Social Systems for Improvisation in Live Computer Music

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Social Systems for Improvisation in Live Computer Music

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Commentary on the portfolio of compositions.

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Declaration of Authorship

I, Shelly KNOTTS, declare that this thesis titled "Social Systems for Improvisation in Live Computer Music" and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where I have consulted the published work of others, this is always clearly attributed.
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- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

I acknowledge that the visuals for the work *Flock*, submitted as part of the portfolio of composition, were programmed by Holger Ballweg according to a design provided by the author. Final aesthetic decisions were made in collaboration.

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Abstract

Social Systems for Improvisation in Live Computer Music

by Shelly KNOTTS

The portfolio accompanying this commentary comprises seven works which are presented here in chronological order. The works can be summarised as follows: a work for laptop ensemble which explores the result of shifting the balances of power within the ensemble; a live score with electronic accompaniment for improvising acoustic ensemble which maps data relating to world politics to parameters in the score; an instrumental score exploring aspects of distributed decision making as human algorithmic processes; a system for large scale telematic laptop ensemble using machine listening as a mixing method; a sound installation which generates a soundscape out of speech samples and synthesis from political tweets; a mixing system for live coders which simulates voting behaviour of a decentralized, flocking population; a performance system for solo live coding, using algorithmically generated code and EEG monitor to interact with the state of the system.

Most of the above works employ visual representations to communicate the function of the underlying algorithms to audience and performers. Although diverse in realisation parameters, the works all share a common theme of exploring the dynamics of improvisation and collaboration, particularly where technological communication systems and algorithms are involved in the sound production process. The underlying political, technological and social themes driving this exploration are discussed in the commentary which follows.

Portfolio Contents

Related Publications

The following publications were written over the course of this research project:

Alessandrini, P. and S. Knotts, 'Introduction to ICMA Array Winter 2017', ICMA Array, 2017. [Publication pending]

Knotts, S., 'Live Coding and Failure', 2017. [Under review]

Gifford, T., S. Knotts, S. Kalonaris and J. McCormack, 'Evaluating Improvisational Interfaces', Proceedings of the Improvisational Creativity Workshop, Monash University, 2017.

Knotts, S., 'Exploring Virtuosity in Live Coding in Flow', Proceedings of the International Conference on Live Coding, McMaster University, 2016.

Knotts, S., 'Algorithmic Interfaces for Collaborative Improvisation', Proceedings of the International Conference on Live Interfaces, University of Sussex, 2016.

Knotts, S., 'Changing Music's Constitution: Network Music and Radical Democratization', Leonardo Music Journal, vol. 25, 2015, pp. 47-52.

Knotts, S. and N. Collins, 'The politics of laptop ensembles: A survey of 160 laptop ensembles and their organisational structures', Proceedings of the International Conference on New Interfaces for Musical Expression 2014, Goldsmiths University of London, 2014, pp. 191-194.

Hutchins, C., Ballweg, H., Knotts, S., Hummel, J., and Roberts, A., 'Soundbeam: A Platform for Sonifying Web Tracking', Proceedings of the International Conference on New Interfaces for Musical Expression 2014, Goldsmiths University of London, 2014, pp.497-498.

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List of Abbreviations

BCI	**B**rain **C**omputer **I**nterface
BiLE	**Bi**rmingham **L**aptop **E**nsemble
DIJTA	*"**D**emocracy **i**sn't **j**ust a **T**weet **A**way. . . "*
DULL	**D**urham **U**niversity **L**ive **L**aptops
E7B	**E**nsemble **7** **B**ridges
EEG	**E**lectro**e**ncephalo**g**raphy
FLO	**F**emale **L**aptop **O**rchestra
GIASO	**G**rande **I**nternationale **A**udio **S**treaming **O**rchestra
ICAD	**I**nternational **C**onference on **A**uditory **D**isplay
ICLC	**I**nternational **C**onference on **L**ive **C**oding
ISEA	**I**nternational **S**ymposium of **E**lectronic **A**rts
OFFAL	**O**rchestra **F**or **F**emales **A**nd **L**aptops
Odg	**O**hrenhoch: **d**er **g**eräuschladen
PLOrk	**P**rinceton **L**aptop **O**rchestra

Chapter 1

Introduction

> Politics refers to actions that attempt to change a balance of power in the strands between nodes, to tilt the balance differently, to shrink one strand and strengthen another, to cut a strand here and make a new connection over there. (Ostertag, 2009, p. 11)

1.1 Context and Theory

This portfolio gathers works which intersect network music and political theory, where ensembles are positioned as radical contemporary music making structures.

In network music systems, computers and performers alike act as nodes in a system (Rohrhuber et al., 2007; Barbosa, 2003; Hugill, 2005). Network connections between computers mean an additional communication channel is open to performers, and text-based chat and data sharing often take place during performances. Network music can be seen as inherently political, as the direction and purpose of the data flow can determine the lines of power in the ensemble and the social politics in play. If we propose then that a network music ensemble is a temporary community, brought together for the purposes of a performance, the building of socially aware network music systems should consider not only the technical and aesthetic needs of the performance, but the social structure which is being built by systems designed for data exchange.

Ostertag's (Ostertag, 2009) description of politics as a dynamic interrelational web provides a useful analogy to understand how network music systems may recreate, re-imagine or critique real life socio-political structures. Social organisation has been an explicit concern of network music ensembles since the late 1970s, when network music pioneers The League of Automatic Music Composers (who later became The Hub) (Bischoff, Gold, and Horton, 1978; Brown and Bischoff, 2005) began experimenting with building their own network structures for passing musical information and directions. Yet power dynamics in music ensembles are not a concern specific to networked ensembles. Cardew's politically motivated Scratch Orchestra explored social utopianism with social interplay at the foreground of the group's activities (Parsons, 1997). Zorn's *Cobra* (1984) also provides an early example of deliberate social organisation in music ensembles, going beyond the musical needs of the ensemble (Zorn, 2004). Free improvisation scenes have sought to break down traditional musical hierarchies, reflecting philosophies of social freedom in their musical exchanges (Bailey, 1993).

Although social organisation in music is not a new territory of academic or musical exploration, the ability of network music ensembles to freely design a live communication structure of musical, textual and other data, constitutes a transformative[1] development in the way that music ensembles can and do organise themselves. This offers as many challenges as opportunities worthy of investigation.

Weinberg (2005b) and Weinberg (2005a) developed a theoretical framework for network music systems based on almost 30 years of network music activity – stretching back to before the development of the world wide web – suggesting, among other things, social strategies for music making using computer networks. However, since 2006 the availability of technology in the western world and the development of social networking sites have fundamentally changed the way we interact online, which has in turn pervaded our offline interactions and musical cultures. For example, Facebook became 'universally' available in 2006 and now has 2 billion users, Twitter launched in 2006 and now has 328 million users (Constine, 2017), and iPhone and Android were launched in 2007. As of 2015 over half of Western Europeans owned a smart phone, meaning they are able to be permanently connected to the internet and social networks (Statista, 2017).

The pervasion of networking in our daily lives has led more musicians than ever to explore the possibilities of networking in music making. Although many network music ensembles and projects developed pre-2006, the high-profile launch of Princeton Laptop Orchestra (PLOrk) in 2006 (Trueman, 2007; Smallwood and Trueman, 2008) kickstarted a new wave of laptop ensembles and orchestras, many of whom followed a radically different model to the early experiments of The League. The PLOrkian model, borrowing the hierarchical structure of the 19th century orchestra with strong role divisions and the power imbalance of the composer-conductor-performer model, provides a structured environment necessitated by pedagogical and research aims. The Hub model, reflected more strongly in European ensembles and non-academically affiliated groups, tends to reproduce band-like structures with collective-style organisation where group members have more freely defined input into technical, creative and organisational aims of the ensemble (Knotts and Collins, 2014). Booth and Gurevich (2012)'s ethnographic study of the collective-style Birmingham Laptop Ensemble (BiLE) identified the roles of performer, composer and system designer as fluid from project to project. Whilst there is a continuum between these two extremes, ensemble structure can be considered in the light of online culture and politics. Such an analysis reveals similar polarities in idealised network structures with left-wing protest movements such as #Occupy viewing the world wide web as a non-hierarchical site for community formation, while corporations and governments seek greater oversight of our online interactions for

[1] As transformative creativity in the sense of Boden (2004)

capitalistic aims (Unknown, 2014). These ongoing battles for freedom, privacy, and neutrality in our online spaces provide ample stimulus for artistic exploration and let us consider the ethics of network system design and ensemble organisation. I contend that building non-hierarchical network music systems is impossible, but that building systems which are self-critical of the power dynamic inherent in building network structures is both possible and ethically important for socially-aware system designers. Unpicking hierarchy and power structures in network music systems requires an interdisciplinary approach where theoretical and practice-based approaches are mutually beneficial. Although the outcomes of the practice-based work presented here consist of a portfolio of works and systems, a much broader approach was taken in the development of the work. I have been active as a practising improviser for the duration of study, exploring many different scenes and settings as a participant and gaining insight into the conventions of interaction in collaborative improvisation.

Actively developing collaborative projects and participating in collaborative residencies and hack events allowed me to explore the dynamics of collaborative creative work and develop ethical practices for organising collaborative projects. This knowledge gives my portfolio a broad base in collaboration and improvisation, feeding into the design of the systems submitted. This chapter gives an overview of the theoretical topics which make up the research content of the thesis, many of which will be developed further in the chapters which follow.

1.1.1 Politicised Programming

Magnusson (2009) points to the political, ethical, and aesthetic nature of technology and how technology design structures human action and interaction. Software technologies in particular, which are capable of reflecting the thought structures of their designers, necessitate a reflective responsibility from the ethical programmer. This is of prime concern in designing socially-aware systems which mediate performer interaction and requires critical reflection as well as active acknowledgement that a value system is percolating through to the performance system. The impact of the system on performer agency should always be at the forefront of the design choices.

In the context of network music systems we can observe how social hierarchy is often reflected in both the functional and terminological aspects of system design. For example, tempo synchronisation clocks by convention use a master-slave architecture, which, although musically and technically functional, not only has unfortunate imperialistic connotations, but reinforces a technological hierarchy where one computer/performer is responsible for sending important technical messages to the other performers, i.e., a top-down, one-to-many power structure.

The League's early works experimented with different structures for information exchange, e.g. the circular network used in their July 1978 performance (Bischoff, Gold, and Horton, 1978), but the size and complexity of the computer networks were limited by availability of technology, leading them to eventually reform as The

Hub in the 1980s, with a centralised structure for data exchange (Manning, 2013; Brown and Bischoff, 2005). However, liberal social ideals were still at the forefront and the centralisation of hardware used to store data served as a locus of information exchange, and enabled free and open access to communal data.

Looking back to the League's techno-utopian ideals points towards the consideration of network music systems in relation to current technopolitical narratives. The political potential of network music systems can be considered in the light of radical democratic theory (Knotts, 2015), that is, forms of democracy which resist consensus with the aim of revealing multiple narratives and renegotiating power relationships (Laclau and Mouffe, 1985). Alongside obviously politically motivated projects, an analysis is given of a number of network music systems which move towards more radical forms of social organisation, or deal with the interesting middle ground between total performer agency and mediating multiple (and sometimes many) performer inputs into a coherent musical form.

One of the striking characteristics of such systems was that although there was evident desire for network structures which enable social creation of music, there was also a mistrust that mass-music making could achieve competent music without tightly structured interface choices or the imposition of traditional musical hierarchies on top of seemingly socially-aware system design. Burtner's *NOMADS* system (Burtner, Kemper, and Topper, 2012) is interesting in this regard as the 'sociosynthesis' element takes highly structured inputs from audience members which are summed to make one layer of the performance, yet this is overlaid with professional performers who generate the bulk of the musical material and can be relied upon to provide a coherent musical structure. A troubling dynamic is instantiated where professionals are supported by mass input, facilitated by interfaces which make many of the musical choices and offer 'performers' little agency. Although an undoubtedly interesting experiment with social music making, questions arise as to how we could take a more ethical approach to developing coherent musical structures without restricting the agency of performers, or at least find interesting responses to the power inequalities inherent to this type of musical interaction.

Cross (2003) states that music 'may afford cost-free modes of engaging in and rehearsing social interactions' (Cross, 2003, p. 109), pointing towards music making as a 'safe' domain for testing cultural theory. We might consider then that network music systems, as the only music making activity which utilises the technology which is integral to contemporary social interaction and community formation, should interrogate the nature of these interactions and structure the exchange of available communication channels – sound, visuals, text, data – in ways that reflect and critique the nature of online interaction. With the development of social networking, interface design and algorithms have become integral to our social interplay with data collection, content personalisation, and behaviour prediction mediating the potential interactions we have and, e.g., character limits, 'like' buttons, and even Instagram filters informing the content of our interactions. Algorithmic mediation and content creation, and interface design in network music systems are central topics explored throughout this thesis.

1.1.2 Improvisation, Performer Agency, and Consensus

Relating to deliberative democratic ideals which resist consensus and the desire to avoid traditional composer-performer hierarchies, an important goal in my research into interface design was to not impose strict musical choices on performers, and therefore to have somewhat musically neutral[2] design choices which focus on performer interaction rather than content and structure. Deliberative forms of music making of course already exist: Murnighan and Conlon (1991) studied the deliberative interactions of string quartets and how they related to the groups' success; and free improvisers frequently describe their in-performance interactions as a 'musical conversation' (Bailey, 1993). For this reason, the majority of the works making up the portfolio involve some form of improvisation, and many of them were developed in a process that included workshopping and discussing the development with performers and collaborators.

Collaboration is of course an important element of the free improvisation scene, with ad hoc and diverse collaborations driving forward both the musical development of individual musicians and of the genre as a whole. Prévost (1995) and others have written about the political nature of free improvisation, relating it to the liberation of musicians from traditional ensemble hierarchies, and musical sound from archetypal musical structures. However, as can be observed in other social structures, a total lack of structure leads to hierarchies being built on societal hegemonic lines – e.g., race, gender, expertise (Mouffe, 2013). This reflects itself clearly in the tendency in free improvisation for performer biographies and cultural histories not according to musical style or ethos, but as a list of past collaborations, trading on the social capital which is built up through playing gigs with consecutively more senior figures in the scene (Bell, 2014). Strong arguments then can be made for developing systems to combat naturally developing hegemonies.

Consensus is also an interesting avenue of exploration in relation to free improvisation. The temporal nature of free improvisation and the imperfect communication channels of sound and vision mean that immediate action and reaction without conferral is the standard route available to the unfolding of the performance. Musical dialogue, harmonious or antagonistic, directly drives the collaboration. Network music systems with the ability to collect data and provide text based communication in-performance, as well as the possibly controversial ability to restrict access to technical resources, allow us to investigate consent and consensus in the context of musical interaction. Obvious arising questions include how can we determine musical consensus, and is consensus always desirable.

[2] Systems which do not impose any particular stylistic or motivic musical traits on performers, but try to algorithmically 'organise' free improvisation.

In the context of this thesis, this is of most concern to the three works for laptop ensemble: *Controller*, *Flock* and *Union*, which deal directly with social mediation, and to a lesser extent the instrumental works *On Edge* and *Dissonant States*, which require varying levels of performer agency and distributed control. *Union* deals with concepts relating to consensus and consent. Over the course of the thesis performer agency became an important aspect of the systems I was designing, therefore later pieces are musically 'neutral' systems which work with freely improvised inputs and explore the nature of algorithmic mediation.

1.2 Research Questions

Through the works which follow I explore technological mediation of collaboration, hierarchy, intra-group interaction and performer agency using network technology as an intermediary. The following overarching questions provided stimulus for the work:

- How does network technology reformulate the conditions of collaboration in music performance?
- Are there ways we can use networking to manipulate interaction between performers in particular to modulate agency, control and intra-group hierarchy?
- How can we form a socio-political critique through system design? What are the tools and approaches that would facilitate this?
- What can we learn from real world political systems in the age of social media that could provide stimulus for music making?

1.3 Practice-based Research Methodology

The following section summarises my approach to the practice-based elements of the research, which, echoing the interdisciplinary nature of the theoretical research, demonstrate a broad approach to researching the aforementioned concepts.

During the course of my PhD I maintained and developed my activity as a computer music improviser, most prolifically as a practising live coder. I explored the dynamics of improvisation in diverse contexts, across scenes including DIY/noise, free improvisation, electronic and computer music. I was active within telematic and network music contexts, and the live coding community, performing at Algoraves (Collins and McLean, 2014), in clubs and other contexts. I also engaged in many collaborations with various strategies such as live coding duos: UIAESK! (with Holger Ballweg) – working with analogue and digital feedback loops; ALGOBABEZ (with Joanne Armitage) – live coded pop music; and *[Sisesta Pealkiri]* (with Alo Allik) – with generative audio-visuals; mixed ensembles with Rhodri Davies and Mariam Rezaei; John Pope and Faye MacCalman; and Portfolio Improvisers. Some of these

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FIGURE 1.1: ALGOBABEZ performing at an Algorave with visuals from hellocatfood (Antonio Roberts).

collaborations were short term and most involved little rehearsal, but all had an impact on how I thought about collaborative improvisation both as a practitioner and as a system designer.

The most pertinent collaborations to the research were the larger scale collaborations OFFAL (Orchestra For Females And Laptops), BiLE (Birmingham Laptop Ensemble), FLO (Female Laptop Ensemble), GIASO (Grande Internationale Audio Streaming Orchestra), DULL (Durham University Live Laptops), each of which I had a different role and level of involvement in. These ensembles provided longer term contexts for testing out theories and practices relating to networked collaboration, including ensemble organisation and collaborative performance, through testing the systems I developed or participating in other performances. Each ensemble offered a different perspective on longer term collaboration: DULL was an experiment in developing a live coding laptop orchestra with amateurs; GIASO offered a first opportunity to explore telematic collaboration; BiLE, now largely inactive, was most influential in its approach to developing a framework for network music systems and non-hierarchical working methods; FLO developed strategies for performing with large groups of female performers; OFFAL moved into the territory of art activism, developing a global community of female performers and developing strategies for long distance, low cost and technologically inclusive collaboration.

Another context for developing my research theory and ethos was a number of residencies and events I attended which involved collaborative development of creative projects. This began early in my PhD when I attended Thinking Digital Art Hack and developed a project on the theme of 'decentralisation' with three other

FIGURE 1.2: Live coding with Shaun Blezard, Rachel Musson and Julie Kjaer at Sound and Music Portfolio Improvisers Residency, Wooda Farm.

artists over a six hour period. I have attended several hack-style events since, culminating in December 2015 with Rewriting The Hack, an event I co-developed with digital media researchers Suzy O'Hara and Victoria Bradbury. This event provided the opportunity to develop a process for politically engaged collaborative creative production and has certainly shaped my thinking on working in collaborative contexts. Other notably residencies were Digital Media Labs (See Figure 1.3), and Sound and Music Portfolio Improvisers Residency (See Figure 1.2) both of which provided time and space to develop collaborative art works, resulting in developing my personal practice alongside tools and strategies for working with differently skilled collaborators. All of these events provided the opportunity to test new ideas and have pushed the boundaries of my current knowledge and skill set through working with artists and technologists from diverse backgrounds.

Observations from these formative activities were grounded by theoretical study and the development, testing, and evaluation of the systems which are now submitted for examination.

1.3.1 Evaluation Methodology

Given the focus of the work on intra-group interaction, in almost all cases, the iteration loop of developing the works included prototyping, workshopping and testing

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FIGURE 1.3: Taking part in a collaborative digital arts residency at Digital Media Labs, Barrow-in-Furness.

with performers. During testing I sought feedback from performers, and where possible I requested additional feedback after performance. The evaluation and discussion sections for each of the submitted works contains self-reflection on the development, realisation and performance(s) of the work. As I was often a performer of the works, my own experience of performing the work is shared, alongside performer feedback where possible.

In presenting the work there was opportunity to informally discuss the work with audience members, and this often helped to shape the next iteration of the work or guided my reflection. Though this feedback was of course valuable, as the focus of the thesis was on intra-group dynamics, I considered evaluation by means of formalised audience feedback to be beyond the scope of this thesis.

1.4 Thesis Structure and Contents

The chapters which follow outline the pieces and systems which make up the portfolio submitted for examination. The works are discussed in chronological order, and demonstrate a development in thinking over the time of study from *Controller*, which is an exploration in using an algorithmic interface to shift power dynamics in an ensemble, to musically neutral systems. *Flock* and *Union*, which attempt to mediate interaction according to musical content and deal with themes of consensus and consent. The instrumental and mixed works *Dissonant States* and *On Edge* deal with improvisation in the context of musical structure informed by democratic data and distributed decision making respectively. *"Democracy isn't just a tweet away..."* explores online political rhetoric, examining the relationship between Twitter as a form of modern-day democracy and real world politics. The final work *Flow* playfully explores the pseudo-collaboration between humans and algorithms which results from live coding performance, using EEG data from the performer's interaction with the system to alter the system's behaviour creating a feedback loop of action and interaction. The papers written for conference and journal publication during the course of study inform the chapters of this commentary.

1.5 Summary of Contributions to Knowledge

- An overview of the current state of network music ensembles including an analysis of common models for laptop groups (Knotts and Collins, 2014).
- Mappings of political theory and real world socio-political interaction onto network music ensembles [Chapters 3 and 7].
- Design of politically conscious music making structures[3]. This is a thread which runs through all the works, and in Chapters 5 and 7 I consider this specifically in the context of online community formation and algorithmic mediation techniques.
- Exploration of the tensions of real world data gathering in the context of network music [Chapters 5 and 6].
- Development and testing of various strategies for ensemble organisation, particularly relating to participation and performer agency [Chapters 2, 3, 4, 5, 7].

[3]Politically conscious design should consider the intra-group dynamics imposed by the system as integral to the design process

Chapter 2

Controller

2.1 Introduction

Controller is a work for laptop ensemble which uses the potential of network interaction to exploit changing and unequal power dynamics in collective computer improvisation. The work examines the political implications of socially formulated interface design.

Laptop ensemble composition provides many possibilities for exploring power relationships among performers and many network music pieces deal with shared sound spaces or shared controllers in order to facilitate collective action, whether PowerBooks UnPlugged's laptop republic (Rohrhuber et al., 2007), or the shared interface of a reacTable (Jordà et al., 2007).

Controller comments on this democratic potential by providing an interface which varies during performance to change the level of control participants have. Furthermore the work brings to the foreground for performers and audience the complex underlying group dynamics of interaction, with an ongoing negotiation of 'who controls what'.

The piece extends the notion of 'composing democratically' for laptop ensemble into the arena of 'composing democracy', that is, creating a musical structure out of shifting group dynamics, with political action at the forefront of the compositional design.

2.2 Facilitating and Disrupting Democracy in Music Systems

Laptop ensembles are a relatively new arena for collective performance which have grown substantially in the last decade. Although few ensembles explicitly deal with the sociopolitical, their uniquely malleable communication structures make social experimentation both technically feasible and an intriguing avenue for investigation.

Although the centrality of communication infrastructure design makes social politics a pressing concern for socially aware laptop ensembles, social design has also been explored by instrumental groups. Cardew placed social politics at the forefront when forming the Scratch Orchestra by introducing a draft manifesto which explicitly dealt with organisational procedures for ensuring a democratically formed group structure (Parsons, 1997).

While the Scratch Orchestra was striving towards a harmonious (and increasingly hardline communist) system based on equality, John Zorn's game piece, *Cobra*, dealt with disruptive forces in the structuring of social spaces (Zorn, 2004).

Cobra is a framework for improvisation which sets out particular rules for ensemble interaction. Players may indicate at any point that they want to suggest a new action for the rest of the group, but this is guided by a 'prompter' who becomes a mediating force by deciding which player's suggestion is followed and communicating this to the rest of the group. In this way a democratic situation is formed whereby the responsibility for musical actions is distributed to the performers, but the prompter acts as a centralised decision making force directing the group in who gets to make decisions and when.

However, a second element of the piece allows players to take subversive action, either by acting as a lone guerilla performer who improvises outside of the given directions or by forming a guerilla group which acts according to its own set of rules. Cobra therefore both instigates the possibility of a mediated democratic situation - assuming the prompter is not corrupt in their actions - and a means of disrupting this system through subversive action.

2.3 Composing Social Spaces in Network Music

One of the new possibilities afforded by digital musical instruments is the ability to allow multiple performers to shape the same sound source. The reacTable for example allows multiple people to connect together blocks controlling samples and processing on a shared table top surface. Networked digital instruments allow this interaction to take place across multiple physical interfaces. LNX_Studio for example allows multiple performers to play the same software synthesisers (as described in Roberts and Wakefield (2016)), and Rohrhuber and de Campo's Republic is a live coding environment where all code executed is shared with all performers.

A previous work of mine, *XYZ* (Knotts, 2013), also dealt with issues of ownership, by letting performers 'fight' to take control of the parameter controls of other performers' sound patches. This piece took inspiration from Gresham-Lancaster's *Stucknote* (1994) (Brown, 2002) in which each performer designs a sound with one parameter, but all performers can access the control for that parameter. Both these pieces require some form of informal social negotiation to take place to perform the piece.

Designing spaces for shared sound making, however, requires consideration of the social interaction which is afforded by the interface. The reacTable is round to allow easy movement to other parts of the table, encouraging performers to interact with blocks placed by other performers.

It is possible in Republic to overwrite the sound of others by creating a new sound with the same name as another performer's sound. Rohrhuber and de Campo sought to break down ownership barriers through allowing spatialisation of sounds over multiple laptop speakers and through enforced sharing of sound generating code, or as Rohrhuber puts it 'the identity of each single person is delocalised as much as possible' (Rohrhuber et al., 2007, p. 5). Furthermore to break down the barriers of audience and performer the performers are also situated as listeners – to the results of abstract algorithmic processes written in performance – by positioning the group dispersed among the audience.

Technological affordances and social conventions go hand-in-hand to define the inter-group interactions. It might be technologically possible to overwrite other performers' sounds, but it would not be considered good etiquette, so it is usually not part of the practice conventions when performing with the tool.

2.4 Interface Design and Interactions

Various studies, including Bryan-Kinns and Healey (2006), have investigated the particular implications of interface design on group dynamics and collaboration in network music systems. Of particular interest to the development of Controller is Fencott and Bryan-kinns (2010) which looked at the effect of shared and private spaces in collaborative improvisation, with an aim to evaluate whether participants approached collaboration differently when working processes were more or less private.

Fencott's experiment utilises a shared workspace where participants design sounds as part of a group improvisation. In each of the three situations a different level of privacy is used. In the least private situation all sound designing actions are audible and visible to every participant. In the most private situation each participant has a personal workspace where they can design sounds before sharing with the group.

Fencott's observations included that the 'private' space was perceived as a space for experimentation and 'drafting' of ideas, whereas the 'public' space was seen as the locus of collaborative action. A key observation was that far less editing of others' contributions was made when the private space was available for individual work. This implied that participants saw a greater sense of individual ownership of ideas when material was developed outside of the collaborative area, which restricted the impulse to directly intervene with the musical choices of others. Fencott also observed that the allocation of musical roles was more fluid when working primarily in the 'public' spaces.

2.5 Controller: Design and Structure

2.5.1 Introduction

Controller is an investigation into the dynamics of collaborative improvisation in a shared sound making environment, but where the performers have varying levels of control over the sound. I designed a networked GUI (Graphical User Interface) for controlling sound and a partly algorithmic control mechanism which modifies performers' ability to contribute to shaping sound.

To facilitate this dynamic interaction I designed a simple interface (See Figure 2.1) which controls both the sound and other performers' access to changing sound parameters. The algorithm modifies which aspects of the GUI are available to performers, disrupting their abilities to contribute to both the sound and social aspects of the piece.

2.5.2 Interface Design

Each performer accesses the sound making via a simple GUI on their laptop. The interface consists of three types of control:

- Sliders which can be used to control sound parameters. Changing a slider's position sends control values using OSC to set parameter values of a shared sound space;
- buttons which turn the sliders on other performers' GUIs on and off;
- knobs which affect the frequency of OSC messages sent from a performer's slider to the shared sound space.

The interfaces are linked via the network so that changing the setting of an interface element on one laptop changes the setting accordingly on all other laptops.

2.5.3 Structure

The performance is structured by shaping the relative levels of control performers have over time. In each section the visibility of interface elements of each of the performers' GUIs changes through a combination of 'random' allocation and 'special events'.

