIS. In other words, the physical and musical connections created by the design are unintuitive and overly abstract. In addition, many of the physical actions demanded of the performance carry two or more, sometimes conceptually dissonant, functions. For example, a simple strike of the snare drum may at one point or another contribute to a sequence or code that triggers an event, while simultaneously decreasing spectral brightness and thus affect the freezing section of the patch. This excludes the major significance of creating an acoustic sound in the first place. Ultimately, the heightened significance attributed to every sonic utterance does little more than overload one's musical mind. Almost paradoxically, the system also seemed to operate without much prompt from the performer which only added to my frustration.

This work was in my opinion a failure, but had a lasting effect on my compositional outlook as well as my transfunctional approach and methodology. I realised that any software I was to create would ideally feel like an instrument in its design. Good software should work in tandem with its acoustic instrument, interfacing with the essence of both the sound and performance, not trying to repurpose it. It was clear to me that I could spend time reworking and redesigning my patch in order to have it respond as I would like, but I predicted that I would continue to fall short of my transfunctional goals. I set *Glyph* aside as a reusable method for working with non-specific audio before returning to the basics in my next attempt at percussive transfunctionality.

5.3 *Perpetua*

During my aforementioned hunt for unusual DSP combinations I began exploring the unique delay possibilities offered by the [*gen*~] object. Gregory Taylor's[21] article on ringing delays provided me with a framework for creating complex timbres which could be tuned precisely.

Since the gen~ object gives us access to audio on a per-sample basis – and thus lets us set feedback loops that are tighter than the signal-vector variety that MSP provides, there's a lot of room for creating new sounds. - Gregory Taylor[22]

[21] Gregory Taylor, "gen~: The Garden of Earthly Delays", Last modified December 3, 2018, https://cycling74.com/tutorials/gen-tutorial-1-the-garden-of-earthly-delays

[22] Gregory Taylor, "gen~: The Garden of Earthly Delays"

Initially this technique was integrated into *Glyph*'s patch, but it was removed early on because of its dense and overpowering output. Once that project was abandoned I returned to the ringing delay, and with some minor alterations and post-processing it would eventually form the basis of the patch for *Perpetua* (Fig. 10). The patch uses sample-by-sample delay structures available within [*gen*~] to create an intricate system of feedback loops. The nature of the feedback and interpolation between samples can be varied to alter both the timbre and pitch of the resulting feedback.

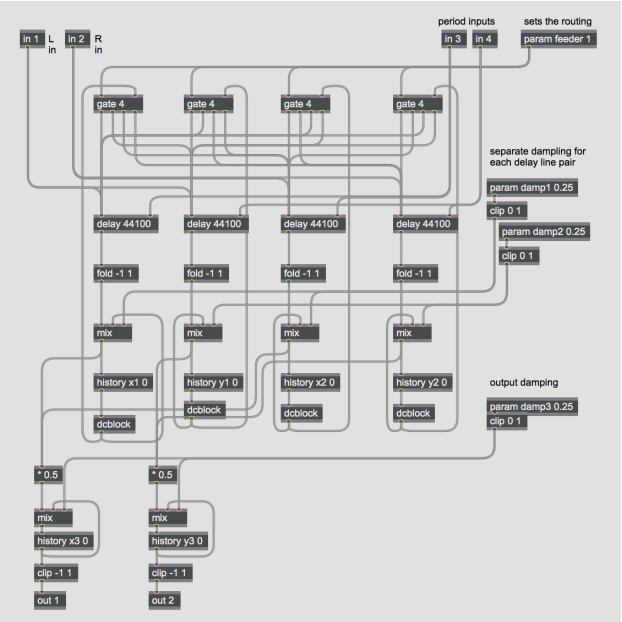

Figure 10:
The gen~ subpatch is a refined version of Taylor's.

It became apparent to me at an early stage that this effect was best paired with the already sonorous ring of cymbals. The outcome of this pairing could be classified as a drone. Depending on the cymbals used and the input parameters affecting the feedback loops, a myriad of distinct droning sonorities can be obtained. Over time I would refine which combinations worked best together while using the fewest cymbals. The final version of the piece features two individually miked cymbals played with mallets and four distinctly tuned drone subpatches. Mallets are used to extract the timbre of the cymbals without creating large dynamic spikes that would lower the level of nuance in the performance. Every one of the four drones were designed to work well with both cymbals, but more specifically, Drones 1 & 3 match the 20-inch cymbal best while Drones 2 & 4 match the 17-inch cymbal best.

Performing with this EIS is particularly enjoyable. Since feedback is the primary method of sound generation, the patch incorporates a huge spectrum of variance and sensitivity meaning performances are never identical. Changes in timbre are created very gradually over time as new material is assimilated into the feedback loop. The musical consequence of this is that the rhythmic structure and tempo of the cymbal performance directly affects the texture of the drone's sound. In addition, moving around the playing surface of the cymbal creates varied pitch material which in turn effects the tone and resonances of the feedback loops. This relationship is quickly apparent to the player and encourages a precisely controlled interplay between the fluctuating inharmonicity of bronze cymbals and the unruly resonance of ringing feedback loops. It is these perceivable connections and simple design choices that facilitate music creation above variety of sound output.

The changeable nature of this performance environment does not lend itself to a rigid score. Early on, I was unsure what structure the final piece would take. I found that my music had increasingly become texturally focused over time and was advised to adopt a more 'Eastern' approach to the structural development of the work. Accordingly, I took cues from the music of La Monte Young[23] and his contemporaries. The resultant score took a more generalist approach, dictating aspects of texture, form as well as theme & variations. This outlook bears similarities to the tradition of 'raga' music from the Indian Classical Tradition and the sections were titled accordingly. In all, the piece is roughly 50 minutes in duration, explores a range of rhythmic themes, cymbal and drone combinations and can be subdivided into four separate stages or 'ragas'. I believe Perpetua's close adherence to the transfunctional method and ambitious structure places it among the most essential works within this entire study.

5.4 Contextualisation

The subject of ‘meaningful control’ is a central consideration that directs many of the musical decisions made during the course of this study. In the context of this chapter, it led to a complete reconsideration of the overall approach to the EIS for percussion. Designing EIS is a unique challenge since there is always the opportunity to create sound or have live musical decisions made without the need for user input. Electronic sound can be self-propelled, predetermined or sometimes controlled to a misleading extent. The debate surrounding the amount of performance intervention that electronic musicians exercise in general is not one that interests me personally. I am however keenly interested in the manner in which performance is handled by electronic musicians and how musical events are communicated and shared with the audience.

[23] Young, La Monte, "The Tortoise, His Dreams and Journeys, by La Monte Young", Last Accessed December 3, 2018, https://www.youtube.com/watch?v=Km0LKiGs_8g

In the case of *Glyph,* I was unhappy with the link between sound and performative action. I have found that some audiences expect there to be a certain degree of speciousness between musical action and resultant sound. Sometimes, the opposite effect can be achieved, whereby simple on/off playback cuing can masquerade as generative musical gestures[24]. *Perpetua* is a difficult piece to perform live simply because of the way in which it operates. There are several measures I could've taken to remove these challenges through the use of limiters, automated mixing and sampling methods, but I am happy with the clear sound to action relationship and associated performance challenges.

5.5 Further Reflection

Converting the established functional roles of an instrument is a delicate undertaking. Musical control of software should be achieved by ergonomic means akin to the craft of instrument design. Playability must be considered during the development process to ensure that the link between the physical act of performance and the eventual musical intention is tangible rather than esoteric.

Glyph was unlikely to succeed since it closely followed the framework of a non-transfunctional piece. This chapter has detailed how the sonic augmentation or repurposing of a performance doesn't necessarily constitute transfunctionality. Perpetua, on the other hand, acts as a rare demonstration of the potential for seamless functional change via simple DSP systems.

Mapping physical actions to musical events is a fine art. Following this study of percussive transfunctionality, research time was devoted to other, more palpable links between performative action and musical control.

[24] Sewon Jung, "Live Performance for Video Tracking with Max/MSP & Jitter", Last accessed August 5, 2019, https://www.youtube.com/watch?v=BWf_sy87qNI

Chapter 6 - Ergonomics & Movement in *Arianna*

6.1 Background

Throughout this study, I have consistently investigated the ergonomics of EIS to facilitate their inclusion into common performance practice. Furthermore, my working definition of 'instrument' has revolved around the performer's meaningful interaction with musical parameters. In many of the most successful pieces cited up to this point, this interaction has involved a physical action akin to an instrumental technique. This intrinsic link was not lost on me and became my primary focus during the relatively lengthy period of time associated with the creation of this chapter's piece. My immediate technical challenge was to dissect and quantify aspects of movement in order to link physical action and musical change within the software realm. Although I identified a number of possible means for achieving this, the 'Microsoft Kinect' (Fig. 11) seemed the most practical, versatile and affordable.