Performances of *Controller* always have the same basic structure, as follows:

- Players start with a small number of sliders to control the sound, which are chosen randomly;
- the number of sliders and rate of change of the allocation of interface elements increases with each section;
- in the second half buttons appear to allow performers to control the slider allocation;

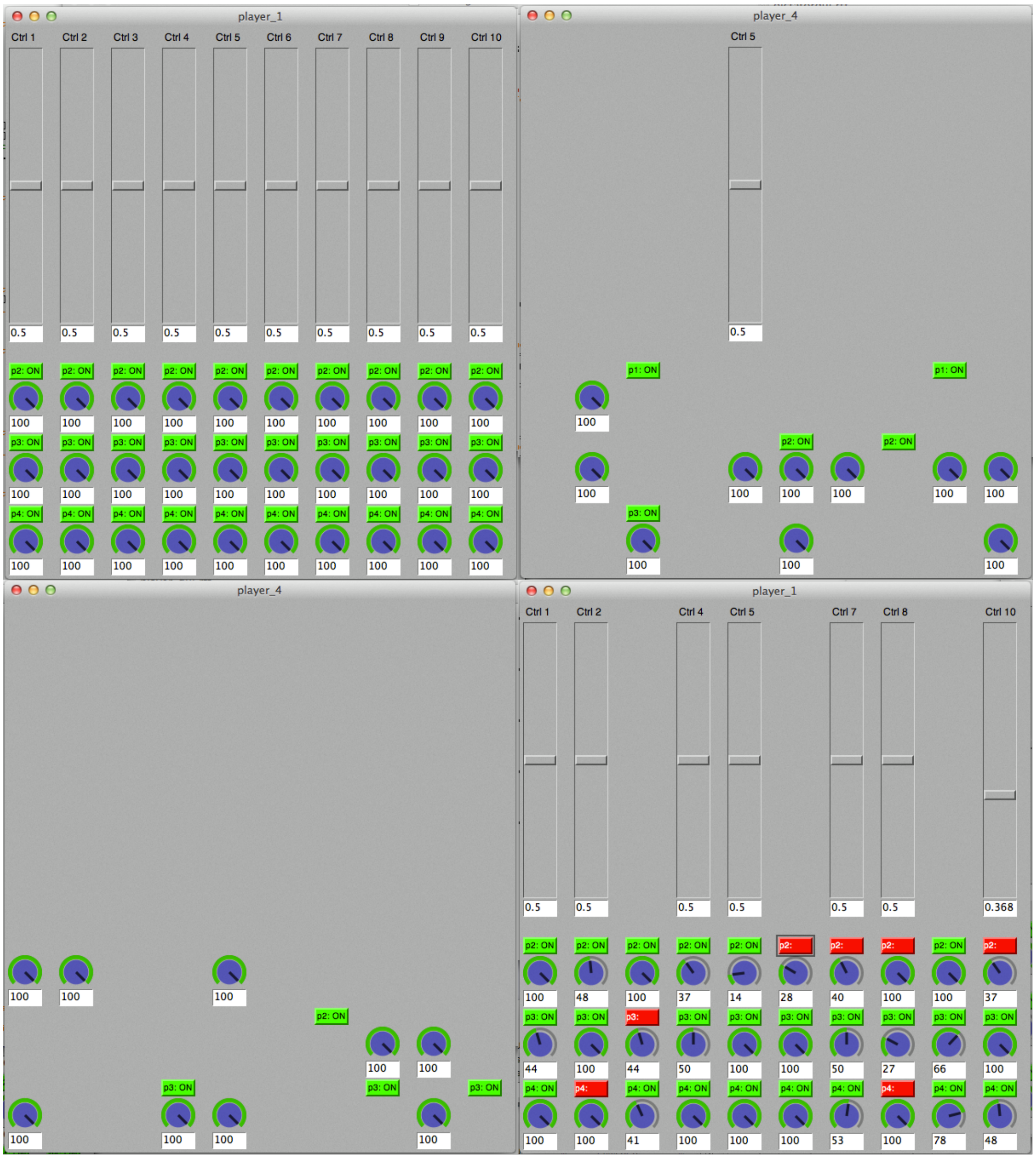


FIGURE 2.1: Four different states of the interface in *Controller*.

- towards the end of the piece knobs are allocated to change how 'effective' other performers' sliders are.

Overall, there is a shift of focus from the first half where performers are mainly concerned with the sound parameters of the performance, to the second half where performers are also concerned with the social parameters.

'Special events' are interspersed within the broader structure to add variation. They include:

- One player has all controls and other players none. This could be described as the 'autocratic' setting as one player has the power to distribute sound control to other performers as they wish;
- all players have access to all controls. This is a more anarchistic model of social interaction;
- two settings in which the algorithmic processes deliberately subvert the intentions of performers: short periods where the visibility of interface elements changes very fast, making it very difficult for players to interact with the interface;
- and sequentially changing the slider settings to random positions, thus changing the character of the sound algorithmically.

Variation is built into the algorithm controlling the structure such that the timeline will be different in every performance. This combats the establishment of 'performance routines', and performers learning the interface, in the endeavour for musically and socially 'fresh' interactions on each performance.

2.5.4 Interaction with Sound

The shared sound performers interact with is made up of several 'sound scenes' which can be crossfaded between using slider 1.

Across the sound scenes a combination of both simple and complex parameters is used. For instance one sound scene has very direct correlations between sound and controller and another has very abstract correlations whereby the movement of several sliders is needed to change the character of the sound. In some scenes the sliders are algorithmically mapped to parameters, with the result that there may be sliders which are not mapped to any parameter at all.

The varying levels of complexity of control are designed to require varying levels of team work in order to influence the sound. In the directly correlated scenes one performer moving one slider can change the overall sound output, but in scenes with more complex mapping there may need to be some coordination of slider movements between performers to have any effect on the sound.

2.5.5 Performer Interaction with the Interface

As indicated in the score, performers are restricted to using their computer mouse or touch pad to interact with the interface. Subverting this rule – for example, by live coding algorithmic setting of sliders – while not explicitly prohibited, is discouraged.

If a performer sends too high a density of parameter setting messages, all elements of their interface will be hidden for a set period of time. This is designed to restrict performers to only change one interface element at a time, such that no one performer can take too much control and team work is encourages over individual action.

2.5.6 Aesthetic Design Considerations

As Fencott and Bryan-Kinns concluded, interface design has particular implications for the social interaction of performers. Several of these considerations in *Controller* are discussed above, and further considerations are as follows:

- The choice of interface elements is designed to make it easier to interact with the sound than with the social elements of the piece, i.e., small buttons and knobs are used to control social aspects and larger sliders are used for controlling the sound. This asserts the primary role of the performer as interacting with sound, perhaps reinforcing social control as subversive behaviour.

- How many controls they have relative to other performers is not revealed to performers – perhaps a measure of social hierarchy (Lin, 2002). Nor is an indication given as to whether interface changes are the result of human or algorithmic intervention.

  This is to counteract the possibility of performances becoming competitive, and performers retaliating against other performers' social actions – and vice versa, allows performers to act in the social realm anonymously.

- A graphic display gives the audience an overview of the current state of social and musical politics, giving this aspect of the piece a performative element (See Figure 2.2). The graphic shows the current state of all performers' GUIs.

- The level of difficulty of performing with the interface varies over the course of the piece – through modulating the rate of change – in essence asserting the algorithms as having ultimate social control by regulating the interaction of performers with the interface.

2.6 Evaluation and Discussion

Controller has been trialled with two laptop groups whose feedback on performer experience we will discuss here.

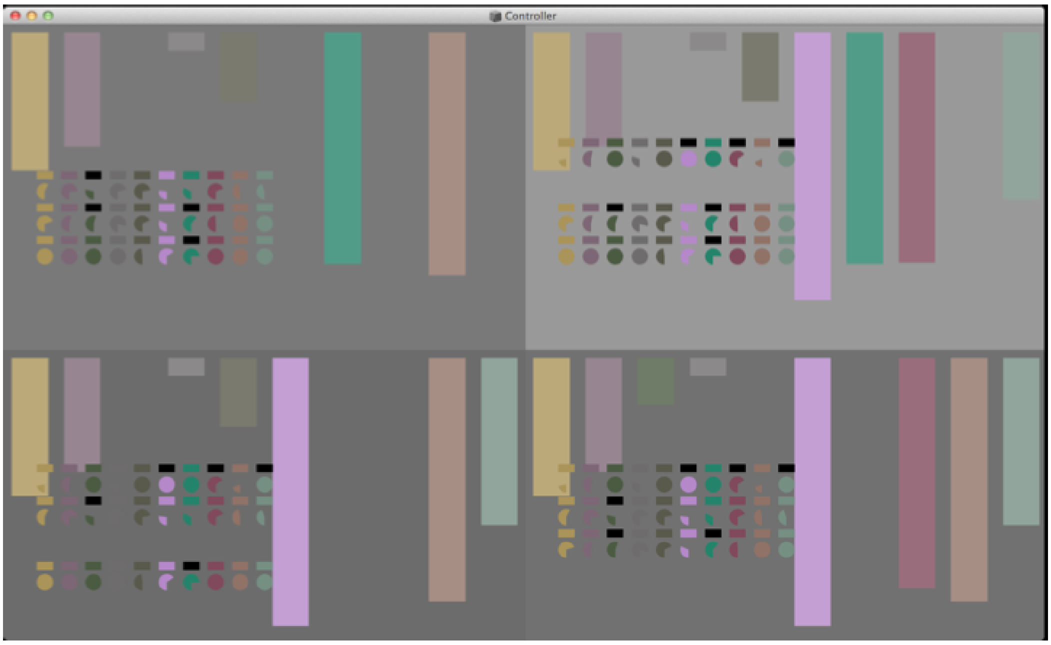


FIGURE 2.2: Example audience graphic showing the current state of each performer's interface.

The first group, a trio from the, fleetingly existent, 'Scratchtop orchestra' based in Durham, played *Controller* a total of four times giving fairly positive responses. They commented that they found Controller to be a novel performance experience and extracts from this performance can be seen in the portfolio documentation. In contrast, members of Birmingham Laptop Ensemble (BiLE) who played the piece twice in rehearsal had critical first responses, which are reported here as extremely helpful to the development of such work. One performer, and the author, were part of both groups and therefore performed the piece 6 times.

Members of BiLE reported feelings of disempowerment and disengagement, due to interruptions in the performance flow – i.e., objects that they were using to control the sound suddenly disappearing, requiring the performer to have a quick change in approach to the performance.

One member of BiLE felt totally frustrated with the interface and stopped trying to control the sound after a few instances of a slider they were using disappearing. They decided instead to interact with the piece by methodically clicking the ON/OFF buttons to turn faders to the off position.

Another element which seemed to be key in disengaging BiLE was the abstract allocation of faders to elements of the sound. Performers commented that they would prefer to have more information about the function of faders, in the form of labels, or to have a greater sense of influencing the sound on moving a fader.

Experience level of performing with the interface seems to have had a fairly strong influence on the satisfaction levels of performers. The BiLE member who also performed with the Scratchtop trio commented that 'Due to having played the

FIGURE 2.3: Members of the 'Scratchtop orchestra' performing *Controller* in the studio.

piece a couple of times, I learned to let go of the notion of trying to influence the whole piece. This got me more engaged by making me aware of the influence I have in specific parts of the piece and trying to use that influence and to try to work with the other players to achieve some musicality.'

Another differentiating factor seemed to stem from the performance mindset and how willing performers were to subsume their own will to the system of the piece. The performer who was part of both groups talked about the piece itself appearing to have free will: 'Though the players have varying amounts of control, I felt less like the players are playing the piece, but rather that the piece allows the players to play itself to varying degrees.' This performer explained that they felt that the intentions of the performers seemed secondary to the 'intentions' of the system.

The effect of this seemed to be a refocussing of intention more on the local control of what is happening in a particular time rather than in trying to focus on the overall structure of the performance, with performers almost universally stating they did not feel as though they had much control over the larger structure of the piece.

In this sense *Controller* falls into the category of an exploratory system (Weinberg, 2005a), the role of performers being that of working out what they can do within the confines of the system rather than what they would like to do given free choice – perhaps having some parallels to autocratic political systems and indicating that even some elements of autocracy can be enough to bring a sour political taste.

Members of the Durham-based group appeared to embrace the 'exploratory' style of performance and to see the limitations imposed by the interface as a challenge. Yet BiLE members were much more concerned by the limitations and saw this as a restriction on their ability to act as performers.

This was in some ways surprising as BiLE as a group is generally open to experimentation with network structures and committed to finding new ways of interacting (Booth and Gurevich, 2012). However, it is also the case that BiLE has been concerned from its inception with structures of social organisation (Hutchins, 2012). Perhaps this indicates a greater awareness of the social implications of the interface amongst group members and therefore a more negative reaction to what could be seen as a disruption to freedom of musical and social interaction.

Finally, with regard to the interaction with other players, members of BiLE mentioned that they thought having a chat window would help with being able to make musical decisions collectively.

One BiLE player commented, however, that they felt they were able to get a sense of interaction and intentions of other players through seeing the fader movements the other players were making and that the best musical results came when players were acting conscientiously in their fader movements, i.e., by not making too many changes and by being mindful of the fader movements of others.

Comments about the use of the buttons to switch other players' faders on and off ranged from it being a boring thing to do, to that they felt switching off faders had most influence on the performance when it annoyed another player, leading to tit-for-tat retaliation in switching off faders of others.

2.7 Conclusions

Precedents for considering democracy and subversion in musical groups were discussed alongside the implications of collaborative music making in network music situations. An overview, analysis, and preliminary evaluation of performer experience in *Controller* was given.

In the next chapter, a more refined approach to sociopolitical organisation of improvisation is investigated, which allows a little more top level freedom for performers. In *Dissonant States* I make connections between different forms of real world governance and levels of improvisation in the interpretation of music notation.

Chapter 3

Dissonant States

3.1 Introduction

Dissonant States uses live notation and a scale of partial notation and improvisation to explore performer agency in improvised performance. Smith (2015) describes live scoring techniques as moving agency from the performers to the score (or algorithm/composer), and *Dissonant States* explores how different types of directions and levels of algorithmically generated complexity can inform and communicate performer agency. Aspects of performer cooperation are explored by using musical material relating to dissonance, which fundamentally requires more than one (monophonic) instrument to produce. An algorithmically produced score challenges the limits of the performers by varying the time given for interpretation of score pages, and by producing sometimes impossible sets of performance directions.

Dissonant States uses a collated data set (see Appendix A) relating to aspects of democracy in world states. I consider *Dissonant States* as a novel approach to sonifying data through mapping data points to aspects of dissonance, using several factors to build pitch sets with levels of relative dissonance (see Table A.1 in Appendix A for full specification of data and mappings). Dissonance is an infrequently used musical characteristic in data-sonification, but seemed appropriate to explore in the context of political data as dissonance is a fundamentally relational aspect of music. I use Lach Lau's theory of Harmonic Roughness (Lach Lau, 2012), calculate dissonance curves for generated pitch sets, and choose the closest match to map to data for overall democracy in a country. *Dissonant States* considers the potential of a live score as an interface for data-sonification.

Other sonifications of global socio-political data exist, such as *Navegar é Preciso* (2006) by de Campo and Dayé which 'traces the route of the first circumnavigation of the globe led by Magellan (1519-1522) by sonifying social statistics of the countries along the way' (Schoon and Dombois, 2009, p. 10). Their sonification however focussed on economic rather than democratic data, which was mapped directly to electronic sounds (De Campo and Daye, 2006).

In this chapter I argue that using global democratic data as stimulus for partially notated music sets up a(n admittedly tongue-in-cheek) power-structure dichotomy between improvisational and notated musical forms, exploring the fuzzy boundary that Ross Smith describes between score-level and performer-level agency (Smith, 2015). This is used to broadly comment on the relationship between different modes of performance practice, the relationship between performer, algorithm, and composer, and their effects on performer agency. This is made explicit through connecting performance practices to real world citizens' freedom in different forms of political systems.

The chapter which follows explores dissonance and score design as aspects of sonification; live scoring techniques; the data sets used to generate the score and how they map from data to musical aspects; and we conclude with evaluation and discussion of two performances of Dissonant States.

The appendix (A) which accompanies this chapter details the data used, specifics of the data mapping, an example mapping and technical description.

FIGURE 3.1: Schallfeld Ensemble performing *Dissonant States* at the International Conference on Auditory Display 2015, Graz.

3.2 Political dynamics as a Metaphor for Improvisation as a Democratic Practice

A thread running through this thesis is the position that improvisation is a social and democratic music practice which offers high levels of agency to music performers. The pieces that make up the portfolio examine how we might navigate performer agency in algorithmic music systems from multiple angles. In *Dissonant States* we use data relating to real-world democracy ratings to set up a dichotomy between improvisation as a practice offering full-performer agency as representative of democratic political systems, and fully conventionally notated music with its traditionally authoritarian relationship between performer and composer as having characteristics conforming with autocratic political systems.

The political structures of global states are used metaphorically to express this, with pages of the score generated from data relating to democratic states offering the performers more freedom of interpretation, and pages relating to more autocratic states requiring more strict adherence to score parameters devised by composer and algorithm. The algorithmic design allows for the possibility of impossible sets of performance directions, making the challenge for performers greater in the autocratic sections as they must try to perform **all** directions given.

A constant electronic part sets the harmonic groundwork for each section, reminding us of the ever present influence of the composer/state in musical/political systems even in the most democratic states.

Performers are asked to respond to the score as it is generated in real time, traversing political boundaries, and modifying their level of socio-musical versus score interaction over the course of the piece. Considering the music ensemble as a socio-political formation whose internal power structures are informed by the characteristics of the stimulus used to generate music, we draw a metaphor between the improvising performers and real-world citizens adapting their behaviour to governmental policy changes or varying styles of governance.

Finally, dissonance – in varying degrees – is used as the main musical material of the piece, as working with multi-pitch structures integrally requires collective action to fully express the musical material. Varying levels of inter-group interaction is required in this task depending on the number of performers and pitches, and level of freedom in each particular section. For example, in the autocratic sections the performers are directed to perform each pitch once, meaning they are most likely to have a dissonance interaction with the constant electronic part, whereas in the freely improvised sections there is greater scope for musical interaction with other members of the group.

In the following section we briefly discuss sonification techniques and the potential of dissonance as a sonification parameter.

3.3 Sonification Techniques

Sonification is a field of study concerned with translating data into non-speech sound. It is a sub-topic of Auditory Display, which also considers speech sounds, and the interfaces and technical setups used (Hermann, Hunt, and Neuhoff, 2011). Although primarily used in scientific research to generate new perspectives on complex data sets, sonification allows us to use data as a stimulus for musical creativity (Doornbusch, 2002), exposing aspects of data to wider audiences. In *Dissonant States* we primarily use sonification as a way to connect relevant real world data to ideas around performer agency in live music systems.

Although several models exist for sonification, one of the more widely used approaches is parameter mapping, where attributes of the final sound are derived from the mathematical translation of data values scaled to produce perceptible changes in sound over time (Hermann, Hunt, and Neuhoff, 2011).

Another, more interactive approach, is model-based sonification. Here a model is an interactive instrument which responds to user action, giving the user subsets of the data in auditory form only when requested via the interface. In reality, sonification systems are often a mix of parameter-based, model-based and other approaches to rendering data.

In *Dissonant States* both parameter and model-based approaches are used. The data-parameter mapping is described in Appendix A and Section 3.5, and I describe the potential of dissonance as a parameter mapping in the next section. I also argue in section 3.3.2 that an improvisatory live score could be an interesting approach to model-based data sonification, as the performer's improvisational choices, as well as the score's given ruleset, impacts the audience's perception of the dataset (in much the same way a GUI-based scientific sonification interface gives users a particular set of possible interactions).

3.3.1 Dissonance as a Sonification Parameter

Dissonance has received little attention as potential sonification mapping parameter. The studies (Sethares, 2005; Horiguchi, Nakashima, and Nakanishi, 2016; Mercer-taylor, 2015; Csapo et al., 2009) which consider it generally examine intervallic dissonance as a dichotomy of consonant versus dissonant intervals. Little evaluation into the level of information communicated via relative dissonance has been done. The lack of interest in this area points towards the difficulty of using dissonance as a sonification parameter in scientific fields when the intended audience are untrained listeners.

The general purpose MUSE sonification system (Lodha et al., 1997) had the capability to map data to 4-part harmony so that data values can be mapped to more or less dissonant interval sets. The focus in this project was producing distinct harmonic categories which could be distinguished between by untrained ears. So mappings used basic harmonic structures as the least dissonant categories and tone-clusters as the most dissonant category, though limited evaluation of the effectiveness of the harmonic mappings was done, and current standardised sonification toolkits do not usually allow for easy mapping to harmonic parameters.

Musification is a subset of sonification that ties data mapping strategies to melodic, rhythmic, and other musical structures. In the quest of making data mappings comprehensible for untrained ears much research in this area focuses on traditional musical structures such as tonal harmony, and are less concerned with experimental approaches to composition.

Coop (2016) argues that musification can be used to reach the full potential of sonification by 'engaging' the listener through the use of musical craft. Vickers and

Hogg (2006) go further, proposing that Varese's definition of music as organised sound is directly comparable to sonification as sound organised according to data structures. They argue that any musical parameters and logic – including electroacoustic, free jazz, and experimental – can be used as part of a sonification as long as the structures are clearly communicated.

Using Vickers and Hogg's approach, in *Dissonant States* I focussed on timbral dissonance as the key parameter mapping element of the sonification as there is a clear metaphor between levels of inclusion and political freedom, and the inclusion of many pitches and potentially jarring sounds. Concentrating the musical material mainly on aspects of dissonance allows the listener to focus their attention towards the characteristics of the pitch sets, understanding the metaphorical relationship between the underlying political data and the relative level of dissonance more clearly than if this was one of many musical parameters used in the composition.

Lach Lau's (Lach Lau, 2012) research into dissonance curves was a big influence on the development of Dissonant States, not least as DissonanceLib, his dissonance library for SuperCollider, was a major building block in the technical development of the work.

Prior studies in the use of dissonance as a sonification parameter tend to focus on arithmetic approaches, however in *Dissonant States* I use Lach Lau's library to calculate dissonance according to sensory roughness (Sethares, 2005). Roughness is related to beatings between sounds, that is, fluctuations in dynamics (Sethares, 2005, p. 43) produced as a result of interferences between the amplitudes of two periodic sounds. Furthermore, it also refers to those interferences that happen between the partials of a single sound (Lach Lau, 2012, p. 2). This theory of consonance and dissonance stems from Helmholtz and considers dissonance as related to timbre – not harmony (Von Helmholtz, 1912) . This means that the dissonance level is dependent on register and spectrum. Sethares (2005) considers the spectral roughness of a pitch and its partials against a transposed set of partials to determine an overall level of spectral roughness of an interval or set of intervals. An overall harmonic roughness value then is determined by the number of pitches, their intervallic relations, the range of the pitch set and the register they are played in. In our sonification mapping therefore all of these parameters are used in the generation of pitch sets which have a harmonic roughness with an approximate mapping to the overall democracy level of a country.

A full explanation of the data sets used and the mapping of data to sound parameters is included in Appendix A along with an example mapping for one of the datasets used. We now turn our attention to aspects of live scoring techniques used in the development of *Dissonant States*.

3.3.2 Live Scoring as Model-based Sonification

Vickers and Hogg (2006) comment on the similarity between sonification and performers playing abstract musical scores. As an example they position a pianist as a complex Auditory Display as their interaction with the score is turning a representation of (musical) data into sound in order for the audience to understand better the structure of that data.

Model-based approaches to sonification consider the interface for the sonification as giving the user a set of options for interacting with the data. The data is presented not as a fixed sonic representation but as an interactive instrument where the user can pick and choose which parts of the representation to play and in what order.

Although the order of the data representation is fixed in Dissonant States, we can still consider the score as a model-based sonification as performers have the agency to choose (within the sections) how and when to render the material into sound. Taking this argument further, we can argue that the performer's agency within the sonification model increases according to the size of the pitch set, and depending on the ruleset in play. Score pages with larger pitch sets give the performer more options for interaction, and the mapping of data to more or less improvisation could be compared to how restrictive a computer interface is in guiding user interaction.

In *Dissonant States* the performers are actively mediating the data through interpretation of the score. The performers have some agency to the design of the sonification, choosing the exact mappings of score data to melodic and harmonic information.

The audience experiences the data through the performer interpretation, and through the optional projection of the score. As this role of the musicians as data-interpreters directly affects the audience's ability to interpret the relative democracy levels in each of the states, key decisions were made regarding which elements of the sonification are fixed and what is left to performers' interpretation and interaction with the score.

Some set elements in the score include the time line of the piece. This magnifies the importance of political change over time, i.e., it will always be the case that the audience will perceive pockets of fast political change, which seemed to be an important aspect of the structure of the data to convey, and is therefore flexible in its interpretation by the performers.

From the opposite perspective, the dual mapping of dissonance and improvisation allows the audience to more accurately perceive the improvisatory behaviour of performers in a given section.

In the next section we will consider the design decisions in the development of the live score and their role in the musical choices of performers.

3.4 Live Scoring

Live scoring techniques offer, amongst other things, the possibility for animated notation and the live interaction between the performer, audience and/or composer, and the notation. With roots in graphic and open scoring systems and in algorithmic music composition, Freeman and Street (2008) describe live scoring as the 'merged expression of algorithm and performer'. They determine one of the motivations of using live-scoring systems as mediating the output of algorithmic music systems via expressive human performers. Live scoring techniques can also be used to allow multiple versions of the same piece to exist through incorporating randomised elements in the score generation processes, or to include elements of improvisation or aleatoric sound generation in pieces without the need for complex scoring systems and notation.

In *Dissonant States*, live scoring is used to generate a unique set of pitches (where multiple pitch parameters combine to produce the correct dissonance value for each section (see Appendix A) in each performance and to allow the algorithmic generation of performance directions. This ensures that each performance of *Dissonant States* includes elements of improvisation, whilst maintaining the link between the musical output and the structure of the data used to generate the score. The motivation for using live scoring to express political data lies in the possibility to mediate data via human group behaviour, modelling real world political freedom through elements of team work, social conscience and a dichotomy of notated versus improvised music.

3.4.1 Score Design

McClelland and Alcorn (2008) define three categories of live scoring: 'pages', 'scattering' and 'scrolling'. In *Dissonant States* the nature of the data – in sequential groups categorised by country – lends itself to the 'pages' style of live notation. Hutchins, 2016 describes the challenges and opportunities of 'pages' style live notation in relation to his graphic live score *Imramma* (2016):

> Because the choir was reacting to score changes in real time, they had not had an opportunity to imagine a new approach and so, with limited time to respond, they chose to interpret those circles in a manner very similar to how they had for the Cardew. (Hutchins, 2016, p. 154)

As standard music notation is used in the case of *Dissonant States*, I would argue the ensemble is less inclined to 'revert' to a previous interpretation of material as in graphic notation, as the basic building blocks of the musical material is given, freeing up the cognitive capacity of performers to concentrate on interpretation.

Freeman and Street, 2008 identify a challenge of live scoring as requiring high levels of sight reading from performers, either limiting the level of 'liveness' of the score or limiting the complexity of the type of notation which can be used. Graphic scoring may be one approach to producing live scores which are easily readable, yet allow performers to add complexity to the musical structure and more easily perform expressively. They describe mixing simple staff notation with graphic notation depending on the particular demand of sections (harmonic clarity versus non-synchronous rhythmic complexity).

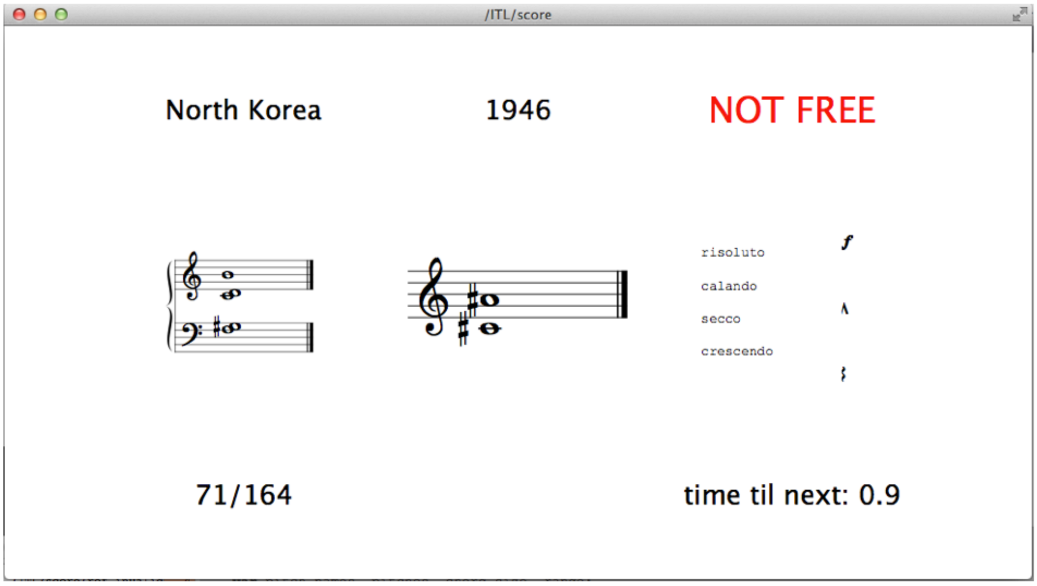


FIGURE 3.2: Example score pages from *Dissonant States*.