Figure 11:
Microsoft Kinect Camera Array

Through the aid of software, the Kinect is able to locate the human body amidst its surroundings and track primary joints and appendages as they move through space in three dimensions. It became clear to me from earlier experiments that this coarser method of motion tracking would have the widest application across my entire compositional practice. At the very least, by incorporating the Kinect into a performance I would have access to more performer input data than before by an order of magnitude. The particular nature of this hypothetical performance was at this time still unsettled, yet experimentation would allow its form to be conceived of very naturally.

Another crucial benefit of the Kinect was its status as a mass manufactured technology. This made it both widely available and well supported by hackers and innovators in the online technology community. This allowed me to use existing software while getting acquainted with the Kinect's tracking abilities. Firstly, *Synapse*[25] was chosen as the preferred software for decoding and interfacing with the information relayed by the Kinect's camera array. The Max tool *Kinect via Synapse*[26] then became my means of unpacking this data for use in the DSP environment.
At this stage I was able to begin devising a performance built around motion tracking. It was apparent almost immediately that composing for vocals would afford me the widest variety of movement options while still providing an interesting audio signal for use with DSP.

In an attempt to keep my research focused on the sonic aspect of my musical practice, I then began designing patches for use with vocal performance. I devised a number of vocal effects setups that could have data from the Kinect 'plugged in' to them. My most thoroughly planned system used pitch shifting to map gestures or body positions to pitch transpositions and chords. After presenting this performance outline to my supervisor my oversight became clear; the choreography that would accompany this system was not of the right standard. In short, the link between Theremin-like arm movements and pitch transposition might create far too patent a connection between movement and transposition. Even referring to the movements within a piece as 'choreography' was not consistent with my thought process at this stage. Although I had sought to incorporate movement into the realm of the vocal 'instrument' I hadn't yet fully conceptualised this new arrangement. Now that I was composing for both vocals and movement, I would have to become cognisant of good writing practice in both of these dimensions. This realisation led me to better familiarise myself with the arts involving body language and movement. Composing for my newly devised 'instrument' also required an improvement in my ability to create non-standard, prescriptive scores. Ultimately, my new approach would have to balance elements of technology, sound, choreography and composition in ways totally foreign to me. This experiment may have lasting effects on my compositional philosophy and the realm of transfunctionality in general.

[25] "Synapse for Kinect", Last Modified November 28, 2017, http://synapsekinect.tumblr.com/post/6305020721/download
[26] JP Belladonna, "Kinect via Synapse Max Interface", Last Modified November 28, 2017, https://cycling74.com/tools/kinect-via-synapse-max-interface/

6.2 *Arianna*

The piece that would eventually be named *Arianna* was devised in response to a list of compositional considerations. Since I had already earmarked several forms of DSP for use with vocal performances, I was primarily concerned with the route the accompanying choreography would take. My earlier attempts were marred by overt, almost ostentatious movements that would detract from the performance as a whole. These movements were a direct result of the need for diverse sets of input data when controlling musical parameters. I found that understated body movements were difficult to measure and map effectively to musical controls. On the other hand, I was struggling to wield these wilder gestures artistically given my inexperience with arranging for movement. Providing sonic material that could contextualise these brash movements was an equally insurmountable task at first. At this point, my search for comparable art practices to this combination of sound and choreography paid dividends. I turned to operatic practice in the form of Claudio Monteverdi's *Lamento d'Arianna*[27] as a point of inspiration. This piece is one of my favourites from the operatic canon and provided me with a template of a musical and choreographed scene meeting on equal terms. Anna Caterina Antonacci's[28] performance demonstrates a wide range of movements suitable for musical control, combined with a musical performance that is integrated into the context of the scene. This approach led to envisage a programmatic piece in which both vocal performance and movement were intrinsically linked by meaning and context.

With this goal in mind I set about creating a tribute to Monteverdi's work by reimagining the setting of this scene through the EIS. In this newest version, technology, song and movement would meet to programmatically depict the libretto of *Lamento d'Arianna*.[29] To begin, I dissected the text into five distinct sections, each serving as a portrayal of a different emotion. I designated different DSP techniques to each of the sections respectively. This provided a programmatic link between technology and the text it was designed to enhance. I believe this transparent link between technique and the portrayal of emotion could be problematic in other contexts but given the ostentatious pantomime that opera can sometimes be, it serves a purpose here. Once this process was complete, I began to prescribe each of these sections with specific sets of choreography. By keeping the gestures and body positions within each section distinct, I could design code that would apply different sets of DSP techniques depending on which of the five positions was assumed during a performance. Once this had been established, I could map subtler movements of single body parts to parameter control. This hierarchical classification of movements facilitated the use of a wide range of DSP techniques without the need for increasingly convoluted control schemes.

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[27] Claudio Monteverdi, "Lamento d'Arianna Score", Last modified December 3, 2018, http://www2.cpdl.org/wiki/index.php/Lamento_d%27Arianna_(Claudio_Monteverdi)

[28] Anna Caterina Antonacci, "Anna Caterina Antonacci - "Lasciatemi morire", Lamento d'Arianna (Amsterdam 2007)", Last modified December 3, 2018, https://www.youtube.com/watch?v=LARI9cIub1k

[29] Monteverdi, "Lamento d'Arianna Score"

This careful design process allowed for the software to serve the musical goals in a more natural manner. Since each section of the piece had distinct choreography, many audio-related changes could be made in the background without sacrificing performance visuals. These changes would in turn facilitate simpler parameter mappings that could be masked behind natural, programmatic movements. I carried this pursuit of natural EIS integration into my scoring approach. After the technical introduction, I make no explicit reference to the software that operates throughout the piece. I wanted my score to be as intuitively interpreted as possible given the large number of forces at play. Each page corresponds to one of the five aforementioned DSP/ text-based sections. The score is meant to graphically set the choreography of each scene, display the associated libretto and communicate an emotion upon which melodic interpretation will be based. The score is designed to resemble a handwritten diary or note, perhaps one the titular character could have penned herself.

The first page displays the libretto in a font chosen for its emulation of handwriting. The text was superimposed over an irregularly curved line to add to this effect. Staff notation featuring a melodic excerpt from Monteverdi's earliest published score is included and altered. The range of movements to be used to control effects parameters is communicated through three full body portraits. The distressed tone of the second section is portrayed through dispersed bodies of text and illegible notation. The third uses portraits and alterations to the text to communicate wrathful exclamations. The final two pages rely on simulated teardrops and blood-spatter to communicate themes in an equally efficient manner. I believe that the accompanying EIS needs only general performative directions on my part. Since I value the performer's interpretation of my composition above all else in this context I wanted my score to mirror this. Arianna's score could be classed as an interpretive score, but I would argue that it is very particular in its communication of this piece's key elements. Often, I find standard music notation to be an unsatisfactory representation of my music's eventual sonic goal and by extension, my performative vision. This score affirmed the continued incorporation of graphic elements into my compositional documentation.

6.3 Contextualisation

In my opinion, there is no greater realisation of the potential that voice with electronics than the music of Pamela Z. Her level of performance and innovation was not something I thought I could achieve, especially within the short amount of time that I could commit to the vocal study within this project. Her ability to perform and improvise with complex musical devices in live settings is remarkable and not something I could realistically expect to find in a musician on short notice since it takes years to acquire these skills. In addition, her gesture-tracking devices are mostly bespoke and designed over years of testing with very able engineers[30].

Having said that, being exposed to Pamela's work inspired my approach to this vocal study. I was greatly influenced by her operatic delivery, use of effects and the relationship between voice, gesture and performance. I deliberately strayed from the precise and intricate movements Pamela uses in her music, favouring the more accessible movements of a staged scene. The Kinect was the most obvious, affordable and attainable method of tracking a performers movement through space. This change in aesthetic is also felt in the sonic world of *Arianna* as it features more concrete and literal musical vocabulary, as opposed to Z's often ethereal or metaphorical displays.

6.4 Further Reflection

Arianna is a particularly illustrative example of many facets of my compositional development. My music for solo performers often involves a convergence of numerous creative factors. *Arianna* demonstrates how something viewed as a 'performative enhancement' is often better utilised as a musical element requiring compositional consideration and even inspiring compositional development itself.

The performance itself wasn't best communicated through standard notation, with an emphasis instead placed on interaction, experimentation and interpretation. When designing EIS pieces for unknown performers, it can be unrealistic for the composer to expect to dictate every aspect of a piece for an essential new instrument. Without a catalogue of musical context to reference, it can be close to impossible to communicate precisely how to perform on a new EIS through paper alone. This admission is necessary at times and can serve to direct me towards the true priorities of a transfunctional score.

[30] Pamela Z "Pamela Z: Memory Trace | New Frequencies | YBCA", Last accessed: August 5, 2019, https://www.youtube.com/watch?v=ntSPtFQdyBA

Lastly, the incorporation of movement tracking into my repertoire will allow for the design of a myriad of nonintrusive performance peripherals in future works. As I accumulate techniques regarding the use of motion tracking and similar technologies, I can begin to improve the ergonomics of my EIS while also reducing the amount of equipment needed for large scale or ensemble works.

Considering factors such as ergonomics and intuitive performance systems is an essential skill when writing transfunctional music. There are, however, many more potential contributing factors for consideration if one wishes to write such music and have it adopted by the existing players and curators of similar musics. Perhaps none are more crucial than the matter of 'practicality'.