This freedom is also not without its drawbacks however. As these perspectives demonstrate, we could surmise that this approach potentially prevents real novelty in interpretation taking place in performance.

In *Dissonant States* I hoped that the simplicity of the material combined with the unpredictability of the performance directions would push performers into new directions on each performance, as they navigate the complexity of reconciling performance directions not normally used in conjunction with new combinations of pitch material and performers in each section.

Winkler (2004) describes using graphic notation as a new challenge for performers as successful performance relies on performers 'knowing the system' over them 'learning the notes'. This provides us with a useful analogy for *Dissonant States* as political systems require citizens to act within given limits, and we can see our performers in *Dissonant States* as performing within limits which change in each section of the performance. Smith (2015) argues that 'agency lies primarily with the performer to activate or dynamize the conventional score, whereas the dynamic score has agency over the performer; movement is perceptible, not of the eye, but to the eye'. *Dissonant States* deliberately plays on this tension in agency by instructing the performers to act with differing levels of freedom depending on the data associated with a particular political state.

Finally, Freeman and Street (2008) describe how failure can also be an integral part of a live scoring system. In Didkovsky's work *Zero Waste* (2002) for piano and computer-generated score, the performer's inability to interpret the score is fed back into the system informing the next sections of the score. In *Dissonant States* a much simpler approach is taken to addressing failure, with the algorithmically generated performance directions offering sometimes impossible criteria for performers. This was a deliberate attempt to model governance styles which present citizens with an impossible set of choices, e.g., asking citizens who have been advised not to work on medical grounds to seek employment which would be physically harmful to them.

3.4.2 Data Scores

A number of previous works offer useful models for mapping data to live notation.

Julie Freeman's *Translating Nature: B) Nanotextures* (2007) uses data relating to nano-technology to produce abstract graphical representations to be interpreted by the performers (van 't Klooster, 2012). The data used in the score is mediated both by the composer's abstract graphic representation, and by the performer's interpretation giving audience members only a very high level representation of the data structure as detail is lost at each point of the mediation process.

John Eacott's *Floodtide* (2008) uses live data relating to tidal streams to generate pitch and rhythmic material for scores using conventional and simple notation in real time for human performers (Eacott, 2012) . The scores are performed in public places over long durations, serving as a reminder of the natural environment to passing audience members. Eacott describes an expanding definition of sonification, including his work *Floodtide* as an example of a potentially inaccurate representation of the input data. We can consider then that outside of scientific uses, liberal interpretations of data may be just as useful in communicating aesthetic ideas as entirely accurate mappings.

3.5 Dissonance as a Mapping for Political Dissent

Developing *Dissonant States* began from the idea of mapping political dissent to sonic dissonance. The logic of the mapping is that the more democratic freedom a state allows, the more room there is for conflicting political positions and many voices and opinions, whereas in autocratic states usually only the ruling party has a public platform for political position. In these states dissenting voices are often silenced, meaning autocratic states may appear outwardly harmonious due to the oppression of political freedom.

A two part approach was taken to representing the countries data. Firstly, the data is used to calculate a pitch set with relative levels of dissonance relating to the democracy data for the country. This gives an outward appearance (or auralisation) of the level of political harmony (or multiplicity) in the country. Secondly, the rating for freedom in the country defines the level of improvisation the performers use in the interpretation of pitch sets and other performance directions.

Alongside the pitch set a number of performance directions are given – randomly chosen from a large set of possible directions – and the direction for freedom determines how accurately the performers should try to interpret the instructions. As the instructions are randomly chosen it is sometimes the case that they are conflicting – e.g., Fortissimo and Sotto Voce could be given in the same section. In recognition of the often unreasonable demands of autocratic governance in the 'not free' sections performers are asked to interpret as closely as possible the performance directions, even when conflicting. In the 'free' sections the performers may use the directions as a guide but do not have to follow the instructions if they so wish.

3.6 Evaluation and Discussion

Dissonant States was performed by two different ensembles: Ensemble7Bridges (E7B) (Figure 3.4) and Schallfeld Ensemble (Figure 3.1), both of whom have a background in contemporary music performance practice. Unfortunately the Schallfeld Ensemble performance was not documented, but from personal recollection provides a useful comparison for evaluating the system.

E7B workshopped the piece before performance giving the feedback that they found the sections where the pitch sets change very fast difficult as they were unable to even read the performance directions never mind play them. Hoadley (2012) mentions a sight reading delay of 0.3-1.3 seconds depending on the complexity of the material. Responding to this research and the performers' critique I extended

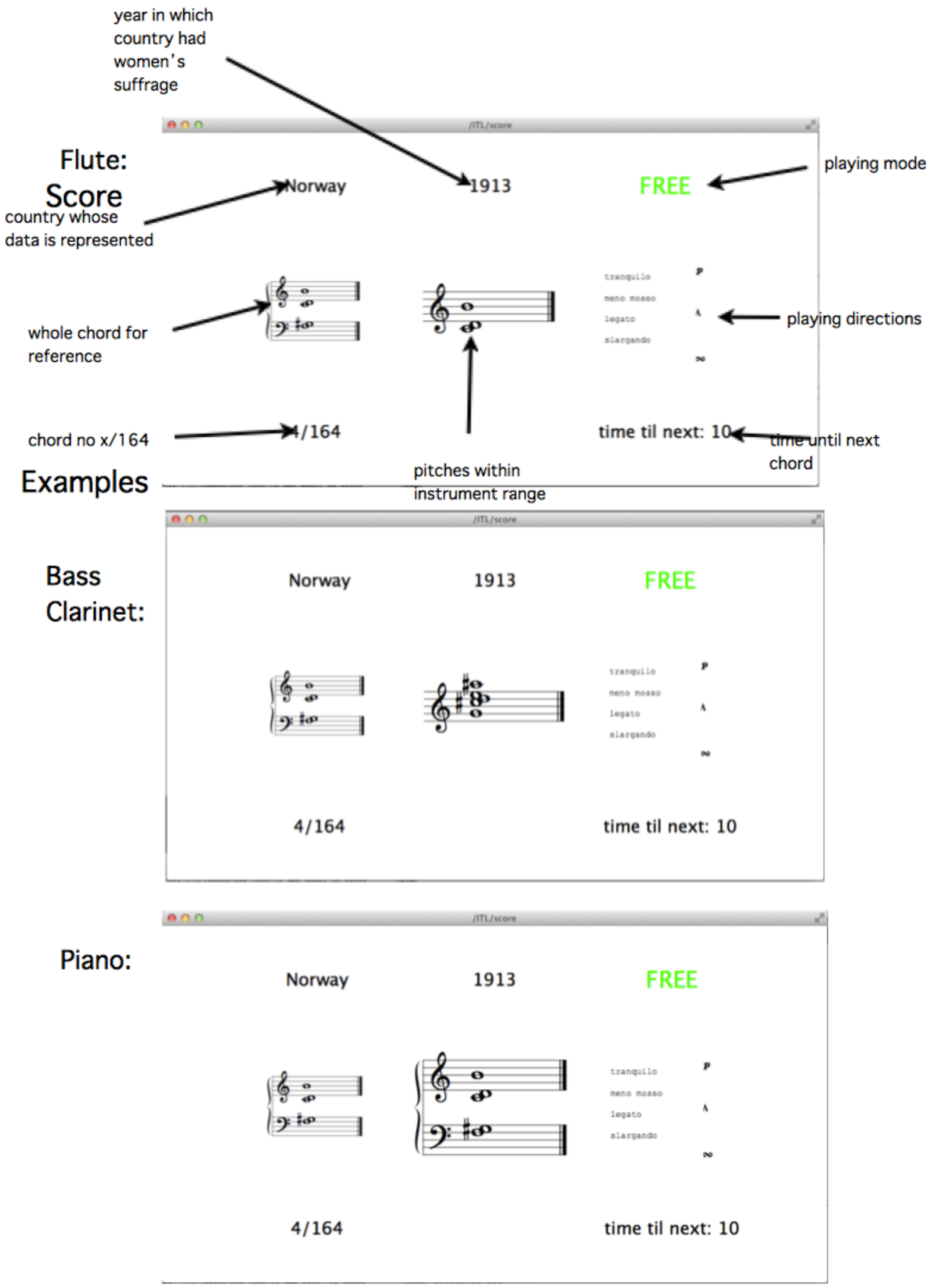


FIGURE 3.3: Three versions of the same score page mapped for each performer. The flute part is annotated here to show aspects of the data:score mapping.

the duration of the performance from 10 minutes to 15 minutes, thus increasing the minimum duration by 50%. This meant very few of the pitch sets last less than 0.3 seconds, and as my musical material is very simple, this seemed to give the performers a more adequate amount of time to attempt to play them.

E7B were also critical of the fact that the performance directions were sometimes conflicting. As the conflicting performance directions were conceptually important to the aesthetic idea of the piece I left these in. The Schallfeld Ensemble were less troubled by this aspect of the piece. Though I did not ask for specific feedback on their in-performance solutions to conflicting directions, I did not find them detrimental to either performance. In comparison the two performances were stylistically different, indicating that the system is not overly restrictive on performer agency and allows personal expression. The contrast in playing style between 'FREE' and 'NOT FREE' sections was evident in both performances despite the different improvisatory styles. In the future I would be interested to perform the work in free improvisation contexts and see how this musical aesthetic might imprint itself on the work.

Still from a video filmed and edited by Simone Tarsitani

FIGURE 3.4: Ensemble7Bridges performing *Dissonant States*.

3.7 Conclusion

Dissonant States explores a number of means of algorithmically generating material for improvised performance, i.e., data sonification, live scoring, generative algorithms. Through these technological lenses we can interrogate the proposition of Mccormack and Inverno (2016) that successful technologically-mediated improvisation requires software systems that do not put restrictions on performer agency. The piece uses a real world scale of democracy to produce a musical scale of performer agency, defining interaction with partially notated music, alongside a ruleset which modifies the performers' behaviour in relation to each other and the system, and a scale of difficulty – through fast versus slow score page changes and varying difficulty in interpreting performance directions – which modifies the ability of performers to transform the data into sound. Dissonance was chosen as the main sonification parameter both for metaphorical reasons and because it fundamentally requires co-operation between performers to produce. It is also an aspect of music which can easily be perceived when presented in a simple format. Most crucially Dissonant States aims to use the structure of the performance system to modify improvised behaviour, asking performers to modify their actions and their relation to the system and to each other depending on the exact parameters of the current ruleset in play, proposing that even subtle changes in a musical ecosystem have great impact on social interplay and performer agency.

In the next chapter we consider the varying types and levels of performer agency which may be experienced in a distributed control system, modelled on live algorthmic performance practices and network communication structures.

Chapter 4

On Edge

4.1 Introduction

On Edge is an algorithmic composition performed by humans. The score is generated in SuperCollider and it, together with several rulesets, defines the behaviour of the human performers and their musical output.

Concepts from network music, and its distributed control systems, and live coding performance practice, which combines human and algorithmic activity, were instrumental in developing *On Edge*. I apply these practices to an instrumental ensemble, exploring the limits of task complexity which can be carried out by humans and algorithms. The machine-like tasks – e.g., combining several simple patterns in a more complex one – are carried out alongside tasks more suited to humans than algorithms – determining score positioning of other performers through listening to pitch and rhythmic characteristics.

I model networked systems by distributing tasks related to interrelational behaviour and sound generation across multiple performers. I also reference algorithmic performance practice by designing simple rulesets to be used in combination, and a mechanism by which performers can intervene in the instruction sets and actions of others.

The sound is produced by a group of any size of monophonic acoustic instruments, with 4-8 being an ideal number. The musical material is deliberately mechanical, with complexity built through this combination of rules and through the layering of several of these algorithmically produced musical lines as performers play almost constantly throughout the piece. As the piece progresses, the set of instructions – which should be simultaneously executed – grows in number and diversity, increasing the complexity of the sound production task and exposing the limits of human cognitive ability and the fallibility of human action.

I investigate aspects in which humans may be worse at interpreting algorithmic instructions by working with musical material which is complicated by the human capacity for hearing, i.e., metrical pulsing at multiple tempi and in multiple note groupings.

Five different roles contribute to the final outcome of the improvisation: the composer – who designed the algorithm to produce and follow the score and set limits of the performance including the temporal structure; the algorithm – which produces a graphic score according to the composer's instructions; the conductor – who chooses how the musicians should follow the score, and how they behave in relation to each other; the acoustic musicians – who act as the output of the process, make decisions about some elements of the music content and decide how to move around the score in relation to each other and conductor directs; and the 'assistants' – who issue additional instruction at a given rate.

The assistants added an unforeseen theatrical element to the piece, with human effort clearly on show through the assistants running backwards and forwards distributing directions to performers.

4.2 Rhythmic Complexity

The musical material of *On Edge* is rhythmic pulsing at shifting tempi. More often than not a performer plays at a different tempo than the other performers. This was chosen as the material on which to develop the piece as it is easy to define algorithmically and to 'perform' with a computer, but a relatively difficult tasks for humans performing in a group. Several music psychology experiments have shown that there is a tendency for humans to conform a tempo tap with one that they hear (Repp, 2005; Hove, 2009), so maintaining a range of tempi and tempo transitions in a music ensemble is relatively complex.

Combining multiple tempi can be traced back to Nancarrow's experiments with player piano. Nancarrow used simple punchcard technology to generate multiple streams of material in several tempi, combined with mechanised sound production to produce rhythmic complexity which is near impossible for the pianist. The interplay of social and technological elements are clear in the player piano pieces. On moving to Mexico in 1940 he struggled to find performers who were sympathetic to the style and complexity of his music so he focussed his attention on the player-piano. This allowed his music to be performed, but also the piano roll medium facilitated experimentation with complex rhythmic and temporal parameters, which would have been unplayable for a traditional human music ensemble. One of the defining characteristics of this body of work is the temporal conflict among simultaneous layers of rhythmic material, which Nancarrow termed 'temporal dissonance'. Nancarrow described 'temporal dissonance' as the final frontier of musical complexity (Thomas, 2000).

The ability to generate high rhythmic complexity has long been associated with algorithmic and computer music. Xenakis conducted some of the earliest experiments in using computing to aid with generating complex mathematical structures for scores to be played by humans. The first computer generated score, *The Illiac Suite* (1957), also used simple algorithmic rule sets to generate human playable scores. At the time, generating complex sound with computers was limited by computing speed and power and extremely time consuming, so score generation was a practical method to to harness the potential of computers. However, there was also an interest in the expressivity that performers could bring to computer generated compositions (Freeman and Street, 2008).

More recent computational approaches to human-playable rhythmic complexity include Ryan Ross Smith's live scores (Smith, 2015) which use rotating metronomes to indicate note onsets to performers allowing accurate tempo interpolations and tempo canons.

These efforts suggest that playing temporal dissonance is a difficult task for humans who have aural awareness of their surroundings, and therefore was an ideal candidate for the material basis of developing a piece about humans performing algorithmic material.

4.3 Humans Following Live Algorithms

Many examples exist of humans following algorithms performatively – even standard western music notation itself is a sort of algorithm. As computing becomes a more integral part of productive and social life it is natural that composers more explicitly explore computational directions for music making. The perceived complexity of computational systems is often reflected with human fallibility as counterpoint, forming an essential part of the process-based music production.

Scores which include specific reference to algorithms include Andre Damiao's *Diacriticos* (2013), which uses SuperCollider-style code combined with graphic elements as notation for an instrumental ensemble. The conditionals used in the code formation set up a cybernetic system where performer action is dependent on the action of other ensemble members (Damião, 2013). Jean-Luc Gionnet's *Dyslexic Harp* (2007) sets out a process to be carried out by a harp player in the dark, with errors in the process to be followed by a particular signal. The performance directions state that the work is considering the performer as computer, and the piece is 'like a test' (Gionnet, 2007).

With live coding facilitating improvised algorithm design, live coders have also explored writing algorithms for humans to follow. Magnusson (2011) draws comparisons between live coding and music notation and developed *Coding the Marimbist* in 2015. The piece uses a code-like language developed for a marimba player to follow. Magnusson writes algorithmic instructions during the performance for the marimba player, which build in complexity. He writes new directions depending on her interpretation of the last one. This serves to highlight the gap between human and computer modes of understanding – humans being somewhat more unpredictable than computers!

Kate Sicchio's *Sound Choreography<>Body Code* (Sicchio, 2015) involves a human performer responding to live written choreographic instructions. The piece is in collaboration with Alex McLean who is writing sound code and a movement score which is interpreted by a dancer. In turn, the dancer's movements are tracked using a Kinect motion sensor, and used to change both the sound and movement code, creating a feedback loop between the performers.

4.4 Human vs. Algorithmic Difficulty

Another short piece composed during the course of the PhD (*Chroma*, see Appendix F), also explored the potential of exposing human and technological fallibility through algorithmic composition. The score is an algorithmically extemporised chromatic scale (using a mix of computer and human enacted algorithms) performed by cello and contra-bass flute in unison. Cello and contra-bass flute have a similar range, but a drastically different level of flexibility and ease of playing. The piece exposes the limits in tuning and tone of the contra-bass flute by requiring the performer to play the entire range of the instrument at piano or quieter. This is accompanied by the cello, an instrument on which this task is much easier. To even out the difficulty and to produce a stronger variation in tone over the course of the piece, the cellist performs the entire piece on the C string. The interesting parts of the piece are where the friction is obvious between the notated music and the capabilities of the performer to produce the score material accurately on their instruments.

4.5 Distributed Control

On Edge explores the algorithmically instantiated performance and improvisation practices discussed in the previous sections. However, in *On Edge* the full instruction set is determined by the intersection of multiple humans given a subset of instructions. Much of the work of this thesis explores ways to use network-technology to distribute control of the performance in such a way that group decision making is preferred. In these systems, normally performers are given equal decision making power, or at least the agency to make the same 'type' of decision in regards to their own improvisation (such as in 5 and 7). In *On Edge* tasks are distributed so that each performer has responsibility for only one type of task in the performance, giving them different types of agency within the music production ecosystem.

In a similar way, Hummel's *Mind Your Own Business* (Hummel, 2017) splits the task of live coding between a number of performers, allowing each performer to focus their cognitive facilities on only one task. In this piece, the live coding task is split into synthesis design; patterns; effects; and amplitudes, with each task being undertaken by a single performer. This leads to a break in the normal feedback cycle whereby a single action can be attributed to a sonic result, by building a complex web where the output is related to inputs from several performers who have no knowledge of the algorithmic actions of others. This removes the agency of each performer to have total control over separate parts of the total ensemble sound, instead requiring them to work together on all parts of the sound creation. Part of the complexity of this task relates to the unpredictability of the actions of others.

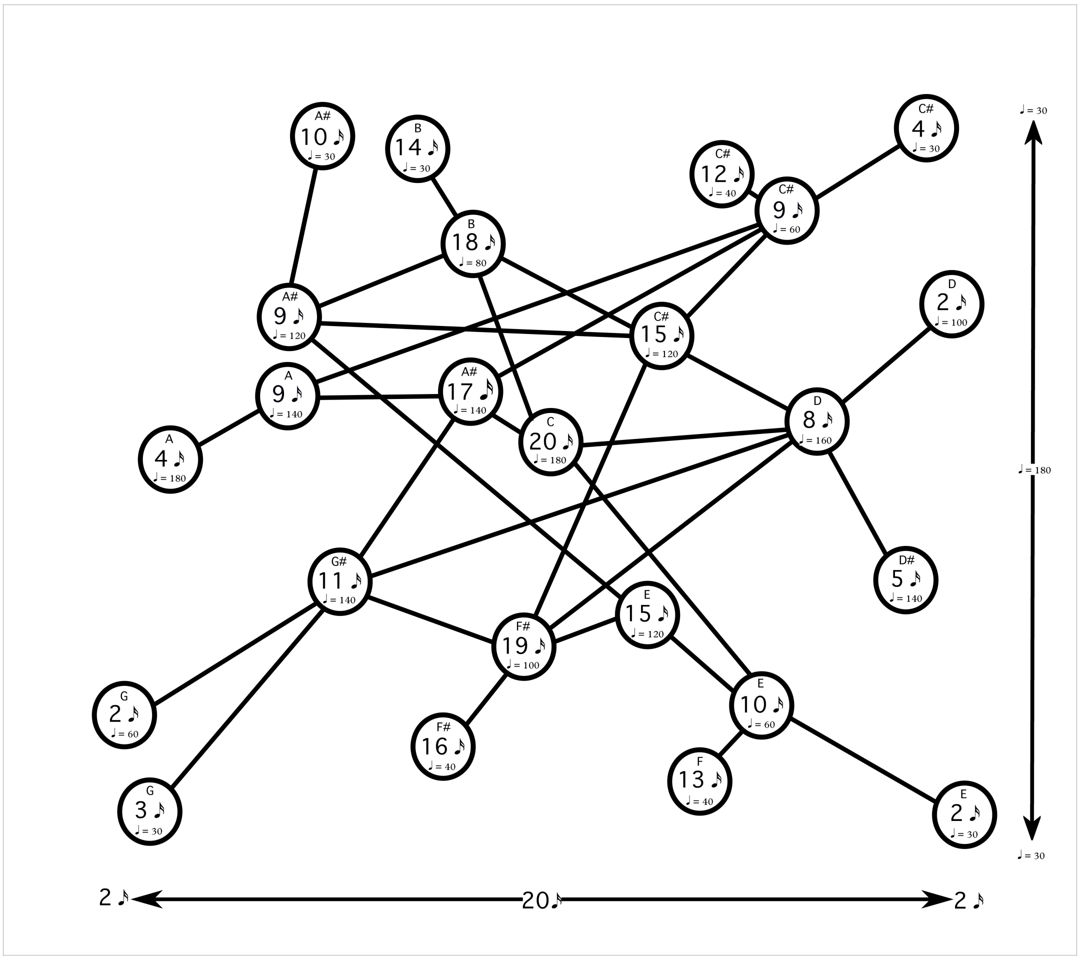


FIGURE 4.1: Full score for *On Edge*.

4.6 The Score

In the following sections I discuss different aspects of the score, including, the aesthetics of the visual design, the interpretation of the notation, role divisions and the algorithmic generation of the score itself.

4.6.1 Network Diagrams as Score

The aesthetic decision to use a network diagram style representation for the score is a graphical reference to the decentralisation of music production used in the piece and a way to emphasise collectivity as part of the performance. The network diagrams are also representative of the structuring of communication, which is a key aspect of the piece. As I will discuss in section 4.6.5 each group of performers has particular communication channels and modes of communication which influence the agency they have in the performance.

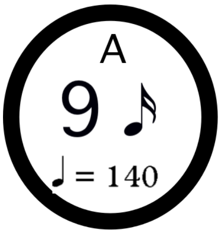
On a musical level, the node and edge design facilitates particular musical behaviour, which influences the sound – i.e., the act of performers moving towards or away from a particular node instantiates a feeling of rhythmic and harmonic convergence and divergence as the paths join or separate.

The score consists of two main features defining rhythmic pulsing and possible paths between different pulses. The nodes in the score (represented by black circles) contain pitch, tempo, and note grouping information. The paths between them (represented by black lines), denote the possible transitions between nodes. Performance directions included in the score explain that performers have a number of choices for how to transition between pitch selection, tempi, and note groupings in the paths between nodes. Combining these options in various ways means there are 16 possible transitions for each edge. The time taken to transition between nodes should generally be proportional to the length of the line on the score. Performers can stay at nodes for between 5-10 repetitions of the note grouping, during which time they can either play the note grouping, rest, or mix rests and note groupings.

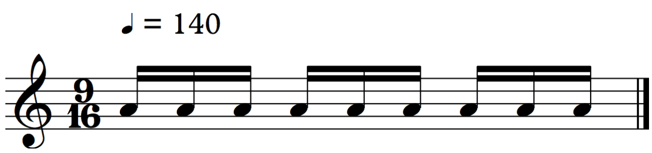
4.6.2 Musical Material

The musical material of *On Edge* is made up of rhythmic pulsing at different pitches and tempi, and the transitions between those different pulses. This was designed with algorithmic composition in mind. It is extremely easy to programme a computer to perform these musical cells in isolation – and also easily achievable for human musicians to perform (up to a certain tempo). However, the transitions are a more complex programmatic task and transitioning accurately between multiple tempi concurrently to other performers, who are conducting their own transitions, is fairly difficult for human instrumentalists.

Translating the information from a single node into sound is programmatically simple, and – in isolation – easy to play. For example, the following node may be notated as such:



(A) Example of a node from the score of *On Edge*.



(B) The node translated into standard musical notation.

FIGURE 4.2: Notation in *On Edge*. Example 1.

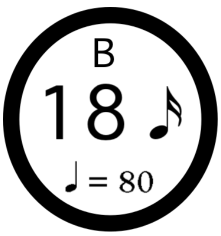
or represented by just a few lines of simple code (realised here in SuperCollider):

```
Pbind(
        \amp, Pseq([0.8,Pseq([0.1],8)], inf),
        \dur, 0.25,
        \legato, 0.1,
        \midinote, 69,
).play(TempoClock.new(140/60));
```

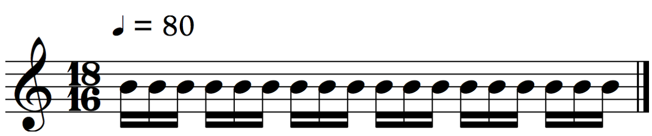
Complexity arises out of the collision of multiple tempi, for example another performer may play the following simultaneously:

```
Pbind(
        \amp, Pseq([0.8,Pseq([0.1],17)], inf),
        \dur, 0.25,
        \legato, 0.1,
        \midinote, 71,
).play(TempoClock.new(80/60));
```

or:



(A) Example of a node from the score of *On Edge*.



(B) The node translated into standard musical notation.

FIGURE 4.3: Notation in *On Edge*. Example 2.

This is easy to achieve algorithmically as playing one tempo over another is a simple mathematical operation. In the human realm this task is most readily achieved by keeping an internal tempo and blocking out the conflicting tempo of the other performers.

At the beginning of the performance each performer must choose (without discussing with other players) an initial node from those at the outer edges of the score which have only one connecting edge. They can stay at this node for as long as they choose before transitioning to the next node. After this first transition they move around the score as they wish, choosing their own paths between nodes and making whichever transitions they choose until they receive signals from the conductor.

The conductor has three choices to direct performers:

- The default motion is free movement, i.e., the performers choose whichever paths they like to move around the score, as described above.
- 'Come together' directs performers to attempt to reach the same nodes as other performers. They can achieve this by listening to the pitch, tempo and note groupings of other performers.
- In the final movement option performers must try to avoid following the same paths as other performers. If they find themselves at the same node as someone else, where possible they should exit the node via a different path.

These movements were designed to give different sound characteristics to the overall texture: that of converging on the same material, diverging away from the same material and of a more anarchistic free movement.

In each of the seven minutes of a performance, additional performance directions are given to performers, which they must (at least try to) follow. These directions are given by 'assistants' who shape the music by giving cards containing different categories of direction to the performers. In each section they can give a greater maximum number of cards and can make more changes to the performance directions. The diversity of the types of performance direction also increases over time, leading to a musical transition from relatively mechanistic pulsing at the beginning to more complex and expressive melee towards the end. In workshopping the piece the act of the assistants giving out increasing numbers of directions gave an unexpected theatrical element to the performance. The very visible physical effort of the task of both giving and following the directions, emphasised the complexity of the task with increasing intensity.