Chapter 7 - The Practicality of a Transfunctional Ensemble

7.1 Background

For a composer who works with both technology and acoustic instruments, 'practicality' is a concept that majorly informs my decision making. Many aspects of the compositional process are directed by the constraints imposed by outside forces. For example, whenever I compose a piece of music with the goal of having it performed, I must consider the real-world opportunities that are available to me. Although I might like to create a piece for 500 bassoons and 500 VR headsets, the task of assembling the necessary musicians, equipment, venue and funds would obviously be monumental. Hyperbole aside, there is a challenge associated with locating a suitable combination of performer and transfunctional technology, even for a solo performance. I have found that this challenge rises exponentially in difficulty as more musicians are added to a performance. As a result, writing for ensembles can require creative solutions for coping with personnel and settings that may not be receptive to technology. Incorporating EIS into ensemble situations is a relatively niche pursuit which will often require certain musical compromises. This chapter explores two ensemble projects that required very contrasting compositional approaches. Although both pieces adopt a textural focus, the means by which their soundscapes are realised differ greatly.

Throughout this thesis I have detailed an ever-changing approach towards scoring my compositions that is deferential to the relationship between performer and EIS. As I have become increasingly savvy to the factors that inform my scoring approach, I can more readily identify the primary performance elements that must be communicated in order for my vision to be achieved with each new composition. How coarse or fine my performance instructions are may vary depending on the context. As I create a piece, I am cognisant of two categories of compositional techniques that I dub 'microtechniques' and 'macrotechniques'. This mental framework allows me to take stock of the acoustic and technological tools that I will need to achieve my goals. 'Microtechniques' are the precise performance elements that take place over short durations of time and require explicit forms of notation. 'Macrotechniques' are those which can be described in more imprecise and abstract terms. Although certain musical elements often fall into one category more often than not, it would be inaccurate to describe these two concepts in more certain terms as they are changeable depending on the musical context. Since transfunctionality can feature scoring directions aimed at both acoustic instruments and interactive technology, it is not often possible or even necessary to incorporate every minute detail of a performance into the associated score. In this chapter, I will detail how the overarching theme of practicality directly influences my music, its associated techniques and scoring methods.

7.2 *Hō-ō*

Hō-ō was composed for a two-day recording session with the Scarlett String Quartet. Since the piece would be recorded in such a short period of time with limited rehearsal, I had to work with very clear constraints in place. Most of the musicians I was working with weren't versed in more modern technological practices, so I decided to employ microtechniques within the score, leaving the software to perform transformative work without any prompts. This situation is typical of many ensemble settings in my experience. Limiting the number of technical elements in a piece like this facilitates its live performance. Often, individual controllers or even instrument-specific microphones are not used in live settings, especially with groups larger than a quartet. My solution to this was to create software that would use DSP techniques that were compatible with all recording methods. The sonic inspiration for this piece was the traditional Japanese court music known as 'gagaku'.[31] I wanted to simulate the large, cacophonous textures of gagaku with a much smaller group and thus achieve a form of transfunctionality. I called upon several techniques from early works within this portfolio to achieve the necessary timbral and textural transformations. The patch alters audio of the whole ensemble to increasingly layer and enhance the textures. Only a single microphone and stereo speakers are needed for a live production while the various forms of DSP are synchronised with timings on the score in a similar fashion to *Creidhne*.

'*Hō-ō* ', roughly translates from Japanese as 'phoenix', which was the inspiration for the design of the shō (Fig. 12). This traditional instrument has a fascinating timbre which I emulate firstly through orchestration by using chord voicings found on the instrument itself. I then employ extended techniques and specific directions to further mimic the natural resonance and vibrato of a shō performance. These shō chords serve as an introduction to the work and are later used to create overlapping frozen textures, akin to *Epochs*, which accompany the gagaku section. Since it is not possible to create sufficiently dense textures with four instruments to rival an entire court ensemble, a revised looping system using Rodrigo Constanzo's [*karma~*][32]was devised. Much like *Creidhne*, this layering system recalls early material to accompany the live sound. [*karma~*] however, blends the start and endpoint of each looped section making it much more suitable for a more general, non-timed application. The reuse and repurposing of material by the patch was an attempt to capture the regenerating properties of the phoenix from Eastern mythology. I was mindful of how best to represent gagaku on the page without separating it from its performative essence. I employed scoring techniques where rhythmic content is loosely described in favour of more accurate pitch tracking. I also felt that this method of scoring visually represented gagaku more precisely.