4.6.3 Score Generation

The score for *On Edge* is algorithmically generated using SuperCollider. The algorithm generates 12 nodes in the central part of the score, plus twelve 'starting' nodes in the outer part of the score. The nodes are distributed randomly in each of the areas (outer and inner). Edges are drawn between the outside nodes and their closest

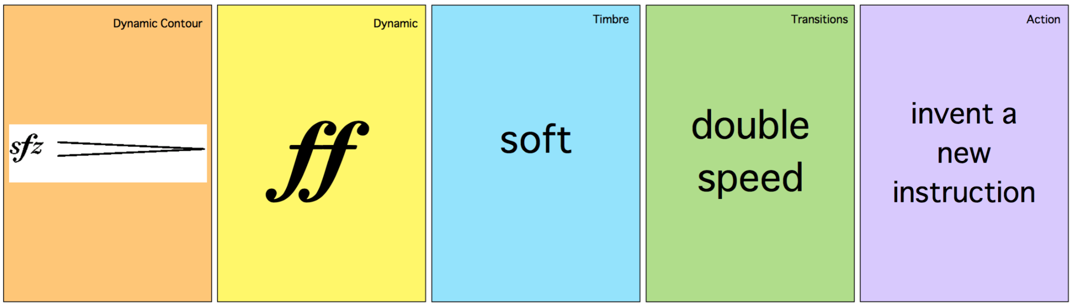


FIGURE 4.4: Direction cards given out by the 'assistants' in *On Edge*.

inside node. Finally edges are generated between randomly selected pairs of nodes in the central section.

A guide grid is drawn to determine the pitch, note groupings and tempi of each of the nodes (See Figure 4.5). Tempo is scaled between $crotchet = 120$ in the centre and $crotchet = 60$ at the top and bottom of the score. Note groupings are scaled so that there are 20 notes in a group at the centre and 2 notes in a group at the far left and far right. Pitches are determined according to a clock face arrangement with pitches ordered chromatically in a circular arrangement around the score.

After the score is generated in SuperCollider, I then used a graphics programme to draw the final version of the score according to the pattern produced algorithmically. The piece was developed for the Ives Ensemble composition workshops held at Durham University in Autumn 2014. I realised one version of the score for the purposes of this workshop, but the template algorithm could be used to generate new patterns for other performances.

4.6.4 Role Division

From the above exposition we can see there are several parties with clearly defined roles in the production of a performance of *On Edge*:

- The **composer** designs the social interaction and task division, as well as defining the basic musical material, time based structures, and possible performance directions. The composer also wrote the algorithm determining the limits and conditions of the score design.

- The **algorithm** is responsible for fine level details of choices over sound production, routes between nodes, and the exact placing of nodes. These further define the limits of the performance and specifics of the musical material.

- The **conductor** makes choices about directions for broad performer behaviour – 'come together' is clearly a more cooperative mode requiring deeper listening than the 'free movement' mode. Free movement is a more anarchistic mode where actually not listening to others would be beneficial for tempo accuracy.

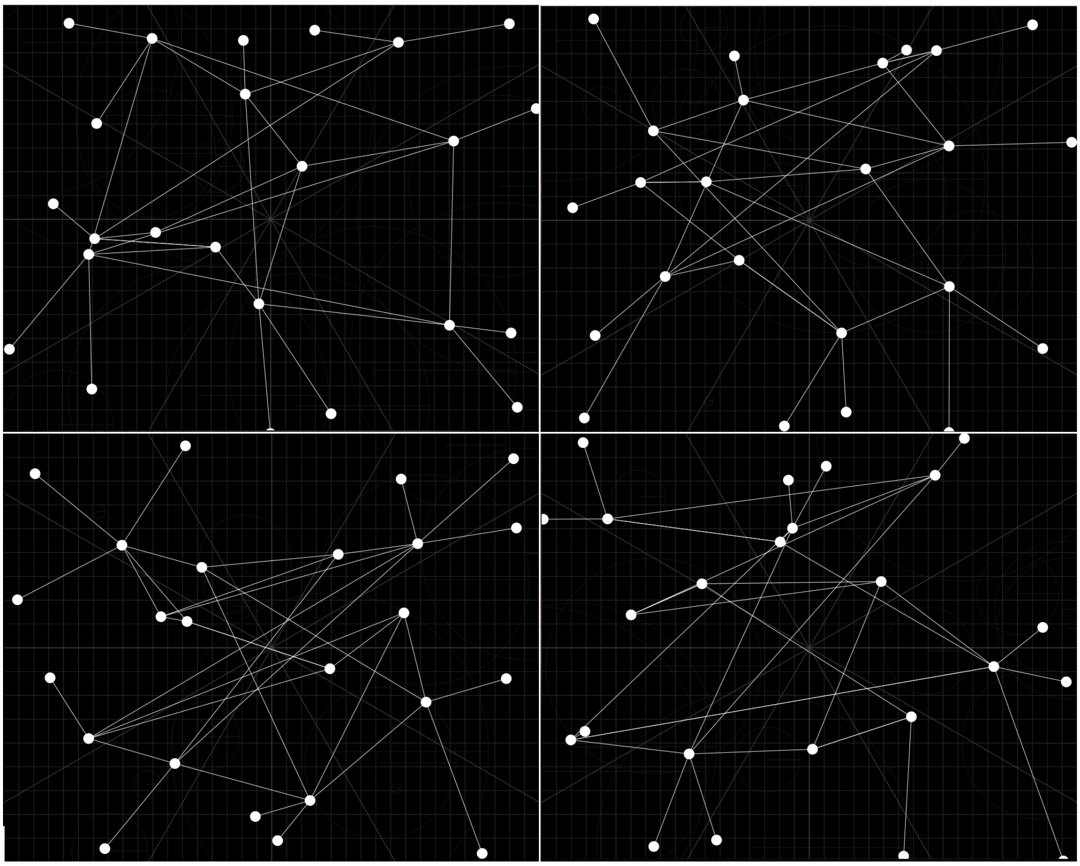


FIGURE 4.5: Templates generated with SuperCollider for producing scores. The templates include guide grids determining the tempi, note groupings, and pitch boundaries.

- The **assistants** make micro-structure decisions about the performance, deciding which directions to give the performers and at which point. Their influence gets larger as the piece goes on and they have the option to give a greater number of directions. The job of 'assistant' is split across several performers – one for each 1-2 instrumentalists. It is up to the assistants to decide whether to make musically cooperative or destructive decisions with their allocation of directions.

- The **instrumental performers** mediate all of these decisions in the task of sound production. They contribute decision making on the exact paths, types of transitions, and lengths of time spent at nodes. However, structurally they have perhaps the lowest level of agency of all participants. As sound producers though they have the highest level of interpretive responsibility, combining the score, conductor, and assistant directions into actual sound.

4.6.5 Feedback Loops

In live coding literature, Rohrhuber et al. (2007) theorises live coding as a feedback loop, with the output of the algorithm having an impact on the future decisions of the live coder. In Hummel's *Mind Your Own Business* we can see this feedback loop develop an extra layer of complexity by splitting the task of live coding a single sound among several performers who are unaware of the algorithmic actions of the others. In *On Edge*, we have a similarly complex feedback loop which includes distributed control where performers have varying levels of agency.

Each of the roles described in the previous section have particular communication channels that are used to convey information to other contributors. I have summarised these communication channels in Figure 4.6 which shows a simplified version of the communications web created by the performance. I use solid arrows to convey direct instruction and dotted line arrows to convey implicit communication, by listening or other cues, which may impact on the decisions made by one of the actors.

Through this analysis we can see the interrelational nature of the music production process involved in a performance of *On Edge*. Where a performer may not direct the actions of another performer, the improvisational nature of the interaction with the score materials means the decisions they make may inform the decisions of another performer. At best, the performers are always listening and reacting to the other performers in making their decisions to follow a particular path or give a particular direction.

4.7 Evaluation and Discussion

On Edge was workshopped by the Ives Ensemble as part of a composition workshop at Durham University. A concert performance by the New Art Music Ensemble

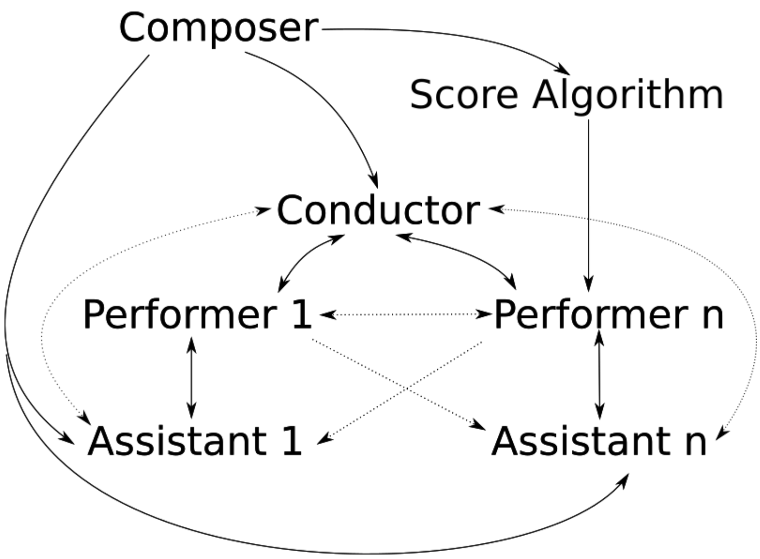


FIGURE 4.6: Communications web in *On Edge*.

was scheduled for the department's Klang Festival, but was cancelled due to lack of sufficient rehearsal time.

From the workshop with the Ives Ensemble it became clear that significant rehearsal time would be required to achieve the level of tempo accuracy and clarity of transitions needed to produce the intended sound characteristics. The complexity of the performance task, combining directions given in real time with the ongoing temporally dissonant rhythmical pulsing became apparent. For this reason I do not feel the recording included in the portfolio is representative of the intended musical aims, although the piece did meet its aims of exploring the complexity of humans following algorithmic instructions and distributed decision making systems.

An unintended aspect of the piece that was revealed in the workshop was the theatricality of the assistant role – I had not anticipated the physicality of giving up to twelve directions per minute on pieces of cardboard to the instrumental performers.

Perhaps sitting in contrast to this was the conductor's role, which involves merely signalling the beginning and the end of the piece and giving occasional hand signals while the other performers work tirelessly to produce the music. This could be seen as an explicit critique of the traditional hierarchy of composer → conductor → performer discussed in other chapters.

4.8 Conclusion

On Edge experiments with improvisation where the musical material is largely defined but the task of defining the structure of the performance is left open, and is split between a number of decision makers. The complexity of interpreting the score and performance directions builds over the course of the piece, and the 'assistants' have more involvement with changing performance directions as the piece goes on. The conductor has a very simple role, but one which determines the level of interaction between performers. The musical material used in the performance is deceptively simple, with the complexity lying in the interaction between performers and in accurately transitioning from one tempo to the next. These tasks are simple to execute on machines, but much more difficult for performers to follow, acting independently of – and in dissonance to – other members of the group.

Temporal dissonance is used as a simple musical parameter, focussing the attention of the piece on the interaction between performers and the emergent theatrical characteristics. The limits of complexity and physicality of human performers carrying out instruction-based tasks is explored.

The piece explores the dynamics of distributed decision making and control structures. The strength of networks lie in their ability to decentralise control and information distribution systems such that failure in one part of the network system does not affect the function of the system as a whole. In *On Edge* we explore how decentralising control and communication simplifies some aspects of musical performance while the interdependency adds complexity in other aspects.

In the chapter that follows, centralised decision making is implemented to mediate a decentralised ensemble, using algorithmic control to facilitate collaboration between geographically dispersed and temporally asynchronous performers.

Chapter 5

Union

5.1 Introduction

Union is a performance system for telematic improvisation which developed out of my collaborative work with two female-identifying[1] laptop ensembles: FLO, and OFFAL. *Union* explores the role of musical consensus in improvised music making, and develops strategies to circumnavigate the challenges of collaboration at a geographic and temporal distance using imperfect technologies. Feminist ideologies relating to non-hierarchical interaction and non-interventionist technology (Iannello, 2013; Baines, 2012; Smith, 2014; Haraway, 2006) played a role in the design decisions taken in developing the system. Various considerations led to the development of an algorithmic mixer, prompting reflections on the narrative impact of algorithmically made curatorial decisions. This chapter also explores the points of technological friction and resistance inherent in such a system and how this resistance impacts on the musical output and audience reception of performances.

In *Union*, a primary design decision was that the interaction with the system should be practice-neutral – i.e., a performer should be able to take part in the performance without any significant intervention in their normal performance practice. Socially aware system design acknowledges the non-neutral role of designers and programmers in developing communication structures, so another concern was that the performer input should drive the interaction and not allow arbitrary interface or sound design decisions made by the composer. For this reason, the primary point of interaction in *Union* is via Music Information Retrieval algorithms which allow data collection and analysis to feed into the algorithmic curation system. The main point of influence of the composer in Union on the musical narrative is in the decisions to use consensus and fairness as the primary curation criteria and in the way these concepts are implemented in the system.

In the introduction to the thesis we explored how network music systems are often concerned with the structuring of multi-modal data exchange, including musical, textual, symbolic, and meta-data. Networked performance systems should consider the affordances created for system users by data exchange structures and

[1] OFFAL use an inclusive definition of “women” and “female” and welcomes any member who identifies with a gender other than male.

interfaces, and importantly, the social dynamics and power imbalances implicitly created by the system. In *Union*, this focus on consensus and fairness aims to ameliorate social and technological hierarchies present in improvising electronic music ensembles. The system uses a mixing algorithm for multiple audio inputs in order to avoid in-performance human hierarchies. Union reflects critical perspectives on online algorithmic curation such as Facebook's news feed and Google's search results ranking, considering the role of algorithms in human narrative development. Visuals were developed for Union to communicate the behaviour of the algorithm and the human interaction via online chat. We consider how the social and technological resistance inherent in the system is communicated through human and technological narratives.

5.2 The Algorithm

Detailed technical description of *Union* is contained in B. I will discuss the aesthetic concerns of the system here.

Knotts (2015) examined the potential of data-centric network music systems to open up additional inter-group communication mechanisms. Modelling democratic political systems, in developing *Union* I was interested in how data-channels could be used to build consensus forming mechanisms which are unavailable to un-augmented improvising acoustic music ensembles.

Also specific to electronic and algorithmic music ensembles is the ability to mediate the input of performers. This is also explored by Green (2012) in *Exchange. Value.* which uses audio analysis as the basis of restricting performer input. Mediating performers' input is one strategy that provides the possibility to combat the formation of socio-technological hierarchies in ensembles, whereby socially high-ranking or more experienced performers may play more than those with lower social status. Mediation and consensus forming techniques are often used in radical democratic political groups (e.g. Unknown, 2014) for the same reason of levelling the social playing field. Key to 'programming' the social interplay in a mediated ensemble then is designing an algorithm which enacts a form of consensus.

In *Union*, I used musical data collection and analysis to develop a method of consensus deduction, and kept a running sum of time 'on air' to approximate even distribution of input among performers. I will discuss these key factors of the algorithm design in the section that follows.

5.2.1 'Consensus'

Modelling the performance system on democratic thinking as an efficient means to develop consensus among groups of humans, *Union* consists of a curation algorithm which considers the sonic 'average' to be the point of agreement between performers. This form of consensus is derived from Pressing's theory of 'associative' vs. 'interrupt' generation in improvisation (Pressing, 1987). Pressing describes two ways to continue an improvisation – the former being associative, where new material is strongly derived from the current material, and the latter being interrupt, where new material is significantly different to the previous material and usually signals a section break. This provides a useful method for determining musical agreement and disagreement in a group improvisation.

The algorithm uses a machine listening library to analyse live audio streams generated by performers and calculates at regular intervals the relative distance of each performer's audio from the mean audio data for that section of the performance. Audio levels of the inputs are then linearly scaled from 1 (at the mean audio data point) to 0 (at the performer furthest from average).

5.2.2 'Equality of Participation'

The algorithm is designed primarily to seek consensus among performers, however – as would be the case in deliberative democracy – two mechanisms exist to expose alternative/dissenting narratives and to ensure participants have equal opportunity to direct the course of the performance. The data relating to the outcome of the curation algorithm is collected at the end of each section and how much time each performer has their stream turned on is recorded. When the difference between the 'on air' time of the least and most played performers gets too high, the algorithm mixes the least played performer highest, creating an opportunity for musical section breaks and ensuring that there is approximately equal participation in directing the musical narrative amongst the group. An algorithm which controls density also forces section breaks by occasionally reversing the criteria for mixing, i.e., by mixing the least average stream loudest. This could be compared to the democratic necessity of allowing opposition or activist voices a platform, offering alternatives to the status quo. Though 'on-air time' is clearly an imperfect measure of equality in music making (e.g. in a string quartet performers generally play for the same amount of time, yet there's a clear hierarchy of contribution and status), this solution responds to the specifics of laptop performance. The lack of acoustic and physical limits of the instrument means that every player could theoretically play constantly at full bandwidth and there are no inherent hierarchies between performers related to the instrument. I argue given the lack of acoustic restriction equal time share is a suitable proxy for equality in this context.

5.3 Designing a Performance System for a Female-only Laptop Ensemble

Union was developed initially for a performance by the laptop ensemble FLO and later became the principle collaboration system for OFFAL . Many of the design decisions arose out of the desire to maximise female participation in collaborative

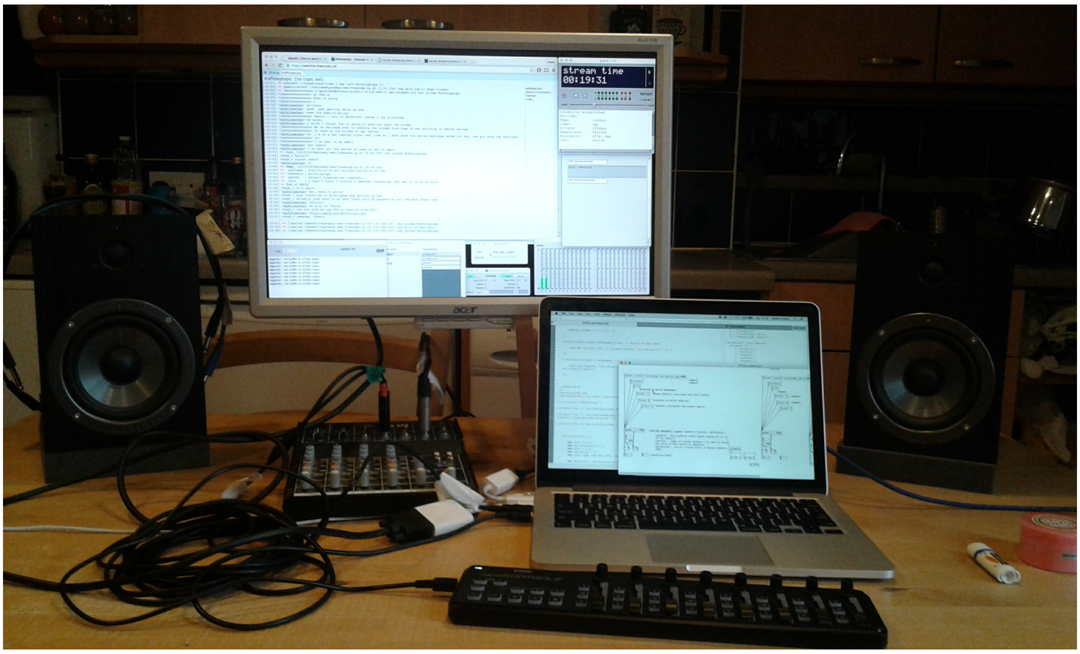


FIGURE 5.1: Taking part in a *Union* performance from my kitchen. Image shows hardware, software and communications setup.

electronic music making, critique gender biases in electronic music scenes, and to design a music making environment which resists normative social hierarchies.

Prior to developing *Union* I had performed a number of times with the Grande Internationale Audio Streaming Orchestra (GIASO) and many of the design decisions for the audio streaming infrastructure in *Union* mirror those of the GIASO. The primary concerns in order to maximise participation included: low cost, minimal impact on performance setups, minimum technical skill requirements and an ability to run the system on low quality internet connections. Though I tested several pieces of streaming software in developing the system, sending Ogg-Vorbis encoded streams (high quality compressed audio) via an IceCast server met all the requirements for a low entry barrier to participation, and meant that anyone who has some means of making sound via a computer and access to an internet connection would be able to take part.

As IceCast is optimised for online radio broadcast, stability is prioritised in the software over delay times, therefore the main drawback of using an IceCast server in a performance context is the large delay time between sending and receiving streams. For long distance collaboration the delay can be in the region of 3-10 seconds. When performing as part of a large group, every performer is performing with a different delay time between sending sound and receiving the mixed audio stream back at their location. Clearly this temporal asynchronicity has a profound effect on the ability of performers to engage in direct musical exchange. For example, rhythmic figures can not be played synchronously, and quick call and response exchanges are somewhat impractical. The system lends itself more naturally to drone-like, non-rhythmic or soloistic playing. Latency is, of course, a major concern in telematic music projects, and if not addressed technologically (e.g. (Mckinney, 2014)), requires some aesthetic consideration (See e.g. Neuhaus's *Auracle* (2004) in Kim-boyle (2009)).

Considering the above conditions, the design priorities in developing a mixing algorithm for *Union* were as follows: (i) to aid musical structure for performers who are playing asynchronously; (ii) to aid structure development in a system which is inclusive to less experienced performers; (iii) to combat the development of natural hierarchies, i.e., where more experienced players would tend to play more than less experienced players; (iv) to avoid a performer-mixer hierarchy, whereby the performer in the space would have more power to inform the narrative of the performance than the performers providing audio material; (v) to provide a more efficient means to mix 'fairly' than a human mixer.

5.4 Narrative Impact of the Mixing Algorithm

As with curation algorithms in our online interactions, using an algorithm to mix multiple audio inputs influences future actions (Eslami et al., 2015). Multiple possible outcomes could result from different combinations of the input audio streams, but only one of these is heard by participating performers. A different decision by the algorithm at any point in the performance would necessarily result in a different reaction from performers, and potentially an entirely different narrative structure.

Crucially, this is the point at which the role of the system designer in informing the performance interaction should be acknowledged. Deciding that the algorithm should base its mixing calculations on 'average' audio characteristics is a non-neutral decision. In this case, I was interested in the tendency of Facebook news feeds and Google search algorithms to reinforce previously held views and behaviours (Eslami et al., 2015; Brin and Page, 2012), and how this may be applied in musical environments. In addition I tried to design a mixer which was reactive to multiple participant inputs, and to build a logic which foregrounds collaboration over individual action, but there are many other logical ways in which a mixing algorithm may calculate mixing parameters, which could have entirely different results.

Avoiding hierarchy within interactive systems, although possibly desirable, isn't necessarily realistic, but aiming for social awareness of the implications of the systems that we build, is worthy of attention. *Union*, to some extent, avoids prioritising performers' technical skill and social status in the act of mixing, but a differentiation does exist between the roles of the system designer and the performers. The performers had no input into the design of the mixing algorithm – beyond giving general feedback – and therefore have no control over certain aspects of the performance. They cannot change the way the system functions, only the way they act within the constructs and limits of the system. For example, an individual performer

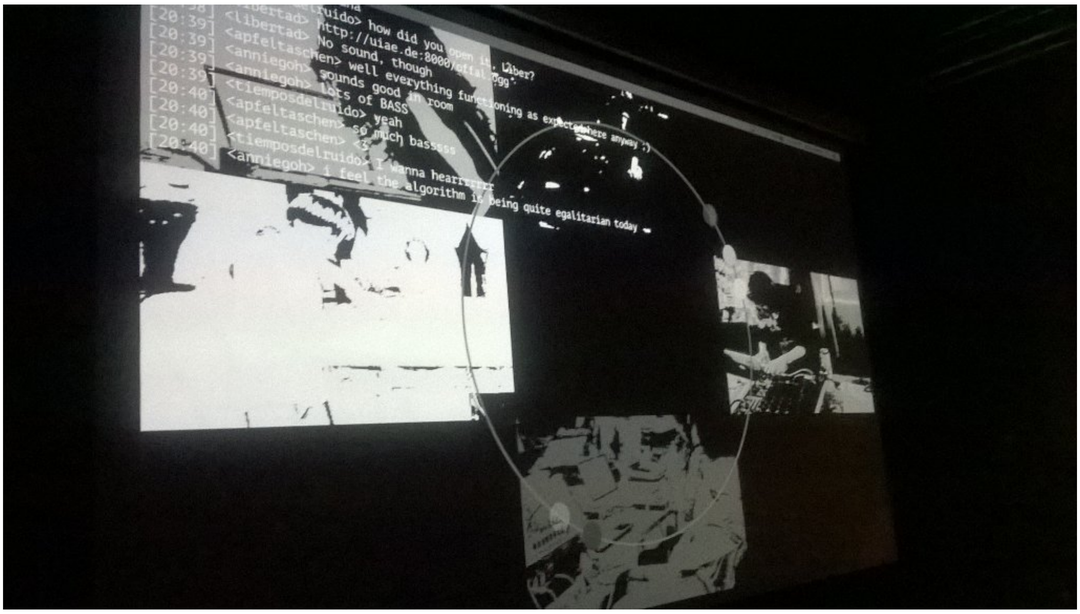


FIGURE 5.2: A performer commenting on the mixing algorithm in *Union*.

developing their own continuous long form structure, would not be a possible approach to performing with *Union*. The way the system functions preferences shorter structural motifs in reaction to the audio mix, or repetition of similar material in short chunks. Performing with *Union* requires the performer to accept the balancing of performer freedom against collective action in ways that were predefined by the system programmer.

5.5 Human Narratives in *Union*

Although comprehending a performance of *Union* does not require an in-depth knowledge of the functioning of the mixing algorithm, developing a narrative of human interaction with the system and with geographically distant performers did seem important to the reception of the piece. In telematic music performance, performers lack the opportunity to communicate visually with each other, and therefore can lose a sense of how other performers are relating to the performance. Physical gestures cannot be followed and responded to. One method however that does give performers an opportunity to respond to what they hear, is to use an online chat client to communicate during performance. This is a common method in network music systems to allow deliberative exchange between performers, and the chat window can act as a site of social cohesion.

The importance of social interplay in network music is perhaps highlighted by the common decision to project the performers' chat so that it is visible to the audience (see, e.g., Ogborn (2012), Mckinney (2014), and Surges and Burns (2008)). In telematic systems this often becomes the focal point for audience members in understanding the relation between sound production and performer action. The chat functions to provide a narrative on the performers' interaction with their own sound production and the sound production of others. The chat window is also commonly used by performers to discuss technical setup and issues.

As well as a space for community cohesion, in *Union* the chat also serves as a space for community problem solving. As the chat is projected to be visible to the audience, the technical difficulties become part of the narrative of the performance. Audience members can connect audible technical issues to performers or specific technical problems. This community interaction, and the frustrations, or joys, of performers, informs the reception of the sound in much the same way that audience members might experience, e.g., a guitarist dealing with a broken string.

In part this projection of the chat serves to counter technologically hierarchies that exist around music technology (Born, 2005) through public discussion of our technical problems.

5.6 Organisational Structures and their Narrative Impact

An in-depth discussion of organisational structures in laptop ensembles is contained in Knotts and Collins (2014). OFFAL as an ensemble aims to use a decentralised organisational system. Although the group was initiated by Joanne Armitage and myself, we distribute knowledge to ensemble members whenever possible and encourage peer learning and sideways knowledge transfer. All technical sessions take place on Internet Relay Chat (IRC), and often more experienced members of the ensemble help to troubleshoot technical issues new members are having. In performances with *Union* I tend to be the ensemble member who is in the concert space running the technical infrastructure – mostly for the practical reason that having developed *Union* I know the technical setup better than other ensemble members. As stability has often been an issue with the system – owing to the lack of specifically designed streaming software and the unpredictability of running the system on different network setups – I am usually responsible for monitoring technical stability, problem solving, and helping ensemble members troubleshoot any technical issues that arise during performance.

However, although I have this key technical responsibility, as we use non-standardised technical setups, often problems arise which other ensemble members are more able to help with than I am, and in many cases other ensemble members help to solve technical issues at performance time.