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[31] JVC, "Gagaku | Court Music of Japan [1981, Full Album]", Last accessed December 3, 2018, https://www.youtube.com/watch?v=nQU8AdluxtI
[32] Rodrigo Constanzo,,"karma~" Last accessed December 3, 2018, http://www.rodrigoconstanzo.com/2015/05/karma/

Figure 12:
The shō features dummy pipes to mimic the shape of wings

The compositional direction of *Hō-ō* was informed by a very common set of performance parameters, a string quartet who work best with precise scoring techniques, limited technical intrusion and a short timeframe. Since my use of EIS interfacing was essentially confined to a microphone, I had to be certain that specific events would align with specific DSP techniques. I did this through careful planning while varying techniques, textures and density throughout the timed score. I do foresee more accommodating circumstances for my music arising in the future. Even so, this piece has served as a crucial exercise in creative problem solving. Within this portfolio, *Hō-ō* serves as technological counterpoint to the piece entitled *'The Gate'*.

7.3 *The Gate*

Following my work with vocals and Kinect, I was intent on exploring EIS & choir combinations. I was immediately drawn towards spatialisation since choirs tend to inhabit large performance spaces. I was also greatly influenced by my own preconceptions concerning what ramifications writing for a 'choir' would have on my use of technology. Consequentially I composed *Alba Rosa*, a piece of choir music suited to octophonic panning that was notated traditionally, keeping all use of technology firmly in the background. The spatial element of this composition was almost an addendum to the performance of the piece within the score. If I were to rework this composition with fewer time constraints I would put the spatial control in the hands of the singers to create a truly transfunctional piece, but as it stands this work's EIS is not exactly satisfactory. My preconceptions regarding contemporary choir culture and a lack of opportunities led me to create this piece as a proof of concept for possible transfunctionality within choir writing. Thankfully while visiting Belfast as part of my Utrecht Network Young Researchers Scholarship I encountered a group known as HIVE, based at the Sonic Arts Research Centre, Queen's University Belfast. When I presented *Alba Rosa* to the HIVE choir I was surprised by their response to say the least. They weren't accustomed to working with standard notation and were hoping for a piece that incorporated more of my technical flair. I obliged them in my second effort entitled: *The Gate*.

Since HIVE is based in SARC, my plans were not limited by equipment shortages. *The Gate* directly contrasts *Hō-ō* in its dispersal of micro/macrotechniques. HIVE don't work with traditional notation, so I was limited in what I could communicate through a score and in an unusual position regarding the adoption of technology. This led to an approach which handed transfunctional control over to the individual performers while the score was left to primarily define the macrotechniques of structure and pitch centre. Aside from the usual technical opener, the directions given to the performers are contained within a single page. This page is interpretive and was inspired by the game-like rehearsal methods that HIVE employ. It acts as a 'Lovecraftian' summoning ritual for the Outer God 'Yog Sothoth'. The text is a combination of various online rituals written in English, Akkadian and R'lyehian (the fictitious language of H.P. Lovecraft's imagined deities). Black writing denotes information pertaining to the general structure and orchestration, while purple writing acts as lyrical content. The 'Theme of the Ancient One' is a five-note cell (E, F, G, Ab, B) intended to guide the various pitch improvisations.

The accompanying EIS contains a separate signal path for each performer and features elements similar to *Arianna*'s DSP chain. The singers can interact with the patch in real time through a customised phone app within the TouchOSC[33] programming environment. Faders, knobs, pads and buttons give them reign over spatialisation, reverb levels, gain, digital distortion, pitch shifting, looping, playback settings and signal routing. The use of a touchscreen adds a distinct layer of instrumentalism to the already involved live performance. This piece will require further work and rehearsal to account for the wide spectrum of microtechniques in play. This EIS, perhaps more than any other within this study, will require practice and dedication since it requires techniques that differ so greatly from the everyday skills these singers employ. This could be seen as an insurmountable impracticality in many choral settings, but I value the sheer amount of control afforded by this peripheral and the sonic potential it brings.

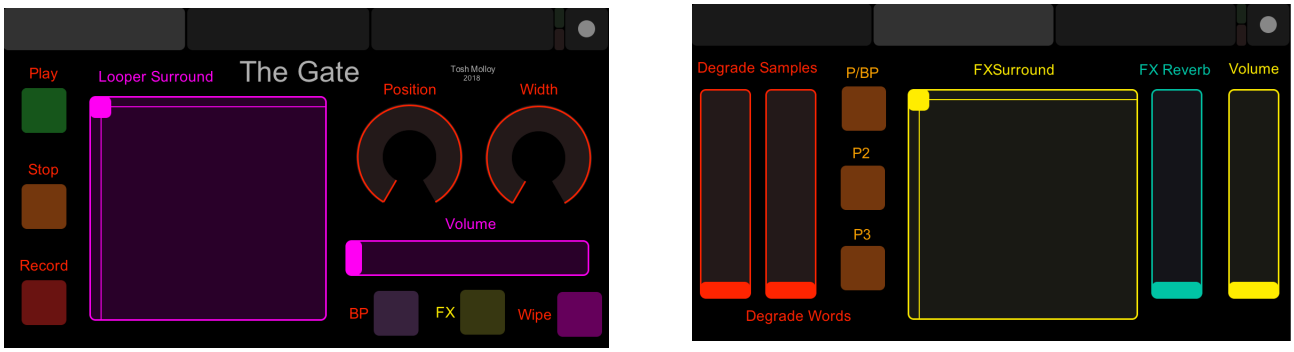

Figure 13
Pages 1&2 of the phone app for The Gate.

[33] Hexler, "TouchOSC", Last accessed December 3, 2018, https://hexler.net/software/touchosc

TouchOSC is a uniquely versatile and simple creative tool that pairs well with my musical approach. A library of pre-set touch interface elements can be created, placed and resized quite easily. Messages from the interface can then be sent over a network before being intercepted and unpacked by Max/MSP. I was able to sort different DSP techniques into different pages within the app layout and arrange them in the most user-friendly manner. Since programming these layouts takes very little time, I was able to quickly trial and test layouts and even respond to feedback from HIVE after our first session. It should be noted that the included demo recording of *The Gate* only makes use of the second page of the TouchOSC application. Depending on both the proficiency level of each individual performer and the overall creative direction the group intends to pursue while interpreting this piece, the range of effects available within this EIS can be incorporated to different degrees. My philosophy was to facilitate all levels of technological fluency in this particular design. The option to focus on the nuanced control of a small set of DSP options is facilitated while also catering for a potential need for advanced patching, layering, panning and general experimentation.

7.4 Contextualisation

Practicality and live performance constraints are a major consideration for the modern composers. The terms of many Calls for Scores in particular can be affected by limitations of finance, practice time, technology and production quality. Although apps like TouchOsc allow for the affordable distribution of digital musical interfaces, I believe that using just a microphone and 'hands-off' software is the most accessible means of bringing expanded ensembles to the stage.

I was adamant about writing a piece that would function without the need for a technical budget and believe *Hō-ō* is a successful demonstration of how to meet this condition. Joshua Hey's (2017) piece *Lens Flare From Alpha Centauri*[34] similarly showcases how electronics can enhance a string quartet performance without the need for complicated or cumbersome peripheral equipment. My transfunctional approach, however, demands that further steps be taken regarding the design of the software since much of Hey's use of reverb could effectively be emulated by a performance space. Hey's piece demonstrates a masterful use of gestural scoring techniques and extended techniques with reverb adding a spatial dimension that cannot be ignored. This electronic component is still considered optional[35], unlike *Hō-ō* which does not sound remotely the same without its software's intervention.

[34] Joshua Hey, "Lens Flare From Alpha Centauri", Last accessed: August 5, 2019, https://vimeo.com/226509314
[35] Joshua Hey, "Lens Flare From Alpha Centauri By Joshua Hey", Last accessed: August 5, 2019, https://www.youtube.com/watch?v=7zZs-eGPAtc

This difference is evidence of a contrast in aesthetic and technical approach. While the music of *Lens Flare From Alpha Centauri* was designed to interact with a reverberation effect in a general sense, *Hō-ō*'s score is directly intertwined with the technological peripheral. In this transfunctional context, technology acts as a new form of orchestration, an instrumental technique not granted by the physical element of the instrument. It facilitates textures and timbres not generally available to a string quartet. The software does this dynamically in that it changes its function repeatedly throughout the performance as the timed events are reached. The varied sonic results these two pieces for similar forces achieve suggests room for future innovation.

7.5 Further Reflection

The reality of ensemble writing within a transfunctional compositional style is that practical and creative hurdles will present themselves. While adapting to these hurdles, one should note the personnel involved and facilities available alongside all of the usual musical and philosophical considerations. I believe that opportunities for acoustic ensembles twinned with expanded instrument systems are severely limited by the current musical climate and can only become more common through the continued stretching of that which is seen as standard live performance.

The fruits of such a reimagining might be numerous, since technologically infused music tends to become increasingly versatile and varied over time. Modern music has adapted to fit all manner of contexts, physical spaces and changing perceptions. Indeed, the astute observer will notice that the works featured in this chapter are musical reapplications of technological concepts introduced earlier in this thesis. This uncanny property of transfunctional music will be key to its ongoing development.