5.7 *Union* as Social Resistance

> Why so many women in early electronic music? Back then there were very few women composers of any kind. That was partly because men

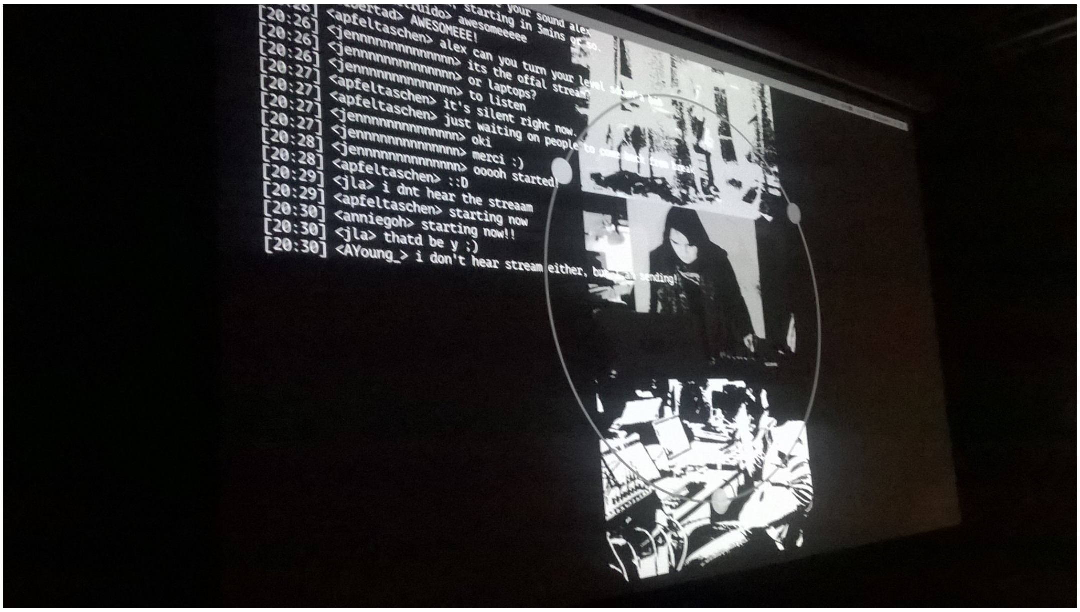


FIGURE 5.3: Performers discussing technical problems during a performance of *Union*.

> controlled access to performance, presentation, preservation and publication resources . . . In contrast, electronic equipment did not treat women any differently to men. We were able to turn our musical ideas into sound and then play them for people without the almost-always-male establishment gatekeepers and their biases. (Spiegel 2016)

As Laurie Spiegel elucidates, electronic music making by women has long been an act of social resistance. Pauline Oliveros has been a prolific force in the development of practices and technologies for telematic music making (Oliveros et al., 2009). It is difficult then to not equate telematic music making by women to an act of resistance against the normal social structures of electronic music making.

Removing women's bodies from the act of performance resists ideas around female embodiment in music making. However, the gendered nature of the performance is restated through projecting obscured images of the women performing with laptops during the performance, tying sound-making activity to gendered bodies, without putting the body at the centre of the performance (McMullen, 2006; Bosma, 2014).

Connection between the performers and the audience then takes place through the dialogue of the performers, which is necessarily technical in nature, resisting audience expectations of female behaviour and engagement with music making. These expectations remain to such an extent, that despite the name of the ensemble, audience members have still occasionally made gendered remarks after performances about what the 'guys' in other physical locations were doing during the performance.

5.8 Evaluation and Discussion

Of all the pieces and systems included in the portfolio, *Union* has had the most opportunities for testing and evaluation: five performances by OFFAL and two with FLO. Each performance with the system had various contextual restrictions and considerations, testing the limits of its usefulness as a collaboration system. Every performance included between four and eight performers, with never more than two performers in the same physical location. A total of fourteen performers have performed with the system. A comparative assessment can be made with OFFAL, as one OFFAL performance took place using a different software system offering opportunity to assess the level of influence the system has over the musical output of the group.

In the first two performances of *Union* the sound was projected on eight speakers with the eight audio streams equally spaced in the sound field. Using point sources for each of the streams aimed to give audience members the ability to associate sound gestures with different performers and distinguish between streams. This was moderately successful in the first performance, but poor room acoustics and a non-uniform speaker arrangement limited the effect of this in the second performance. In the third performance the panning system was developed such that sounds move according to their relation to the mean stream. In this version the streams are at first equally spaced in the sound field, and in each section the sounds move towards the mean stream's position relative to their distance between mean stream and least average stream. This element of the system is the least commented on by audience members – however, I feel that this gives the acoustic space more movement and with an ideal sound system would allow the ability to perceive how closely aligned the incoming audio streams are.

Audience members frequently commented on the chat and how it gave them a sense of narrative to the performance, perhaps reflecting the desire to connect the sound making to human action.

In addition to the chat projection, a visual aspect was developed which showed (highly processed) photos of the currently audible performers. These two developments seemed to be relatively successful in showing how the algorithm is functioning to audience members and linking sound to specific performers. A further addition to the visuals also showed a simple visualisation of the panning, aiding with understanding of the relationship between the mixing and panning of the audio streams.

OFFAL has thrice performed with a different system: *OFFAL Command-Line* (`https://github.com/offal/commandline`) which was collaboratively developed by several members of the group over a serious of online brainstorming sessions. The technical development and interface design was largely undertaken by the author, with feedback from other group members. In the first performance of *OFFAL Command-Line*, five performers were present in the concert location and two additional performers took part telematically. In the second performance four performers were co-located in the performance space, and in the third three performers were physically present and five online. Taking inspiration from live coding performance practice, in *Command-Line* performers interact via a web-page interface where a select set of instructions can be combined to give performance directions to other players or to the whole group. The instructions must first be 'suggested' to the group. If the suggested direction receives approvals from 50% or more of the performers the direction then becomes live. In *OFFAL Command-Line* the participation in musical narrative development is far more active than in *Union*, and feedback from other performers is far more direct – through the directions given and approved. Interestingly, *OFFAL Command-Line* resulted in a strongly contrasting performance to the group's performances with *Union*. Although this may partly be an artefact of having more performers in the same space, I'm inclined to suggest taking a more active role in the musical narrative of other performers was the main driving force in the different musical aesthetic and that both interfaces have a distinct effect on performers' musical interaction.

Commenting on the experience of performing with *Union*, one performer said:

> Working with Union ebbed between feelings of OFFAL functioning as a (disparate) collective of individuals to an amorphous haze. Though challenged at times by latency, there was often a feeing of connectedness through the system, but this was at times frustrated by a feeling that the algorithm was not 'allowing' your sound though. There were moments of my sound that I would have liked to highlight that got lost in the mix, and at times a certain streams could become dominant. The setup took some while to get used too, although we generally worked through that together.. !

5.9 Conclusion

Union began as a seemingly simple solution to a technical problem of how to deal with bringing structure to a geographically dislocated and temporally asynchronous performance. However, building and working with the system threw up many interesting aspects of performance narrative and technical and social resistance in telematic music making. Narrative is developed in the performance through the performers' interaction with the algorithmic procedure and with each other, and exposed to the audience through projecting the chat client. Comparisons can be drawn between the mixing algorithm and online curation algorithms which moderate our online interaction based on past actions, reducing our future possibilities. Designing a performance system for a female-specific laptop group allows us to resist normative social structures and think non-hierarchically, and removing female embodiment from

FIGURE 5.4: A rare occurrence of numerous OFFAL member in the same room: Performing with *OFFAL Command-Line* at ICLC2016, Hamilton

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electronic music performance allows a rethinking of audience expectation of female performers, emphasising technical and musical over physical aspects.

Chapter 6

"Democracy isn't just a Tweet Away..."

6.1 Introduction

"Democracy isn't just a Tweet Away..." (*DIJTA*) is a generative sound installation which explores the dynamics of political tweeting and the imperfection of algorithmic analytics. The title of *DIJTA* quotes the title of Gedmin (2010), an opinion article in the mainstream media critiquing the narratives around social media and democratization, particularly in light of the Arab Spring movement. Politics has become increasingly mediatized in the 21st century (Esser and Strömbäck, 2014) and the movement of political action from localised organisation and mobilisation to online group formation and political lobbying makes social media important forces in today's political world. Twitter is used by politicians to communicate with the populace and deliver political messages. The use of Gedmin's quote references this increasing mediatization of politics, and challenges utopian views that more political communication necessarily equates to more democracy.

With 328 million active users the Twitter population is larger than most countries, and Twitter has been credited with mobilising political uprising in Arab states as well as impacting elections. Politicians can reach large numbers of the electorate through Twitter, with Barack Obama setting up his Twitter account in 2007 prior to his 2008 election which was largely an internet led campaign (Cogburn and Espinoza-Vasquez, 2011). He was successful in mobilising difficult to engage groups . The benefits of having a wider reach and more personalised political campaigning however are perhaps balanced by the negative effects, e.g., that the short format of tweets don't allow any depth of political discussion. A darker side of politicised tweeting has also emerged in the recent months, with Trump directing attacks via Twitter, e.g., at Alicia Moncado during his 2016 campaign (Marx, 2017), and even being accused of declaring war via the medium. The terseness of tweeting often means that Twitter-based politics is more about emotive language and likeability than about facts and figures or pragmatism. The need to condense political debate into short sharp messages with reach to large parts of the populate dilutes the nuance and complexity of political issues in the need to create attention grabbing text

(Papacharissi, 2015).

In *"Democracy isn't just a Tweet Away..."* I wanted to directly reference the political narratives around the potential of social media as a democratic platform, as well as interrogate the problematic nature of considering a platform with a 140 character message limit as a viable place for legitimate political debate, and the over-reliance on algorithmic methods for informing real political discussion. These debates seem ever more important as political developments see politicians turning to Twitter rather than more traditional means as a primary communication channel with the electorate .

Another political factor which has changed as politics moved online is polling and the ability to predict election outcomes. The UK 2015 election, the US 2016 election, and the Brexit referendum were all predicted wrongly by the pollsters, leading to industry questions on how to predict more accurate results when using online polling and the issues of echo chambers and algorithmic narratives (Sturgis et al., 2016).

DIJTA is an attempt to look at cross-party political narratives and how online politicising may differ from traditional forms of political campaigning. A critique of algorithmic prediction of human behaviour is explored. In the piece I use algorithms including word usage analysis and sentiment analysis to analyse political tweets (Wang et al., 2012; Tumasjan et al., 2010). These algorithms are still less accurate than humans at determining sentiment (e.g. 60% (Agarwal et al., 2011), 80% (Go, Bhayani, and Huang, 2009)). Audiogrep is used to analyse political speeches for word usage, and the new tweets are synthesised using a combination of word analysis and speech audio.

Early experiments for *DIJTA* include the live coding performance *#Algorithm#Rave* which uses live tweets containing the words 'Algorithm' or 'Rave' to generate melodic patterns using a simple vowel to pitch mapping. The performance is accompanied by a textual representation which displays the most commonly used word in the tweets containing 'Algorithm' and 'Rave', generating a two word narrative accompanying the performance. The original intention was that these word strings would act as performance directions for the live coder, however it proved difficult to follow the regularly generated and diverse word sets whilst also concentrating on live coding. Although this demonstrated the potential to use Twitter as a large scale live opinion polling medium, the results were somewhat abstract and hard to link back to their origins.

The installation was presented on two occasions – once at ICAD in July 2015, using Twitter data related to the UK general election, and once at Ohrenhoch: der Geräuschladen in Berlin, using data relating to the Labour party leadership election.

6.2 Precursor Projects

DIJTA grew out of two projects prior to it which used the Twitter API to algorithmically generate sound and text: *Generic Conference Man* (2015) and *#Algorithm#Rave* (2015).

6.2.1 Generic Conference Man

Generic Conference Man is a project developed by Antonio Roberts and myself in a few hours at A Yorkshire Hack in January 2015. A Yorkshire Hack was part of the Arts Council England Digital Utopia event in Hull. *Generic Conference Man* was inspired by Rosa Menkman's *Bullshit Bingo Cards* (2014) (Menkman, 2014). It took a satirical look at conference 'buzzwords' particularly in the field digital arts. We used the Twitter API to collate tweets which used the conference hashtag. We then ordered the words by frequency, and cut out the words used less than three time. Antonio made a short video with a man in a suit speaking the words: `https://www.youtube.com/watch?v=JtovczWBr6w`. We used this as a way to determine the most talked about topics at the conference, but also to make a light-hearted critique of the repetitive nature of digital arts narratives. Given more time we would have made a version with live API calls and data analysis, but as development time was limited the version we made used a static data set representing a few hours of conference-related tweeting.

6.2.2 #Algorithm#Rave

#Algorithm#Rave was developed around the same time as *Generic Conference Man* and used the Twitter API to build a narrative around a live performance. During performance the API makes regular calls to collect the most recent tweets containing the words 'algorithm' and 'rave'. The collated tweets are then analysed, and the most common word in each set (excluding 'algorithm' and 'rave') is printed in the visuals. I considered this as a kind of crowd-sourced commentary on the performance – allowing audience members to make their own connection between the sound and the generated text. I had originally imagined using the text to inform my musical decisions, however, it turned out to not be particularly practical to concentrate on both coding and constructing a musical narrative around abstract word strings. In the second performance I made a more direct connection between the text and the sound by mapping each vowel of the selected text to a vowel sound, making melodic and rhythmic patterns out of the tweets. I live coded other sounds around the emerging melodic patterns.

FIGURE 6.1: Performing *#Algorithm#Rave* at an Algorave at Access Space, Sheffield. The visuals show the generated word pairs on the left and the last code line executed on the right.

6.3 The Installation

The physical setup of the installation used a speaker array positioned close to the listener in a U formation. This was intended to simulate the effect of entering a voting booth from a visual perspective and to allow a singular experience, with just enough room for one person inside the speaker array.

The sound itself is produced by collating tweets written by UK political leaders in the run up to the UK political events, such as the general election on 7th May 2015. The tweets are analysed for their word usage and then re-synthesised using audio recordings of political speeches from the party leaders. The speeches are cut up into individual words and reordered to form an audio version of the tweets.

A secondary analysis of tweeting takes place which looks at how often the words used in the tweets by the political leaders are used by the general population in the UK, by searching for tweets which contain the most frequently used word by the political leaders. This analysis is intended to give an idea of the relevance of political topics to the general population.

Various types of sound processing is used on the 'audio-tweets'. Words which are more commonly used are less processed – and therefore more audible to visitors of the installation. Infrequently used words are processed to the point of being unrecognisable, forming an incomprehensible backdrop of vocal-like sounds.

6.3.1 Algorithmic text analysis

Politicians' use of rhetoric was analysed in various ways using algorithmic methods. Data analysis has become an integral part of electioneering, with the Conservative UK general election campaign in 2015 using in-depth data analysis methods to target swing voters with personalised messages. However, other ways data has been important in recent elections include that pollster predictions – which rely ever more heavily on internet-generated data – produced incorrect results in 2015 and 2016 (GE 2015, Brexit referendum 2016, US presidential election 2016). The growing complexity of globalised politics and a multiplicity of electioneering tactics has made voter behaviour harder to predict than in previous years.

I used a number of tools to analyse the text of political tweets. Sentiment analysis can be used to detect if a tweet is broadly negative or broadly positive, though the level of accuracy is relatively low. I used this to determine the scale used in the melodic element of the generated sound, i.e., by mapping positive results to major scales and negative results to minor scales.

I used an open source library called Audiogrep (`https://github.com/antiboredom/audiogrep`) to algorithmically transcribe political speeches, resulting in a full transcription with time points for each word or phrase. I used this data to then produce 'audio tweets' by finding the words used in the tweets amongst the politicians' speeches and building an audio file out of single words. The transcriptions produced by Audiogrep are wildly inaccurate, however, the audio tweets produced are an approximation of the input text. I use this as a reference to the limits of algorithmic analysis, and to critique the 'noise' of politics.

6.3.2 Description of Data

The various iterations of *DIJTA* used data collected from the official Twitter accounts of major UK political party leaders. Rapid turnover of party leaders in the period 2015-2017 means this has included the Twitter accounts of Natalie Bennett, David Cameron, Theresa May, Ed Miliband, Jeremy Corbyn, Nigel Farage, Nick Clegg, Tim Farron, Vince Cable, and Nicola Sturgeon.

In addition, tweets are collected from the Twitter population at large which had similar word usage to that of the political leaders' tweets.

Political speeches in the run up to elections and presentations of the installation were also used as a source of audio and word usage analysis.

6.3.3 Description of Sonification Processes and Technical Realisation

The sound output uses one channel per political leader, i.e., 2-5 channels. Sound is hard panned so that voices are localised in the speaker relating to each politician. The politicians are located in relation to their relative position on the political spectrum, i.e., Green Party far left, UKIP far right, etc.

The database of political leader tweets is collated by running API calls on daily basis in the run up to a presentation of the installation. The database of UK population tweets is updated in real-time every 15 seconds – the maximum frequency of calls permitted by the Twitter API.

The sound produced includes a mixture of:

- data-pitch mapping: each tweet is mapped melodically, using the sentiment analysis to determine scale (as described in Section 6.3.1). I map the vowels to individual pitches using a vowel synthesis Ugen. The length of each pitch is determined by the number of letters until the next vowel. This enabled the generation of repetitive melodic and rhythmic patterns related to the tweeting.
- audio tweets: relevant audio tweets as generated by the process described in 6.3.1 and 6.3.2 played at infrequent intervals in the speaker relating to a particular politician. The unprocessed speech draws attention to a particular political message (if a significantly garbled one).
- FFT processing: I also use granular and FFT techniques to process the audio of the speeches, adjusting the processing according to the frequency of the current words (as determined by Audiogrep). This type of processing retains the sonic properties of vocal sounds but distort the meaning of the words to varying degrees.

6.4 Realisations

DIJTA was presented twice: at International Conference on Auditory Display (ICAD) in July 2015, and at a small gallery, Ohrenhoch: der Geräuschladen (Odg), in September 2015. Each installation had different criteria which impacted on the technical setup and sound production modes used.

6.4.1 International Conference on Auditory Display

At ICAD I used a 5-channel speaker array to project the sound (see Figure 6.2) with each politician hard panned to a single speaker. I positioned these in a tight arch around the laptop – both for the reason that it was in a large room with several other sound installations, and for aesthetic reasons. I intended this to give the feeling of walking into a voting booth, simulating the experience of engaging with the political process. This also gave the feeling of a more personal experience as there was only space for one person to stand inside the speaker array at a time. I positioned the speakers at ear height for acoustic reasons, but coupled with the speech-based sound, this also gave the strange impression of five people electioneering at very close quarters. The soundscape in this version was very dense, making the installation as a whole a fairly intense experience.

FIGURE 6.2: *"Democracy isn't Just a Tweet Away..."* setup at ICAD 2015, ESC Gallery, Graz.

6.4.2 Ohrenhoch: der Geräuschladen

At Odg I modified my data collection to reflect current political events. This took place shortly after the Labour party in the UK elected a new leader, Jeremy Corbyn, so I used political speeches from Corbyn and Conservative party leader (and Prime Minister) David Cameron from around the time of the Labour leadership election. I also used tweets from the Twitter accounts of the two leaders.

The setup at Odg was very different to that of ICAD. There were several rooms with a multichannel speaker setup already installed. These consisted of a shop, with a large front window and three small rooms in the basement with a connecting staircase. The rooms were fairly reverberant and the speakers used were HiFi quality. There also was no accessible internet connection in the space.

Given the different acoustic qualities of the room and equipment, I decided to modify the installation from the previous version. In Odg I used the FFT manipulation of speeches to a greater extent and removed the melodic mappings as these sounds were overbearing in a larger and more reverberant space. I used the preinstalled speakers to play the FFT-based drones, filling the space with a undulating texture with vocal like qualities.

I tried to recreate a similar feeling to the ICAD installation by adding a stereo speaker pair in the shop space where audience members could sit and listen at close quarters. I used these speakers for more recognisable speech samples with Jeremy Corbyn panned hard left and David Cameron panned hard right.

As there was no stable internet connection available at this location, I used a static data set which I collated in the week before the presentation.

6.5 Conclusion

DIJTA uses imperfect algorithmic methods to produce a generative soundscape related to political tweeting. The imperfect methods are used in reference to the limitations of algorithmic methods in determining public and political opinion. The

FIGURE 6.3: Multiple rooms with pre-installed speaker array at Ohrenhoch: der Geräuschladen.

soundscape uses primarily vocal-like sounds and speech samples with varying levels of acoustic clarity to reference the noise of politicising and the over-use of 'soundbites' to deliver political messages. The installation considers political responsibility in the realm of social media – which takes on a whole new meaning in the era of Trump(!) – and how short-form political messages may overly rely on emotive language at the expense of nuanced and informed debate. This lack of nuance can be seen to contribute to increasing polarisation within politics, with populations strongly divided on political issues. This is of particular importance as the population of Twitter and other social media sites are now bigger than many nation states, and there is an increasing need to consider the role of social media on a societal level.

The algorithmic nature of the data collection and sound generation in the installation means it can be easily adapted to new formats and datasets, as demonstrated by the two versions of the work, and even adapted to a 'performative' version like in *#algorithm#rave*.

In the next chapter we return to collaborative improvisation systems, this time modelling the behaviour of social groups in an imaginary voting context.

FIGURE 6.4: *"Democracy isn't Just a Tweet Away..."*, main speaker setup at Ohrenhoch: der Geräuschladen, Berlin, September 2015.

Chapter 7

Flock

7.1 Introduction

Flock is an algorithmic system for mixing the sound output of multiple co-located improvising electronic musicians. The system enacts a simulated voting system, whereby a population of simulated voters regularly cast votes for their preferred musician. The incoming audio streams are then mixed proportionately to the number of votes received.

The mechanics of the system bears relation to *Union* in that SuperCollider's SCMIR library (Collins, 2011b) is used to collect feature data of the incoming performers, and this is used as the basis for deducing simulated voter preferences. Voters are generated with a set of preferences for particular feature data values and vote for the input with the closest average values to their preferences. The dynamics of the system applies the principles of flocking bi-partite social networks in Rosen, Kim, and Nam (2010) to a musical context, in that the preferences of voters are continuously recalculated according to their environment and social connections.

Flock critically explores voting systems as a means of directing musical improvisation. The intention was to model the mechanics of the interactions between politicians and opinion polling on the formation of political policy. For this purpose live coding is proposed as the optimal performance practice to model the interaction, as Rohrhuber and de Campo's conversational programming (Rohrhuber and Campo, 2009) theory proposes that live coding acts as a method for testing musical algorithm outcomes and adjusting the code according to output. In this instance, the performer reacts both to their own judgement of the algorithm outcome and that of the voting population. We can draw a parallel here to the way politicians adjust narratives around political policy according to public perception.

SuperCollider is used as the live coding system as it is a relatively musically neutral interface to develop musical responses to the preferences of a population of listeners. Building synthesis modules from scratch allows performers to develop timbrally diverse musical responses to the system and to differentiate themselves from other performers.

A simulated voting system was preferential to collecting audience opinion for pragmatic reasons and to ensure cognitive diversity. Humans are unable to listen with full critical capacity to three simultaneous sound streams and form judgement in short time spans while simultaneously appreciating the performance on an aesthetic level. Furthermore the social exchange required for a flocking ecosystem style network is not possible in a concert setting and new music audiences are not sufficiently large and diverse to encompass the level of cognitive diversity required to make 'good' democratic decisions (Landemore, 2013).

7.2 Theoretical Background

The flocking algorithm which underpins the voting process in *Flock* is based on Rosen, Kim, and Nam, 2010. They considered political protest through the lens of flock theory, providing a useful analogy comparing the social dynamics of protest movements to those of Jazz music, which can be generalised here to improvised music. This analogy is also supported by Borgo (2005), who also draws comparisons between jazz music and various forms of social organisation. Rosen highlights the variety of structures and patterns of interaction used both in music and in protest organisation and uses classical music as a counter example to jazz, likening it to hierarchical bureaucratic social organisation. This provided a first stimulus for explicitly implementing a model of social flocking in the context of an improvised performance.

Rosen's model describes global protest movements connected via social media, where decentralised self-organisation is seen as a progressive and efficient model of organisation, and communication networks such as Facebook are key facilitators in building and maintaining these structures. In the context of my study of the social dynamics of network music ensembles this provided a further motivation to apply his theory.

Rosen's flocking model evolved out of Reynolds (1987), who applied three simple rules to independently moving 'boids' to simulate the behaviour of bird flocks. These rules relate to the direction, position in relation to neighbouring boids, and average overall position of the boids. Rosen repurposes these three key behaviours to develop a ruleset for self-organising human groups:

- Structural distance: groups should have shared values, yet be constantly receptive to new ideas;
- Collaboration: maintaining a shared understanding between group members governs the direction and speed of group movement;
- Decentralisation: where group leadership exists it must constantly shift in order to maximise on distributed group knowledge and to minimise energy decay.

7.3 Voting and Flocking Systems in Music

Previous implementations of flocking behaviour and voting systems in musical performances have primarily aimed to connect audiences to performers through offering an active role in the music creation for audience members, and to explore distributed creativity, resulting in complex social dynamics, social interplay between audience and performer(s), and emergent organisational structures.

7.3.1 Flocking Systems

Freeman's work of the same name (Freeman et al., 2015) uses computer vision to detect flocking behaviour in audience members. The positions of audience members, saxophonists and dancers are tracked during the performance, and the collected data is used to drive the generation of live notation for the saxophonists. Audience members affect the notation of a saxophonist if they are within a certain radius of that performer. The mapping used means that the more participants are within a certain area relative to the performer, the denser the notation generated is.

Freeman noticed the impact of environmental factors on participant behaviour, noting that the greater the number of participants on stage, the less creative the participants are in their interaction with the music creation and each other.

7.3.2 Voting Systems

Facilitated by mobile and network technology, voting and audience participation systems have become more common in guided improvisation and network music performances in recent decades. Voting systems in music enable quantitative communication channels which allow performers a global view of the ideas and opinions of audience members. This may act as a feedback system against which performers can modify their musical behaviour, or give specific musical direction. Generally the aim is to balance performer autonomy in improvisation with collective action, decentralising control and instilling greater social responsibility in performers.

Inter-group Voting Systems

Hutchins' *Laptopera: Act I* (2011) (Hutchins, 2012), developed for BiLE, implemented an interface where performers could change parameter values of the sound they are controlling only via '+' and '−' buttons on the interface. All performers in the group have access to the same voting buttons. A meta-control changes the level of 'social → antisocial' action, modulating the amount of group vs. individual control over parameters. This control acts on a poetic level, encouraging particular performer behaviour, rather than imposing technical restriction. The effect then is a psychological one, emphasising the social nature of the performance and asking performers to place themselves and their actions on a continuum of responsibility.

OFFAL's *Command-Line* interface, briefly mentioned in the chapter on *Union*, implements a system of 'approval' for performance directions. Performers can suggest performance directions for other players or the whole group, but they do not become effective unless consensus is gained from a minimum of 50% of the group.

This type of inter-group voting allows quantitative communication channels between performers, facilitating a type of decentralized'group conducting' where social interaction and majority rule shapes the progress of the music. This effectively limits the level of autonomous action a performer can (or should) take, and fosters an awareness of the actions and ideas of other group members.

These systems are appealing as a multi-tasking laptop performer is able to continue sound making while also utilising the network to engage in an ongoing negotiation with other performers on the course of the music. Quantitative methods are effective in providing a quick gauge of group opinion without diverting attention from the creative tasks for too long.

Audience Voting Systems

Hajdu's *Quintet.net* Hajdu, 2005 includes the option for remote listeners to submit a form to the conductor of a telematic ensemble regarding many aspects of the music. The conductor receives this as a set of overall statistics on which they can base their directions to performers. Hajdu compares this form of feedback to democratic political processes.

The multimedia improvisation group The Tin Men and the Telephone developed *Tinmendo* (`https://vimeo.com/151440447`), a mobile phone app to be used by audience members to direct an improvising ensemble. In one possible mode, the app offers audience members several options of performance directions to vote for at regular intervals. The audience members are given a time frame in which to vote for their preferred direction, then the performers follow whichever direction received the most votes. Audience members are only asked to contribute to decision making on one musical parameter at a time though (e.g., tempo or mood), meaning that the possibility to direct the course of the music is largely defined by performer decisions on all other parameters, rather than by collective audience action. Although there is potential performer interest in receiving live feedback from an audience, in simplifying the music making task to single parameters, systems such as *Tinmendo* risk a novelty factor. My observation of the performance was that audience members tended to vote for the most extreme option available in order to have the greatest immediate impact on the music, rather than making the kind of considered choices with the most effective long term structural impact which trained improvisers make to maintain musical sense. The end result is that the performers then must try to weave together a series of extreme directions without losing musical flow, reducing the impact of the voting to one of supporting the performers' showmanship rather than supporting any genuine collective action.

Another mobile app enabling audience interaction with the music creation process is *Open Symphony* (Wu et al., 2017). Audience members are assigned to a particular performer and can choose between various graphical symbols which relate to modes of playing, such as 'drone' and 'improvisation'. Whichever symbol receives the most audience votes in a particular time frame gets added to the graphic score for that performer.