Chapter 8 - Conclusion

8.1 Compositional Development Revisited

Over the course of my research, I have written for a relatively complete cross-section of the acoustic instruments found in Western Art Music contexts. I think this has proven transfunctionality's wide range of applications as a general approach to composition. The ability for multiple forms of 'subversion' to be achieved is promising for future work in this field. Regarding which works are most successful in this regard, I would suggest *Perpetua* and *The Gate. Perpetua* sees harmonic aspects of the cymbal's timbre overtake their dynamic qualities as the central focus for the composer involved. I believe this piece features the largest functional change brought about by any of my EIS to date. *The Gate* on the other hand, while not equally transformative in the same regard, sees the choir depart from its often rigid performance niche into a more spatialised setting. The mobile device served as an unprecedented resource for me. The sheer number of participants in a choir performance was a daunting design hurdle before I began to use it to my advantage.

Regarding 'control', I believe a solid foundational survey of a diverse set of peripherals has been completed. *Arianna* and *Perpetua* are potentially the most successful EIS interfaces in I've created to date. Thanks to the very particular pairing of acoustic and software elements, *Perpetua* sees the performer control sound predominantly through the cymbals themselves, something I believe is hugely beneficial. On the other hand, the pedal controls are abstract and somewhat awkward. Future developments of this EIS may see changes to this control scheme. *Arianna* is quite the opposite, with physical movements being utilised and tracked effectively, while the acoustic instrument (the voice) is used primarily as source material for the DSP system. My intention regarding control was to cast a wide net over the various options available as control surfaces and I believe I was successful in this regard. I have also learned that all control options are valid, wherever they lie on the spectrum. Even a more 'hands-off' philosophy as seen in *Creidhne* has several practical benefits in a professional performance setting.

My quest to broaden my compositional horizons in a very systematic fashion has taught me to alter my design approach based on the musical context. The rigid planning of musical material contained in scores like *Epochs* and *Creidhne* have shown me that simple technology and concepts can be expanded upon by traditional scoring means. The chordal structures and intricate progressions were key to the success of these pieces. In addition, my early identification of the need for disparate scoring techniques ensured that my process did not stagnate, allowing me to cover more ground during my research. I treated each piece as its own project and was careful not to fall into a routine when scoring.

Finally, regarding the performance of my music, I was glad to have so many pieces in my portfolio performed by talented and dedicated musicians. The feedback I received was invaluable and was weaved into each project as they developed. I was lucky to be present at the rehearsal for the majority of these pieces. This allowed me to see first-hand how my scores were received and how I might improve them. I've been happy to work with such a diverse group of professionals and can only hope my music is of a quality befitting their abilities.

8.2 Future Research & Development

I am content that the work that has been undertaken over the past three years is both substantial and extensive. There are however, several planned projects linked to the work within this portfolio that have yet to reach fruition. For example, *Perpetua* was scored for a solo percussionist and two cymbals. I believe a more expansive work for ensemble will be realised shortly after the completion of this study. Many of the concepts introduced in the individual chapters of this thesis are not yet exhausted or even expanded upon to a point of completion.

Arianna sets technology within the storied tradition of opera music. I've found certain choral and drama groups within Ireland to be innovative and forward-thinking. My eventual goal with the concepts I've begun to explore with *Arianna* is to create a modern opera that uses technology to track the most minute on-stage movements.

Epochs exposed me to the many simple and versatile forms of audio freeze. I believe this effect will have powerful applications in the realm of installation and music for public participation. I've currently drafted one such piece that I believe is innately intuitive and instrument-like in its design.

My existing works for ensemble have both been repurposed for installation. Thanks to its dense, layered audio profile, *Hō-ō* is slated for a surround sound mix and visualisation.

I hope to revise the material presented in this portfolio as a source of inspiration for future projects and opportunities.

8.3 Final Thoughts

Transfunctionality is a method of composition that requires an intricate understanding of numerous musical concepts and disciplines. Its purpose is to encourage continued reverence for the time-tested acoustic instruments of the Western Art Tradition in an increasingly diverse technological landscape. Technology has been a transformative force in many forms of music and when applied effectively, it can integrate into the structure we refer to as 'instrument'. Writing for expanded instrument systems is a fulfilling process that allows for the composition of music and sounds outside the realm of a traditional acoustic performance. If designed correctly, the EIS can allow a musician to gain precise control over sonic elements formerly beyond their grasp. This thesis details a working method for devising and developing such unorthodox performances. It chronicles the early stages of my own musical practice, as I attempt to explore boundaries of my sonic palette.

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