7.3.3 Implications and Directions

Audience voting systems are most often 'directed improvisation', occupying an uncomfortable space where audience members who may not have any musical training 'direct' professional performers, who must take account of the directions whilst still producing a coherent performance. Often the decisions audience members are asked to make necessarily relate to high level musical parameters (e.g. style, dynamics, etc.) while the structural and formal musical decisions are still in the hands of the performers. A problematic illusion is created where the audience gets a sense that they are in control of a performance, where often they only have a small impact and the performer does the vast majority of the creative work they are trained to do. Additionally the task of engaging in performer direction often distracts from aesthetic appreciation of the result. This leaves us to wonder what tangible benefit comes from disrupting performer-audience dynamics when audience members lack the necessary skills to contribute to the performance in any fundamental game changing way. I do not dispute that it is possible to design a performance system which includes audience inputs in a meaningful way, nuanced methods of mass audience input such as Ulyate and Bianciardi (2002) and Hara et al. ("Jukola : Democratic Music Choice in a Public Space") point towards interesting areas of exploration, however I have yet to witness a performance including audience voting to direct performers that transcends the novelty value and where some truly new musical experience is created for the benefit of audience members.

7.4 Modelling a Voting System

Given my reservations on the use of audience inputs to direct a musical performance and some further concerns outlined below, I chose to simulate the voting behaviour in Flock. I believed that modelling the population of voters would give a closer approximation of a real world democratic interaction than directly applying an audience voting system in a concert context due to the following factors:

- population size;
- human listening capacity;
- limitations of social interaction in concert format;
- stylistic bias in experimental music communities.

7.4.1 Population Size

Landemore (2013) hypothesises that a key reason for the widespread adoption of democratic processes in social groups is that consulting large groups is more likely to produce the 'correct' decisions [1], due to cognitive diversity within a group. Cognitively diverse groups are able to apply wide ranging experience to a problem to determine better solutions. In order to accurately model a democratic system, a voting population needs to be both large and diverse in opinion, which tends not to be common characteristics of experimental music audiences. Simulating a population allowed me to draw on a larger pool of opinions for the task of curating the performance. The final population size was decided by the safe limits of the CPU of the laptop running the mixing algorithm, i.e., in the testing phase more than 200 voters would cause delays in the voting mechanism. Coincidentally, this is also around the maximum size for a cohesive social group as theorized by Dunbar (1992) by extrapolating the correlation between brain size and social groups in primates to human populations. Greater cognitive diversity would also suggest a greater possibility of fluctuation in opinion – due to more channels of diverse influence – which in a musical context is likely desirable.

7.4.2 Human Listening Capacity and Technical Hurdles

In order to make competent judgements of preference the voters would need to listen with full capacity to three different audio streams simultaneously as separate sound sources. Oliveros (2005) differentiates between Focal and Global listening. Oliveros' Focal listening is also described by Bregman (2004)'s Auditory Scene Analysis Theory, whereby listeners can group sounds into separate streams according to spectral similarity. This becomes more difficult when sounds do not have a consistent harmonic spectrum, as is likely the case in live coded electronic sound. Both Bregman and Oliveros consider focussed listening to several streams in parallel as requiring practice to develop specialist listening skills – skills that cannot be reasonably relied upon in untrained audience members.

Aside from the difficulty of dividing the listening attention, it also is not technically feasible to provide the audience members with monitoring channels for the three streams, and in any case this would take the listeners' attention away from the resulting mix and the ongoing musical process as their listening attention would be dedicated to the critiquing and voting process instead.

Machine listening, however, involves the collection and analysis of auditory data and can feasibly be carried out by machines on large numbers of inputs simultaneously without any compromise on judgement or appreciation capacities. Although, as the 'listening' is mainly the tracking of low level timbral trends, we could critique how 'human' it is.

[1] Though recent political events may lead us to doubt this theory, democratic systems with universal suffrage are undoubtedly preferable for the majority of the population to hierarchical political systems with few decision makers such as monarchies and dictatorships.

7.4.3 Contextual Limitations on Social Interaction

Modelling a flocking network according to Rosen's hypotheses requires open communication channels, deliberation, and the exchange of knowledge and ideas. The current social conventions of experimental music are not able to replicate this bipartite flocking behaviour, as the social conditions and time restrictions of concerts make it impossible to critically discuss musical preferences with our social connections during the performance.

Although it is impossible to exactly model deliberation, the exchange of preference data and the modification of preferences according to neighbours is more effective in a flocking network model than in a human population in the given context.

7.4.4 Stylistic Bias

As I was keen that the system both allowed for diverse improvisation styles and the system dynamics influence this improvisation, heterogeneous musical tastes were desired. One of the concerns of using live audience voting data was that there could be a contextual homogenisation of musical taste with a particular aesthetic bias. Using an algorithmic method allowed stylistically neutral judgement criteria (through the generation of random data sets) to be used as the basis of voting. Although training of stylistically specific corpora could generate populations with particular tastes (Collins, 2016), the population in *Flock* looks only for particular auditory traits and therefore is not influenced by cultural perceptions of particular musical styles or genres.

7.5 Combining Centralised and Decentralised Methods of Music Generation

The model described by Rosen uses the example of political protests and their function in forming and consolidating opinion around particular issues. Rosen describes organisational structures and their components in decentralized groups which form to develop a resistance in political systems.

Decentralising the mode of music production scenarios is a well documented aim of network music systems (See e.g. Bischoff, Gold, and Horton (1978), Trueman (2007), and Hamilton, Smith, and Wang (2011)). However, as we have seen in Chapter 5 there is potential for problematic hierarchies relating to the distribution of knowledge and skill within a music system incorporating audience participation through voting. Although there is some provision for audience input in such systems, the lack of deliberation and qualitative feedback channels can prevent meaningful participation. We can consider then that systems involving a music ensemble responding to audience directions are therefore somewhat centralised, as the means of music production and a great deal of decision making still centres on the professional ensemble.

In recognition of the fact that voting systems by definition include some element of centralisation, my implementation of Rosen's flocking dynamics models a scenario where bureaucratic political systems interact with a decentralised populace, i.e., the interaction between policy generation and opinion polling. We can surmise that political ideas and opinions proliferate in the general populace in the same way as they might amongst a protest group, and that polling and protest can both affect governmental policy (Page and Shapiro, 1983; "Social Movements and Public Policy").

Although in this context we can view our live coding protagonists as the politicians bending their musical offering to the weight of the opinion poll, I wanted the outcome of the voting to have a very direct effect on the musical output. Consequently the voting affects the mix of the three performers: winning no votes means the performer is not able to participate in the performance so the vote can be seen as a directive rather than merely a suggestion of what to incorporate in the musical flow. In this sense the voters have rather more power over the musical output than in the cases of the aforementioned musical voting systems or indeed Rosen's flocking protest groups.

7.6 Live Coding as a Reflective Performance Practice

The mixing algorithm in *Flock* is relatively technologically neutral, such that any three audio signals can be used as inputs into the system without affecting the functioning of the algorithm. However, aesthetically the system was designed with live coding performance practice in mind. In particular, SuperCollider's JITLib is proposed as the ideal music making tool to perform with *Flock* as the machine listening in the algorithm largely monitors the spectral content of the sound. JITLib's focus on the sound synthesis capabilities of SuperCollider forefronts the editing of spectral qualities of the sound more so than sample-based languages, and allows fine grained tweaking of spectral parameters.

Beyond the technical capabilities of live coding to draw on a wide range of sound spectra with the possibility of large spectral shifts, live coding was also a symbolic choice as in this piece I aimed to consider the effects of polling on candidate behaviour and the shifting of political policies in response. Political candidates often test the limits of what is acceptable to the electorate, modifying their policies according to opinion polling and favourability ratings. Live coding also favours an evolutionary performance practice: Often the likely output of an algorithm is guesswork, and the code is then changed in response to this output (Rohrhuber and Campo, 2009) – and, in the case of *Flock*, also in response to the voting outcome. Finally, in order to model a democratic interaction between citizens and politicians, a relatively musically neutral interface was desired in order that the interface itself has as little aesthetic influence on the performer's musical output as possible.

7.7 Algorithm Design

A full overview of the technical design of Flock is given in Appendix C. Here we discuss the aesthetic aspects of design decisions in relation to the theoretical discussions of this chapter.

7.7.1 Adapting Rosen's Model

Rosen's bi-partite network model consists of two types of nodes: human actors, and institutions/events/meeting places. Actors are linked both directly, through their social circles, and via the institutional nodes which they are connected with. In *Flock*, the two types of node used in the bi-partite network are: voters and musical input data.

7.7.2 Voting System

The most highly democratic systems are systems with some form of proportional representation as they allow the voter to make a free choice among candidates, and the final make up of a parliament reflects the votes of the population as a whole rather than only votes for a winning candidate. For this reason the mixing algorithm is based on proportional representation with the outcome leading to a sound mix which reflects the proportion of the vote each performer received.

7.7.3 Flocking Algorithm

The flocking algorithm has several parts which maintain the dynamic nature of the system:

Modelling Rosen's network theory, actors in the network are influenced by the preferences of other nodes that they have a connection with, the outcome of the vote, and how open to influence the node is. After every round of voting, the actor preference values are recalculated according to the neighbourhood's preference, and the values of the incoming audio. The influence of these values are scaled according to the 'autonomy' value for each node, and the relative distance between the nodes. Where this equation results in a value outside of the 0-1 range, a new random value is inserted, giving an element of chaotic behaviour to the system, which would be expected in real-world networks.

Over time the neighbourhood's influence leads to a certain amount of homogenisation of opinion, as ideas can become strengthened by peer agreement. Re-diversification of opinion can come via newcomers entering social groups, and by the randomisation of values that go out of the 0-1 data value range. In *Flock*, nodes have a lifespan and new actors are spawned at approximately the death rate of nodes. Actor death can occur at any point in the node's lifetime, but likelihood of death is scaled by age. The maximum age for an actor is twenty voting rounds, or a lifespan of 3 minutes 20 seconds, i.e., the entire population of actors will change several times during a performance. In order to model two different ways that an actor can join the network and to ensure cognitive diversity, new nodes are either 'children' or unrelated newcomers. The 'newcomer' node has a random preference set, while the 'children' nodes have parents who are connected nodes in the population and therefore similar in preference sets. The 'children' nodes are born with a preference set somewhere in the range of the parents' preferences.

7.7.4 Structural Decisions

Voting takes place every 10 seconds to ensure a constant musical flux and to allow enough voting rounds for development in the preference values over the course of the performance. This also ensures that performers have a regular opportunity to return to the mix by changing their audio output to be more in line with current preferences.

Structural changes are guided both by the flocking dynamics of the system and the outcome of voting – directly affected by the musical decisions of all three performers.

Musical structure: The decisions of performers will affect the mix greatly. Playing with musical characteristics which are strongly aligned with the preferences of voters will likely result in a large skew towards one player. Playing with characteristics which are not strongly correlated to voter preferences will result in a more even mix of several players. Flocking structure: as the flocking of the system changes preferences over time, new musical choices will be preferred.

7.7.5 Visual Design

The visuals in *Flock* (see Figure 7.1) are designed to give performers and audience an overview of the system state and performance process. Voters and performers are represented by coloured circles. Performers maintain the same colour throughout a performance, whereas voters change colour depending on their last vote. A bar chart showing vote share of each performer gives a quantitative overview of the current voting behaviour. It would have been desirable to represent the flocking behaviour of voters through spatial location, however this was not possible with 12-dimensional preference data, so this aspect is approximated with the voters with similar data preferences clustering together near the performer node they are voting for. A secondary representation of the feature data is given with white radar charts inside the voter and performer nodes showing the data values, giving audience additional visual cues as to the data level similarities or differences between performers and voters and how these change over time.

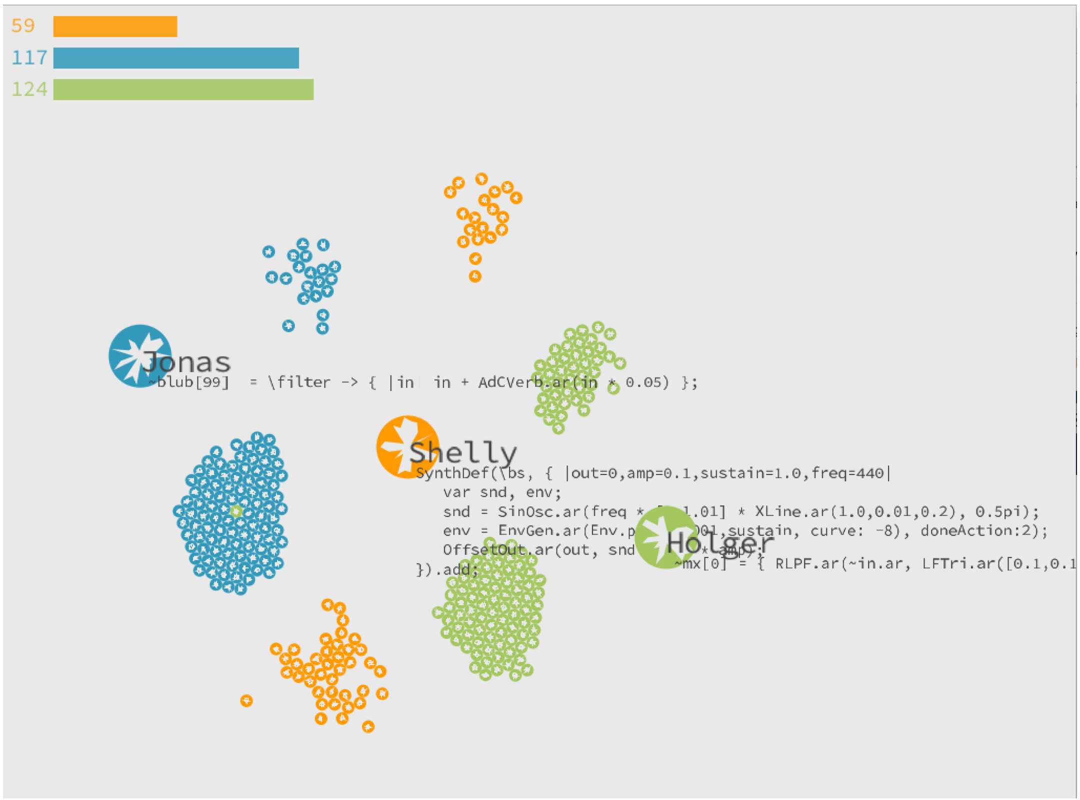

FIGURE 7.1: Visuals for *Flock*, generated using test data.

In line with live coding performance practices – where code projection is typical – the last line of code executed by each performer is shown next to the circle that represents them, giving the audience an insight into the sound production process and the code edits being made by performers.

We chose not to show the network edges, as testing proved that this led to a more cluttered and confusing visual representation due to the large volume of edges in the system.

7.8 Evaluation and Discussion

Five performances have taken place with *Flock* – including three concert performances and two performances for documentation purposes. Although the main purpose of the system was a mixing system for live coders, the system is technologically neutral, so two of the performances experimented with other inputs. The participants of these five performances are as follows:

In the second performance, significant technical issues had a large impact on the structure of the performance as bugs introduced prior to the performance had skewed the algorithmic mechanism to flock towards one input. In the other performances the system behaved as expected, and there was a fairly even focus on each of the performers. In most cases, the system would prefer one performer, with a

TABLE 7.1: Summary of performance tools used in performances of *Flock*.

#	Performer 1	Performer 2	Performer 3
1	SuperCollider live coding	SuperCollider live coding	SuperCollider live coding
2	SuperCollider live coding	SuperCollider live coding	software and hardware synths
3	SuperCollider live coding	SuperCollider live coding	autonomous improvisor
4	SuperCollider live coding	SuperCollider live coding	SuperCollider live coding
5	SuperCollider live coding	SuperCollider live coding	Extempore live coding

FIGURE 7.2: Tim Shaw, Shelly Knotts and Calum Gunn performing *Flock* at ISEA2016, Hong Kong.

few votes going to other performers for large sections before switching gradually to other performers.

On the first tests and performances with the system, as a performer I tried to differentiate myself by playing significantly different sounds from the other performers. However after performing with the system on several occasions, I began to develop strategies for taking more control of my input into the system. In general playing sounds which are similar to those already playing would often cause the voters to switch from my input to the dominant stream, as would playing loudly or very noisy sounds. Likewise, maintaining my sound stream as the dominant stream was often possible by keeping the sound similar, and I could actively switch to being less dominant by making a significant change to my sound output or by playing very quiet or very pitched sounds.

Undoubtedly the voting mechanics had an effect on the performance as I was made conscious of constantly evaluating my performance at regular intervals by the outcome of the periodic voting. I had more of a sense of comparing myself to other performers and playing to 'compete' with them rather than to play musically sympathetically. Small tweaks to the sound I was playing would generally lead to small changes in voter numbers, and larger spectral changes would lead to large voting shifts. Due to the flocking nature of the algorithm, maintaining the same sound output would also lead to small changes in voting outcome as the preferences of the agents were also changing over time.

Other performers commented that they felt less able to control their interaction with the system. One saying they weren't 'completely sure what my sonic output was, complicated by the fact that Flock was deciding on how and when to mix my part in. At one point I altruistically faded myself out, hoping that the system would give less emphasis to me, as I had seemed to be dominating the improvisation. By the time I had faded completely I realised it wasn't actually me after all!'. Another commented: 'My personal actions were guided by a trial-and-error approach. From this position it was difficult to create something together with the other performers.' However, they also acknowledged: 'There was little time to get "acquainted" with the system or in other words: to learn about its behaviours and reactions... I can see how this would change with more rehearsal time with this system.' suggesting that they could see a way that the system may be 'learnable' to an extent. This is supported by another performer, who played with the system several times, and reported a more positive experience. In particular they liked the way the algorithm structured the performance and changed the way they performed: 'I feel like it has a very interesting effect on a trio performance as no player can dominate the soundscape too much and it leads to interesting shifts from trios to duos to solos, with different players being foregrounded over time. Also, trying to play for an algorithm and being muted if it doesn't like it leads to more radical shifts in what I play, as in a normal performance I would refrain from making too radical changes to my sounds in short time frames than when essentially being muted. With the change, the flock might decide that I play something similar than another player and mix us 50:50, producing a surprising and oftentimes amazing juxtaposition.'

7.9 Conclusion

Basing an algorithmic mixing system on flocking dynamics produces an improvisation system which is structurally informed by both the musical behaviour of performers and their responses to the flocking algorithm. Voting systems in improvisation have been used to define musical parameters, but I propose that selecting a preferred musical offering and weighting the performance in the direction of the voting outcome gives more power to both voters and performers. Performers are free to improvise as they wish and voters select their preferred musical candidate – the preferred musical parameters are implicit in this voting mechanism.

The voting system has its basis in proportional representation, as this is regarded as the most democratic form of selecting governance. In *Flock*, performer amplitudes are scaled according to the proportion of the vote received in an attempt to model the way political parties in proportional representation systems have a voice in governance proportional to the number of votes they win.

In the case of *Flock*, I use algorithms to model human behaviour in tasks that are impossible to be carried out by humans. I chose to use simulated voting for a number of reasons:

- In order to profoundly affect the performance, the task of listening, judging and voting needed to happen on a musical structural time scale rather than on the time scale of judging and voting which would be somewhat longer.
- The technicalities of listening to and judging three simultaneous audio streams whilst those streams are being mixed is not feasible.
- The population size of voters allows for divergent clustering of opinion and this population size is somewhat larger than the typical experimental music audience.
- Performances where audiences are engaged in extramusical tasks often distract the audience members from the aspect of listening, as they engage in the novelty of the additional tasks required.

Given the reliance on algorithmic methods, *Flock* follows on from *Union* in the use of Music Information Retrieval techniques for mixing improvisation streams. It follows a similar method of using algorithmic techniques to shape a performance through selection, thereby being non-invasive in the performer's musical flow, whilst pushing the performance in a direction which is informed by the outcome of the mixing algorithm.

The final work looks at solo live coding performance and strategies for live coding with an algorithmic system that makes it difficult to perform through constant interruptions. To make it more frustrating, the frequency of interruption increases according to the performer's stress levels.

Chapter 8

Flow

8.1 Introduction

Flow is a performance system for solo live coding that playfully explores and subverts aspects of cognitive flow and virtuosity in Live Coding. The piece was developed as part of a collaborative residency at Digital Media Labs, UK, in September 2015.

In the performance an EEG monitor is used to access the performer's engagement levels (Miranda and Wanderley, 2006; Miranda and Castet, 2014; Swift et al., 2007; Andujar et al., 2015), allowing the development of a performance narrative relating to both the physical and the cognitive aspects of live coding performance. This narrative is exposed to the audience through a visualisation of data, code and physical activity.

Flow builds on my own live coding performance practice which focusses on writing synthesised sounds in SuperCollider and working in ways which are likely to induce performer error and unpredictable results. A theoretical study I undertook considered the role of error and failure in live coding performance practice. These concepts will be explored in this chapter in relation to *Flow*.

8.2 Virtuosity in Live Coding

In instrumental music practices, virtuosity is commonly linked to physical accuracy and precision at high speed (Ostertag, 2002). In Live Coding, however, the performer's physical interface with music production is typically through the act of typing – although projects including Griffith's *Pattern Matrix* (Unknown, 2017), and the *TOPLAPapp* have explored other interface types (Collins, 2015). The TOPLAP (2010) draft manifesto proposes the 'glorification of the typing interface' may be part of the live coding performance, and Nilson (2007) suggested typing exercises to develop typing skill and accuracy in the performer. It follows that a performance interface which explores physical virtuosity in live coding performance would seek to push the limits of the performer's typing speed and accuracy – while acknowledging that reaching world record speeds is unlikely in the context of a live coding performance (see Collins, 2002, Table. 1).

Sayer (2016), however, proposes that live coding performance relies on cognitive virtuosity more so than physical virtuosity. Rohrhuber and Campo (2009) suggest that live coding performance can be described as a feedback process of translating aesthetic thought into code, perceiving the result, and decoding the difference between imagined and actual sound. It is proposed then, that fully considering performer virtuosity in the context of live coding may include pushing the performer's cognitive virtuosity alongside their physical limits. Possibilities for pushing cognitive limits may include intensifying the conditions under which the performer must comprehend and make logical changes to code and increasing the difficulty of maintaining concentration during a performance.

Flow addresses virtuosity in live coding by reducing time to comprehend and edit unfamiliar synthesis code and including the performer's concentration levels in the feedback loop by using EEG data to modulate the time given to interact with code. Given the unreliable nature of physiological data sensing, the EEG data is used on a threshold basis (detecting above and below average values for that performance), ameliorating issues relating to unpredictable data. The normal concentration timeline where a performer may choose when to shift their attention to new pieces of code is disrupted by only allowing the performer access to one active code line at a time.

The following sections address aspects of Brain Computer Interfaces (BCIs) in music, narratives of human-algorithm interaction, and system design and evaluation of *Flow*.

8.3 Brain Computer Interfaces in Music

In order to explore cognitive virtuosity in live coding performance I was interested in developing a direct link between the cognitive behaviour of the performer and the difficulty of performing with the system.

Lucier's *Music for Solo Performer* (1965) is the first documented work which uses a brain interface to interact with sound. The performer is required to produce alpha waves in order to vibrate percussion instruments (Lucier, 1998). Many other examples exist of sonifying brain activity (Lutters and Koehler, 2016), or using particular emotional states to trigger or navigate sound environments (Pearlman, 2015).

Most systems which interface with the brain for musical or aesthetic purposes deal, directly or implicitly, with biofeedback. As it is not possible for the performer to control all cognitive reactions to visual and auditory stimuli, the output of the BCI impacts the brain activity, building a feedback loop between brain state and aesthetic result (Lutters and Koehler, 2016).

In *Flow*, an EEG monitor is used to access the performer's cognitive interaction with the code, and to expose this performance narrative to the audience. The EEG data is also used to disrupt the feedback loop of human-algorithm interaction described by Rohrhuber and Campo (2009) by changing the performer's ability to interact with the code, developing a more complex interaction where this in turn disrupts the cognitive behaviour of the performer.

8.4 Narratives of Human-Algorithm Interaction

As exposing the process of music production is a key tenet of live coding (TOPLAP, 2010), live coders often project their performance interface. In much the same way that the physical actions of an acoustic musician and their relationship to the resulting sound is observable to the audience, projecting the laptop screen gives the audience insight into how the performer is interacting with the code and sound.

Regardless of code literacy levels of audience members, displaying this interaction reveals aspects of the dynamic interplay between human action, algorithm, and sound output, and the inevitable, and potentially dramatic, inclusion of human or technical error as part of the performance narrative.

In 2014 I began exploring ways to make the interaction between human, interface, system, and algorithm more transparent – in comparison to direct screen projection – in order to position the human narrative as an explicit concern of live coding performance. Alongside graphic representations of the code and system state, I represented the human interaction with code by visualising the typing density. Documentation of this initial attempt at graphic representation can be seen here: `https://vimeo.com/114298725`.

Visualising the typing action revealed to the audience the ebb and flow of the performer's physical interaction with the keyboard interface, perhaps also implicitly suggesting a timeline of cognitive interaction – i.e., the physically inactive periods. Also highlighted is the asynchronous and disjunct relation between physical exertion of the performer and sonic result. Furious typing from the performer may equally result, on future code execution, in smooth drones or complex rhythmic structures.

This disparity between physical action and sonic result proves fertile ground for exploration in live coding performance systems. Armitage (2017) synchronised vibrating motors, which are held by audience members while the performer live codes, to the typing, and Brown (2013), Kiefer (2015), and others have projected webcam images of the performer's interaction with the interface.

In *Flow*, a further human narrative – the performer's cognitive interaction with the performance interface – was explored. The performer's EEG readings are displayed alongside the code, typing timeline visualisations, and typing-reactive webcam images of the keyboard. This gives a multi-narrative view of the performer-algorithm interaction, and reveals the complex temporalities of physical and cognitive exertion and their relation to code state. The next section discusses the development and testing of *Flow*.

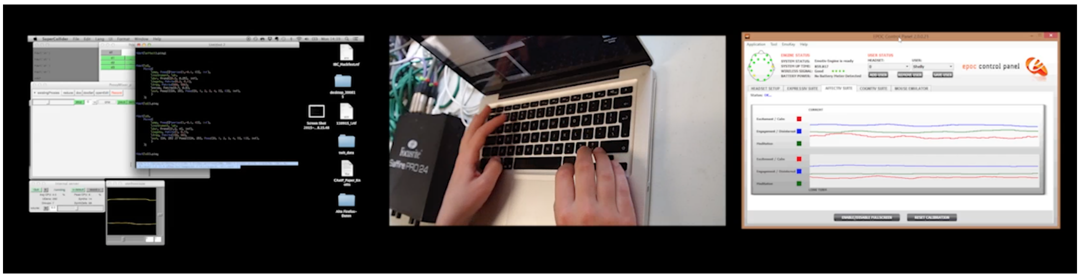

FIGURE 8.1: Documentation of initial test sessions with Gemma May Latham at Digital Media Labs showing the performance interface, hand movement and EEG readings.

8.5 System Development and Testing

8.5.1 Initial Experiments

The first iteration of *Flow* was developed during a residency I undertook in September 2015. Digital Media Labs is a collaborative digital arts residency in Barrow-in-Furness, where media artists from different disciplines spend a week in a co-working space expanding their practice and developing new works. In the initial presentations I saw synergies between my work on human narrative in live coding performance and work by Gemma May Latham on cognitive flow in textiles work. We conducted experiments using a 14-channel Emotiv EPOC monitor on my attention, meditation, and valence levels in two situations: (1) solo live coding and (2) live coding in collaboration with another live coder (Alex McLean). We recorded the EEG data, my physical interaction with the keyboard, and the performance interface, in order to deduce correlation between brain activity, code and sonic state, and performer action. Experiment 1 can be seen here: `https://vimeo.com/161947055`.

A technical error resulted in experiment 2 not being recorded, however observations during the experiments revealed that cognitive flow (i.e., consistently high levels of attention combined with moderate levels of valence (Manzano et al., 2010)) was more likely to take place in a solo performance than when collaborating. This research served as the foundation for building a system which uses measurements relating to cognitive flow as an input into a live coding performance system.

8.5.2 The System

Flow consists of a set of 10-15 algorithmically generated snippets of SuperCollider synthesis code which simultaneously begin playing at the start of the performance. The snippets are presented to the performer one at a time in randomised order. The performer has a short time frame of 15-40 seconds to comprehend and edit each piece of code. This time frame for editing each piece of code is modulated by the live EEG data relating to the performer's concentration and meditation levels (important measures of cognitive flow following Nakamura and Csikszentmihalyi (2002)). If the

FIGURE 8.2: Testing the system with the NeuroSky Mindwave EEG headset at the Digital Media Labs residency.

performer's concentration is low, a long duration is given to edit the code and vice versa, i.e., time to edit a piece of code is inversely related to the performer's engagement levels and the performance is more difficult when the performer's levels of concentration are higher.

As the EPOC headset is prohibitively expensive, after initial tests I switched to using the NeuroSky Mindwave headset which has just one sensor and is designed for meditation and concentration training. The results with this headset suffered more from muscle signal noise than the EPOC, but as the system uses averages and a relative threshold trigger, complete accuracy of data was not required.

A visualisation which shows the performer's physical and cognitive interaction with the code accompanies the performance. The physical interaction is presented through a webcam image of the performer's typing which appears more clearly when typing speed is higher. This is overlaid with the EEG readings for attention and meditation represented with grayscale colour blocks (white = high, black = low) and a 0-100 number reading. The current code snippet is shown, and vertical white lines are used to represent typing density for each code snippet.

The sound is projected in multichannel with the sounds produced by each code snippet equally spaced in the sound field. This aids the performer and audience in relating code editing to changes in sound by tying it to an spatial location.

This system creates a human narrative of cognitive and physical interaction with

FIGURE 8.3: Stills taken from screencast documentation of a performance of *Flow* at ICLC 2016, LIVElab, Hamilton (CA). The images show the visuals that were projected for the audience with different EEG data values and levels of typing intensity.

sound producing algorithms through exposing the audience to multiple representations of the performer action and resulting code. The performer's ability to impact on the musical output depends on quick interpretation and editing of code under time and concentration pressures. This aspect of the performance is represented in the temporal aspects of the visualisation and the fluctuations of the EEG data shown.

8.5.3 Testing and Evaluation Constraints

Since the initial development phase I have performed with the system three times. The first two of these performances revealed that test conditions in the studio are not sufficient to calibrate the difficulty level for the system. In the studio I consistently record attention and meditation levels of between 30-70 with an average at around 50. In the two performances the fluctuations are much higher, with data recorded between 0-100 in both measures and with attention being generally higher: ca. 60-90 and meditation being often low: under 40. It would be reasonable to assume the stress levels induced in performance situations impact strongly on levels of attention and meditation, and that maintaining consistent values is much more difficult. Of course, were another performer to play with the system, differing scales of EEG data would also be expected.

Given that my attention levels in performance were much higher than expected and this reduces the time given to edit code, this made the system much more difficult to perform with than in the studio, further compounding the issues relating to

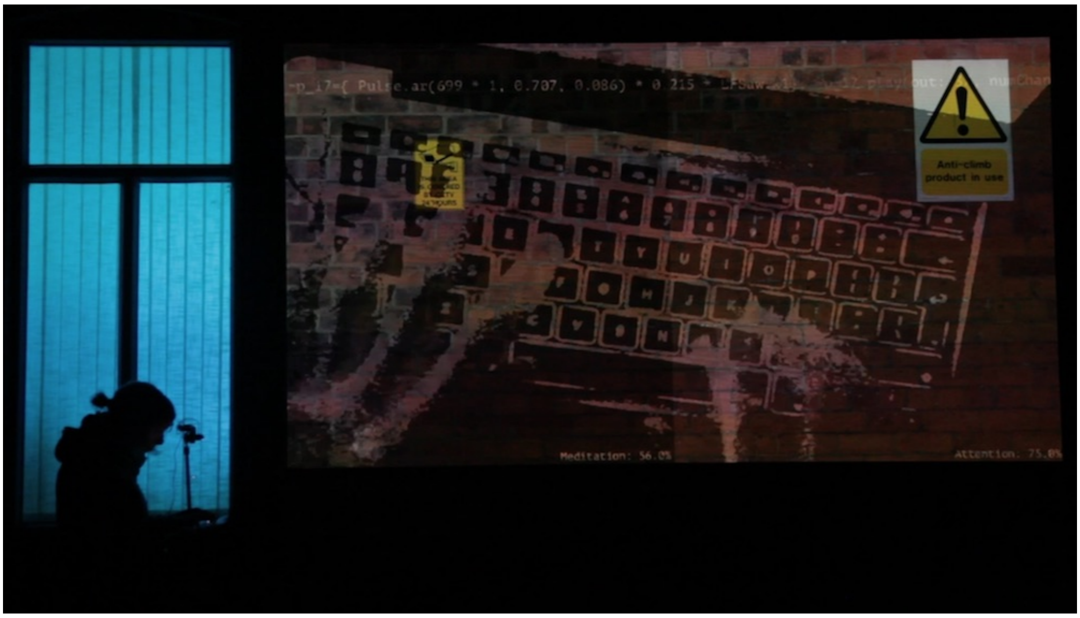

FIGURE 8.4: A performance of *Flow* at Digital Media Labs, Barrow-in-Furness.

performance stress. Although this is intended to be part of the way the system functions, I was often unable to reach a level of control over attention and meditation sufficient to interact with the system in a musically satisfying way.

As it became clear that I needed a way to adjust the system in real time to deal with relative – rather than absolute – stress levels, in the second of the three performances I adjusted the trigger which changes the code snippet such that the system keeps a running average of the two measures and triggers a jump to the next code snippet when the values are above the running average. This seemed to ease the difficulty level somewhat and as a performer I felt more able to interact in an adequate way with the code, however, the performance did still suffer from long periods of fast code changes reducing my ability to edit the soundscape in a musically pleasing way.

In the third performance I changed the system again so that the trigger fluctuates between running average and running average $\times$ 1.1. This seemed to be somewhat more successful as the periods of fast code changes were interspersed with periods of slower changes meaning the difficulty was generally high, but at least some sections had better musical control.

8.6 Evaluation and Discussion

After performing with the system on four occasions I have begun to develop a particular practice to deal with the limitations of the system, which is distinct from my normal live coding performance practice. These adaptations relate to both the micro- and macro-structure of the performance, as well as to the level of risk taking I employ in coding.

Regarding micro-structure, short time durations to edit code lines mean that a sequential style of code editing is more efficient in ensuring a constant musical development than writing longer code edits. For example, when adding a reverb effect to a sound I would normally write, e.g., the following line before executing:

```
~f1 = { GVerb.ar( ~p1.ar, 10, LFNoise0.kr(4).range(0.1, 3))
        * SinOsc.kr(5).range(1, 0) };
```

however, when performing *Flow*, I would write and execute code in the following stages:

```
~f1 = { GVerb.ar(~p1.ar) };

~f1 = { GVerb.ar(~p1.ar, 10, 0.1) };

~f1 = { GVerb.ar(~p1.ar, 10, 0.1) * SinOsc.kr };

~f1 = { GVerb.ar(~p1.ar, 10, 0.1) * SinOsc.kr(5).range(1, 0) };

~f1 = { GVerb.ar(~p1.ar, 10, LFNoise0.kr(4).range(0.1, 3))
        * SinOsc.kr(5).range(1, 0) };
```

This process of code development allows small intermediary changes to be made to the code before reaching the final desired state. So even if I am interrupted by a new code line appearing before I finish writing the entire GVerb line, at least some change may have been made to the sound in that section. Through this process it is also likely that if my attention is diverted to a new line of code and then I get back to this edit, I might change course and choose different values and modulators for the reverb depending on the intervening code changes on other lines and the current soundscape.

Another change to my normal live coding practice is that in *Flow* I am forced to keep shifting my focus onto different elements of the sound. Normally I tend to focus on one element for a long time, adding effects sequentially and developing one aspect, before making larger changes by moving to a new section. In *Flow*, the constant and moving elements of the piece are chosen according to the algorithm's randomisation of code order. The musical development then is 'opportunistic' rather than 'planned', as parts that may otherwise feel like they should change at that point are left until the system gives me access to that line of code.

On being presented with a new line of code my process is as follows: interpret the code, fix bugs, i.e., where I may have half written some code edits the last time I edited that code line, decide on new edits, and then rationalise the order of edits to ensure some modification of the soundscape in this section.

Regarding the macro-structure of *Flow*, performances seem to follow a similar pattern: The first 5 minutes of the piece is spent trying to understand the code and making small edits to locate the sound associated with a line of code. In this section I also often make pitch and amplitude changes to shift the overall sound character of the piece, turning down less interesting code lines and amplifying lines where there is already an interesting sound. I use amplitude and frequency modulation to change the noise character of the piece, and tend to choose a pitch range to centre code lines on. After I have a good understanding of the sonic ecosystem I then make more complex changes, adding effects and developing the complexity of modulation. I find this section of the piece the most rewarding as a performer.

A final difference between this style of performance and my normal practice is that allowing any code line to be too dominant in the overall soundscape would have an adverse effect on the editing of the other code lines, as I would be unable to predict the next point in the piece at which that code line is available for editing again.

8.7 Conclusion

Although the main focus of my portfolio has been on collaborative improvisation systems, *Flow* tackles solo improvisation as mediated by algorithms. Its inclusion in the portfolio is justified on the basis that it is still clear that the intervention of algorithmic processes affects human interaction with the flow of the improvisation, thus human agency is still impacted by the system. Where pieces such as *Flock* and *Union* use algorithms to curate the output of the system, *Flow* is using algorithms to curate the human input into the system. The performer's levels of autonomy are impacted by their own cognitive reaction to the system. In *Flow* I propose that increasing time intensity for live coding activity may increase virtuosic requirements of the live coding performer. Giving the performer unknown code for short durations increases the need for fast cognitive and physical abilities. Coupling this with a process which reduces time according to levels of concentration creates a bio-feedback loop where engaging high levels of cognitive capacity in attempting to understand and edit code snippets works against the performer by giving them less time to interact with the code. Presenting the data related to this process alongside other representations of performer action as part of a visualisation gives the audience insight into the performer's cognitive and physical interactions with the algorithmic processes.

Chapter 9

Discussion and Conclusion

At the outset of this research project my aim was to develop network music systems which enacted a non-hierarchical ensemble structure within the context of a performance. As the theoretical research developed, the focus expanded to include general socio-political concerns of music performances which utilise networked communication and algorithmic mediation of interaction. The outcomes of this investigation were necessarily diverse and include algorithmic distribution of control; sonification of political data; interactive sonic exploration of our online political lives; modelling of idealised voting systems; and feminist activism through networked practices. Working in symbiosis with my compositional work was a deep immersion in live coding performance practice and an exploration of improvisation in diverse musical scenes. Through this I developed an understanding of performing with and through algorithms, and ideas relating to algorithmic mediation of improvisation became a more central topic of the work. My extra-curricular undertakings in diversity in music technology also impacted the way I constructed theoretical reasoning relating to the practical work I produced.

9.1 Emergent Topics

A number of the tools, techniques, and processes I used in this thesis emerged out my engagement with the social implications of particular technologies. I briefly summarise these in this section.

9.1.1 Transparent Processes

Over the course of the portfolio, it became increasingly important to use visual cues to aid understanding of the underlying algorithmic processes. This was partly due to the influence of my involvement in the live coding community and the sentiment shared by my peers of demystifying the technological process behind music production. It also seemed important to make it clear to performers and audience that algorithmic design was mediating the performance, drawing attention to the ethical questions this may raise, and revealing the group interaction with and through the system. I consequently found it useful in monitoring the system function to have a visual representation – particularly in *Flock* and *Union*, where multiple inputs have the potential to be timbrally similar, and system output may not be clear from the audio.

9.1.2 Algorithmic Consensus

As highlighted in Chapter 1, consensus was an interesting avenue of exploration in relation to improvised performances, particularly in telematic contexts. Obvious arising questions which were actively explored through the design process in *Union* included, how can we determine musical consensus, and is consensus always desirable. The approach taken in *Union* was to develop algorithmic methods of deducing a form of consensus (based on machine listening techniques), while acknowledging the system designer's non-neutrality and the impact they therefore have on the collaborative process.

9.1.3 Annoying Algorithms

Some of the algorithms in the portfolio take an interventionist approach to mediating the collaboration, disrupting, antagonising and restraining the performers. I flippantly refer to them as 'annoying algorithms', but I argue here that they play an important part in stimulating collective behaviour. Disrupting a performer's flow is perhaps in contravention to the much accepted importance of flow states in improvisation – Heble and Caines (2014a) dedicate an entire section of the book to the topic. Sá (2017) however offers another conception of flow in improvisation related to continuities and discontinuities – continuities require high embodiment and low cognitive effort, and discontinuities require low embodiment and high cognitive engagement. At its most basic level, algorithmic mediation can create discontinuities which acts as a (potentially helpful) irritant to the performer. These discontinuities act as a resistance, triggering the performer to move out of flow-like interactions with an interface or system, assess current states and redefine their actions in response to the non-human intervention. In the context of collaborative work, I use this device to trigger the performer to shift focus from the individual process towards collective action taking place in the ensemble.

9.2 Designing Collaboration

The systems described in the thesis explore possible synergies between the dynamics of improvisation in music ensembles which use network technology to exchange musical and social data, and the dynamics of online social networking which is fundamentally mediated by algorithms and interface design. The pieces discussed each explore human interaction when data collection and algorithms are used to modify or moderate this interaction, and subvert or enable particular power dynamics within a collaborating group. Through the threads of this work I propose a formulation of network music system design with a basis in socio-political theory. More broadly I critique the structures and practices of music making, using individual experiments to critically explore the processes of production, and interrogate the relationship between performers and technological tools.

Although social and technological hierarchies clearly have not been eliminated, I consider the ways in which systems may impact and/or facilitate human creative agency. Through this, appropriate aspects of the improvisational and collaborative processes are determined, which can abstracted into the system giving partial agency to algorithms. This is done with the aim of using algorithmic intervention to counteract the emergence of intra-group social hierarchy. Though I would not propose that countering hierarchy is always of benefit in music making, artistic practice can be a useful way to model idealised social-structures, or at least critique existent structures.

9.2.1 Agency

The imbuing of cultural artefacts with social agency is discussed by Bates (2012), who describes the cultural roles that musical instruments take:

> Much of the power, mystique, and allure of musical instruments, I argue, is inextricable from the myriad situations where instruments are entangled in webs of complex relationships – between humans and objects, between humans and humans, and between objects and other objects. (Bates, 2012, p. 364)

Although Bates refers to a symbolic cultural agency, it is useful to consider the forms of agency attached to cultural artefacts and processes. In many of the works described here the algorithm is directly managing performer agency, yet design of algorithmic systems for improvisation has a more nuanced and variable relation to performer agency than the traditional performer-composer hierarchy. The designer formulates the terms of interaction, but the improviser chooses how to interact with the system and with the other performers. Systems such as *Union* and *Flock* are not prescriptive of content, giving performers a much higher degree of agency than when performing a work formulated with the traditional composer-performer hierarchy. These works seek to interrogate the relationship between composer and performer and those between collaborating performers with the view to distribute agency more evenly across the music production ecosystem. Other works, such as *Controller*, *On Edge* and *Dissonant States* define the musical content more strongly, but seek to playfully consider agency where control is distributed unequally. Throughout the thesis I have used the terms work and system interchangeably and see my role in them as fluid depending on the particular characteristic of each work. Constant across the thesis however is a critical contemplation of the structures of music making.

9.2.2 Recontextualising Laptop Ensembles

Cultural artefacts can embody political ideals – Qureshi (2000) describes how the sarangi embodies the political history of Indian feudalism and the efforts to recontextualise the instrument. Part of the aim of my research was to rethink laptop ensembles, moving away from the replication of orchestra-style composer → conductor → performer hierarchies seen in many laptop orchestras and towards the techno-utopian ideals of early ensembles such as The Hub (Knotts and Collins, 2014). Connected to this goal was developing systems which do not impose strict musical choices on performers, and therefore to have somewhat musically neutral design choices, which focus on performer interaction rather than content and musical structure.

Socially aware design also includes considering the lines of power the system implements and the individual and collective behaviours facilitated, encouraged, and discouraged by the system. Collaborative improvisation in general involves the balancing of individual freedoms and collective action. Designing these social interactions, however, can be used to counteract the emergence of culturally entrenched hierarchies – as could be seen in communication procedures aimed to promote equality of participation in anti-capitalist protest movements (Unknown, 2014).

9.3 Agonistic Systems

Mouffe's (2013) theory of agonistic politics points to the blurring of boundaries between aesthetic (artistic), political (social), and productive life, and the inclusion of network technology – used for both social and productive life – in music making makes this blur ever more transparent.

Systems theory in algorithmic art already proliferates, but I argue for a heightened awareness of the way our artistic systems relate to real-world interaction with and through algorithms. Building idealised interaction into small scale artistic endeavour acts as a resistance against the loss of freedoms and capitalist gains in our online lives.

New technologies have always been integral in shaping the way music is made, but not until the advent of computer music were tools ubiquitous in capitalist production used in aesthetic music making. Network communications systems were developed for knowledge production and military purposes. The World Wide Web had utopian aims to democratise society, but the more we come to understand these technologies, the clearer it is that resistance to hierarchy needs to be built into the system to counteract the replication of inequality in existing societal structures.

Network music then can be seen as the final expression of this break down in boundaries as the tool of socio-political-productive life is used as the aesthetic. The structure of the network itself – i.e., the very essence of the communication system – becomes the work of art, in turn making the communication system itself unproductive and reflective of the current dissolution of capitalism.

This critique feels ever more urgent as world events point towards an erosion of western democratic systems, and technological systems move to the forefront of our societal organisation. Online platforms such as Twitter have populations greater than small nations, and yet their societal structures are in the hands of engineers, employed for their technical, not sociopolitical expertise and demographically representing only a small subset of their user population (Google Inc. & Gallup Inc., 2016; Ensmenger, 2012). Those same companies are rarely held to account for the abuses they allow to take place via the software they produce (Poland, 2016).

9.4 System Design as Activism

To end, I draw from Lim's recent keynote at Women in the Creative Arts Conference 2017:

> I propose that the aesthetic dimension and what we do as artists is a profoundly useful way of experimenting with what the world is like and can be. Through art, we can experiment with forms that contain, split and spill, organise and disorganise. Those forms expose hierarchies that show prioritisations and investments in different values; their rhythms reveal how we pattern and repeat those values; they show how we are linked to people, their ideas and labour. (Lim, 2017, p. 10)

Fundamentally this project explored the ways we can use computer networks to organise musical collaboration – the outcomes of which were ultimately derived from critically exploring the dynamics of communication with, through, and mediated by technological networks, algorithms, and data collection and manipulation. What began as a project in redefining the hierarchical boundaries between composer, performer, and system designer in the field of network music, was profoundly effected by my engagement with diverse improvisation practices, and not least, my collaborations with women – ALGOBABEZ, OFFAL, Rewriting the Hack, Northern Sound Collective, etc.

Resistance to hierarchy is an inherently feminist practice, and much of the work of this thesis calls for active acknowledgement that through considering the intragroup relationships and power dynamics between composer, system designer, performer, and audience, we can understand the value system that percolates through to each level of the performance system. Though specific activisms are not always performatively expressed at the forefront of the work, critique of power structures that allow some voices to proliferate, while others are under-represented and undervalued, strongly informs it.

Lim refers to cultural production as world-building, which comes with it a responsibility to understand what world you are creating with and through your work. The interrelational nature of network music systems warrants building a theory of system-design based on socio-political theory, as incorporating technologies that increasingly inform our social interactions, into cultural production comes with a responsibility to critically engage with the way they shape our lives in and beyond art production.

9.5 Conclusion

In conclusion I summarise how the practical works engaged with my research questions.

Network music allows us an extra modality of communication beyond that in normal music ensembles i.e. the sharing of data across networks. This opens up many possibilities for structuring interaction through sharing audio (in *Union*), text (in *Union* and *DIJTA*), meta-data (in *Union* and *Flock*) and control values (in *Controller*). Mediating algorithms can be used to process this data in various way, modify performer agency, distribute control and explore approaches to organising a improvised performance.

Each of the works explore this aspect of network music from a different angle. *Controller* modulates performer control of sound through a dynamic interface controlled by a central algorithm; *Dissonant States* uses a static data set to produce a live score as a stimulus for improvisation; *On Edge* references aspects of distributed control which is often part of network music practices; *Union* uses an algorithm to analyse audio data and structure temporal and density aspects of the performance; *Flock* uses an algorithm to analyse audio data and a voting simulation to structure the performance; *Flow* builds on some of the emergent themes of the thesis such as data collection and interventionist algorithms to explore agency in a solo performance.

Many of the works deal with differing levels of agency and control being give to (or taken away from) performers. For example in *Controller* access to musical controls is restricted and in *Union* and *Flock* time is divided between the performers. *On Edge* divides specific tasks between performers, and *Dissonant States* modifies the performer's freedom of interpretation in each section. *Flow* modifies the normal time structure of a performance. In some cases this acts to critique or counteract the emergence of social hegemony (*Union* and *Flock*) and in others it questions the traditional structures and practices of music making (*Controller*, *Dissonant States On Edge*, *Flow*).

I used a wide range of tools over the course of the PhD in order to explore these themes including machine listening, text-to-speech algorithms, sentiment analysis, flocking algorithms, twitter API, BCIs, live coding tools, audio streaming software and live scores. In some cases I was interested in how analytical tools used in social media may be applied in network music contexts and vice-versa, how we might critique online politics through artistic practices.

Dissonant States and *DIJTA* have the most direct relation to real world politics through using political data as source material. In *Dissonant States* I use political structures as an analogy for music practices and in *DIJTA* I critique political narratives in the age of social media through sound and noise. *Flock* models proportional representation as a method for structuring a music performance, and *Union* applies principles of feminist activism in the context of a network music ensemble.

Appendix A

Description of Data Used, Data-Parameter Mapping and Example Case in *Dissonant States*

A.1 Description of Data

Dissonant States utilises a collated data set from several sources relating to democracy in world states. The data used to create the piece includes:

- Freedom House and Economist Intelligence Unit's most recent (in 2014) ratings of citizen freedom and state democracy.
- International Institute for Democracy and Electoral Assistance's data relating to voter turnout in the most recent election for each state or the most recent election for which they have data.
- Several cross-referenced online sources for the year states introduced women's suffrage and state populations.

A.2 Description of Data Mapping

The number of pitches in each pitch set is determined by EIU's rating for inclusivity – a value relating to who is included in democratic processes. The EIU rates inclusivity on a scale of 1-10 (where 1 is the least inclusive), these values are mapped to the pitch sets having between 2-12 notes. This scaling was chosen as 12 is the maximum number of notes which can be played by piano, flute and clarinet in standard performance practice, and 2 is the minimum number of pitches to produce harmony.

The mapping was chosen, as 'inclusivity' denotes how universal democracy is, e.g., whether women are included in the democratic and voting processes. The number of notes in the pitch set is a logical translation from democratic to musical inclusivity.

The voter turnout data is used to determine how many instruments will perform a given pitch set and how dense the electronics part is. This aims to give a sonic impression of the density of democratic participation in a state.

The overall range within which the pitches used can fall is determined using the EIU's rating for competition in the political system. The minimum range used is one octave and the maximum range used is the total possible range of all instruments included in that section, i.e., in a section where only the clarinet and flute play, the range of the pitch set would be scaled from the EIU's 0-10 scale to between 1 octave and the range spanning the lowest note on the clarinet to the top note on the flute.

For each state the overall democracy rating from EIU is used as a value for relative musical dissonance which is used as a target value to generate the pitch set.

The Dissonance class in SuperCollider outputs a value for psychoacoustic roughness for an input pitch set. A function is used to generate possible pitch sets at random of the correct size and in the correct range (dependent upon inclusivity value and which instruments will play). For musical continuity 50% of the next pitch set (or less if the next pitch set is significantly larger than the last) is the same as the previous pitch set. A fitness function then calculates the dissonance value for each generated set. The set with the closest dissonance value to the input democracy rating, if within a reasonable margin of the desired dissonance value, is the set that is used, otherwise more random sets are generated and tested until a close enough match is found.

Dissonance values are calibrated according to the number of pitches in the set to account for widely varying dissonance ranges depending on pitch set size

The year that a country introduced women's suffrage (an important marker of increasing democracy in a state) determines the order of the pitch sets.

The time proportion of the piece given to each country's data is scaled according to the population size, overall democracy level and the timespan until the next country gains women's suffrage, i.e., small autocratic countries would receive proportionally less time than larger democratic countries.

A.3 Example Mapping

The above specifications are used to determine the parameters which represent each country in the piece. We will now examine the mappings for an example data set and how this translates into the musical score.

The first country to instigate women's suffrage was New Zealand, therefore this is the first country in the piece and will be used as our example case (See Table A.1).

The output data values are used to generate a score for the performers, using SuperCollider to generate the pitch sets and live notation software INScore to produce the notation.

A.4 Technical Realisation

In *Dissonant States* each performer uses a laptop screen as their score (See Figure 3.3). Each computer runs a copy of INScore (Fober, Orlarey, and Letz, 2014) with a main

TABLE A.1: Example Data Mapping: New Zealand.

Input Parameters	*Voter Turnout*	*Voter Turnout*	*Inclusivity Rating*	*Competition*	*Democracy Rating*	*Position in Timeline of Women' s Suffrage*	*Population (as % total population of all countries)*	*Years until next women's Suffrage*	*Freedom rating*
Value Range	0-100	0-100	0-10	0-10	0-10	1- 156	0-100	0-9	Not Free/Partly Free/Free
Input Data	74.21	74.21	8.89	10.0	9.26	1	0.063	9	Free
Output Parameters	*Number of Instruments*	*Density of Electronics*	*Number of Pitches in Set*	*Range of pitch set*	*Dissonance Target value*	*Position in timeline of performance*	*Scaling duration of Section*	*Scaling Duration of Section*	*Performance Direction (level of improvisation)*
Output Range	1-3	0-100	2-12	12-max range of instruments in section	0-10	1-156	0-15′	0-15′	Not Free/Partly Free/Free
Output Data	3	7̃4.21%	11	Lowest to highest notes on Piano	9.26	1	-	84.43″	Free

hub computer running SuperCollider sending OSC messages to change score parameters on the performers' laptops (See Figure A.1). On the hub computer a static collated data set is accessed from SuperCollider, where calculation and generation of the parameters of the pitch sets is done prior to performance. The calculation of pitch material uses the Dissonance library in SuperCollider. For each country a large number of possible pitch sets are generated and tested for dissonance level until a best fit is found for the particular input data of that section. The sound for the electronics part is generated in SuperCollider in performance according to the calculated pitch set and data values for vote turn out.

In performance each section uses elements of the static data set, the pre-generated pitch set, and random performance directions to determine the score parameters for the section. These parameters are sent live from the hub computer to the musicians' laptops to ensure synchronisation. Personalised versions of the score for each performer take account of instrumental transpositions, range of the instrument and whether that instrument is playing in a particular section. In an ideal setup, the score is also projected for the audience, giving insight into aspects of the current data set in play.

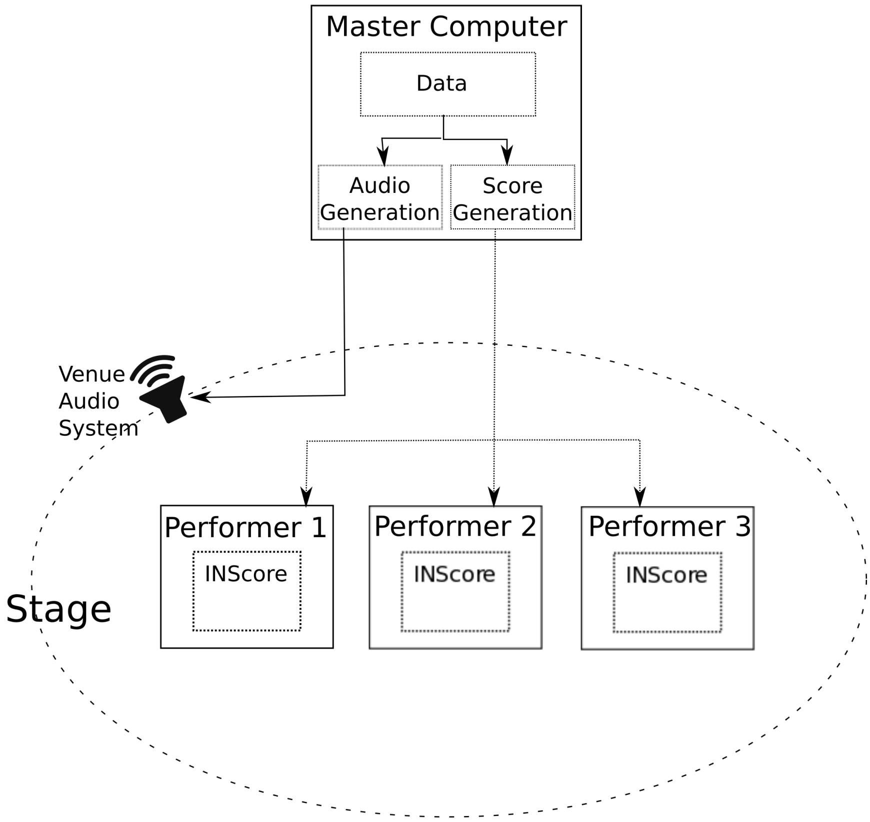

FIGURE A.1: System architecture of *Dissonant States*.

Appendix B

Technical Overview of *Union*

B.1 Overview

Union is a performance system for telematic, improvised performance. When using *Union*, performers send audio streams via the internet to the concert location. The streams are input into an analysis and mixing algorithm which outputs a multichannel mix of the streams. The analysis part of the algorithm uses machine listening to detect similarity between the streams based on audio features. The mixing part of the algorithm is designed to use live data relating to audio features and performer contribution to balance 'consensus' against 'fairness' over the course of the performance. The function and design of the algorithms are described in detail in Sections B.3-B.5 below.

SuperCollider's SCMIR Library is used for live feature analysis of the incoming audio. The data collated is used to rank the streams from most to least average according to the feature data values, and to mix the stream with the most 'average' audio features the loudest, scaling the other streams' amplitudes between maximum amplitude (most average) and silence (least average).

A graph of musical density is generated prior to the performance, imposing one aspect of structure on the performance. Each section has a predetermined number of streams (n_a) which will be audible and every stream after that number (in the most-least average ranking) will have its amplitude set to 0 for that section. Each section has one more or one less stream than the last with a slight tendency towards a build-up in density. Section breaks are implemented by switching to giving the least average stream the loudest amplitude. A final aspect of the algorithm keeps track of the amount of time each stream has had an amplitude greater than zero and balances the aforementioned elements with trying to ensure that all players get approximately the same amount of time 'on air'.

B.2 Technical Setup

Detailed directions for setting up *Union* can be found within the documents attached to this thesis. I will give an overview of the setup here.

B.2.1 Hardware Setup

The audio streaming is run via an IceCast server running on an external server. One laptop is always present in the concert venue to connect the audio received from the server to the in-house sound system and to run the SuperCollider and Processing patches. That computer may also have a faderboard attached with a fader per incoming audio stream. This fader controls the master audio input level of each incoming stream allowing an overall balance between audio streams to be set and allowing the possibility to safeguard against distorted or glitching audio streams to be present in the final mix. The in-house laptop also sends a stereo version of the mix to the IceCast server to allow telematic performers to monitor.

Performers in dispersed locations set up according to their usual hardware setup.

B.2.2 Software Setup

Remote Performers

Outgoing:
Sound generation software → Jack/SoundFlower → BUTT (broadcasting software) → IceCast
Incoming:
IceCast network stream is loaded in VLC or other software → Jack/SoundFlower → audio interface → headphones/speakers for monitoring

Hub Computer

The software flow for the hub computer (where n = number of performers) is as follows:
n Icecast network streams → n mplayer copies → Jack → SuperCollider
→ Processing (video software) → in house projector
→ Jack
→ audio interface → in house sound system
→ BUTT (broadcasting software) → IceCast

B.3 System Architecture

See Figure B.1.

B.4 Audio Analysis and Determining Consensus

The low level analysis algorithm uses SuperCollider's Music Information Retrieval library (SCMIR). The patch extracts the MFCC and Chromagram content of each of the incoming audio streams. This gives an array of feature values for each stream for each frame. At the end of a section the SCMIR data for each stream (s) is averaged

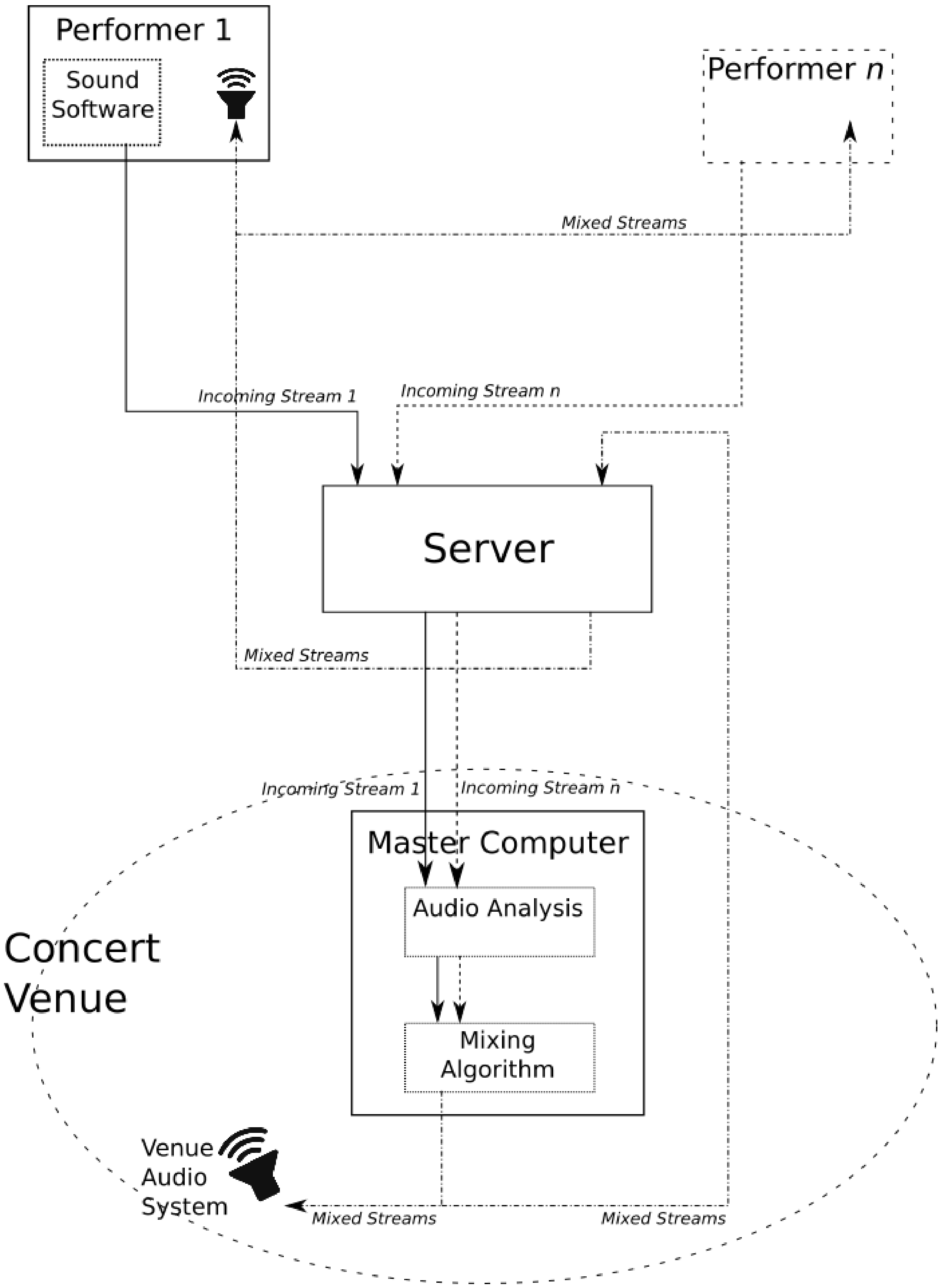

FIGURE B.1: System architecture of *Union*.

to give a mean (m) value array (m_s) of the extracted feature values for that section. The m_s values are used to calculate the overall (o) mean array (m_o) for the section. The m_o is considered to be the point of consensus for the purposes of the algorithm.

The Euclidean Distance of each m_s from m_o is then calculated to determine the distance of each audio stream from the 'consensus' point in terms of audio features. The amplitudes for each stream are then scaled linearly so that $m_o = 1$ and the m_s with the greatest euclidean distance from $m_o = 0$. This means streams closest to the consensus position are the most dominant in the following section.

B.5 Structure

A higher level algorithm is used to determine a structure for the performance. It determines the number of sections, the section durations, and the number of performers audible in each section. When the structure is generated a test function checks that there are at least as many solo sections as performers and the structure is recalculated if this condition is not met.

The following subsections explain how each part of the structure is determined.

B.5.1 Durations

Section durations are determined by using a SCMIR analysis of recordings of the performers playing solo. The SCMIR analysis can be used to detect section breaks and therefore determine typical section lengths idiomatic to each performer's playing style. During the performance these collated section durations are used in a randomly ordered way to determine the points where new average feature data values are calculated, and the new mix is implemented.

B.5.2 Density

The performance always begins with n sections where the number of streams builds from 1 to n streams, adding 1 stream per section. Following from this, a musical form based on density is approximated by adding or subtracting a stream in each new section, leading to an ebb and flow in the density of the performance. The likelihood of adding or subtracting a stream is slightly skewed towards adding a stream so that there is a general tendency to build up to dense textures, whilst avoiding this happening in a linear and predictable pattern.

B.5.3 Soloing

Solos occur throughout the performance and the likelihood of a solo occurring is independent of the adding and subtracting of streams. After each new section the chances of the next section being a solo increases. This probability is reset after each solo, meaning that solos are semi-randomly placed, with a tendency to be relatively equally spaced in the performance.

B.6 Live Algorithmic Procedures

B.6.1 Structural Amplitude Scaling

According to the generated density structure only a certain number of performers will be audible in each section. In the performance, after the amplitudes are scaled according to the euclidean distances from m_o, the structural amplitudes are applied. This means that every performer after the first na, will have their amplitudes set to 0. For examples, if for section i the amplitudes are scaled as follows $[0.98, 0.76, 0.51, 0.49, 0.17, 0]$ but na for that section is 3 the amplitudes will be set as follows: $[0.98, 0.76, 0.51, 0, 0, 0]$. i.e. every amplitude scaling after the 3rd highest value will be set to 0 or silent.

B.6.2 Solo Section Amplitude Scaling

To create structural variation and musical contrast, when solo sections occur the algorithm switches to choosing the stream with the m_s at the **greatest** euclidean distance from m_o, and setting its amplitude to 1 and all other amplitudes to 0.

B.6.3 Structure and Fairness

As the above process would tend to preference the sonic features which are initially most dominant and would likely prevent 'dissenting' voices, a weighting algorithm attempts to balance out the scaling of amplitudes according to some form of equity. A running total is kept for the amount of time each performer's amplitude is scaled to 0 and the structural amplitude scaling algorithm which scales the streams after na to 0 is overridden if the difference between lowest and highest amount of 'silent time' gets too high. In these sections the na performers who have had the most amount of time with amplitude 0 have their amplitudes set according to the euclidean distance scaling algorithm, and all other performers are set to 0. This part of the algorithm also ensures that every player has at least one solo section.

B.7 Panning

Each stream has a default pan position (p_d) evenly spaced in the sound field. The PanAz Ugen in SuperCollider is used to set circular pan positions. The p_ds are adjusted according to the number of output speakers and input streams. During the performance the euclidean distance calculation is also used to modulate the pan positions. In each section the position of a stream is set using the same values as the amplitude array. The most dominant (r_1) and least dominant streams maintain their p_d. All other streams have their position modulated to a position between r_1 p_d and their own p_d so that, e.g., an amplitude array value of 0.5 would be half way between p_d and r_1 p_d, and 0.9 would be the position 90% of the distance between p_d and r_1 p_d towards r_1 p_d.

B.8 Visuals

The visual aspect of Union is programmed in Processing and visualises three aspects of the performance. The bottom layer of the visuals displays grey-scale photos (with filtering and processing) of the performers who currently have their amplitude set to above 0 in a grid pattern. The middle layer visualises the pan positions of the performers who currently have their amplitude set to above 0 using points on a large circle to denote pan positions in the sound field. Finally the IRC chat – which the performers use to communicate during performance – is displayed in realtime on the top layer.

Appendix C

Technical Overview of *Flock*

C.1 Overview

Flock is a performance system for three live coders which uses a software based voting system to mix the audio outputs of the performers. SuperCollider's SCMIR library is used to detect features in the three live coded audio streams. A population of artificial voters is generated at the beginning of each performance, who each have a set of preferences for particular feature data values. At regular intervals, the population votes according to which of the three inputs has audio features closest to their preference data. The three audio streams are then mixed with a relative output level according to number of votes received, i.e., winning 44% of the votes would result in the audio level of that stream being set to 44% of maximum volume.

A flocking algorithm controls the preferences of the artificial voters, voter breeding, and connections between voters, ensuring dynamic voter preferences and a regeneration of the population over time.

Representative visuals show the state of voter preference data, audio feature data, and voting outcomes during the performance.

C.2 Technical Setup

Detailed directions for setting up the system can be found within the documents attached to this thesis.

C.2.1 Hardware Setup

One of the performers' computers acts as the hub computer: it runs the SuperCollider patch and connects to an in-house sound system. An additional computer is used to run the Processing patch for the visuals and is attached to the in-house projector. A local network (Ethernet or wireless) is created to send data from the hub computer to the visuals computer. The other two performers send their sound output to the input of the hub computer's sound card. The audio output can scale easily from stereo to multi-channel output, depending on the in-house system, and audio hardware setup is modified accordingly.

C.2.2 Software Setup

Hub Computer

Incoming:
4 inputs on sound card → SuperCollider *Flock* System Setup

Outgoing:
Internal SuperCollider Live Coding Setup → Jack
→ headphones for monitoring
→ SuperCollider *Flock* System Setup → mix of three incoming streams
→ in-house sound system
→ data transmitted via local network to visuals laptop

Other Performers

Internal SuperCollider Live Coding Setup
→ headphones for monitoring
→ main audio outputs to sound card of hub computer

Visuals Computer

data transmitted via Ethernet/wireless network from hub computer → Processing patch → in house projector

C.3 System Architecture

See Figure C.1.

C.4 Software Description

The SCMIR Music Information Retrieval Library in SuperCollider is used to collect feature data (MFCCs and Chromagram) of the three audio inputs. Every ten seconds a mean of the data is calculated for each performer and the voting algorithm is triggered to determine a new amplitude level for each of the performers in the next section. The old amplitude level transitions to the new amplitude level over five seconds ensuring smooth transitions between sections. A flocking algorithm recalculates the preferences of voters according to their autonomy level and the preferences of neighbouring voters. A longer term dynamic of the system is ensured by regeneration of the voting population every twenty voting rounds (or every 200 seconds), through ageing and breeding of voters. A visualisation of the system displays the current feature data, voting data and the last code lines executed by the performers. Audio inputs are generated by the performers live coding using SuperCollider's JITLib.

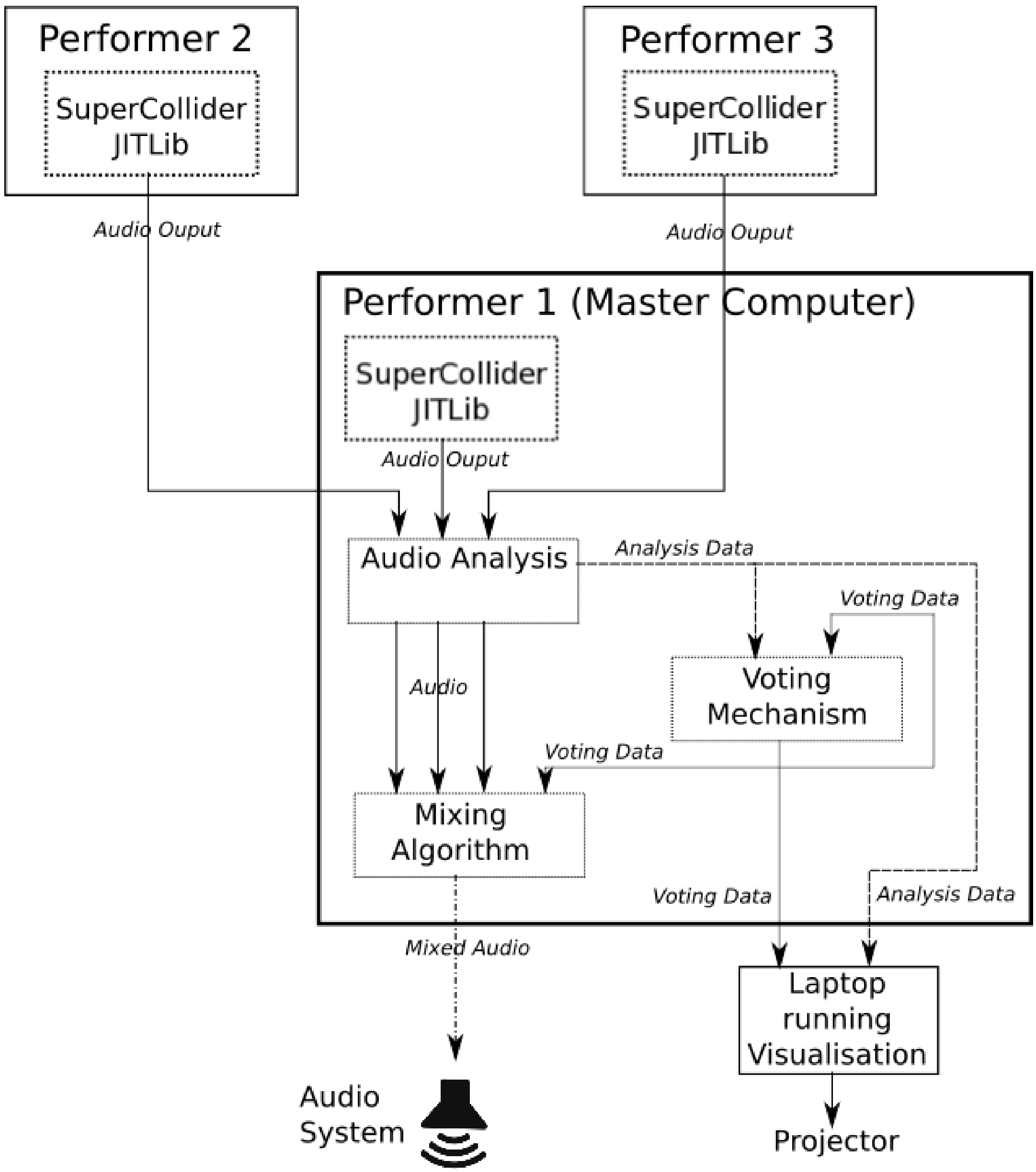

FIGURE C.1: System architecture of *Flock*.

C.4.1 Population Generation

At the beginning of a performance of *Flock* a population of up to 200 (t) voters ($[v_1 \dots v_t]$) is generated who will vote on the incoming audio streams. The voters have the following characteristics:

- a set of feature preferences (f) equal to the number of features (n) being detected in the incoming audio ($[f_1 \dots f_n]$). These are randomly generated values between 0 and 1.
- a value between 0 and 1 for autonomy (a), which controls how strongly the voter is influenced by the preferences of other voters.
- a set of edges ($[e_1 \dots e_x]$) which connect the voter to other voters. These edges will determine which other voters will influence their preference values in the flocking algorithm, and which other voters they can breed with in the population regeneration algorithm.
- an age between 1 and 20.

C.4.2 Voting Mechanism

Every 10 seconds the voting mechanism is triggered. When this is triggered the mean SCMIR data for each performer ($[p_1, p_2, p_3]$) for the previous 10 seconds is calculated to give a feature data set for each player for that section ($[m_1, m_2, m_3]$). For each voter the euclidean distance is calculated from the voter preference data f to the performer average data. The voter then effectively 'votes' for the performer whose average is closest to their preferences. The amplitude of the 3 inputs is then set proportionately to the number of votes amassed. i.e. with a voting outcome of $\frac{[43, 150, 15]}{t}$ amplitudes would be set to or $[0.2, 0.73, 0.07]$.

C.4.3 Flocking Mechanism

To ensure the system is dynamic, voter preferences f are recalculated on every voting round. Each voter has an 'autonomy' value a, which defines how much they are influenced by the preferences of other nodes. In addition, each node has a number of other nodes they are 'connected' to. After each vote, the preference values f of each voter are recalculated according to their autonomy value a and the euclidean distance (d) to the preferences of connecting voters e. The total change of preference is limited to 0.1 and scaled by a. The total change of preference will be the difference between $v_1[f_1 \dots f_n]$ and $v_x[f_1 \dots f_n]$ for each connected node multiplied by a_1 and d. The total change of preference is limited to 0.1 per round and if the preference values go out of range (< 0 or > 1) a new random value is generated. In each round voters gain one new connection to a voter which is connected to one of the voters they are already connected to.

C.4.4 Population Regeneration

Voters have a maximum life span of 20 voting rounds. As the age of the voter increases the chance of it dying in the next round increases. A tally is kept of how many voters die in each round (d_r). New voters are generated (b_r) at approximately the same rate as nodes die or $d_r \times random(0.8, 1.2)$. When a node is between 4 and 10 voting rounds old, it can breed with other nodes to produce new voters. Connected voters of the correct age are ranked according to their euclidean distance to each other and the first b_r voters produce a new voter with f values in approximately the same range as the parent nodes and with e as a subset of the edges of both parents.

C.5 Visuals

The visuals, written in Processing, receive data via OSC from the main SuperCollider patch running on the hub computer. This data includes the feature data of each performer, and voting and preference data of each 'voter', as well as the last code line executed by each performer. The performers and voters are represented by coloured circles, with the larger coloured circles representing the performers and the smaller circles representing the voters. Each circle contains a white circular graph representing the current average feature data of the performer, or the voting preference data of the voter. At each voting round the colour of the voters change to match the colour of the performer they have voted for in that round. The position of each performer and voter circle is determined by a physics engine called Fisica: a virtual spring connecting each voter circle to the 3 performer circles is set to the distance of their preference values f to the performers' mean feature values m, resulting in the nodes trying to position themselves according to these distances, rather than absolute positions being determined. This means that nodes with similar feature preferences cluster together and the whole system moves according to the changing preferences of the voters. A bar chart at the top of the visuals show the current vote tally. The last code line executed by each performer is displayed next to the coloured circle representing that performer.

Appendix D

List of Performances

Controller (2014)
Nov 2014 Demo Performance
International Conference on Live Interfaces, Lisbon

Dissonant States (2014)
July 2015 Schallfeld Ensemble
International Conference on Auditory Display, Graz
June 2014 Ensemble7Bridges
Sound Lab, Klang14 Festival, Durham University, Durham

On Edge (2014)
Dec 2014 Ives Ensemble
Ives Ensembles Workshop, Durham University, Durham

"Democracy isn't Just a Tweet Away. . . " (2015)
Sept 2015 Installation
Ohrenhoch der Geräuschladen, Berlin
July 2015 Installation
International Conference on Auditory Display, Graz
#Algorithm #Rave (2015)
July 2015 Solo Performance
Algorave @ Do It Anyway Festival, Access Space, Sheffield
July 2015 Solo Performance
xCoax 2015, Glasgow School of Art, Glasgow

Union (2015)
Nov 2016 OFFAL
Women in Music Tech, Georgia Institute of Technology, Georgia, US
Sep 2016 OFFAL
Nantes Electronic Arts Recontre, Nantes
June 2016 OFFAL
International Conference of Live Interfaces, University of Sussex, Brighton
May 2016 OFFAL
Navigating Acceleration Conference, Goldsmiths, London
Feb 2016 OFFAL
International Women's Day Concert, Culture Lab, Newcastle Upon Tyne

June 2015 FLO
KLANG15 Festival, Durham University, Durham
June 2015 FLO
PQ15 Festival, Prague

Flock (2015)
Aug 2016 Holger Ballweg, Shelly Knotts, and Autonomous Improviser
Sound and Music Computing 2016, Hamburg
May 2016 Calum Gunn, Shelly Knotts, and Tim Shaw
International Symposium of Electronic Arts, Hong Kong
July 2015 Holger Ballweg, Jonas Hummel, and Shelly Knotts
International Conference of Live Coding, Leeds

Flow (2015)
Oct 2017 Performance-Lecture
Microwave New Media Arts Festival, Hong Kong
Nov 2016 Performance-Lecture
London College of Communication
Oct 2016 Solo Performance
International Conference on Live Coding, Hamilton
Sep 2015 Solo Performance
Digital Media Labs, Barrow-in-Furness

Appendix E

Scores: Portfolio

This appendix contains scores for the following pieces, which are included in the portfolio for examination:

- *Controller* (2014)
- *Dissonant States* (2014)
- *On Edge* (2014)

E.1 Controller

E.2 Dissonant States

E.3 On Edge

Appendix F

Scores: Reference

This appendix contains the score for *Chroma* (2015), referred to in Chapter 4. This piece is not included in the portfolio for examination and is included here for reference purposes only.

F.1 Chroma

Appendix G

Database of Laptop Ensembles

Name	Continent	Country	Band/ Orchestra/ Ensemble	Founded	Still active	Project Specific/Single Performance	Number of Members	Conductor	Director	Student Members	University Academic Staff Members	Non-Academic Members	University Affiliation	Hardware	Software	Composed pieces	Improvisation	Co-located	Network Interaction
The Hub	North America	USA	Band	1986	Yes	No	4-6	No	No		Yes	Yes	No	Heterogenous	Heterogenous	Yes	Yes	Mostly	Yes - data sharing
EMU Ensemble	Europe	Germany	Ensemble	1986	Yes	No	ca. 4-8, but varies	No		Yes	Yes		Yes - University of Ulm	Heterogenous		Yes	Yes	Yes	
MIMEO	Europe	Various	Orchestra	1997		No	8-12	No	No				No	Heterogenous	Heterogenous		Yes	Yes	
MICE (Mobile Interactive Computer Ensemble)	North America	USA	Ensemble	2001	Nothing listed since 2012	No	ca. 194 (2008)		Yes	Yes	Yes		Yes - University of Virgina	Heterogenous	Homogenous		Yes	Mostly	Yes - LAN gaming infrastructure
The Lappetites	International	UK/France	Group	2002	Yes	No	3-4	No	No				No	Heterogenous		Yes	Yes	Yes	Sound and data sharing mentioned but not clear whether in a live context or not.
Laptop Orchestra (Tokyo)	Asia	Japan	LOrk	2002	Yes	No	6-7	No	Yes	No			No			Yes	Yes	Yes	Yes - high performer interdepence
PB_UP	Europe	Germany	Band	2003		No	3-6+	No	No	No	No		No	Homogenous	Homogenous	No	Yes	Yes	Yes - Code sharing
Helsinki Computer Orchestre	Europe	Finland	Orchestra	2003	No	No	22	Yes	Yes				No	Heterogenous	Heterogenous	Yes		Yes	
Twentytwentyone Laptop Quartet	Europe	Lithuania	Quartet	2005	No	No	4	No	No				No			Yes - graphic scores	Yes	Yes	
European Bridges Ensemble	Europe		Ensemble	2005	Yes	No	7	Yes	Yes				No	Heterogenous	Homogenous	Yes		Sometimes	Yes
PLOrk	North America	USA	LOrk	2005	Yes	No	15+	Sometimes	Yes	Yes	Yes	No	Yes - Princeton	Homogenous	Homogenous	Yes		Yes	Varies between pieces
Grainface	Europe	Germany	Band	2007	No	No	4	No	No	Yes	No		No	Heterogenous	Heterogenous	Yes	Yes	Yes	Data sharing in some pieces
Toy Laptop Quartet	Europe	UK	Quartet	2007	No	Yes	4	No	No			Yes	No	Heterogenous	n/a	No	Yes	Yes	No
Luciano and his Live Laptop Orchestra	Europe	Spain	LOrk	2009	No	Yes	<7	Yes	Yes			Yes	No - record label	Heterogenous	Homogenous		Yes - jamming	Yes	Central mixing by conductor, not clear whether sound is send via audio cable or via LAN
Republic 111	Europe	Germany	Group	2009	Yes	No	15	No	No	Yes	Yes		Yes - Universität der Künste, Berlin	Heterogenous	Homogenous	No	Yes	Yes	Yes - code sharing
L2Ork (Linux Laptop Orchestra)	North America	USA	LOrk	2009	Yes	No	10-15	Yes	Yes	Yes	Yes	No	Yes - Virginia Tech	Homogenous	Homogenous	Yes		Yes	Yes - data sharing
LOLC	North America	USA	LORk	2010	Yes	No	5	No		Yes	Yes	No	Yes - Georgia Tech	Heterogenous	Homogenous		Yes	Yes	Yes - code sharing
Electronic Resonance Korps (ERK)	Australia	Australia	Orchestra	2010		No	8-9						No			Yes	Yes	Yes	
Disphilharmonia	Europe	Macedonia	Quartet	2010	Yes	No	4 + 1 robot						No				Yes	Mostly	
Tönstör Laptop Ensemble	Europe	Switzerland	Ensemble	2011		Recurring project	4	No	Yes	Youth Project	No	Yes	No - Verein	Heterogenous					
Beirut Laptop Orchestra	Asia	Lebanon	LOrk	2012	Yes	No	7	Yes	Yes	Yes	Yes	No	Yes - Lebanese American University.	Heterogenous			Yes	Yes	

The table on the left is an example subset of the data collected in support of the research published in Knotts and Collins (2014). The full dataset is available at: https://goo.gl/qGBB4F

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